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Economic Viability of Construction and Demolition Waste Management in terms of Cost Savings - A Case of UK Construction Industry

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Abstract- The excessive building material waste, ineffective management on construction site, lack of data available on waste management strategies, lack of administrative capacity at local and regional level, ineffective enforcement and control of sound business plans and waste practices are common in some UK constriction sites. Today, in most European states, it is economically viable to recycle up to 80-90% of the overall C&D waste [21]. The rapid growth of the construction industry alongside complex activities have been responsible for the increase in the amount of waste generation which often result to the economic consideration in terms of cost-savings. With the increase in management and recycling operational costs and the lack of trained staff and expertise to undertaken appropriate measures to minimize waste, the UK construction industry faces a number of challenges in recent times. This paper aims to present the economic viability of applying the 3Rs principle to C&D waste in terms of cost savings in the UK construction industry.

Keywords*- Construction and Demolition (C&D) waste, 3R principle, Economic theory, Benefit-Cost Analysis (BCA), Site Waste Management (SWM), UK Construction Industry*

I. INTRODUCTION

All over the world, waste may be generated during both extraction and processing of the raw materials as the construction industry consumes a significant amount of natural recourses and often generates large quantities of building waste. Rubbles and other waste and other building waste materials arise from construction activities like demolition, refurbishment works and new construction [1]. Construction is one of the largest sectors of the UK economy and contributed £103 billion in economic output, 6.5% of the total in 2014 as shown in Table 1 [2]. Interestingly, construction, demolition, renovation and refurbishment works account for around 100 million tonnes of waste in the UK each year.

Significantly, construction activities such as demolition, refurbishment and renovation projects generate mixture of inert and non-inert materials, which are predominately referred to as construction waste [3]. Materials resulting from construction and demolition of buildings and infrastructure constitute a significant amount (10-15%) of the total municipal solid waste stream [4]. The UK construction industry is a key sector for the UK economy. It contributes almost £90 billion to the UK economy (or 6.7%) in value added, comprises over 280,000 businesses covering some 2.93 million jobs, which is equivalent to about 10% of total UK employment [5]. The output from the construction sector is at around the 2005 level, and below output between 2006 and 2008.

TABLE I. GROSS VALUE ADDED: SECTOR'S CONTRIBUTION TO THE UK ECONOMY

Year	**Table Column Head**		
	£ billions (current price)	***Real % change***	***% of economy***
1997	43	…	5.5%
1998	47	1.5%	5.7%
1999	48	1.3%	5.6%
2000	56	0.9%	6.1%
2001	59	1.8%	6.2%
2002	66	5.7%	5.7%
2003	72	4.8%	4.8%
2004	76	5.3%	6.8%
2005	81	4.8%	6.8%
2006	86	5.3%	6.8%
2007	91	-2.4%	6.8%
2008	90	0.8%	6.9%
2009	81	2.2%	6.6%
2010	84	-2.6%	6.0%
2011	92	-13.2%	6.3%
2012	89	8.5%	6.0%
2013	92	2.2%	6.0%
2014	103	9.5%	6.5%

Source: ONS, 2014

The construction industry is considered to be one of the largest in terms of economic spending, environmental impact, raw materials/natural resource usage, jobs creation and waste generation. With the increase in C&D waste generation through construction activities, the construction industry has been challenged with issues relating to economic and environmental impacts resulting from lack of waste minimisation techniques. The economic and environmental benefits expected from C&D waste minimization are relatively essential [6][7], since it provides key benefits to both the environment and the construction sector in terms cost savings. One of the key challenges to waste minimization is inability to devise proper management strategy in order to reduce or prevent construction waste stream. This paper aims to address the problem of C&D waste and management awareness, strategies, and current practice in the UK construction industry, further evaluating the economic viability of applying the 3Rs principle to construction and demolition waste in terms of cost savings.

II. WASTE MINIMISATION – CURRENT PRACTICES

A. *UK construction Industry*

Despite recent economic and financial crisis which affected most developed economies, the UK construction industry remains one of the largest in Europe, measured by job created, number of enterprises, and grow value added [8]. Table II below shows the value of construction sector according to type of work in Q1 2015.The private sector, including commercial sector were worth about £6.2 billion, which is about 30% of the total output. The cost saving potential in the UK runs for billions of pounds.

