

ASSESSMENT OF CONSTRUCTION WASTE MANAGEMENT PRACTICE: A CASE STUDY IN COSTA RICA

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ABSTRACT

The construction industry deals with the provision of shelter and infrastructure for a continuing growing population and urbanization, especially in developing countries. This sector is well known as a huge consumer of natural resources; which produces a significant quantity of construction and demolition waste. Data about the situation of construction waste generation in Costa Rica is scarce and the objectives of the study were to develop a baseline study to determine quantities and composition of the waste, as well as, motivators and barriers for achieving a more sustainable activity. This paper draws the findings of the survey undertaken by means of questionnaires, interviews and site visits. The composition basically is wood, soil, piping materials, corrugated roof sheets, wires, packaging materials (paper, plastic and cardboard), cement, concrete, blocks, paints and debris. The amounts (either by volume or by weight) of these streams are unknown since the majority of the companies don't keep track of these data. It is suggested a value of 100 kg/m² as an educated guess of the amount of construction waste produced. This high amount, compared to lower values found in literature for developed countries, could be explained by the general lack of awareness and information on environmental issues as well as lack of technologies, governmental enforcement and market incentives to improve the environmental footprint of the sector.

KEYWORDS

Construction waste: Waste management; Construction; Construction sector.

1 INTRODUCTION

The construction sector plays a key role in shaping and developing the built environment. The industry intervenes in the production of buildings, roads, dams, railways, pipelines, space stations, among others.

This sector has to deal with the continuing growing population and urbanisation, especially in developing countries, resulting in a need for housing. This trend combined with increasing economic development in emerging countries and the magnitude of the sector, calls for reflection on its practices and environmental improvements, which are relevant for the society.

The construction industry and its related materials, service, and supply feeder industries are jointly considered to be both the world's largest industrial employer and the largest natural resources consumer. As much as 50% of all materials extracted from the earth's crust are transformed into construction materials and products [1, 2]. Building activities based on these materials account for as much as 40% of all energy use. When these materials enter the waste stream, they account for some 50% of all waste generated prior to recycling, recovery or final disposal. Moreover, Mocozya [3] indicates that the sector is responsible for 12-16% of fresh water consumption, 25% of the wood harvested and 20-30% of greenhouse emissions.

Therefore it has an undisputed and significant impact upon the environment and society. The main impacts reported by UNEP [4] are:

- Raw material extraction and consumption: related resource depletion
- Land use change, including clearing of existing flora
- Noise pollution
- Energy use and associated emissions of greenhouse gases (CO₂, CH₄, N₂O, HFCs, FCs, SF₆)
- Other indoor and outdoor emissions
- Aesthetic degradation
- Water use and wastewater generation
- Increased transport needs
- Various effects of transport of building materials, locally and globally
- Waste generation
- Opportunities for corruption
- Disruption of communities, including through inappropriate design and materials
- Health risks on worksites and for building occupants

Based on the impacts, the industry has for some time been seriously challenged to become more environmentally friendly and promote sustainability. The minimization of construction wastes has become a pressing issue [5, 6, 7]. Griffith and Watson [8] suggested that the construction industry has been slow to respond those environmental demands compared to industries in the manufacturing, chemicals and process engineering sectors over the last twenty-five years. The pressure is growing however, with increasingly stringent environmental legislation being introduced, the requirement placed by clients upon contractors for environmental prequalification being more widely demanded and, indeed, greater interest, cognizance and expectations being held within the business and commercial world and also by the general public.

This challenge requires the delivery of change within the industry, with new forms of relationships being configured, new and revised methods of working being utilized and more demanding levels of performance being met. Along with all participants to the total construction process the principal contracting organization has a key and vital role to perform as a driver of change. Principal contractors must deliver timely, cost conscious, safe and quality performance on its projects, all within a context of effective environmental safeguard. In the developing world the construction sector represents 2-3% of GDP, and 74% of the 111 million of workers of the industrial sector. Developing countries account for 23% of global construction activity, which represent that in developing countries the activity is more labour intensive. The sector consists overwhelmingly of micro, small and medium-sized enterprises (MSMEs), or more accurately 'micro firms' with ten or fewer employees [4].

In Costa Rica, the construction industry contributes a significant amount to the country's economy [9]. According to the reports of the Costa Rican Construction Chamber (2007) the rate of growth has been one of the most dynamic in the past five years, surpassing the rate of GDP growth. It has been found that there is a strong dependency on the state of the economy and the generation of waste, which means that the better the economy, the bigger amounts of building procured with an increase in the generation of construction waste [10, 11].

