Quantification of Construction Waste Amount

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Abstract

This article outlines the importance of the quantification of wastes for a sound and adequate management of waste in the construction of buildings. It is noted that such quantifications provide a necessary tool for evaluating the true size of the wastes and hence making the adequate decisions for their minimization and sustainable management. This information also provides the essential information for a better pricing of construction bids and hence the user would be more competitive on the market.

Furthermore, the quantification of wastes enables a more adequate planning of the construction site and the related logistics in terms of containers and their management. This will provide the necessary information not only on the amount but also on the type and time of waste generations. Environmental and economic gains are thus incentives for contractors to opt for this prior quantification and planning.

Two approaches for quantification of wastes are outlined. The Component Index (CI) enables quantification of wastes for each constructive component in the overall project. As for the Global Index (GI), this provides the necessary indicators for a given type of building, which can then be used for similar future buildings and hence facilitates the overall estimation of the wastes.

The usefulness of preparing such data files, as well as the necessity for their updating and refining progressively is indicated. As the basis for the quantification of wastes, examples of CI and GI are presented. Data for these data files have been gathered empirically on construction sites and are good indicators for a first approach to the quantification of wastes. The waste managers are encouraged to update and refine these files to their own specific conditions and circumstances.

1. Introduction

This is an era of numbers. Whatever is dealt with in a scientific manner is quantified and expressed in numbers. This is even truer when dealing with technological applications of science. Decision-making has become increasingly based on quantified measurements or predictions expressed in numerical form. However, it is noted that as the complexity of the issues to be decided increases, less hard and reliable data is available. Construction waste is no exception. So far, information on the amount and type of waste generated on construction sites has been few and fragmentary. If adequate decisions are to be made on how construction wastes should be managed on and off the construction site, how they should be used, recycled or deposited, hard data on the amount, type, time and place of their generation is essential.

Until recently, little attention was given to methodically gathering the necessary information on waste generation at construction sites and their possible utilization. Decisions were often based on cursory observations, best guesses and simplified inferences by the construction site managers. The various construction activities are usually itemised and taken into account using the quantification map and the price list of the project. But too often wastes are simply estimated at representing 5% of the construction materials for quantity surveying and pricing purposes. This is by no means the best approach, as without due quantification of the wastes on construction site the true amount and type remains unknown and consequently adequate management of the wastes is hindered.

Quantification thus becomes a crucial tool for making decisions that are environmentally and economically optimised. Such decisions become progressively based on well grounded quantitative data for each activity on a construction site. Each contractor then will be able to base its prices on hard data from its own practice and not on oversimplified guess work. Moreover, contractors will be able to pinpoint the critical points in the generation of wastes, and as a result more able to effectively minimise its generation and become more competitive.

Benchmarking has been used for measuring performance of companies against industry peers. Yet in waste management, the lack of data has meant that the necessary basis for a sound benchmarking process in the construction industry has been missing. This lack of benchmarking has seriously hindered the implementation of more sustainable and innovative practices in the construction industry.

The objective of this article is to underline the importance, provide the necessary information, and suggest a methodology of quantification of wastes actually generated on construction sites for a more sustainable construction industry. Furthermore, this section will provide some examples of indicators for the quantification of wastes in the main activities of construction, based on empirical data gathered on different construction sites. The data is presented as card files that indicate the relevant information needed for an environmentally sound management of construction wastes. These card files are presented as examples and as indicative of what can be done, and can be modified according to the needs of each contractor and specific construction project. These card files can be used as a first approach for the quantification purposes of wastes on construction sites.

2. Construction Wastes Classification by Source and Type

In order to quantify adequately the construction waste, it is useful to have a classification of wastes by source and type of waste generated. There are multiple sources of waste generation on a construction site. On the whole, waste is usually defined as the difference between the ordered materials and the actually applied ones in a construction site. Construction waste thus comprises waste caused by breakage in transportation from the retailer to the construction site, by the handling of material and storage on the site, by the handling up to the application point, and last but not least, the waste generated during the actual application or usage. As can be seen, the overall quality of the site management, equipment used and manpower the determining factors in waste generation. There is also waste generated by packaging of the construction materials that arrive on site and the wastes generated by the workers such as paper, glass and cans which are similar to municipal waste. This article examines waste produced during the application phase and packaging.