TABLE II. VALUE OF CONSTRUCTION OUTPUT BY TYPE OF WORK

Q1 2015			
		£ billions	% of total
Private sector		15.3	74%
	Housing	5.6	27%
	Infrastructure	2.5	12%
	Industrial	1.1	5%
	Commercial	6.2	30%
Public sector		15.3	74%
	Housing	5.6	27%
	Infrastructure	2.5	12%
	Other	1.1	5%
Total		20.7	

Source: ONS, Output in the construction sector, 2015

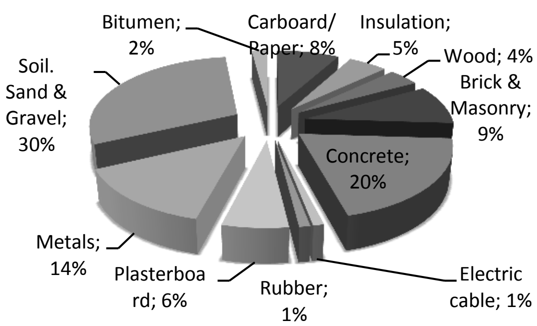

Figure 1. Waste streams at various stages of construction

Table II shows the distribution of cost among sectors in the UK construction industry. Both the private and public sector have increased in total output. The significance of materials cost indicates that major component of material cost, which is about 18% to 65% of the project cost. This shows that building material waste generation from construction activity is enormous in volume and in monetary terms. Therefore, there is a need for an economic evaluation of building material waste within the industry with appropriate waste minimization techniques.

TABLE III. PROJECT COST DISTRIBUTION IN UK CONSTRUCTION INDUSTRY

	Materials	**Construction equipment**	**Labour**
Housing	65%	9%	15%
Infrastructure	26%	32%	18%
Industrial	38%	25%	20%
Commercial	45%	19%	11%
Other	18%	8%	8%

Figure 1 and Table 3 show project cost distribution of C&D waste streams at various stages of construction in United Kingdom in 2014 [9]. The role of reducing waste is not just by the designer, the Government, contractors, subcontractors, suppliers, project stakeholders and client plays a huge role in ensuring better performance of managing construction waste. In practice, almost 8 out of 10 UK construction firms implemented or incorporated a many of proposed activities to reduce or minimize waste [10]. Thus, the segregation of waste, materials handling and improved storage methods were the most common initiatives were used by firms.

The UK construction industry spends over £200 million on Landfill Tax each year. Construction waste typically costs companies 4% of turnover with potential savings of 1% through the implementation of a comprehensive waste minimization program [11]. The UK Government adopt regulation, economic instruments and voluntary agreements to meet targets of ethical, social and environmental performance, pursuit for a step change in the sustainability of procurement, design, and operation of all built assets, to be driven by innovation [9]. It has been reported that 'waste accepted as inexorable'; lack of training, poorly defined responsibilities are underlying issues with designing was reduction in construction [12].

The separation techniques for most materials often attract advance technology options and legislative control with an underlying 3Rs waste management hierarchy principle. Waste management concept is guided by level of hierarchy explained by El-Haggar [13]. This model produces an integrated approach in which options of waste management can be considered and thus serves as a systematic tool for those who generate and manage waste [14]. El-Haggar [13] argued that when waste is being managed effectively it could generate various benefits through the wholelife cycle of the waste from its generation to its end disposal. Significantly, it is believed that proper construction waste management will provide both economic and environmental benefits. A number of construction firms as well as the environment at large will benefit through the cost reduction process involved in waste management.

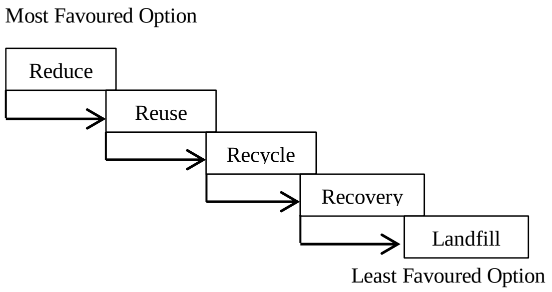

Figure 2. Waste Management Hierarchy (Source: El-Haggar, 2007- Sustainable Industrial Design and Waste Management)

The economic and environment benefits expected from waste minimization are relatively essential as it drives towards the opportunity seen in recycling and the possibilities of selling secondary waste materials as well as the meeting targets on reducing the number of C&D waste being diverted to landfill [14]. Although the transfer of waste to landfill often attracts associated fees/charges and this can be minimized if only waste stream from construction are effectively managed.