In Costa Rica, as well as in many developing countries, construction waste is becoming a serious environmental problem. In many large cities in the world, the construction industry generates lots of construction waste, which causes significant impacts on the environment. As a result public concern is rising in the local community. This study aimed to provide a baseline related to the construction waste in Costa Rica, its quantities and composition, as well as, motivators and barriers for achieving a more sustainable activity.

2 CONSTRUCTION WASTE IN COSTA RICA

There are very few studies done in developing countries related to construction waste (composition and quantity). Also in Costa Rica the literature review showed that the studies done in the sector related to those topics are scarce and unreliable, e.g. Villalobos [12] reported as an indicator of construction waste generation between 11-25 kg/m² while Ramirez [13] between 300-700 kg/m². A study done by Leandro [14] of the Costa Rica Institute of Technology showed that the projects investigated generated a roughly average of 115 kg/m². This is considerable a higher amount than the reported for some developed countries 15-25 kg/m² [1].

This fact suggests that it should be possible to decrease the amount of waste produced in Costa Rica. Understanding the causes, barriers and motivators would be the first step to start analysing how to make the construction industry more sustainable.

In order to understand which was the situation of the construction sector in Costa Rica related to: the kind and amount of waste generated, its causes and the organization of the construction sector; an assessment was planned with the objective to provide a baseline study and a departing point to search for a more sustainable activity.

3 DELIMITATIONS

The construction activity, according to [3], is involved in different stages of the building process: the planning, design, construction, renovation, use and demolition of constructions and each of these phases have a (potential) negative influence on the environment.

There are a large number of different actors, with different fields of interest as well as differences in occupational and educational backgrounds. According to Bueren and Priemus [15], the diversity of these players is great, there are some from public, private and hybrid organizations, and their knowledge and expertise cover a wide range of disciplines. All of them act according to their own professional rules and codes. This research, however, focussed primarily on the phase related to construction of edifices, mainly on the contractors working in the Great Metropolitan Area which represent 96% of the total of construction companies of the database. Besides in this region most of the economic activity takes place and the population density is the highest.

4 SURVEY RESULTS AND ANALYSIS

The company's that participated in the survey were divided in small, medium or large and the size was defined, for this study, by the amount of employees working for it during the survey. Those numbers may fluctuate with the amount of projects that are executed since the companies can hire and fire personnel relatively easy because most of the employees have temporary contracts.

Table 1. Company size.

No. of employees	Label	No. of firms
< 25	Small	11
25 - 100	Medium	9
> 100	Large	9
TOTAL		29

In the responding firms, an average of two thirds of the employees have primary education or up to third year of secondary education while the other third has workers with higher degrees.

4.1 Quantity of construction waste

From the literature review, the following waste generation figures followed.

Leandro (2006):	115 kg/m ²
Villalobos (1995):	11-25 kg/m ²
Cartín (1995):	0.97 m ³ /m ² (300-700 kg/m ²)

The questionnaire revealed a value of 7-170 kg/m². Combined with the other figures an estimated value of 100 kg/m² is plausible and can be used to do estimations of construction waste generation in Costa Rica.

The answers to these waste generating questions showed that companies are not aware and do not keep track of the total amount of generated waste. Four of the five on-site visits illustrated that fact. The visited construction sites and the interviews with the supervisors clearly showed unawareness in topics related to environmental matters related to the sector and lack of information. This lack of awareness in itself is already a cause of waste generation since unaware companies are not likely to take action against polluting activities that they do not even know exist.

Most of the waste generation values found in the literature for different countries provided a total value per year. In Costa Rica it was not possible to find such a value but an estimation can be done based on the assumption of an average generation of 100 kg/m² and the estimations based on the projections of the amount of m² constructed during the last 5 years.

4.2 Quality of construction waste

The type of waste produced is wood, soil, piping materials, corrugated roof sheets, wires, packaging materials (paper, plastic and cardboard), cement, concrete, blocks, paints and debris. The amounts (either by volume or by weight) of these streams are unknown since the majority of the companies don't keep track of these data.

Table 2. Amount of construction waste potentially produced in Costa Rica.

Year	Construction (million m ²)	Estimated amount of waste (ton)
2002	1.3	130000
2003	1.8	180000
2004	3.3	330000
2005	3.7	370000
2006	5.95	595000

Source: CCC

Analyzing the waste streams showed that a considerable part of it consisted of recyclable materials. Therefore recycling can contribute to diminish the need for landfills or disposal sites, diminishing environmental pressure and increasing revenues. One construction company performed a material flow analysis and proved that a recycling rate of 80% is feasible. Some of the respondents also mentioned that some of the waste produced in their projects is already reused, mostly on-site, and some via recycling companies.

