Material waste in the China construction industry: Minimization strategies and benefits of recognition

Sulala M.Z.F. Al-Hamadani[1,2], ZENG Xiao-lan[1,2], M.M.Mian[1,2], Zhongchuang Liu[1,2]

[1] Three Gorges Reservoir Area's Ecology and Environment Key Laboratory of Ministry of Education, Chongqing University, Chongqing, 400045, China.
[2] National Centre for International Research of Low-carbon and Green Buildings, Chongqing University, Chongqing, 400045, China.

Abstract
Waste minimization strategies and the relative importance of benefits of material waste recognition were examined using a survey of construction companies operating in Chongqing city China. The results showed that a remarkable proportion of respondent companies have specific policies for minimizing construction waste. Amongst the strategies, minimizing waste at source of origin is practiced to a large degree by construction companies with specific waste minimization strategies. However, considerable quantities of construction waste are generated. These quantities need to be reused or recycled or combination of them. The study also revealed that recycling is not highly practiced because it needs a lot of capital and an area, except for those high scrap value recycling materials like steel, whereas other non-profitable will be sent to C&D landfills directly.
Respondents' perceptions towards the benefits of material waste recognition revealed that materials waste is primarily considered an environmental and financial problem and its minimization a cost cutting activity and protection of the environment. In contrast, the contractual benefits were considered less important by surveyed companies.

Keywords: Construction industry; Minimization strategies; Waste; 3R; Benefits of recognition; China.

1. Introduction
In the construction industry, it is well known that there is a relatively large volume of material being wasted due to a variety of reasons. The problem of material waste on construction sites is not an isolated issue and is of environmental concern. Therefore, waste minimization has become an important issue in the construction industry. Waste minimization has been defined as: any technique, process or activity which avoids, eliminates or reduces waste at its source or allows reuse or recycling of the waste [1]. There were three main waste minimization strategies used in construction projects: (1) reducing waste; (2) reusing materials; and (3) recycling waste. It has been concluded from many studies that minimization of waste at source must be prioritized when developing strategies for waste minimization. The other strategies are reusing and recycling waste which means putting the materials that are wasted into beneficial use. If the three strategies had not been applied, the generated waste will end up at landfill.

China has developed the same 3R principle. Similar to other countries, the hierarchy of waste management in China is emphasizing on reduce, reuse and recycle the waste and it is said to be the best approach in China [2]. Chinese government improves China's waste management system by way of changing the "China Waste hierarchy" into "The Danish Waste hierarchy", which means to reduce the landfill proportion and increase the proportion of waste reduce, reuse, and recycling (3R) as in Figure 1. The earlier of China's waste hierarchy model, the landfill occupied more than 80% for waste disposal and landfill is the least priority in the waste hierarchy [3]. This execution of the Danish model was successful in reaching a high recycling rate for construction and demolition waste [4]. The scarcity of landfill in China is the reason behind adopting the Danish Waste Model to minimize the usage of land for waste disposal by way of maximizing the waste reuse and recycling.
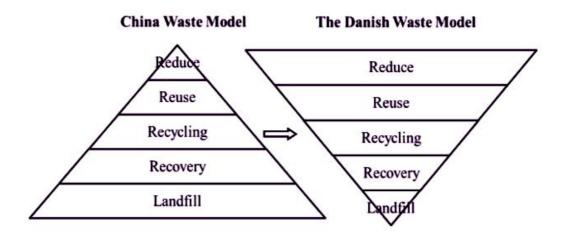

Figure 1. China's adoption for the Danish hierarchy model

Construction material waste recognition can provide financial, environmental and other benefits. These benefits can be appreciated over a short term or long-term period. But overall, cost benefits can be appreciated throughout the whole building process by carrying out an analysis of the life cycle costs. Environmental benefits, which are important to be considered due to the alarming situation of waste in China, where a total of 400 million tons of construction waste was generated in China each year [5], and the share of Chongqing city in 2008 was around 12 million cubic meters of C&D [6].

In this survey, the identification of the benefits of material waste recognition was obtained from literature reviews of both Refs [7, 8]. These are: It helps the contractors to know the real requirements of the project represented in materials, time and cost; It encourages companies and firms to decrease waste; It participates in project success and profit achievement; It keeps environment out of pollution; To get enough finance for a project; and It helps contractors in pricing bids.