B. Construction Waste Reduction Approaches in the UK

Waste minimization in the UK is not a new approach to the construction industry. Waste management in the UK involves understanding and complying with a list of legislation and regulations. The EU Waste Framework Directive provides the legislative framework for the collection, transport, recovery and disposal of waste, and includes a common definition of waste [16]. According to Osmani [9] the current practices in the UK for waste reduction can be broadly categorized into the following and not limited to:

- Construction waste quantification and source evaluation
- Procurement waste minimization strategies
- Designing out waste
- On-site construction waste sorting methods and techniques
- Development of waste data collection models, including flows of waste and waste management mapping, to help with the handling of on-site waste
- Development of on-site auditing and assessment tools
- Impact of legislation on waste management practices
- Reuse and recycle in construction
- Waste minimization manuals, including guides for designers.

The above lists indicate strategies to promote awareness of benefits of waste minimization in the construction industry, including cost savings, and environmental impact and use of secondary (recycled/reclaimed) materials. Interestingly, legislative and fiscal measures are undoubtedly the major driver for construction waste reduction in the United Kingdom, which were directly related to the rising Landfill Tax, increasing cost for waste disposal, and adhering to the Site Waste Management (SWM) Regulation 2008. Sadly, the current legislation fails to impose responsibilities on architects to minimize waste, which is by far most practical way to reduce waste at early design phase, rather than implementing waste minimization measures later on during construction phase [12].

III. PROBLEMS WITH WASTE MANAGEMENT IN CONSTRUCTION INDUSTRY

The UK construction industry has been faced with many challenges to successfully implement waste management strategies in terms of ineffective management on construction site among others. However, the economic benefits in terms of cost savings are still limited. The following key barriers were identified in a few studies found in literature, Osmani [10], Hansen et al. [17] and Saez et al. [18]:

1. *Ineffective management on construction site*: despite the introduction of the SWM regulation 2008, ineffective management on construction site continues to affect the building material performance. A few construction projects are yet to conform to the waste management regulation and not effectively managing their overall waste generated from construction works [18].

2. *Lack of data available on Waste Management Strategies*: the major barrier in construction industry is the lack of appropriate data and awareness of local contractors on waste minimization techniques. This often result to poor waste handling on site [18]. A coherent waste management strategy that must be set up and implemented. It would involve including management plans at all different management levels.

3. *Lack of administrative capacity at local and regional level*:

   The legislative competence and the physical responsibility fro each task of waste management within a country both at local and/or national level must be clearly delegated. Regional and local authorities mainly responsible for planning, enforcement and control, often are not able to fulfill their tasks adequately because of lack of administrative and/or monetary capacity. Transparency and public participation must be enriched [17]. The task of implementing the waste hierarchy in waste management practices within a country must be clearly delegated to the different levels of government (national, regional, local) and to other possible actors including industry, and private companies. The lack of finances, information, and technical expertise must be overcome for effective implementation of waste management policies and practices.

4. *Ineffective enforcement and control of sound business plans and waste practices*: ineffective enforcement of waste management legislation and the development of a realistic business plans and best practices continue to create greater challenges for local authorities and contractors [17].

5. *Poor defined responsibilities and lack of training:* poor defined responsibilities in designing out waste remain greater challenge for the UK construction industry. This is simply means should not be accepted as inevitable for designers such as architects to design in waste reduction measures in many construction projects. Adequate training facilities for designers, contractors, subcontractors etc. must be employed [10].

The UK Construction industry has contributed positively to waste minimization over the years [11]. The 3Rs (reduce, reuse, recycle) principle has been wide employed to achieve a successful waste minimization process within the industry. However, the impact of the waste management legislation particularly, the Landfill Tax, and its effects on waste practices in the industry have raised a number of controversies in recent times [11]. Significantly, management tool such as SMART Waste developed in the UK have helped the construction industry to effectively handle and better manage on-site waste generation and assess the linked cost-saving implications. The SMART Waste tool facilitate on-site auditing, waste management, and as cost analysis for known waste stream.

