A survey on the construction and demolition waste in Mongolia

Tommaso Troiani[1], Somayeh Lotfi[1]

[1] Department of Materials and Environment, Delft University of Technology, the Netherlands (Stevinweg 1, 2628 CN Delft), Telephone: +31 (0)15-27 83821; Fax: +31 (0)15-27 88162
E-mail: t.troiani@tudelft.nl, Corresponding author: s.lotfi@tudelft.nl

Abstract

In many developing countries, the rapid growth of town and cities has generated a rising levels of waste and illegal dumps have become a serious issue. The booming construction industry in Mongolia has resulted in the production of massive amounts of CDW which is one of the largest waste streams. In Ulaanbaatar (UB) and other cities in Mongolia, the construction waste is dumped illegally. In order to promote the sustainability of the building industry, plenty of regulations focusing on reducing or recycling the CDW have been carried out worldwide. This paper investigates the current CDW management in Mongolia and proposes a quantification of the amount of CDW in UB by using a Material Flow Analysis (MFA). Questionnaire surveys and interviews were conducted with main stakeholders in construction and recycling sector. From the questionnaire results, it is clear that the awareness about the CDW issues in Mongolia is low among the principal stakeholders in the sector, such as Government agencies and construction companies. On the other hand, recycling in Mongolia belongs to an informal sector and the lack of investment constitutes a major problem. In this regards, the technical and non-technical solutions to improve CDW management system are proposed. A stricter control of landfilling for CDW and a creation of a dedicated regulatory framework specific to CDW are needed. To increase the recovery and recycling rates of materials an optimum demolition strategy (for example process, costs, logistics, procedures, timing) is recommended.

Keywords: CDW recycling**,** Construction and Demolition waste management**,** Material Flow Analysis**,** Landfilling**,** Mongolia.

Introduction

The construction industry generates about 35% of industrial waste in the world (Construction Materials Recycling Association, 2005; Hendriks and Pietersen, 2000). In many developing countries, the rapid growth of town and cities has generated a rising levels of waste and illegal dumps have become serious issues. In order to preserve the environment and guarantee growth, a number of studies have been conducted and several solutions have been proposed. Most of these solutions seek to minimize and regulate Construction and Demolition Waste (CDW).

In order to promote the sustainability of the building industry, plenty of regulations focusing on reducing or recycling the CDW have been carried out in many countries and regions such as the EU countries (Symonds Group Ltd., 1999), the US (USEPA, 2009) and Hong Kong (Hong Kong government, 2005). In Hong Kong, the Government has implemented an administrative rule that specifies that CDW containing more than 20% inert material by volume (or 30% by weight) cannot be disposed at landfills (Hong Kong Government – Environmental Protection Department, 1998). In addition, since 2003, a Waste-Management-Plan (WMP) method for all construction projects is required (Tam, 2008). However, the lack

of financial incentives together with the increase in overhead costs is considered as the major obstacles for its implementation.
The problem of quantification of CDW is central to establish reasonable policies as well to propose alternative solutions. The first method to quantify the amount of CDW was proposed in the Netherlands by Bossink and Brouwers (1996) who quantified the waste generation during several residential construction projects. Researchers in countries such as Greece (Fatta et al., 2003), Portugal (Coelho and de Brito, 2011), Hong Kong (Poon et al., 2001, 2004) proposed different methods to estimate CDW. In EU, Llatas (2011) and Màlia et al. (2013) carried out studies to propose indicators to estimate the amount of CDW.
The booming construction industry in Mongolia has resulted in the production of massive amounts of CDW. It is estimated that this waste accounts for the large majority of all overall solid waste produced in Mongolia. CDW is thus one of the largest waste streams in Mongolia. In Ulaanbaatar (UB) and other cities in Mongolia, the construction waste is dumped illegally. A huge part of the construction and demolition work is done by small and medium-sized contractors and subcontractors. Thus, small medium enterprises (SMEs) are producing most of the CDW, and their current unsustainable approaches have negative impacts on human health and the environment in Mongolia.
The Mongolian Ministry of Environment reported on average 80,000 tonnes of CDW per year in UB. However, it is only an approximation and it is not clear if this figure is referring to the total amount of CDW or only that registered at landfills. In any case, the uncertainty on total amount of CDW reflects the difficulty of knowing how much CDW is being illegally disposed.
The proposed research will allow to quantify and trace the CDW materials and distinguish the material categories that are more relevant to the developed EU technologies and regulations.