Adopting other waste management and minimization strategies other than disposal in a landfill has become a pressing need for China to reduce construction and demolition waste and increase the lifespan of landfills.

This paper focuses on the following objectives:

- Identifying waste minimization strategies employed by construction companies in Chongqing city, China;
- Determining the relative importance of the benefits of material waste recognition; and
- Suggesting strategies to improve the current C&D waste management situation in Chongqing China.

2. Research methodology

To obtain the aims and objectives, the essential stages of methodology were performed in several stages. The waste minimization strategies and benefits of material waste recognition outlined in the questionnaire were identified from a review of related literature. The questionnaire contained three sections to reach the aim of this research, as follows: Profile of the respondent, waste minimization strategies and benefits of material waste recognition. Respondents were asked to indicate if their company had a specific policy for minimizing construction waste, and if they did, respondents were asked to indicate which of the strategies were utilized by their company to reduce waste generated on

construction project sites. Respondents were asked to indicate if they utilized a combination of the listed strategies or any other strategies not included in the questionnaire.

The five-point Likert scale is used in the questionnaire to quantity opinions of respondents about the benefits of material waste recognition, with the scale ranging from strongly disagree to strongly agree. A total of 90 questionnaires were distributed through direct visits to the construction companies and sites. The target groups were randomly selected from industry practitioners in China Chongqing city. Finally a total of 80 valid responses were received, representing an overall response rate of 89 percent. The data were then analyzed by using statistical analysis techniques including ranking analysis for the benefits. These research activities were facilitated with the aid of SPSS 12.0 software. The process of data analysis is interpreted as follows. The relative importance of all identified benefits was examined by ranking them based on their mean values and standard deviation. In this research, only those benefits with mean values that are greater than 3.00 were recognized as important Benefits of material waste recognition.

Furthermore, five construction professionals and three researchers were interviewed to investigate strategies for construction waste minimization. The interviews were conducted in May 2014 and each lasted about 30 min. The selection of these professionals was based on their prominent experience in construction and demolition waste management (Table 1).

Table 1. Interviewees profiles in the interviews

Expert no	Position	Affiliation	Experience in C&D waste management (Years)
1	Professor	University	10
2	Professor	University	12
3	Associate professor	University	10
4	Project manager	Contractor	7
5	Project manager	Contractor	8
6	Site engineer	Contractor	5
7	Supervision engineer	Supervision company	6
8	Supervision engineer	Supervision company	9

3. Results and discussion

3.1 Respondents' profile

Respondents' occupation clarifies that the majority of respondents, 48% in this survey are Civil Engineers, followed by 14% Project Managers, 11% Construction Technicians, 9% Site Engineer, 6% Architects, 6% Cost Engineers, 5.0% Quantity Surveyors and 1% Foreman. So, a total of 62% of the respondents was a combination of Civil Engineers and Project Managers. It can be noticed that Civil Engineers and Project Managers play a major role in this research. This indicates that the majority of respondents are highly involved in the construction site problems.

The respondents' years of experience in descending manner as follows: 32% from 1 to 3 years, 21% from 5 to 10 years, 18% from 3 to 5 years, 13% more than 20 years, 10% from 10 to 15 years and 6% from 15 to 20 years. This means that most of the respondents have a good understanding about issues in connection with the construction.

3.2 Construction material waste minimization strategies

The results from the present survey show that a remarkable proportion of construction firms have a specific policy for minimizing construction waste. Table 2 indicates that 69.5% of the respondents' construction firms had specific policies for minimizing waste on construction project sites, while 30.5% did not have a specific policy for minimizing construction waste.