Thus, the UK Government has introduced a landfill tax, aggregate levy and other waste management regulations that encourage the diversion of waste from landfill, promote reuse and recycle strategies, and emphasise environmental responsibility. Further measures are needed in terms of cost-savings for reuse and recycling operations if the construction industry is to realize waste minimisation as part of its core activity [19]. The ultimate cause of waste are due to design issues, however, key contributing factors such as procurements, handling of materials and construction operations [20]. There is a need for the construction industry to understand these key factors and be able to mitigate the extent of the problem by evaluating the cost saving potential in managing C&D waste on site.

IV. SIGNIFICANCE TO ECONOMIC MODEL

A. Economic viability in terms of cost savings

The economic viability of C&D waste handling on construction site is investigated and evaluated in this section. This section focused on justifying how the cost saving potential can be achieved in the construction industry. It is important to understand the economic model and its significance to achieving the economic feasibility of managing C&D waste. Economic model, however, provides an outlet for research in all areas of economics based on rigorous theoretical reasoning and on topics in mathematics that are supported by the analysis of economic problems [21]. However, the conventional economic feasibility in terms of cost-savings of handling construction waste is often carried out by a standard measure of profitability derived from a Benefit-Cost Analysis (BCA)[22].

BCA is considered for this study to estimate the economic viability of C&D waste handling on construction site. The study attempt to evaluate overall project cost, amount of waste generation, sources, waste composition and the cost of reuse and recycling of C&D waste. A few studies argued that argued that the economic impact of recycling can be measured through industrial output, total income, value added and number of jobs created [22-23]. The study estimated the net benefits to evaluate the economic viability of reuse and recycling of C&D waste on the project site. The net benefit can be expressed using economic theory by Eq. (1):

$$N_B = T_B - T_C \quad (1)$$

Where $\mathbf{N_B}$, is the net benefits, $\mathbf{T_B}$ the total benefits and $\mathbf{T_C}$ is the total costs. The total benefits ($\mathbf{T_B}$) are all the advantages of reusing and recycling of C&D waste. This is considered the sum of all direct, indirect and intangible benefits. Thus, the total benefits can be expressed further in Eq. (2)

$$T_B = P_{CS} + T_{SM} + CS_{WCT} + CS_{LF} + I_B \quad (2)$$

Where $\mathbf{T_B}$ is the total benefits of reusing and recycling of C&D waste on the site, $\mathbf{P_{CS}}$ the purchasing costs savings by reusing an recycling of C&D waste, $\mathbf{T_{SM}}$ the turnover from selling of scrap C&D waste materials, $\mathbf{CS_{WCT}}$ the waste collection and transportation cost savings by reusing and recycling of C&D waste, $\mathbf{CS_{LF}}$ the cost savings from landfill fees by reusing and recycling of C&D waste, and $\mathbf{I_B}$ is the intangible benefits. The total costs are all the incremental costs associated with the reusing and recycling of C&D waste. This is the sum of all direct and indirect and intangible costs respectively. Total costs can be expressed by Eq. (3)

$$T_C = CS_C + EP_C + S_C + T + I_C \quad (3)$$

Where $\mathbf{T_C}$ is the total costs of reusing and recycling of C&D waste on the site, $\mathbf{CS_C}$ the collection and separation costs of C&D waste, $\mathbf{EP_C}$ is the equipment purchasing costs, $\mathbf{S_C}$ is the storage costs, T the transportation cost od disposing waste to landfill and $\mathbf{I_C}$ is the intangible costs. The economic feasibility of a recycling program often depends on whether the added cost (time, effort and resources/equipment) associated with the recycling activities is less than the avoided costs (tipping fees, labor, haulage, maintenance, taxes, and local permanent fees) as shown in Eq. 4 below [4; 24].