Hence, wastes generated on the construction site can be classified in the following three classes according to their origin:

- Building waste, generated during the construction process due to defects, damages, breakage or simply due to excess.

- Packaging waste, generated from packaging of materials and products delivered to construction site.
- Wastes produced by workers, similar to municipal waste such as paper, glass, cans, etc.

The main types of waste from construction activities are as follows:

- wood,
- metals,
- mineral debris (such as stone, bricks, mortar and concrete),
- plastics,
- papers and cardboards,
- glass
- hazardous wastes (such as paints and glues).

Occasionally there are also other specific wastes, depending on the type of construction and materials used, such as plaster, gypsum board or carpets. Wastes from packaging also consist of wood, plastics and cardboard and papers. Wood palettes are usually returned and reused by the retailer. Wastes produced by workers due to catering activities are for the most part organic materials, aluminium cans, glass and paper. It is noted that wastes generated on site are collected according to its type and dealt with irrespective of its origin.

3. Proposed Method for Quantification of Construction Waste

The quantification of wastes according to type is the fundamental task of the site manager or the person in charge of planning and management of the construction. This task has to take place before the actual construction activities begin, and must continue during the construction phase. Quantification of wastes by relevant type is essential for the management and organization of a construction site, as well as the provision of logistics for waste management.

Prior to the start of actual construction activities, it is essential to carry out a thorough analysis of the project, construction processes and materials that will be used. The review and critical analysis of the project at this stage should provide a fairly accurate estimate of the amount and type of waste foreseen. Based on this estimate and considering the construction schedule and available space, the number, type, size and location of the containers is decided. Furthermore, the access for delivery and disposal vehicles is also determined.

The schedule of the construction work is an essential tool, as it provides the timetable for waste generation and thus the required information on the logistics of the waste management for any given time span. The logistics of wastes are also affected by several other factors such as the shape of the containers, waste material density and the number of intervening workers.

Based on the experience accumulated on waste management, the following approaches are proposed for the estimation of construction wastes:

1. ***"Global Index"*** **Approach:** This approach is based on the global data from similar construction types that provides the amount of waste per square meter of construction. The global data is gathered from previous construction works and registered on data files are used as a global index for a given construction. It is noted that this index can be used also for quantification of waste from a region or even from the whole country.
2. ***"Component Index"*** **Approach:** This approach provides the amount of waste generated from each construction Component ou component that composes the project. The construction component has a specific function in the building and is usually performed by a given professional on the site. Furthermore, it has a unit of its own, i.e. for example unit area or volume.

It is noted that both of these methods are acceptable and their applicability depends on the accuracy of the data available rather than the method itself. Furthermore, the Global Index can be of great benefit for regional and national planning of Construction Waste treatment and recycling.

It is suggested here that contractors, or those in charge of construction waste management, should create their own data base for "Component Index" (CI) and progressively expand, refine, and detail them further to provide a sound basis for quantification.

In the following sections, the methodology used for data gathering, creation of data bases and its utilization for future planning is outlined and examples of Global Index and Component Index are presented and their application is discussed.

4. Data Gathering

Obtaining the actual site data is a tedious and sensitive empirical work. As stated before, the amount of waste generated on a given site depends mainly on the construction design, construction process, quality and type of construction materials, available equipment and finally, but not the least, the skill of the workers. Hence the data obtained is site and project sensitive. However, the data gathered on one site may be used for the planning of future, similar construction projects. Additional information can further refine and specify the data. It is noted that in this way the data gathering is an ongoing process and tends to be developed progressively.

The main data needed is the amount of waste by each type, the way it is generated and the time period in which it is generated. Further information deals with the possibilities of using the wastes on the site. This information is useful as wastes may become sub-products and cease to be accounted as waste.

The data gathering should be repeated for a given construction activity and the way the measurements are performed and registered has to be decided. Based on the experience gathered so far, the waste generated on site should consider a given *Construction Component.*. The Construction Component (CC) as defined here is the minimum unit for data gathering and used later for quantification of wastes. The Construction Component is a specific and independent part of the construction. Examples of CC are:

- 1 m^2 of concrete retaining wall 0.20m thick,
- 1 m^2 of ceiling,
- 1 m^2 of roofing
- 1 m^2 of interior partition wall
- 1 m^2 of tiles in kitchen or bathrooms,

There are some 30 different "Construction Components" in a building construction project. It is suggested that at least three measurements should be made for establishing a reliable data base. Care should be taken as to ensure that data is actually representative of the work being carried out and the waste produced. This can be done ensuring a minimum volume of work for each data and guaranteeing the accuracy of measurements.