Table 2. Proportion of the construction firms with a specific policy for minimizing construction waste

Specific policy (Y/N)	Proportion of construction firms
Yes	69.5%
No	30.5%

The distribution of the waste minimization strategies adopted by respondents who had specific policies for minimizing construction waste is shown in Table 3. Only 25 (44.6%) of respondents consider the recycling waste only as a waste reduction strategy. It is interesting to note that the number of respondents increased from 25 (44.6%) to 45 (80.4%) in the recycling category when it is combined with minimizing waste at the source of origin. Minimizing waste at source of origin is widely practiced as a waste minimization strategy by construction firms with specific waste minimization policies. Similarly, only 30 (53.6%) of respondents in this category limited their waste minimization strategy to reusing waste only. It is also notable that the number of respondents raised from 30 (53.6%) to 42 (75.0%) when minimizing waste at the source of origin involved. Reusing waste strategy is applied by construction firms, since they use the generated materials in other projects. This strategy is applied in renovation and rehabilitation projects. 32 (57.1%) of the respondents agreed with minimizing waste at the source of origin only as a sole waste minimization strategy. However, the number of respondents increased dramatically to 53 (94%) when a combination of reusing and recycling waste practiced with minimizing waste at the source of origin. Other waste minimization measures given by respondents include: ordering just what is needed of material; take-back arrangement with suppliers; appointment of waste manager on site; using materials before expiry dates; use of more efficient construction equipment; accurate measurement of materials during batching; good construction management practices; encourage re-use of waste materials in projects; recycling of some waste materials on site; and use of low waste technology.

Table 3. Distribution of waste minimization strategies employed by respondents' firms with specific waste reduction plans

Waste reduction strategy	Frequency (Agree)	Percent	Frequency (Not agree)	Percent	Total
Combination of re-using waste, recycling waste and minimizing waste at the source of origin	53	94.6%	3	5.4%	56
Combination of recycling waste and minimizing waste at the source of origin	45	80.4%	11	19.6%	56
Combination of reusing waste and minimizing waste at the source of origin	42	75.0%	14	25.0%	56
Minimizing waste at the source of origin only	32	57.1%	24	42.9%	56
Reusing waste only	30	53.6%	26	46.4%	56
Recycling waste only	25	44.6%	31	55.4%	56

3.3 Benefits of material waste recognition
It can be seen clearly from Table 4 that all benefits receive a mean value of greater than 3.000, which implies that these benefits are all critical and important in terms of construction material waste recognition. The analysis on the benefits of material waste recognition shows that the environmental benefit is ranked first by respondents, yet the mean value of the second important benefit 'It encourages companies and firms to decrease waste' is 3.84 indicating the agreement of most respondents with the benefit of waste reduction. These findings are evidence of the increasing interest and awareness of the environmental issues in the Chinese construction industry.
The third and fourth important benefits in the ranking are 'To get enough finance for the project' and 'It participates in project success and profit achievement' with mean values of 3.73 and 3.68 respectively. This indicates that the financial benefits of material waste recognition are important aspect for Chinese construction practitioners. The importance of the financial aspect is totally obvious for the construction industry in Chongqing city, which its average growth rate of investment in construction activities is about 25.4% from 1997 to 2006 [9].
It has been also noticed from this study that 'It helps the contractors to know the real requirements of the project represented in materials, time and cost' and 'It helps contractors in pricing bids' are the lowest two important benefits of material waste recognition with mean values of 3.63 and 3.41 respectively. This shows that contractual benefits are considered relatively less important by the respondents of this survey.

Table 4. Ranking of the benefits of material waste recognition

The benefits of material waste recognition	Mean	Std. Deviation	anking
It keeps environment out of pollution	4.05	1.113	1
It encourages companies to decrease waste	3.84	1.037	2
To get enough finance for a project	3.73	1.125	3
It participates in project success and profit achievement	3.68	0.965	4
It helps the contractors to know the real requirements of the project represented in materials, time and cost	3.63	0.933	5
It helps contractors in pricing bids	3.41	0.990	6

3.4 Recommended strategies to improve waste minimization
Based on the interview discussions with construction professionals and researchers. Several strategies were suggested to improve the existing construction and demolition waste management in Chongqing City, China. These are: providing guidelines on effective waste management methods; enhancing on-site waste management plans to minimize the waste; adopting low-waste construction technologies and behavior; involving environmental protection in the design stage and implementing waste minimization's design; developing an appropriate waste landfilling charge scheme; and developing a mature market for trading recycled materials.

