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Cradle-to-cradle - A concept for the disposal of buildings at the end of their lives?

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ABSTRACT

The construction industry has a vital role to play to find solutions which are ecologically compatible, economically acceptable and socially responsible in equal measure. The purpose of this paper is to discuss alternative disposal methods of buildings at their end-of-life with respect to opportunities for cost saving and responsibility for reducing environmental burdens. Tougher laws and increasing charges for land fill encourage the application of new procedures for disposal.

Instead of putting a burden on future generations and the environment, waste salvaged from disposal can become a resource to be recycled and re-used. The application of cradle-to-cradle concepts to disposal of buildings contributes to the recovery of materials out of the life-cycle with zero loss in material performance. The possibilities for sorting waste as well as material separation are not entirely taken into account in present disposal projects.

This paper identifies how significant improvements in the quality of disposal waste can be achieved by the application of selective deconstruction procedures. The efficiency of the selective deconstruction method depends on a high degree on the selecting and sorting of materials. The application of selective deconstruction can contribute to the economic efficiency of disposal projects while simultaneously increasing the quality of the salvaged materials for re-use and recycling.

Key words: Cradle-to-cradle, disposal, building, selective deconstruction, life-cycle

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1 INTRODUCTION

The construction industry is arguably one of the most resource-intensive and environmentally damaging industries in the world (Sustainable Construction Task Group, 2000). Sustainable construction is a description for the application of sustainable development in the construction industry (CBP, 2003; CIRIA, 2001). According to Helen and Qiping (2002) a wide acceptance of sustainable development has led to a demand for policies on sustainable construction in the last few years. The construction industry has a vital role to play in finding solutions which are ecologically compatible, economically acceptable and socially responsible in equal measure. Such solutions can only meet the needs of all external and internal stakeholders if they are managed in an efficient, profitable and fair manner, as illustrated in Figure 1.

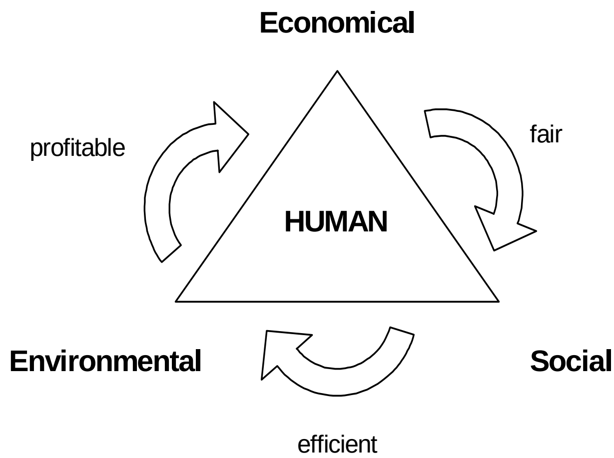

Figure 1: Interplay of sustainable dimensions

Delivering more sustainable construction requires action from all those engaged in constructing and maintaining the built environment (CIRIA, 2001). The sustainability of construction involves different components, such as the minimization of whole life-cycle costs, the use of energy more effectively and the minimisation of mineral extraction. Sustainability assessment in construction can be done at different levels. According to Langford et al. (2000) one appropriate division is into the global level, local level, building sector level and building project level. In particular, the building sector level is concerned with the sustainability of the building industry as a whole. Issues such as the adaptive use of buildings, reuse and recycling of materials, and the efficient use of energy will have a significant impact on the sustainability of a building sector. Sustainable construction is desirable in all phases of the building's life span – planning, design, construction, operation, maintenance and disposal – a minimisation of energy flow is as important as the preservation of natural resources (BMVBW, 2001; Lützkendorf, 2002).

Disposal of buildings at the-end-of-their-life produces a large amount of waste materials with a great potential for reuse or recycling. The minimisation of waste salvaged from disposal projects and the achievement of a recovery rate as high as possible has priority in the handling of projects at the end of their lives. Shakantu et al. (2002) placed the role of logistics in re-use and recycling of disposal waste at the centre of effective waste management. It is essential to look for the best disposal procedure that contributes to a large amount of reusable and recyclable materials. The purpose of this paper is to discuss alternative disposal methods of buildings at ends of their life with regard to optimising environmentally friendly dismantling.