To try to make a correlation between the waste streams and the company's environmental behavior, an indicator was prepared, and here defined as "environmental performance". It is based on questions related to some good environmental practices used by the organizations. They were: if the company monitors the amount of waste produced and which indicators are used, if it has a waste management plan or someone in charge of environmental topics for the construction sites, if the company had any environmental friendly technologies to decrease the environmental impact of construction in the last two years and questions related to separation and reuse of waste.

The results are shown in Table 3. Statistical analysis demonstrated that there is no significant correlation between the occurrence of waste streams and the level of environmental performance, or the size of the company.

That is an indication that the waste streams, as such, cannot be prevented given the current technological and organizational characteristics of the Costa Rican construction sector. Maybe attention to environmental measures can decrease the magnitude of the waste streams.

Table 3. Environmental performance, statistical analysis.

Environmental score	No. of Companies	% Companies
Low	11	36.7
Medium	15	50.0
High	3	10.0
Total	29	96.7
Missing	1	3.3

4.3 Environmental impact

The pollution of the site and its surroundings is the principal manifestation of environmental effects created during the construction works. The impacts can be to the air, water and soil. Pollution to the air is mainly due to the dust produced and the common practice of burning the combustible waste to reduce its volume. The surface and ground waters are affected by surface runoff and infiltration during heavy rains (2000-4000 mm/year) that may transport fuels, oils and paints that are improperly stored. Besides construction waste is sometimes dumped in the ocean or onto the river beds. The soils are affected as well, by the practice of leaving waste in the ground that often is covered with vegetation at the end of the projects. Another impact on the environment is the abundant use of wood as a casing material, which results in an extra pressure on forests that are already under stress.

4.4 Causes of waste generation

The causes of waste generation are mainly related to legislation and law enforcement, awareness, technical aspects as: material sizes, material handling and revenue.

Legislation and law enforcement

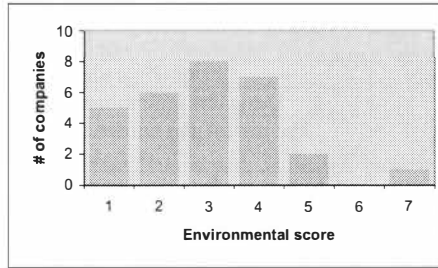
The country has plenty of laws and regulations to protect the natural resources but has a lack on their enforcement, the fines to be paid in case of breaking the law are very low and there are no policies that can help the sector towards sustainability.

Awareness

The awareness concept, meant as the importance that the company gives to the protection of the natural resources or the environment in general, was assessed during the survey. Awareness of environmental problems is one of the most important precursors for environmental benign developments. Questions used to analyse this concept were related to the incorporation of environmental practices in terms of: including the environment into their accounting, personnel promoting environmental practices within the company, environmental criteria when choosing the suppliers or sub-contractors, knowledge of where the waste is disposed of, recycling activities, information required and technical assistance related to sustainable construction, environmental certifications, measures to save input materials and waste management plans. Generally, the outcomes of the questionnaire and the information of the interviews showed a low level of awareness related to environmental matters and particularly of construction waste. Based on the "responding firms" scores on individual questions an overall score depicting the environmental performance is devised. Table 4 shows an overview of the scores.

Table 4. Environmental performance distribution.

Score	No. companies	% of companies
Low < 2.5	13	45
Average 2.5 - 5	15	52
High > 5	1	3
Total	29	100



The need for information and technological assistance is also an indicator for awareness. The survey demonstrated that most of the information required is related to legislation and few of the companies look for information or technology related to sustainable construction which shows that they are looking for a way to reduce their environmental pressure, whether motivated by economical or ecological reasons.

Technical aspects

Knowledge of the causes of waste generation from the technical point of view is essential. Incompatible standard sizes of construction materials are causing a major problem related to waste generation. More than 50% of the companies experience this problem in more than half of their projects. Incompatible standard sizes also have the highest number of companies experiencing this problem “on all projects”.

Table 5 shows from a list provided the problems encountered that are either related to material management or causes that are related to the material suppliers. The score is based on the importance assigned by the respondents a score was calculated ranging from 0 (for never occurs) to 4 (occurs on all projects).

Table 5. Waste generating technical aspects.