Material and methods

1. Surveys and interviews

Conditions in the Mongolian CDW sector have been qualitatively investigated using two questionnaire surveys and semi-structured interviews with main stakeholders in construction and recycling sector. The surveys were based on similar questionnaires found in journal articles (Tam, 2008; P. Villoria Saez et al., 2013) but tailored to the Mongolian needs. The semi-structured interviews followed a general outline but allowed for areas of interest to be explored in further detail (Punch, 2005). The interviews were intended for gathering further comments; elaboration and interpretation in the results obtained from the questionnaire. The questionnaires were distributed to each target group and a response rate of 75% was considered satisfactory.
A first survey was carried out to clarify the common practices among construction companies and their level of interaction with other stakeholder within the industry. To obtain a representative sample of the companies to be interviewed, TUD selected 70 active construction companies which are divided in:

- 45 active construction companies in UB area.
- 35 active construction companies outside UB. The 35 construction companies covered almost every *Aimag* (province) in Mongolia, included the Omnogovi province.

The number of construction companies constitutes the 10% of the total members of Builder Association. In total, 700 construction companies are active in Mongolia from which 450 companies are active inside and 350 companies operate outside of UB.

A second survey was directed to the main stakeholders in the recycling sector in Mongolia, such as scavengers/collectors, collection points and recycling industries. Recycling industries are most commonly concentrated in capital city along with Mongolia's population and industry. For reasons of efficiency, factories tend to locate themselves near the source of materials or end markets, or both. A total of 21 recycling industries are currently operating in Mongolia and 20 industries are located in the seven districts of capital city UB. Namely the following entities are operating in cooperation and non-cooperation with the Mongolian National Recycling Association (MNRA). The two questionnaires are shown in Table 1.

Table 1. Questionnaires sent to construction companies and to recycling companies in Mongolia.

Survey	Section	Required information
Survey to construction companies to investigate CDW sector in Mongolia	General Information	- The number of construction projects for each company - Location of different construction projects. - Different types of constructions (Residential / Non - Residential). - The number of employees for each company and years of experience in the construction sector. - List of the information needed to be provided at the beginning of a construction project.
	Construction information	- Relation between construction company and hired contractor. - Material Wasted: average different materials quantities (Bricks, Concrete, Plastic, Glass, Wood) wasted in a construction project. - Type of inspections received during a construction process. - The exact sequence of operations for the construction process.
	Construction material procurement	- The suppliers' information for each material. - Average prices for construction materials.
	Demolition information	- Collaboration with contractors. - Type of permit needed to perform the demolition. - An average number of workers necessary to perform demolition and the average number of days to complete it. - CDW produced during a demolition. - Level of knowledge of asbestos risks and procedures followed to treat hazardous waste.
Survey to recycling industries operating in Ulaanbaatar	General information	- Current waste flow and different stakeholders in the waste supply chain - Location of the production site and proximity to end-market - Human resources operating on site
	Technological information	- Production capacity - Type of secondary materials recycled and attitude toward CDW - Standards followed to produce recycle products - Technology used in the recycling process

2. Methods to quantify the amount of CDW

In order to quantify the amount of CDW in UB, the methods proposed by Fatta (*Estimation methods for the generation of construction and demolition waste in Greece, Fatta et al.*, 2003) and Llatas (*Methods for estimating construction and demolition (C&D) waste, C. Llatas*, 2013) were applied.

In this study, the proposed MFA calculates the total amount of each material-i TW_i in tonne/year by the following expression:

$TW_i = DW_i + CW_i$ (1)

Where TW_i is composed of the amount of material-i coming from demolition activity DW_i and construction activity CW_i, both expressed in tonne/year.

To quantify the amount of DW the proposed methodology starts from an analysis of the municipal context, in particular of the buildings in the capital Ulaanbaatar and of the main types of structures-j with the highest probability of been demolished, Bricks and Concrete structure. Furthermore, it is necessary to quantify total demolition waste for the different types of structure-j, DW_j in ton/year.