$$N_B = T_B > T_C \quad (4)$$

Company can engage in cost-savings by reusing and purchasing recycled building material rather than buying virgin building materials from the market [22]. Purchasing costs savings is very essential in quantifying cost benefit for C&D waste. Therefore, if any construction company could not reuse and recycle building waste materials it would be needed to buy those materials. The study found out that estimated purchasing cost savings for C&D waste is the sum of the cost saving from materials market price and the transportation cost savings expressed in the Eq. (5) below

$$P_{CS} = CS_{MP} + TCS \quad (5)$$

Where **P_{CS}** the purchasing costs savings by reusing and recycling of C&D waste, **CS_{MP}** the cost saving from market price and **TCS** the transportation cost saving. The study shows that waste minimization is economically viable and also plays a key role for the improvement of environmental management. The economic determinant of recycling operations lies within this context, as cost remains a key aspect of choices for best practices for waste minimization. Outcome of the study shows that cost of handling waste practices is considered highly than its benefits. However, evaluating all monetary terms for physical benefits and associated costs for intangible items provides the economic viability of C&D waste handling on construction site. In performing BCA of waste minimization using the 3Rs principle, all the benefits and associated costs are carefully considered.

The study attempted to measure all benefits and costs in terms of monetary value as well as those costs and benefits with non-monetary value, which is described above as tangible benefits (**I_B**) and intangible costs (**I_C**). Total benefits consist of both the direct and indirect benefits relating to purchasing costs savings (**P_{CS}**) and waste collection and transportation cost savings (**CS_{WCT}**) respectively. We argued that waste practices have many cost-related challenges in terms of improper planning, lack of incentives, designing out waste at the early stage of project. However, a number of approaches have been proposed over the years to mitigate the impact on waste generation. To address the underlying cost-benefit issues and to promote waste minimization in many construction sites the following strategies are discussed.

V. STRATEGY TO ADDRESS THE PROBLEM

Investigating the ineffective waste management practices on construction site, this aspect of the research study suggests appropriate strategies that can be used within the industry to address the extent of problem at hand. The cost-saving potential relating to waste minimization within the industry remains a key measure to justifying the economic viability of C&D waste handling on construction site.

1. Effective Co-ordination – Partnering and Collaboration

To minimize waste generation, improve building material recovery process, there is a great need for construction professional to work in partnership and ensure information sharing within their network. Study suggests that contractor will benefit from waste reduction in the cost of waste disposal, rather more benefits will be seen from waste minimization perspective if partnering is encouraged. There is no unified view as to what partnering relationships are in the construction industry. A few studies have supported this concept as an approach to improve construction industry [25; 26; 27].

The definition of partnering in construction was cited in these studies as a long-term commitment between two or more parties in which shared understanding and trust development for the benefits of improving construction. Despite great interest, efforts to implement the partnering concept in the construction industry are yet to yield the positive effects that have occurred in other industries [28]. This perceived underperformance is as a result of the tendency to focus on mutual relationships between, clients, contractors, designers, sub-contractors and suppliers [29]. To ensure that optimum benefit from 'zero waste' and best waste management practices are achieved, the supply chain in construction should consider 'partnering' as a robust approach to mitigate the problem.

2. Designing Out Waste – Role of a Designer

Designers such as architects, civil engineers, technicians are required to design building following guidance from the WRAP "design out waste" [11]. Designers should consider standard sizes, densities, positioning and height to enhance the process of waste minimization and primarily to achieve cost savings in construction. Recyclable building materials are required to be incorporated in design at the early phase of design and construction. Architects have a major role to play in providing the right specifications when designing out waste. This approach presents a proactive target options to reduce waste, recognizing that some key solutions on a project are most likely to achieve waste minimization, along with cost savings, carbon reduction and other related benefits.

3. Enforcement and Incentive – Robust Policy Implementation

Addressing the lack of enforcement and local control should start from Government's intervention in ensuring waste management legislation is put into practice. The UK Government should provide a robust approach to implementing the waste management legislation. Although, the EU Waste Framework Directive have been a start-point to EU environmental concern and effective management of waste across it states, the UK however derived its legislation from this framework. Study suggests that the UK government should carefully consider sustainability in this context in order to ensure that citizens understand the benefits of the 3Rs principle across all industry-sectors not just in construction at a whole.

Other aspect of policy implementation is the introduction of landfill tax to promote waste minimization and lack of incentives for producing secondary materials (reusable and recyclable materials). There is a need for the Government to design a Tax credit for firms who create secondary materials (recycled building products) directly on-site or off-site. We study suggests that the Government should revise the Landfill Tax regulation 2013 and develop provisions for substantial incentives for the construction industry to embark more on recycling operations and reduce the rate of waste stream being diverted to landfill. The Government plays a major role in major in ensuring the construction industry improves amount of C&D waste at its source.