Waste generation influencing aspects	Score
Incompatible standard sizes available on the market	2.30
Errors by tradespersons or labourers	1.93
Designers unfamiliarity with alternative products	1.77
Environmental unfriendly attitude of project team and labourers.	1.73
Changes made to the design while construction is in progress	1.72
Complexity of detailing on the drawings	1.52
Use of incorrect material, thus requiring replacement	1.37
Damage to work done caused by subsequent subcontractors	1.29
Bad weather	1.23
Required quantity unclear due to improper planning	1.17
Ordering errors (too much, too little)	1.13
Incomplete contract documents at the beginning of the project	1.10
Selection of low quality products	1.10
Delays in passing of information to the contractor on types and sizes of products to be used	1.10
Materials supplied in loose form	1.10
Damages during transportation	1.07
Inappropriate storage leading to damage or deterioration	1.07
Equipment malfunctioning	1.00
Lack of possibilities to order smaller quantities	1.00
Purchased products that do not comply with specifications	0.93
Errors in contract document	0.77
Accidents on the construction site	0.72

One of the major material suppliers for buildings are companies from United States of America that use the Imperial System of measurement (British), which is not compatible with the SI-measures used by Costa Rica. Besides the sector has to deal with a colonial heritage, which is the unit 'vara' used to measure wood during its colonial Spanish period. One 'vara' equals 84 cm. A wooden bar 'pulgada madera' measures, 1 inch x 1 inch x 4 varas. Materials supplied from countries using SI dimensions are not compatible with materials coming from countries using other systems; therefore extra waste is generated to fit all the pieces together. This standardization topic is already analysed by the Camara Costarricense de la Construccion [16] and efforts have been made in order to look for solutions for this situation.

A common practice within the builders is to request future owners to buy more materials than actual needed. This is profitable for the contractor who can benefit from increased turnover and convenient for the construction workers. They do not have to work meticulously in order to get the most useful sections out of a piece of wood or a steel bar. Obviously, this practice generates waste. Luckily, leftovers are used to construct ladders, sieves and scaffoldings. However, when the construction is completed, these materials turned into waste. A useful practice is an unknown amount of informal recycling by construction workers.

4.5 Motivators and barriers

The survey included questions about the most important motivators and barriers to environmental building practices. The responding firms identified environmental awareness and cost reduction as important motivators to use more benign construction practices while economic motivators are: reduction of material loss and accidents as well as saving raw materials.

Many measures to reduce the environmental pressure are linked with increased material efficiency and hence with economic benefits, however, in the construction sector the profits are very high in the order of 50%. As a result, the companies are not so eager to invest time, effort and money in ways to increase their profits a few percent.

Barriers were analyzed from different perspectives: knowledge, technology, economical and governmental. The most important barriers to acquire knowledge are: the lack of money to implement environmental programmes within the companies and the lack of programmes and studies on sustainable construction at the formal education entities. When the technology barriers were analyzed, three were mentioned as the most important ones and are related to the lack of knowledge on appropriate technologies and their implementation, the assumption that a cleaner construction process has higher costs, and the fact that designers work isolated without having an integral approach in the design process.

From the economical point of view the most mentioned barriers are the lack of financial instruments like taxes and subsidies and the fact that the prices of the construction works do not reflect the environmental cost. This implies that companies are willing to use more expensive technologies if only they could price their houses higher.

Several governmental aspects are considered important barriers. Inconsistencies between different governmental agencies rank highest. Bureaucracy and lack of governmental support to use sustainable technologies are also considered important. This result is in line with the previous result that companies would behave different if there would be taxes, subsidies or incentives.

One last aspect important to analyse as a barrier is the low education level of the majority of the workers participating in the construction process. The construction sector in the country is labour intensive, with workers sharply divided between a small group with high level of education, mainly composed by skilled engineers and managers that are organised on a permanent basis, and a lower bigger group consisting of employees with very low motivation, working on site, which are hired with temporary contracts and low salaries. The training of these workers takes place on site in an informal way. It is common to hire unskilled migrants from Nicaragua, which in many cases are illegal.

5 CONCLUSIONS

The literature related to the quantity and composition of the construction waste in Costa Rica is very limited and the existing one has discrepancies, therefore the value of 100 kg generated waste per square meter constructed floor space was taken from available literature and the questionnaire in order to have a picture of the magnitude of the problem or the magnitude of the waste.

The most important waste categories are wood and soil, piping materials and roof sheets. Often, the waste is mixed and only 50% of the companies indicated that they separate the waste to some extent. The most used fractions for waste separation are wood, metals and mixed waste.

The survey helped to find the causes of waste generation, which are related to the lack of governmental motivation and enforcement of the existing legislation. There are no policies aimed at the reduction of the environmental pressure of the construction sector. Besides, the lack of financial measures to influence the behaviour of the sector like taxes, increase in disposal fees, subsidies and grants, support for research programmes and the establishment of useful pilot projects are causes mentioned by the respondents.