By using the formula proposed by Fatta (*Estimation methods for the generation of construction and demolition waste in Greece, Fatta et al.*, 2003), the applied models for DW is as following:

$DW = ND * NF * SD * WD * D$ (2)

- DW = demolition waste in tonne
- ND = number of demolitions
- NF = mean value of no. of floors
- SD = surface of each building being demolished
- WD = generation rate of each demolition
- D = density of waste

Different percentages, x_{ij}, of each material in each building category were adapted from Llatas (*Methods for estimating construction and demolition (C&D) waste, C. Llatas*, 2013) as shown in Table 2.

Table 2. Percentages of material-i in each of the building structures in UB

Materials/ Buildings	Brick structure	Concrete structure
% Stony materials	91%	90%
__*Concrete*	7%	50%
__*Ceramics/ blocks mixture*	74%	25%
__*Concrete/ceramics*	10%	15%
% Metal	2%	3%
% Plastic	1%	1%
% Glass	3%	3%
% Wood	3%	3%

The final step it is represented by the quantification of the amount of each material-i studied DW_i by the following formula:

$DW_i = \sum_j DW_j * x_{ij} \quad \forall$ material-i (3)

The amount of CW is directly related to the classification characteristics and construction techniques employed in each building; CW will therefore vary between projects.
Given the plurality of projects actually running in UB, CW_i coming from each material-i is studied by using quantification in (Table 3 and Table 4) as proposed by Llatas in *Methods for estimating construction and demolition (C&D) waste*, *C. Llatas*, 2013 as shown in Figure 1.
To calculate the total amount of construction waste in tonne/year, the total surface SC in m^2 is then multiplied by weighted averages CDW generation, WG. Hence, the formula to obtain construction waste is given by:

$$CW_j = SC * WG \qquad \forall \text{ category of building-}j \qquad (4)$$

Finally, the amount of each material wasted in construction CW_i is obtained by splitting the total amount in tonne/year by the rounded average percentage of waste composition x_{ij} calculated by:

$$CW_i = \sum_j CW_j * x_{ij} \quad \forall \text{ material-}i \qquad (5)$$

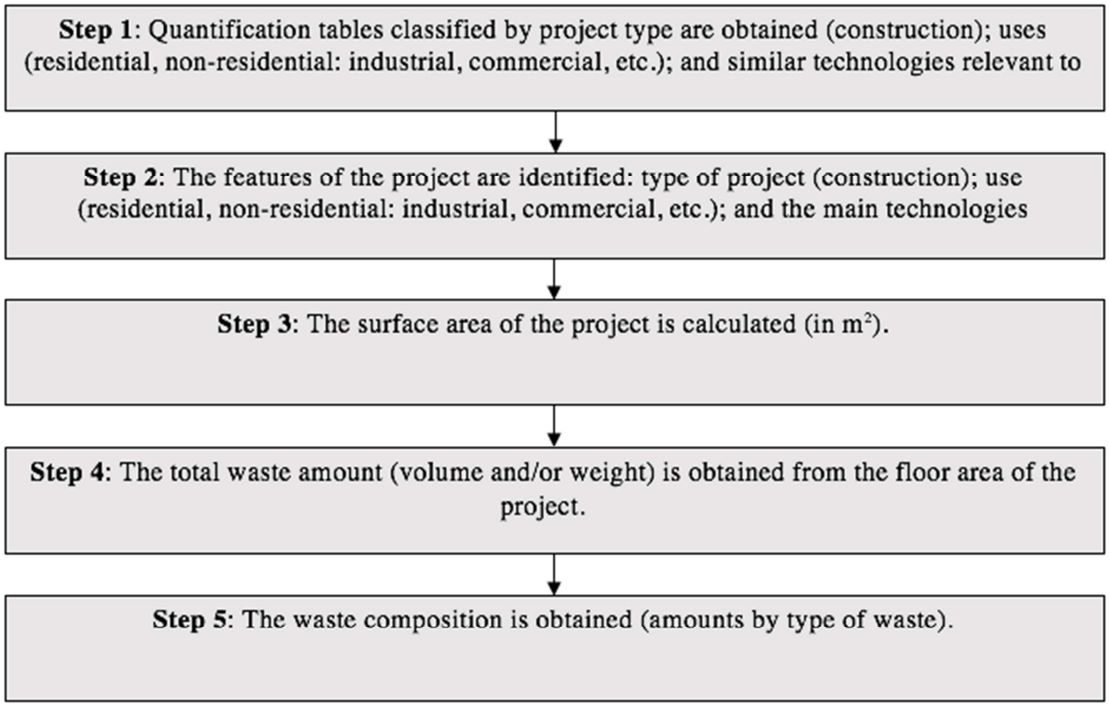

Figure 1. CW quantification methodology [*Methods for estimating construction and demolition (C&D) waste*, *C. Llatas*, 2013]