For the estimation of Global Index, the total waste generated on a given site is measured and all the data regarding the waste and the site is registered. Hence, the data of each waste produced per square meter of area constructed becomes available and used for quantification of wastes for similar future projects.

5. Data Gathering for Component Index

The first step is to define the list of Construction Components relevant for waste quantification. Usually each construction project provides a list of quantities for different tasks that compose the construction. In the absence of this list, the first step would be to elaborate the list according to the documents and plans of the project.

The construction components (CC) are detailed in terms of material used and the type of waste generated in their production. Data will also contain further information regarding the size of the CC considered and the waste generated expressed in kg of waste by unit of area or volume of the CC.

Further information regarding the final destination, the possibilities of prevention, reutilization, recycling and economic potential may also be identified and registered. All the data has to be organized and structured in the data base in order to become useful information for the quantification of waste.

Hence, each data file is structured in three parts:

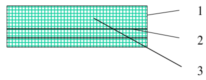
I) Description of the Construction Component

This part of the data file provides at least the following information (see Fig 1):

- A schematic view of the construction component, indicating parts that form the CC;
- A brief description of the technical characteristics of the CC;

- An indication of its location in the construction project.

Figure 1: Description of the Construction Component [1]

S 1	Foundation		
	Scheme:	**Technical characteristics:**	**Indication:**
		Grade of form work: 0,5 m² form work/m³ concrete; grade of armouring: 30 kg steel per m³ concrete	Data base on consultation of experts

II) Composition of the generated waste due to the CC

In this section of the data file, the following information is indicated (see Fig 2):

- The constructive elements needed for one unit of the CC;
- The characteristics in size and mass of the constructive components for one unit of CC;
- The amount of each type of waste per unit area or volume of the construction component including waste from packaging (kg/m^2).
- The total sum of waste generated by each component, as well as the range of data obtained as a percentage of the average value.

Figure 2: Composition and amount of waste generated [1]

	Foundation [per m² building construction surface]												
	Nr.	onstructon component (BE	Construction design		Construction - specific Waste Codes [kg/m² construction]							Sum	Span
			Thicknes	Mass	specific Waste						Packaging use		[%]
			[cm]	[kg/m²]	Con.Rubbl	Wood	Gypsum	Mineral woo	Metal	Other			
Buildup	1	Formwork (Wood material)	2,1	2,70		0,39						0,39	10,0 - 30,0
	2	Armouring		12,50					1,00			1,00	8,0 - 10,0
	3	Concrete	50,0	1.246,00	24,92							24,92	1,0 - 3,5
	4												
	5												
	6												
	7												
		SUM		**1261,20**	**24,92**	**0,39**			**1,00**		**0,00**	**26,31**	

III) Waste Management Potential

This part of the data file consists of indicating the most adequate final destination for each type of generated waste which is summarized in five options, namely: Prevention; Recycling; Energy Recycling; Landfill without treatment; and Landfill with treatment (see Fig. 3).

Figure 3: Waste Management Potential [1]

Waste - management potentials											
		BEL.Nr	Specific Waste						Packaging use	Sum	Comments
			Con.Rubbl	Wood	Gypsum	Mineral wo	Metal	Other			
Disposal route	Prevention	1	0,26								Futher Use
	Material recycling	2,3					1,00				
	Energie recycling	1		0,39							
	Deposit without treatment										
	Deposit with treatment										

6. Global Index (GI)

The GI is a global presentation of data related to a specific construction such as office building or one family dwelling. The information is of a general nature and uses the overall indicators generated from the building sites. This data file states the data for global waste production to be used in planning phase of the project.

Global Indexes are prepared for a specific type of construction, e.g. residential buildings, office buildings, hotels, etc. Furthermore, for each type of construction 3 levels of quality are distinguished, high, medium and low. It is assumed that high quality building generates larger amounts of wastes and low quality buildings generate lower amount of wastes.

The structure of these files may be as follows:

I) Construction Description:

This section states the building type, fundamental construction parameters and quality of the construction. Relevant drawings and pictures of the site and the project are also included.