There is a general lack of awareness of environmental issues among the construction sector. Additionally a lack of information, technologies and governmental or market incentives to use those technologies frustrate the efforts of those trying to improve their environmental response. As a result, more waste is generated than when these technologies are applied. The generated waste, in turn, is frequently disposed (legally or illegally) instead, of being reused or recycled. The law enforcement is lacking and recycling initiatives are not well known among the construction sector.

At a company level, the most significant cause for waste generation is unawareness. This results in low interest in sustainable ways of construction and is thus a barrier to decrease the environmental pressure. The respondents also indicated that a lack of money to implement programs is a barrier. However, there is also unawareness of the potential profitability of sustainable technologies. But since the profits in the sector are very high this will not be a very important motivator.

The standardisation of materials play an important role in order to reduce the waste generated. This topic has been already tackled by the Camara Costarricense de la Construccion.

The need for information and technological assistance is also an indicator for environmental awareness. The fact that companies search for information or technology related to sustainable construction shows that they are looking for a way to reduce their environmental pressure, whether motivated by economical or ecological reasons.

Universities who should act as information providing agents are considered not so useful by the responding firms, as do many other institutions including the National Centre for Cleaner Production.

In order to reduce the environmental pressure, the CFIA and the CCC could play a very important role because of there extensive network, that allows them to influence the sector both on governmental as well as on company level. Standardisation of materials plays an important role, which has been already tackled by the Camara de la Construccion.

Builders can improve their operations through a better understanding of their activity in an integral way, taking into account not only the cost, quality and schedule of the projects but also the environment.

Probably no sector has more potential to contribute to the achievement of sustainable development than construction and most attention has to be devoted to analyse the proper

management of the materials that enter in the production process, and future research should continue in this line.

REFERENCES

- [1] Environmental Protection Agency U.S., 1995. Residential construction waste management demonstration and evaluation, Office of Solid Waste, NAHB Group.
- [2] Arpad H., 2004. Construction materials and the environment, *Annu. Rev. Environ. Resour.* 29, 181–204.
- [3] Mocozoma D., 2002. International Report on Construction Site Waste Management and Minimisation, International Council for Research and Innovation in Building and Construction.
- [4] UNEP Industry and Environment April-Sept 2003, pp 5-12.
- [5] Tam, V.W.Y., Tam, C.M., Zeng, S.X., 2004. Comparison of environmental performance assessment (EPA) for construction in Hong Kong and the Mainland China, University of Hong Kong.
- [6] Begum R. A., Siwar C., Pereira J. J., Jaafar A. H., 2006. Benefit–cost analysis on the economic feasibility of construction waste minimization: The case of Malaysia, *Resources, Conservation and Recycling*, 48 (1), 86-98.
- [7] Poon, C.S, Yu, A.T.W., Ng L.H., 2001. On-site sorting of construction and demolition waste in Hong Kong, *Resources, Conservation and Recycling*, 32 (2), 157-172.
- [8] Griffith A., Watson P., 2004. *Construction Management. Principles and practice.* Palgrave Macmillan, USA, pp 7-8.
- [9] The Economist Intelligence Unit, June 2006, London.
- [10] Hogland W. (Ed). Bengtsson L., Carlsson B., Elander P., Holmstrand O., Hult J., Meijer J.E., MonteliusM., Nilsson P., Persson B.L., Persson I., and Seman P.O., 1996. Landfilling, Report N. 3206, Internal Report 1996:5 Department of Water Resources Engineering, Lund University.
- [11] Stenis, J., 2005. *Industrial Management Models with Emphasis on Construction Waste*, PhD Dissertation, Lund Institute of Technology, Sweden.
- [12] Villalobos, A.J., 1995. *Estudio de Generación de Desechos en la Construcción de Viviendas de Mampostería*, Lic. Dissertation, Universidad de Costa Rica, Costa Rica.
- [13] Ramirez, M., 1995. *Impacto físico y financiero de la generacion de desechos solidos en la construccion de dos proyectos hoteleros*, Lic. Dissertation, Universidad de Costa Rica, Costa Rica.
- [14] Leandro, A.G., 2006. *Researcher Costa Rica Institute of Technology*, Personal communication.
- [15] Bueren M van, Priemus H., 2002. Institutional barriers to sustainable construction, *Environment and Planning B: Planning and Design*, 29, 75-86.
- [16] Camara Costarricense de la Construccion, January 2007.