Table 3. Average Demolition waste generation rates (kg/m^3) [Methods for estimating construction and demolition (C&D) waste, C. Llatas, 2013]

Type of construction	**Heavyweight**		**Lightweight**	
	Residential	Non-residential	Residential	Non-residential
New building construction	120-140	100-120	20-22	18-20

Table 4. Rounded average percentage of waste composition by volume in construction (%) [Methods for estimating construction and demolition (C&D) waste, C. Llatas, 2013]

Rounded average percentage of waste composition by volume in constructions (%)*	
	Heavyweight construction: masonry, concrete, etc.
15 Packaging Waste	0.6 – 0.7
15 01 01 Paper cardboard pack	0.02 – 0.04
15 01 02 Plastic packaging	0.05 – 0.07
15 01 03 Wooden packaging	0.5 – 0.55
15 01 04 Metallic packaging	0.02 – 0.03
15 01 06 Mixed packaging	<0.01
17 C&D Waste	0.3 – 0.4
17 01 01 Concrete	0.15 – 0.2
17 01 03 Ceramics-bricks	0.1 – 0.13
17 01 07 Mixed concrete ceramics	0.02 – 0.03
17 08 02 Drywalls	
17 09 04 Mixed C&D waste	0.03 – 0.04

Discussion

1. CDW management based on the interviews and surveys results.

Waste management in general in the UB city is facilitated by the city municipality. Collection services are operated through a mixture of direct services and sub-contracts with service providers. UB Municipality has recorded statistics on the amount of CDW entering into each of the three landfill sites via data obtained from its weighbridges. These statistics offer insight into the current patterns of waste generation from the construction industry. The distribution of CDW between the three landfill/dumpsites in UB is shown in Figure 2. The majority of the generated CDW is dumped in Narangiin Enger and Morin Davaa sites while only a small amount is being disposed at Tsagaan Davaa site. In the mentioned Figure the data for year 2015 stands for the duration from January to August resulting smaller numbers compared to the complete year of 2014.
Illegal dumping represents a serious problem in UB, about 20% of all waste generated in the city is illegally disposed. The numbers from all three official landfills in 2015 reports 65,859 tonnes of construction waste registered. It is reported that the city municipality spent 200 million Tugrugs to clean up illegal CDW in 2011. Backfilling off vehicles delivering materials to site is a common approach to waste collection in the construction industry in UB.

This approach utilises the empty vehicle whilst offering additional revenue for the driver. It is understood that much of this work is done on an informal "cash-in–hand" basis and may be executed without the knowledge of management from either party (e.g. construction company or transport company).

Illegal disposal of construction waste can occur at construction sites or anywhere else. A number of construction sites have reported that construction waste from the construction activity is buried under the site itself. Demolished building materials also are often disposed following the same mechanism. Otherwise illegally disposed construction waste ends in areas along the construction truck route. This route is often route between construction sites, and construction material producers, including gravel quarries.