II) Construction Components and Waste Generation

The list of all the major tasks comprising the project is presented, indicating the quantities of each task in m^2, m^3 or kg in the construction. The amount and type of generated waste for each task is also indicated including waste from packaging.

III) Waste Generated

This section of the card file includes all the generated waste on the site, whether in volume or in mass. This section becomes, thus, a fundamental tool as it summarizes all the information in the previous sections of the file and based on it the estimation of the generation of waste for the studied building is performed. (See Figures 4 and 5).

IV) Management Indicators

Based on the total waste generated and the total area and volume of the building studied the management indicators are calculated. These indicators are used for quantification of wastes in similar buildings. Data from GI provides the necessary information on the volume, mass and type of the generated waste per square meter of building.

Figure 4: Construction Components and Waste Generated [1]

Construction	Type and Size	Planned performance		Main type of waste (Kg)							Used packaging (Kg)		
		unit	amount	wood	foil	metal	concr.	mixed	hazard.	other	Paper	Plastic	other
Earthworks:													
	Site implementation	m2	360										
	Excavations												
	excavation soil	m3	200							306000			
Foundation:													
	Foundation and beams												
	concrete	m3	24										
	reinforcement	t	1,0										
Structure:												10,7	
	Concrete elements	m3	82										
	Formwork	m2		164,3									
	steel nails					30,0							
	Reinforcement	t	9,0			26,8							
	Joints	m2	245										
	expanded polystirene							3,3					
Exterior wall:													
	Exterior masonry	m2	285										
	Construction phase												
	ceramic bricks							417,0				22,1	
	Windows and doors fitting												
	ceramic bricks							75,5					
	Plumbings and services fitting												
	ceramic bricks							100,0					
Interior wall:													
	Interior masonry (plasterboard)	m2	350								10,6		
	plasterboard							448,2					
	internal metalic structure					46,0							
	mineral wool							5,0				15,6	
	plaster coat (paper bags)										3,8		
Ceiling:													
	Double ceiling (plasterboard)	m2	310								3,0		
	plasterboard							124,2					
	internal metalic structure					11,1							
	mineral wool											1,6	
	plaster coat (paper bags)										2,5		

Figure 5: Summary of the Waste Generated on a Given Site (GI) [1]

Waste	Amount in m³	Amount in t	Density in t/m³
Type			
Wood	1,4	0,22	0,15
Foil	0	0,00	-
Metal	0,6	0,12	0,20
Concrete	1,76	0,04	-
Mixed Construction Waste	121,5	1,94	0,25
Hazardous Waste	0	0,02	-
Other	180,0	306,00	1,70
Paper Packaging	7,3	0,15	0,02
Plastic Packaging	5,8	0,09	0,02
Other Packaging	0	0,00	-
Sum	318,4	308,58	

Figure 6: Management Indicator for a Given Building [1]

Core numbers	Waste amount m³/m³ gross volumn	Waste amount m³ / m² gross floor area	Waste amount m³/ 1000 Euro construction costs	Waste amount t /m³ gross volumn	Waste amount t / m² gross floor area	Waste amount t / 1000 Euro construction costs
Wood	0,00146	0,00438	0,00875	0,00022	0,00066	0,00131
Foil	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000
Metal	0,00061	0,00184	0,00368	0,00012	0,00037	0,00074
Concrete	0,00178	0,00535	0,01070	0,00004	0,00011	0,00021
Mixed Construction Waste	0,31874	0,36923	0,73845	0,00197	0,00591	0,01182

Construction Waste Management

Used containers	Type and size	waste type	duration in months	number of containters	containter costs in Euro/month	transportation costs in Euro/transport	disposal price in Euro/t
Waste bags	Plastic bags 0,25 m3	light wastes	12	40			30
Waste containers	Plastic containers 0,25 m3	heavy wastes	12	5			30

7. Summary and Conclusions

This article outlined the importance of the quantification of wastes for a sound and adequate management of waste in the construction of buildings. It was noted that such quantifications provide a necessary tool for evaluating the true size of the wastes and hence making the adequate decisions for their minimization and sustainable management. This information also provides the essential information for a better pricing of construction bids and hence the user would be more competitive on the market.

Furthermore, the quantification of wastes enables a more adequate planning of the construction site and the related logistics in terms of containers and their management.

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References

[1] Handbook of Wastetool, 2006

This article is based on a document prepared by the author for Wastetool Handbook.