2 REQUIREMENTS FOR THE MANAGEMENT OF DISPOSAL WASTE

2.1 Laws and legislation for disposal of waste

It is necessary to provide an overview of the relevant laws and legislation in the area of building disposal. While it is almost impossible to enumerate all of these, among the European and national legislation in this area the most important for this paper are specified in the 'Framework Directive on Waste' (EEA, 1991). The Directive establishes a framework for the management of waste across the European Union. One of the main principles of the directive is that Member States are called on to take the 'necessary measures to ensure that waste is recovered or disposed of without risk to the air, water or soil, without creating a nuisance in the form of odours or noise, and without adversely affecting the countryside' (EEA, 1991). Member States have to issue permits to companies engaged in waste disposal or recovery. The permits have to include requirements regarding disposal techniques and methods, sites, technical requirements and security precautions.

The Government in Britain has also begun to encourage more sustainable construction by the establishment of legal regulations to influence the market. The landfill tax was introduced in October 1996 to provide a fiscal incentive to minimise waste. There are two tax bands, applied to active and inactive wastes. The current rates of landfill tax are £21 per tonne for active waste and £2 per tonne for inactive waste (HM Treasury, 2006). The government has already stated that the standard rate of landfill tax covering active waste will increase by £3 per tonne each year, towards a medium to long-term rate of £35 per tonne (HM Treasury, 2006). Thus, the government wants to encourage more efficient construction and more innovative re-use and recycling of materials in order to minimise the construction and demolition waste which goes to landfill.

Figure 2 illustrates a waste management hierarchy with a descending order of priority, wherein the most desirable goal is waste prevention. It is clear that such a goal will not be achievable for most disposal projects, so further options for the re-use and recycling of disposal waste have to be considered. Only if waste cannot be prevented, reclaimed or recovered, should it be disposed of, using the best practicable environmental option (DETR, 2000a). Figure 2 also shows the selected waste management options in relation to the level of sustainable construction. Thus, the higher the priority of waste, the higher the level of sustainability will be.

Figure 2: Waste management hierarchy

2.2 From a cradle-to-grave towards a cradle-to-cradle concept for disposal

Disposal waste arises from the refurbishment, dismantling or demolition of buildings, bridges, pavements and other structures (EEA, 2002). It mostly includes brick, concrete, hardcore, subsoil and topsoil, but it can also include quantities of timber, metal, plastics, glass and special waste materials (DETR, 2000b). Shakantu et al. (2002) point out the various opportunities that derive from such a complex waste stream such as reducing waste and costs associated with the disposal process. A cradle-to-grave life-cycle of waste incorporates mainly the stages of raw material extraction, manufacturing, build, use and disposal of waste (McDonough and Braungart, 2002). It consists of taking resources out of the ground and converting them mostly to elements that are designed to be thrown away after disposal. According to Braungart et al. (2006) the concept of cradle-to-cradle takes account of the embedded energy in disposal waste and therefore simply follows the principle that it takes enormous energy to make, but it is easy to recover and re-use. The application of cradle-to-cradle concepts to the disposal of buildings contributes to the recovery of materials out of the life-cycle by a closed loop process with zero loss in material performance (Braungart et al., 2006; Newcorn, 2003).

Cradle-to-Cradle strategy is rooted in the system of the natural world, which in fact is the effective application of resources obviating the need for efficiency (Braungart et al., 2006). The materials of building elements which return to industry at the end of their life can be used to produce equally valuable new elements. Consequently the construction industry can reduce costs by recovering valuable materials from buildings at the-end-of-their-life (Newcorn, 2003; Shakantu et al., 2002).

The selective collection of recoverable materials, as an essential part of any disposal activity, has a big potential for saving money (Canvangh, 2005). Through carefully selecting building components it could be cheaper to manufacture or recycle the recovered building elements into materials again, thus lowering or containing overall costs (Braungart et al., 2006; Newcorn, 2003). Especially in the field of mineral waste new ways have been developed, such as the use of recycled aggregates for the production of concrete. According to Seemann et al. (2002) and Baron (1999) the selection of materials requires extensive manpower and incurs the highest costs with the smallest output, while machines offer lower costs and a shorter overall disposal time. On the other hand, the possibilities of sorting of disposal waste as well as material automated by preparation devises are not entirely taken into account in the current procedures.