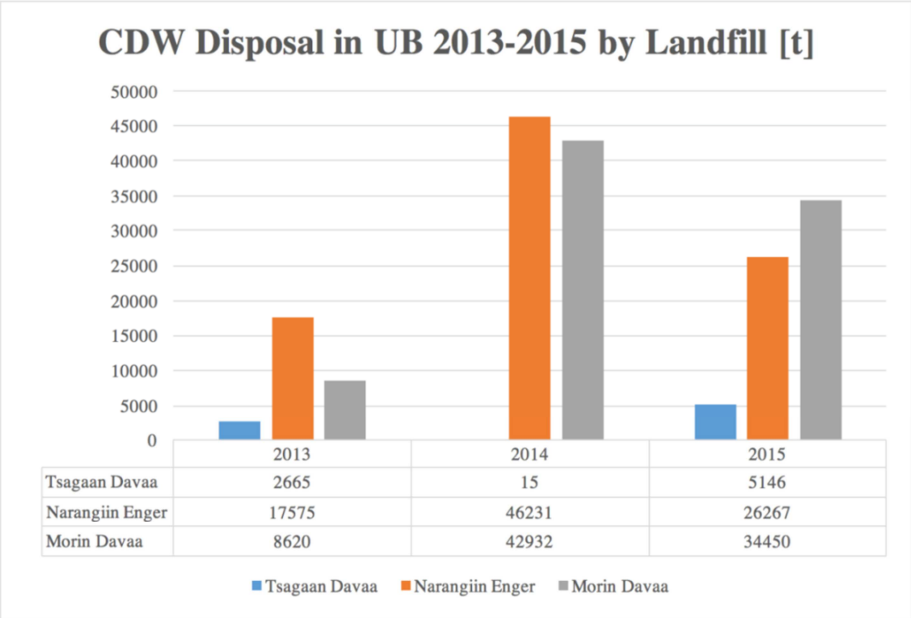

Figure 2. CDW disposal in UB during the period 2013 – 2015 divided by the three principal landfills

It is important to highlight the poor monitoring and evaluation system in Mongolia. The processes described in official regulations and documents concerning handling, transporting, and disposal of CDW, respective roles and responsibilities are not reflected properly. Conceptually there are a number of entities assigned to monitor and evaluate proper management of CDW, however their absence is felt as illustrated by the presence of illegal disposal practice and sites. The lack of attention to monitoring transportation and disposal of CDW, is especially evident compared to other monitoring activities regarding construction industry in general, such as land rights.

After presenting information from the questionnaire survey about practices adopted by construction companies in Mongolia, the following conclusions can be drawn:

- Lack of awareness and culture regarding waste management by Government agencies.
- Lack of support and human resources from key stakeholders such as Inspection Agency.
- Lack of incentives from construction regulatory authorities and low costs of sending materials to landfill.
- Lack of community attention on CDW management.
- In the building materials industry in Mongolia processing technology and equipment are often obsolete.
- Demolition activity is not followed by the separation of CDW because companies have no incentives to perform this task.

- Construction companies do not collaborate with recycling companies, most of the time they are not aware of the existence of recycling sector in Mongolia.
- Lack of a database for the buildings of UB create a big obstacle to a clear understanding of the quantities of CDW produced after a demolition.

2. Recycling sector in Mongolia

Recycling is a new concept in Mongolia. The Mongolian recycling sector plays an important aspect of Mongolia's environment and society. A strong and sustainable recycling sector is essential for Mongolia to utilise resources more efficiently and maximise the full value of materials. At present there is limited information on the recycling sector and the potential for this sector to contribute to environmental, economic and social outcomes. The key reasons underlying this lack of information are the following:

- The recycling sector is often considered along with the waste sector and it is not always possible to isolate the data and information that relates to the recycling sector alone.
- The recycling sector is often highly integrated with other sectors, particularly transport, waste and manufacturing, and it is not always possible to, or there has been no attempt to, isolate the data and information that relates to recycling activity.
- Recycling sector is not clear belong to which government department collect data information, and strategy. There is no fixed law and regulation for recycling sector.

One of the purposes of the in-depth interviews conducted for the research was to arrive at an understanding of the effectiveness of current waste management policies and regulations. Waste management reform is in its early stage of development since Mongolia's transition to market economy. The relevant legislative acts for this sector were started to be developed from 2000.

Comparing to other countries, recycling sector in Mongolia is an informal sector and a limited amount of data, and information are registered. The industry should be regulated by the government both at municipality and districts levels. Furthermore, the lack of investment constitutes a major problem, most of actual recycling plant's equipment is obsolete and a strong renovation is needed.

The Municipal Governor's Office is in charge of waste treatment along with its executive agencies including environmental protection authority and district maintenance companies. Furthermore, there is a lack of potential policies, techniques, financial resources and human resources.

3. MFA results

3.1. Demolition waste quantification

Future DW is calculated from the number of End-of-Life (EOL) buildings which are going to be demolished according to UB Municipality in the period 2015-2018. By following the aforementioned procedures, from a total of 32 concrete buildings and 275 brick buildings, the following numbers are estimated:

- DW Brick = 1,359,072.00 tonne
    - *NF* = mean value of no. of floors that building has = 3,96
    - *SD* = surface of each building being demolished = 975 m^2
    - *WD* = generation rate of each demolition = 0.8 m^3 / m^2
    - *D* = density of waste = 1.6 tonne / m^3
- DW Pre-cast = 97,335.71 tonne
    - *NF* = mean value of no. of floors that building has = 3.69

- *SD* = surface of each building being demolished = 644 m^2
- *WD* = generation rate of each demolition = 0.8 m^3 / m^2
- *D* = density of waste = 1.6 tonne / m^3

The specific amount of each material-i is presented in Table 5 and Figure 3.