4. Conclusions
This paper has presented results from a survey on waste minimization strategies employed by construction firms and the relative importance of benefits of material waste recognition. The results of the survey indicate that a sizeable proportion of construction firms have specific policies for minimizing waste generated on construction project sites. Amongst the firms which do have a specific waste minimization policy, minimizing waste at source (either alone or in combination with other waste minimization strategies) was the most widely practiced waste minimization strategy. However, unlike recycling, it is perceived to be more effective only when undertaken in combination with other waste reduction strategies. This can be attributed to the fact that it is practically impossible to minimize waste at source to the point where waste generation is completely eliminated. Therefore, any waste that is generated after minimization at source would need to be reduced using another waste minimization strategy such as reusing or recycling. From the analysis on the benefits of material waste recognition, conclusions can be drawn that the environmental and financial benefits are considered strong drivers for material waste recognition, meanwhile the contractual benefits are perceived relatively less important by respondents. Also, it is interesting to conclude that environmental issues have climbed the ladder to become a priority in the China construction industry.

Acknowledgment

References
[1]   Poon C.S., Jaillon L.A. Guide for Minimizing Construction and Demolition Waste at the Design Stage. The Hong Kong polytechnic University, 2002.
[2]   Hoornweg D., Leader T.T, Lam P., Chaudhry M. Waste management in China: Issues and recommendations. East Asia Infrastructure Department, World Bank, Washington DC, 2005.
[3]   National Bereau of Statistics of China, "China Statistical Yearbook," 2009.
[4]   Danish Environmental Protection Agency, "Waste in Denmark," 2012.
[5]   Lu K.A. The actuality and integrate using of China's construction wastes. Journal of Construction Technology, 1999, 128(5): 44-45.
[6]   Chongqing Environmental Department [Internet]. Chongqing (CN): Evaluation of the construction and demolition waste landfills in Chongqing city. [Cited 2009 September 4] (in Chinese). Available from: http://jjckb.xinhuanet.com/jcsj/2009 06/04/content_161872.htm
[7]   Al-Moghany S.S. Managing and Minimizing Construction Waste in Gaza Strip. Palestine: Islamic University of Gaza, 2006.

[8]   Al-Hajj A., Hamani K. Material Waste in the UAE Construction Industry: Main Causes and Minimization Practices. J. Architectural Engineering and Design Management, 2011, 7(4): 221-235.

[9]   Chongqing Municipal Bureau of Statistics [CD-ROM]. Beijing: Chongqing Statistical Yearbook; 2003-2007.

Sulala M. Z. F. Al-Hamadani (Sulala Mohammed Zaki Fattah Al-Hamadani) holds a Master Degree in Environmental Engineering from Chongqing University, Chongqing, China. He has got his bachelor of science in civil Engineering from University of Mosul in Iraq. He also has four years of work experience in the construction industry in Iraq, Oman and UAE. At present, his research interests mainly focus on construction waste management and minimization.
E-mail address of the corresponding author: solalazaki85@yahoo.com

Xiaolan Zeng is an associate professor of Department of Water Science and Engineering in College of Urban Construction and Environmental Engineering, Chongqing University. She holds a Doctor Degree of Municipal Engineering from Chongqing University. Dr. Zeng has been engaged in research on water pollution control for about 20 years by now and has more than 30 relevant papers published. At present her research interests mainly focus on exploration of leachate treatment technologies and mechanisms**.**
E-mail address: Wendyzeng@cqu.edu.cn

M.M. Mian (Md Manik Mian) holds a Master Degree in Environmental Science from Bangladessh Agricultural University, Mymensingh, Bangladesh. He has got his bachelor of science in Environmental Science and Resource Management from Mawlana Bhashani Science and Technology University in Bangladesh. He also has work experience on Development Research. He is currently enrolling in Chongqing University, Chongqing, China in Environmental engineering. At present, his research interests mainly focus on construction waste management.
E-mail address: manikmbstu@gmail.com

Zhongchuang Liu holds a Master Degree in Environment Science and Engineering from Chongqing University, Chongqing, China. He is currently PhD student in Chongqing University. At present, his Doctoral research interest is in the area of Environment Science and Engineering.
E-mail address: liuzhongchuang@163.com