3 DISPOSAL METHODS AT THE END OF A BUILDING'S LIFE

3.1 Disposal cost

Disposal revenues and costs are the anticipated value at the end of the economical life span of a building and include expenditures for demolition, preparation for recycling and/or re-use and disposal as waste (BSI-ISO, 2002; El-Haram and Horner, 1998). Factors that influence the disposal costs are e.g. size, height, type of construction, volume of recyclable elements and resale value. The disposal of buildings is driven by the relatively highly externalised costs of landfill charges, labour costs and the duration of the disposal process (Guy and Shell, 2002). A cradle-to-cradle concept for the disposal of buildings contributes to a high-quality re-use of materials and to a reduction of disposal costs.

3.2 Condition survey of common disposal methods

A detailed analysis of the proper disposal method is necessary for the profitability of a disposal project. In particular, the severe land fill regulations and increasing disposal charges demand a reconsideration of ways for reuse and recycling. The Department of the Environment, Transport and the Regions points out that companies who are carrying out dismantling and recycling procedures together may have a better chance for profitability (DETR, 1994).

Generally, there exist internal and external conditions which have to be taken into account in order to achieve the maximum outcome both in terms of sustainability and profitability (BMVBW, 1998). Internal conditions (inside the company) include the proper equipment, knowledge of modern disposal procedures, and special qualification of the staff. External conditions consider the correct assessment of the building and unforeseen circumstances. Only a comprehensive analysis and calculation combined with consideration of environmental and social impacts can ensure the success of a disposal project. Schultmann and Rentz (2002) and Lauritzen (1998) highlighted the impressive reductions in disposal times and costs that can be achieved by project scheduling. There is an increasing number of firms working at the disposal sector of buildings. The quantity of firms in the UK rose from 1991 to 2001 by about 70%. There is clearly a trend to an increasing economical importance for disposal of buildings at the end of their lives (DTI, 2002).

3.3 Demolition

Among the different procedures for disposal of buildings, demolition represents the 'traditional' method. Augusten (2001) defines demolition as "destruction of the material structure with separation of connections whereas a recovery of units and recycling or reusing is not possible". In general, there is no selective separation of materials accompanying demolition. Several methods can be used for a proper demolition of facilities: the choice of the best one depends on several conditions. The most common are removing or breaking off, grabbing, smashing, tearing and blasting of walls, concrete and reinforced concrete. However, another very important factor that has a great impact on the choice of the proper procedure is the economic one. The resulting mass has to be disposed of in the cheapest way. Therefore, it is absolutely necessary to consider all potential costs for the disposal project. Broadly, demolition can be regarded as a low technological process, since rapid destruction and disposal of structures are often the main aims of the contractor.

3.4 Selective deconstruction

To reduce waste and cut costs associated with building disposal more and more attention is focussed on deconstruction. Instead of demolition, deconstruction can be used for a disposal project. Deconstruction means the destruction of the material structure without separation of connections. It includes the partial or complete dismantling of a building in its components. Selective dismantling instead of demolition helps the separation of different building materials and contributes to the high quality re-use and recycling of materials. Although the process is not new, many contractors in the industry want to know under what conditions deconstruction is cost-effective.

Legal regulations are becoming tougher and the costs of land fills are rising (HM Treasury, 2006). Particularly, strengthened legislation, such as the German waste act, requires that different materials have to be separated as well as possible (Federal German Government, 1994). Several studies have shown that dismantling strategies like selective deconstruction are not necessarily disadvantageous from an economic point of view (Gensior, 1999; Schultmann et al., 2001). Thus, the costs for selective deconstruction can be decreased while the quality of the recovered materials can be maintained or increased. In particular, the immensely increasing costs for land fill gives developers and demolishers a great incentive to reuse and recycle as much material as possible. The sharp fall in the volume of waste disposed to landfill by 28 per cent between 1997 and 2005 as a result of the increase of the standard rate of landfill tax demonstrates the potential for selective deconstruction (HM Treasury, 2006).

Selective deconstruction can be financially viable and contribute to the reduction of wastes disposed to landfill. It requires an effective sorting of the different material before and during this process. The main factors affecting a deconstruction process are the technical requirements, cost and time constraints. Generally, selective deconstruction of buildings takes more time than demolition. Often it takes from two to ten times longer than demolition (Rentz et al., 1994).However, it is a relatively new kind of disposal and the technique is still in its infancy. As technical possibilities and experience grow, this ‘time-disadvantage’ will decrease more and more. Poor quality of recycled materials and contamination of materials can reduce the quantity that can be economically re-used or recycled. Since selective deconstruction contributes to a high recovery rate of waste the cradle-to-cradle concept for waste management and selective deconstruction have synergistical effects.