Table 5. Specific amount of each material-i from demolition activity

	DW [t]	**% DW**
Concrete	130,373.95	9%
Bricks	937,099.62	64%
Mixed concrete	136,815.87	9%
Metal	30,101.51	2%
Plastic	14,564.08	1%
Glass	43,692.23	3%
Wood	43,692.23	3%
Total	**1,456,407.71**	100%

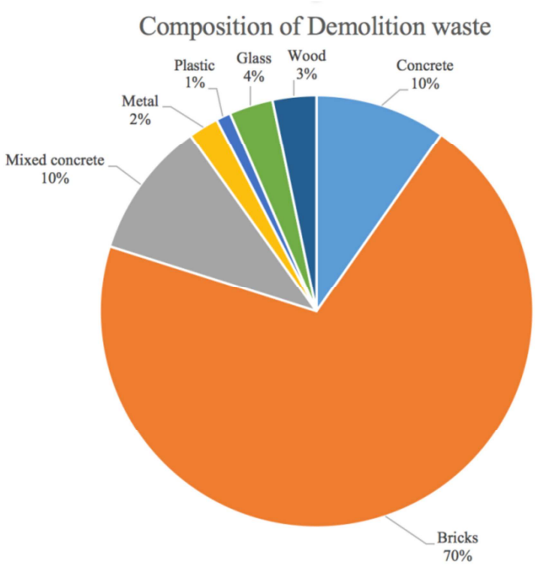

Figure 3. Composition of DW

3.2. Construction waste quantification

UB is facing an important transformation in the last years and number of construction sites has started to increase again after a small interruption during 2013-2015. Figure 4 shows the number of active construction sites for each district.

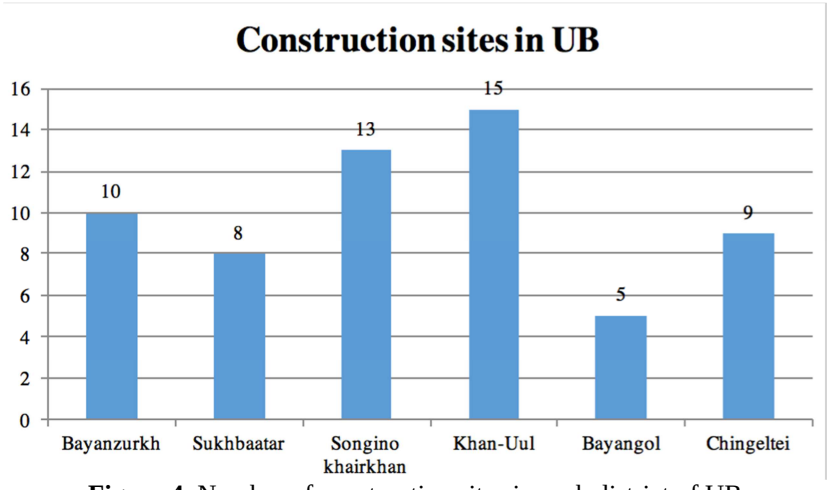

Figure 4. Number of construction sites in each district of UB

Actually, 60 construction sites are open in UB with an average surface of 700 m^2.

Multiplying the total surface for WG = 130 kg/m^2, construction waste CW is obtained and amount of each material CW_i is calculated using the method explained in section 2.2 Methods to quantify the amount of CDW.
The final result is shown in Table 6 and figure 5. All the waste produced is going to disposal sites and it can be noticed that wooden materials represents the biggest amount mostly because of wooden packing used in the construction site

Table 6. Specific amount of each material-i from construction activity

	CW [t]	% CW
Concrete	1,092	20%
Bricks	709.8	13%
Mixed concrete	436.8	8%
Metal	109.2	2%
Plastic	273	5%
Glass	0	0%
Wood	2,839.2	52%
Total	**5,460**	**100%**