The development of the Site Waste Management Plans and other legislation such as Energy Performance of Building Directive, UK Climate Change Act 2008, and Environment Impact Assessment are tested tools to provide a better waste handling on many construction sites. However, the construction industry faces key challenges such as improper management execution and attention to detail on economic and environment impact with waste generation. We believe that the introduction of Tax credit for recycled materials will further create incentives for many local contractors and recyclers. Developing robust policy context will help create awareness on economic benefits of reusing and recycling C&D waste.

4. Education and Training

Lack of training and education to promote waste minimization remains a major challenge facing the UK construction industry. Since the introduction of the SMART Waste tool in the UK, there is a need for education and training to unskilled labour and other construction professionals to gain knowledge on waste minimization and the need for cost-savings as well as environment impact. Therefore, the many construction firms has the duty of care and the responsibility to ensure their workforce are fully educated and trained to handle waste directly on and off construction sites. Training in construction is introduced to improve skills, increase competitive edge and respond to many challenges employers face [30].

5. Access to Information – Waste Management Strategies

Lack of data available on waste management strategies continue to affect a number of small construction firms in the United Kingdom. A lack of data available on waste management strategies must be overcome and extensive monitoring requirements must be met to successfully implement the waste minimization initiative. Access to information often helps a number of project stakeholders; client, contractors, sub-contractors and suppliers understand the business case for waste minimization program.

VI. IMPLICATION TO PRACTICE

The proposed strategies can help the construction industry in a number of ways in terns of cost-savings and environmental impact. However, managing C&D waste has become one of the major environmental problems in the world. The proposed strategies to mitigate this problem are stated in this study. The study further suggests that the Government and other project stakeholders should continue improving waste minimization on construction sites. Significantly, the introduction of 'tax credit' will further encourage local contractors, recyclers, and aggregate users to consider secondary (reusable and recyclable) materials as a better option.

Waste minimization technique help reduce the significant quantities of construction waste sent to landfill and encourage cost-savings for both economic and environmental benefits. More efficient use of building material would make a major construction to reducing the environmental impacts of construction including reducing demand for landfill and the depletion of finite natural resources [11]. Major improvements in building materials efficiency are possible without increasing costs by minimizing the overall creation of waste resulting from inefficient design and also reducing the quantity of material sent to landfill.

Clients, project stakeholders and contractors can secure best practice for waste minimization from an early design stage in construction in terms of cost savings and demonstrating corporate responsibility throughout the construction lifecycle. However, the benefit derived from cost-savings through waste minimization practices provides many local contractors the opportunity to recycle market where waste can be seen as a resource.

VII. COST/BENEFITS OF REDCUING WASTE: A CASE STUDY

Waste minimization is known as a primary focus for most waste management strategies. Reducing, reusing and recycling waste can help to reduce costs on construction projects. Achieving the costs and benefits of reducing waste in construction can be achieved through good practice from early design and planning stage. The current case study identifies project at design stage, the costs and benefits achieve through waste reduction and the recovery on a construction project.

The case study is a £23m new build concrete-frame office with plant room and lower ground floor parking. The project is constructed using substructure, frame, floor, roof and external walls is a block work inner skin with aluminum rain-screen cladding. Significant savings can be made by targeting good practice wastage rate for the 10+ components offering the biggest savings in the value of materials wasted. The cost-saving potential below will be shared across the supply chain where client and principal contractors can increase their share through the procurement process.

TABLE IV. DESIGN POTENTIAL

	Value of materials wasted (£)	Cost of waste disposal (£)	Total cost of waste	Total cost of waste as % of construction value
Best practice	202,072	45,043	247,115	1.07%
Good practice (all components)	94,235	19,228	113,463	0.49%
Targeted practice (top opportunities)	100,350	20,976	121,325	0.53%
Improvement over baseline	**£101,722**	**£24,067**	**£125,790**	**0.55%**