Depending on the measures, selective deconstruction is often connected with a higher effort for initial inspection and planning. The effects on the costs need to be estimated at a higher accuracy, than with demolition. As a result markets for recycled building materials continue to develop and selective deconstruction will become more attractive. In particular this procedure can be economically viable if the value of the materials recovered offsets the additional labour costs associated with dismantling the building. Selective deconstruction deals with dismantling stages which are primarily structurally conditioned. In order to reduce the cost for selective dismantling and to encourage the use of cost efficient technologies, deconstruction, sorting of waste and the potential use of recycling plants should be combined in an integrated approach.

Figure 3 demonstrates the rough sequence of a selective deconstruction procedure. The procedure starts with the removal of selected materials while continuing with the removal of non structural elements. In the next stage, structural elements will be dismantled after pre-treatment. Finally, the dismantling of residual material will take place. The first and the last stages are mostly part of demolition projects.

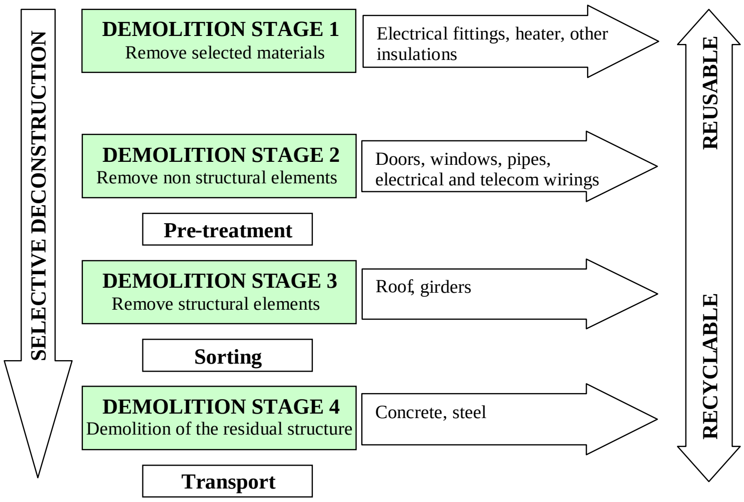

Figure 3: Demolition stages for selective deconstruction

4.5 Comparison of demolition and selective deconstruction

The selection of an adequate disposal method for buildings is crucial for future disposal projects in relation to sustainable construction. A detailed analysis and a weighing of advantages and disadvantages of each method are necessary. The most important advantages of the two methods previously described are summarised in Table 1. The arguments are likely to increase the use of selective deconstruction, at the expense of demolition with its high amount of waste for land filling. The costs for selective deconstruction depend to a high degree on the dismantling stage.

Table 1: Advantages of demolition and selective deconstruction

Demolition	Selective deconstruction
- Short project time - Lower labour costs - Easier calculation of costs - Higher site safety through less work by hand and more clear procedures	- Minimisation of landfill charges - High potential for saving transport costs - Resale of salvaged material can offset the costs of deconstruction - Increase in reputation for the company - Less use of natural resources through embedded energy in selected materials - Creation of new jobs through labour-intensive selection of materials

4 CASE STUDY

The case study presented here is derived from an earlier selective deconstruction project in Germany (Rentz et al., 1994). The purpose of this case study is to illustrate that selective deconstruction following a cradle-to-cradle concept for disposal of buildings offers a more profitable route than demolition. The case study compares selective deconstruction and possible demolition in the year 1993 with disposal in the year 2002 in order to demonstrate that selective deconstruction with a high rate of re-use and recycling of disposal waste is technically and organisationally realisable.

The aim of the project in 1993 was the realisation of a selective deconstruction project for the first time. The selective deconstruction of the 'Hotel Post' in Dobel in the rural district of Calw took place in cooperation with the German-French Institute of Environmental Research in Karlsruhe. The half-timbered building which was erected in the year 1910 had a Gross Enclosed Volume of 4,950 cubic metres and a total waste amount of 1,095.89 tonnes. The project costs are divided into labour & plant, disposal charges and transport, while the planning costs were included in the costs for labour.