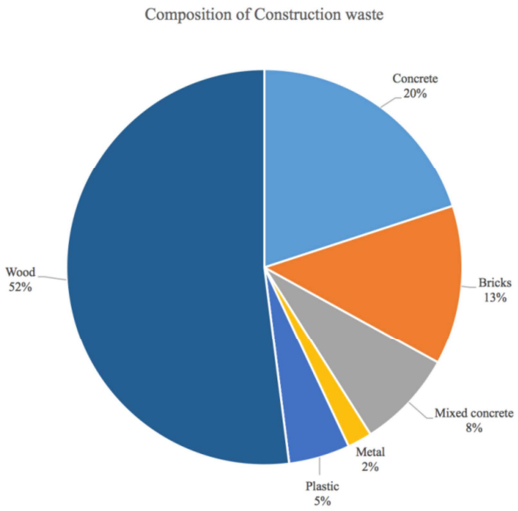

Figure 5. Composition of DW

3.3. Total CDW in Mongolia

To summarize the results obtained from quantification of CDW, UB is expecting a total of 1,461,867.71 tonne CDW over the next years (2015-2018). It is important to notice that Concrete and Bricks account for the large majority of the total amount and as expected, construction waste is marginal compared to demolition activity. Statistics show that the amount of CDW is booming every year in months March, September and October. Thus, it is obvious that the weather is a determinative factor in Mongolia to run the construction or demolition projects.

Conclusions

In Mongolia, CDW management represents a significant challenge because the performance of SMEs in construction and demolition debris management is still poor. There are difficulties which keep SMEs away from good CDW management practices. In addition, CDW recycling SMEs in Mongolia face a lack of knowledge and the technical capability to deal with negative environmental impacts. Furthermore, there are no specific regulations or certifications for a proper demolition of an End-of-Life (EoL) building, recycling and reuse of CDW in Mongolia.
The purpose of this study has been to identify and document the current CDW management situation in Mongolia and quantify the amount of CDW in UB by using a Material Flow Analysis (MFA). The results indicate the lack of awareness regarding CDW among

stakeholders, especially Government agencies and construction Companies. The Government agencies lack of the support and human resources to effectively monitor illegal disposals and enforce CDW regulations. Construction companies do not collaborate with recycling companies and do not have any incentive from regulatory authorities to use recycled building materials in new constructions. On the other hand, recycling sector in Mongolia is an informal sector and a limited amount of data is registered. Furthermore, the lack of investment constitutes a major problem, most of actual recycling plant's equipment is obsolete and a strong renovation is needed.

Following the EU practices a stricter control of landfilling for CDW is needed. Setting proper landfilling regulations will be a major driver towards better CDW management. In addition, the landfill disposal fees and taxes, governmental encouragement for environmental friendly practices and granting the related activities and management of demolition waste are key factors.

The CDW producer should develop a system which minimizes the adverse environmental impacts and maximizes the recovery of resources (recycling, reuse). For that reason, the implementation of a waste management policy with not only economic instruments (taxes on landfill), but legal measures such as: selective demolition obligation, voluntary agreements and responsibilities is needed. In this way, even during the production phase, the foundations are laid for the effective and environmentally compatible avoidance and recovery of waste.

Once, legal framework is set up, it is necessary to create standards for recycled products to ensure quality and ease market tendency to buy those products. The implementation of secondary raw material regulation and standards is needed. Looking at concrete as the main waste flow estimated in Ulaanbaatar, EU standards can be applied and adapted. In EU, recycled concrete aggregates can be used as the substituent of the natural coarse aggregates for new concrete production. Use of up to 30% concrete aggregates as substitute of natural coarse aggregate is a common practice in the mortar and concrete production facilities.

To increase the recovery and recycling rates of materials an optimum demolition strategy (for example process, costs, logistics, procedures, timing) is recommended. In the Netherlands, selective demolition of EOL buildings is one of the common practices in CDW management projects. The difference between conventional and complete selective demolition is that in selective demolition the workers use light mechanical tools in order to recover the highest percentage of materials that can be reused, whereas in conventional demolition the workers use heavy equipment (explosives, wrecking balls, bulldozers) and, as a result, the generated waste is mixed and the recovery of materials is difficult.

Acknowledgment

This research has received funding from the European Commission under the European project SWITCH – Asia II "Improving resource efficiency and cleaner production in the Mongolian construction sector through materials recovery".