TABLE V. COST/BENEFITS SUMMARY

Achieving cost reductions (BENEFITS)	Baseline	Targeted practice	Improvement
Value of materials wasted: construction materials are a valuable resource, yet it is common to see high levels of waste through damage on site, off-cuts, over-ordering of materials and the need for rework	**£202,072**	**£100,350**	**£101,722** (0.4% of construction value)
Cost of waste disposal: Every skip or container of waste carries a cost. Whilst segregated metals are often removed at little or even zero charge, the majority of wastes carry substantial costs - and these are set to rise with the annual increase in landfill tax	**£45,043**	**£20,976**	**£24,067** (0.11% of construction value) (£20,672 saved through reduced waste arising and £3,95 saved through increased segregation)
Combined savings			**£125,790**

At the baseline, cost is 201,072 with targeted practice of £100,350 (improvement - 0.4% of construction value). Cost of waste disposal shows £45,043 at the baseline, targeted practice of £20,976 with an improvement of 0.11% of construction value. Table V shows that about £20,672 saved through reduced waste arising and £3,395 saved through increased segregation. The cost saving potential achieved as a result of management strategies to designer's approach to design waste at the early stage of construction. Practical solutions to good practice for the current case study indicated that £20,672 is incurred in order to achieve cost savings of £125,790. The benefits of using recycled materials are achieved by cutting down construction material value wasted and the reduction in the cost of waste disposal.

On the other hand, the cost required to cut down waste or enhance material recovery is determined by experience of contractors, aggregate users and recyclers during planning and waste management strategies implementation. However, building materials provide the largest cost reduction potential and demonstrate good practice at baseline. The potential cost saving for the reduction in value of materials wasted (i.e. £101.722) justifies the cost of waste minimization and management. The study suggests that designers need to look for opportunities to design out waste, contractors need to develop a quality SWMP and a materials logistics plan as well as the ensuring that all waste received are recycled wherever possible.

VIII. CONCLUSIONS

With the success of waste minimization techniques in many construction site, there are still some challenges found with management with the UK construction industry. These problems have both economic and environmental impact as clients, contractors, recyclers, aggregate users and others are striving to address the extent of the problem. Scrutinizing a number of reasons for the problem, excessive building material waste, ineffective management on construction site, lack of data available on waste management strategies, lack of administrative capacity at local and regional level, ineffective enforcement and control of sound business plans and waste practices are few of a number of reasons that considerably affect the construction industry as a whole.

The economic viability of managing C&D waste on construction site can be justified by the cost-savings potential in many cases. However, by understanding of proper waste management, the total benefits will continue to exceed cost associated to waste operations as a whole. The paper investigated the problem of C&D waste and management awareness, strategies, and current practice in the UK construction industry, and extended study scope to evaluate the economic viability of applying the 3Rs principle to construction and demolition waste in terms of cost savings.

The study found out that net benefit of reusing and recycling of C&D waste is estimated at a significant amount of total project budget. Realistically, the UK construction industry can, in fact, save money by implementing waste minimization practices using 3Rs principles in managing wastes on construction sites.

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REFERENCES

[1] Fagiya, O.O., Georgakis, P. and Chinyio, E. (2014), "Quantitative Analysis of the Sources of Construction Waste" Jounral of Construction Engineering, Hindawi Publishing Corporation, vol. 2014, pp. 1-9

[2] Rhodes, C. (2015), "Construction industry:statistics and policy: Briefing paper Number 01432 House of Commons Library

[3] McGrath, C. (2001), "Waste Minimisation in Practice" Resource, Conservation and Recycling, 32(1), pp. 227-238 (number 4)

[4] Srour, I. M., Tamraz, S., Chehab, G, R. and EL-Fadel, M. (2012), "A Framework For Managing Construction Demolition Waste: Economic determinants of Recycling", Construction Research Congress 2012 ASCE

[5] Department for business Innovation & Skills (2013), "UK Construction: an economic analysis of the sector" Crown copyright

[6] Hunt, N. and Shields, J. (2014), "Waste Management Strategy 2014 and beyond", Loughborough University.