The rate for pre-sorting wood and metal as well as mineral material in 1993 are adopted from Rentz et al. (1994). Prices for construction waste have been evaluated from the local landfill sites. Furthermore the costs for labour & plant and transport in 2002 are calculated from the price index for building and the development of labour costs between 1993 and 2002 given by the Federal Statistical Office. This gives us an increase in costs for a disposal project today of about 20% which is equal to an annual price increase of about 2% in this sector. The decreasing volume of activity in the building sector and high price competition within the German construction sector contribute to this lower price rise.

The difference in the total demolition costs amounts to 8% between the years 1993 and 2002. Comparing the single cost categories for demolition, they are about 8% higher for labour & plant, about 7% for disposal and about 20% for transport. The effect of a new waste classification for wood as well as higher demands for mineral waste as a result of stricter regulations, such as the German Waste Act, is included in the calculation of the disposal costs for the year 2002. Consequently, the mixed disposal waste salvaged from demolition offers less opportunity for reuse in the year 2002. Additionally, a reduction of about 10% in labour & plant costs in the year 2002 has been included, to take account of technological progress over the years.

The calculation of costs for selective deconstruction shows that the total project costs for deconstruction would have to remain at almost the same level as in 1993. Comparing the single cost categories for demolition they are about 5% lower for labour & plant, about 18% lower for disposal and about 20% higher for transport. An enormous potential for saving money could have been achieved through the re-use and recycling of almost 75% of all material which would generate revenue and reduce total disposal costs. Furthermore the pickup of some 56 tonnes of wood equal to approximately 66% of the whole amount of wood has a great influence on the reduction of disposal charges.

The comparison of each cost category is shown in Table 2 based on prices in 1993. It can be clearly recognised that high profitability can be achieved by selective deconstruction. In direct comparison the use of selective deconstruction is about 27% cheaper in 1993 and about 33% in 2002 than demolition.

Table 2: Costs of demolition and selective deconstruction

Costs	1993			2002		
	Demolition	Selective deconstruction	Difference	Demolition	Selective deconstruction	Difference
Labour & plants	€ 26,633	€ 32,404	22%	€ 28,744	€ 30,721	7%
Disposal charges	€ 45,743	€ 10,582	-77%	€ 48,817	€ 8,706	-82%
Transport	€ 6,976	€ 15,178	118%	€ 8,371	€ 18,214	118%
TOTAL	**€ 79,352**	**€ 58,164**	**-27%**	**€ 85,932**	**€ 57,641**	**-33%**

There is a striking difference between the disposal costs of demolition and selective deconstruction. It can be seen that there is a high proportion of net disposal charges in demolition, while selective deconstruction has a higher proportion of transport costs, which are lower than disposal charges.

Selective deconstruction offers the most competitive disposal method under the given basic conditions. In particular, the increase in disposal charges and the strengthened legislation encourage selective deconstruction as the most profitable way of disposal of buildings. However limitations also exist on the assessment. Social impacts and benefits have not been considered due to the limited data available for the year 1993. The benefits and costs of the social influence for such a waste management concept are potentially significant in assessing the overall effects of disposal activities. Also, the costs of remanufacturing or re-using recovered materials and the emissions associated with the transport of these materials could have a substantial impact on the assessment of sustainability.

5 CONCLUSION

The construction industry is seen as a key indicator of growth and prosperity. It has a great responsibility for the implementation of sustainable approaches. This paper has demonstrated the lack of opportunities for cost saving and for reducing environmental burdens in the present disposal methods for buildings.

The application of cradle-to-cradle concepts to the disposal of buildings contributes to the recovery of materials with zero loss in material performance. The creation of cradle-to-cradle concepts for disposal waste encourages the development of modified procedures for disposal of buildings. Strengthening legislation and greater disposal regulations for waste disposal as well as the public's growing sustainable awareness increase demand for new disposal methods.

The application of selective deconstruction can contribute to disposal projects for buildings in an economically efficient way without neglecting ecological issues. As the selective dismantling and sorting of materials in deconstruction generally is more labour intensive than traditional demolition methods, the cost also tend to be higher. Selective deconstruction combines dismantling, selecting and sorting of materials. On the other hand, the cost of selective deconstruction can be decreased by the amount of recovered materials for high-quality re-use and economic recycling.

Acceptance of selective deconstruction by the industry depends on demonstrating the economic advantages bought about by a high level of dismantling and conscientious sorting of materials. Further research should be undertaken to investigate the social costs and benefits associated with selective deconstruction procedures using full cost accounting.

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