The authors would like to thank all the Mongolian Partners Caritas Czech Republic, Mongolian University of Science and Technology and Mongolian National Recycling Association for their help in collecting data necessary for the MFA and in conducting the surveys.

References

Bossink B.A.G. Brouwers H.J.H. 1996. Construction waste: quantification and source evaluation. Journal of construction engineering and management ASCE 122, 55-60.

C. Llatas, “Handbook of Recycled Concrete and Demolition Waste Methods for estimating construction and demolition (C&D) waste”, 2013.
Coelho, A., de Brito, J., 2013. Environmental analysis of a construction and demolition waste recycling plant in Portugal - Part II: environmental sensitivity analysis. Waste Manag. 33, 147e161.
“Country Analysis Paper: Mongolia”, Fourth Regional 3R Forum in Asia, March 2013.
European Directive 2008/98/EC. Waste Framework Directive. 2008.
Hendriks, C.F. Pietersen, H.S., 2000. Sustanaible Raw Materials: Construction and Demolition Waste. RILEM Publication, Cachan Cedex, France.
Hong Kong government – Environmental Protection Department, 2006. Environmental protection department, Hong Kong.
Fatta, D., Papadopoulos, A., Sgourou, E., Moustakas, K., Kourmoussis, F., Mentzis, A. & Loizidou, M. (2003) Generation and management of construction and demolition waste in Greece-an existing challenge. Resources, Conservation and Recycling, 40, 81-91.
Kourmpanis, B., et al. "Preliminary study for the management of construction and demolition waste." *Waste Management & Research* 26.3 (2008): 267-275.
Japan International Cooperation Agency (JICA). Project Team for SWM in Ulaanbaatar City, “Strengthening the Capacity for Solid Waste Management in Ulaanbaatar City”, Final Report, 2012
M. Henry, Y. Kato, “Understanding the regional context of sustainable concrete in Asia: Case studies in Mongolia and Singapore”, 2013.
Malia. M., de Brito, J., Pinheiro, M.D., Bravo, M., 2013. Construction and demolition waste indicators. Waste Management, Res. 31 (3), 241- 255.
Ministry of Construction and Urban Development Mongolia. “Current Situation and Future Trends in Mongolian Construction and Urban Development Sector” Warsaw, Poland, 21Jan 2013.
Nakajima, S. (2000) The state of deconstruction in Japan. In: Kibert, C. J. & Chini, A.R. (eds): Overview of Deconstruction in Selected Countries, CIB Publication 252, Cambridge, UK.
Paul H. Brunner and Helmut Rechberger, “Practical Handbook of Material Flow Analysis”, published in the Taylor & Francis e-Library, 2005
Solís-Guzmán, J; Marrero, M; Montes-Delgado, MV; Ramírez-de-Arellano, A. A Spanish model for quantification and management of construction waste. Waste Management. 2009, 29: 2542–2548.
Solis-Guzman. 2009. A Spanish model for quantification and management of construction waste. Waste Management 29, 2542-2548.
S. Lotfi, J. Deja, P. Rem, R. Mróz, E. van Roekel, H. van der Stelt, Mechanical recycling of EOL concrete into high-grade aggregates, Resour. Conserv. Recycl. 87 (2014) 117–125.
S. Lotfi, J. Deja, M. Eggimann, E. Wagner, R. Mròz. Performance of recycled aggregate concrete based on a new concrete recycling technology, Construction and Building Materials. 95 (2015) 243-256
Lotfi, Somayeh, et al. "An experimental study on the relation between input variables and output quality of a new concrete recycling process." *Construction and Building Materials* 137 (2017): 128-140
Tam, V.W.Y. 2008. On the effectiveness in implementing a waste-management-plan method in costruction. Waste Management 28, 1072-1080.
Tam, V., 2009. Comparing the implementation of concrete recycling in the Australian and Japanese construction industries. J. Clean. Prod. 17 (7), 688e702.

US Environmental Protection Agency, 2009. Estimating 2003 Building-related construction and demolition materials amounts. The Office of Resource Conservation and Recovery, Golden, Colorado.
Villoria Sáez, P; Del Río Merino, M; Porras-Amores, C. Estimation of construction and demolition waste volume generation in new residential buildings in Spain. Waste Management and Research. 2011 doi: 0734242X11423955.
Z. Wu et al, “Quantifying construction and demolition waste: An analytical review”; 2014.