[7] Begum, R. A. and Siwar, C. (2006), "A Benefit-Cost Analysis on the economic feasibility of Construction waste minimization: the case of Malaysia", *Resources Conservation & Recycling*, pp. 86-98

[8] UKCES (2012), "Sector Skills Insights: Construction

[9] Abdelhamid, M. S. (2014), "Assessment of different construction and demolition waste management approaches", Housing and Building National Researcher Center Journal, pp. 318-326

[10] Osmani, M. (2012), "Construction Waste Minimization in the UK: Current Pressures for change and approaches" Procedia – Social and Behavioral Sciences, **40**(2012), pp. 37-40

[11] Waste and Resource Action Programme (2009), "Designing out Waste: a design team guide for buildings"

[12] Osmani, M, Glass, J. and Price, A. D. (2006), "Architect and contractor attitudes towards waste minimisation:, Waste and Resource Management, **59**(2), pp. 65-72

[13] El-Haggar, S. M. (2007), "Sustianable Industrial Design and Waste Management: Cradle-to-cradle for Sustainable Development, Elsevier Academic Press Maryland Heights, MO.

[14] Tam, V. W.Y. and Tam C. M. (2006), "Evaluations of existing waste Recycling methods: A Hong Kong study", *Building and Environment*, Elsevier, **41**(2006), pp. 28-32

[15] Hwang, Bon-Gang and Yeo, Z. B. (2011), "Perception on benefits of Construction Waste management in Singapore Construction Industry" Engineering, Construction and Architectural Management, **18**(4), PP.394-406

[16] Aadal, H., Rad, K. G., Fard, A. B., Sabet, P. G. P., and Harirchian, E. (2013), "Implementing 3R Concept in Construction Waste Management at Construction Site*", J. Appl. Environ. Biol.* Sci., **3**(10), pp. 160-166

[17] Hansen, W., Christopher, M. and Verbuecheln, M. (2002), "EU Waste Policy for Regional and Local Authorities" Background paper for the Seminar on Household Waste Management Capacity Building on Eurpean Community's Envrionmental Policy, Eco-logic

[18] Saez, P. V., Del Rio- Merino, M and Porras-Amores, C. (2011), "Managing Construction And Demolition (C&D) waste – A European Perspective", International Conference on Petroleum and Sustainable Development IPCBEE **26**(2011) pp. 27-33

[19] Williams, I.D. and Turner, D.A. (2009), "Waste Management Practices in the Small-Scale Construction Industry", Waste Management Research

Group, School of Civil Engeering and the Environment, University of Southampton

[20] Assem, Al-Hajj, Karima, H. (2011), "materail nWaste in reh UAE Construction Industry: Main cause and Minimization Practices" Heriot-Watt University Research Hateway, Architectural Engineering and Design Management, **7**(4), pp.221-235

[21] Jain, M. (2012), "Economic Aspects of Construction Waste Materials in terms of cost savings – A case of Indian construction Industry" International Journal of Scientific and research Publications, **2**(10), pp. 1-17

[22] Begum, R.A., Siwar, C., Pereira, J.J and Jaafar, A. H. (2006), "A Benefit-Cost Analysis on the economic feasibility of Construction waste minimization: the case of Malaysia", *Resources Conservation & Recycling*, pp. 86-98

[23] Swenson, D. (2007), "Economic Impacts of Recycling In Iowa" Iowa Department of Natural Resources RW Beck

[24] Calvo, N., Varela-Candamio, L. and Novo-Corti, I. (2014), "A Dynamic Model for Construction and Demolition (C&D) Waste Management in Spain: Driving Policies Based on Economic Incentives and Tax Penalties, Sustainability, **6**(1), pp. 416-435

[25] Egan, J.S.(1998), "Rethinking Construction", Department of the Environment, Transport and the Regions, London.

[26] Glagola, C.R. and Sheedy, W.M. (2002), "Partnering on defence contracts" Journal of Construction Engeering and Management", **128**(2), pp.127-138

[27] Eriksson, P.E., and Nilsson, T. and Atkin, B. (2008), "Client perceptions of barriers to partnering", Engeering, Construction and Architectural Management, **15**(6), pp527-539

[28] Bygballe, L. E., Jahre, M. and Sward, A. (2010), "Partnership relationships in construction: A literature review", Journal of Purchaing & Supply Management, **16**(2010), pp.239-253

[29] Miller, C.JM., Packham, G.A. Thomas, B.C. (2002), "Harmoization between main contractors and subconstractors: a prerequisite for lean construction? Journal of Construction Research, **3**(1), pp.67-82

[30] Construction Industry Training Board (2014), "Skills and Training in the Construction Inudtsry 2014" CITB