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Solid construction waste management in large civil construction companies through use of specific software - case study

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ABSTRACT. In the current construction market there is a high demand for sustainability. In addition to that the Brazilian government is enacting tougher and tougher legislation on the disposal of solid construction waste. These demands increasingly make the construction company responsible for the entire lifecycle of its waste as well as the accompanying cost and environmental impact of solid waste. A software program was used in the research which allows construction companies gather information about waste. This helps the decision makers, at all different levels of the company improving waste management through better decisions. The software program was used during the construction of two residential buildings, constructed by a large construction company in the South of Brazil. Five key performance indicators were used by the construction company team: Generated Waste Height (cm), cost per built area (R$ m^{-2}), Waste Segregation Quality Index (WSQI), Effective Waste Management Index (EWMI) and Waste Management Quality Index (WMQI). After four months the total cost of waste management was R$ 83,551.71 for site A and R$ 91,668.02 for site B. About 70% of the waste was raw material waste. The software program provided information not previously available, which made it possible to calculate the cost of material loss, indicating corrective actions, all without losing sight of cost reduction opportunities for the management of Solid construction Waste (SCW).

Keywords: construction solid waste management, performance indicators, management information system.

Gerenciamento de resíduos de construção civil em empresas construtoras de grande porte por meio de software específico – estudo de caso

RESUMO. A demanda do mercado por sustentabilidade e a legislação brasileira para o gerenciamento de resíduos sólidos, inclusive de construção civil, impõem que construtoras sejam responsáveis por todo o ciclo de vida dos resíduos, custos e seus impactos ambientais. Nesta pesquisa foi utilizado um software que permite às empresas construtoras produzir informações de gerenciamento de resíduos para os tomadores de decisão em diferentes níveis de influência da empresa, auxiliando-os a aprimorar o gerenciamento dos resíduos. O software foi implantado em duas obras de edifícios residenciais de uma grande empresa construtora no sul do Brasil. Foram aplicados cinco indicadores: altura dos resíduos (cm), custo por área construída (R$ m^{-2}), Indicador de qualidade da segregação (IQS), Indicadores de Eficácia (IEGR) e Índice de Qualidade do Gerenciamento dos Resíduos (IQGR). Em quatro meses o custo total do gerenciamento de resíduos foi de R$ 83.551,71 para a obra A e R$ 91.668,02 para a obra B. Cerca de 70% é resultante do desperdício de matéria-prima. O software apresentou informações anteriormente não disponíveis, que permitiram conhecer o custo de perda de materiais, direcionando as ações corretivas, sem perder de vista oportunidades de redução de custo para o gerenciamento dos RCC.

Palavras-chave: gerenciamento de resíduos de construção civil, indicadores de desempenho, sistema de informações gerenciais.

Introduction

The construction sector is without argument a highly relevant economic sector in Brazil since it represents 5.8% (Instituto Brasileiro de Geografia e Estatística [IBGE], 2013) of national GDP and employs 3 million people (Instituto Brasileiro de Geografia e Estatística [IBGE], 2015).

However, it is recognized as having a high environmental impact, through the consumption of natural resources, landscape modification and the unregulated generation and final disposal of solid waste.

Figures from research on construction waste conducted by the Instituto de Pesquisa Econômica Aplicada [IPEA] (2012) indicated that about 31 million tons of Solid Construction Waste (SCW) are generated in Brazil each year, which demonstrates the sheer volume of materials waste and the serious impact it has on the environment.

In other countries the generation of construction waste is also relevant. According to a report entitled 'Service Contract on Management of Construction and Demolition Waste - SR1' (Monier, Mudgal, Hestin, Trarieux, & Mimid, 2011) published in February 2011, the annual weight of SCW generated in the 27 EU member countries is 970 million tons.

Currently, most construction companies are still treating environmental management and more specifically waste management, as a regulatory issue, which must be complied with in order for the enterprise to legally function, rather than a strategic issue, which is able to bring competitive advantages to the company. However, the market demands sustainability, resources saving, transparency and accountability (Lazlo & Zhexembayeva, 2011).

Many companies have adapted to these demands. With the improvement of environmental management, many companies are starting to integrate it into the broader process of decision making and began treating it as strategic issues (Harrington & Knight, 1999).

However, the construction sector still have a long road ahead in order to reach full maturity and fully exploit the competitive advantages in waste management. An important step in this evolution is recognizing that environmental issues are corporate priorities.

These decisions on waste management involve adopting a set of values and practices which can be difficult to effectively check in companies. These include top management commitment, establishing policies, effective comunication, constant monitoring and training of human resources (Oliveira et al., 2010).

It is important that this process occurs in the context of quality or environmental management, following the already established methodology which is based on the adoption of the Plan, Do, Check, Act (PDCA) () principle. In this cycle, monitoring (Check) is critical because it is where the measurement and interpretation of results of the productive activity take place, which in turn guide the implementation of corrective actions and improvements.

Waste management has never been a primary goal in construction, therefore it is rarely monitored or evaluated properly, making it difficult to improve the processes, hence making it virtually impossible to fully comply at least with the relevant legislation.

ABNT ISO 14031 (Associação Brasileira de Normas Técnicas [ABNT], 2004, p. 2), which deals with guidelines for the Environmental Performance Evaluation, defines monitoring environmental performance as: "The process that facilitate management decisions regarding the environmental performance of an organization and comprising the selection of indicators, data collection and analysis, evaluation of information comparison with environmental performance criteria, reporting, reports, reviews, periodic reviews and improvements of processes".

Therefore all the work necessary for the development, implementation and maintenance of a company's waste management strategy, as well as its actions that promotes sustainability, requires periodic monitoring by means of indicators to assess whether the objectives and goals are being met.

Indicators can also be translated into indices that condense information obtained through the aggregation of data. The indices are needed at the highest level of decision-making, expressing an overall result, flowing from the results of several actions taken to meet a common strategic objective (Bellen, 2007).

To serve all levels of the organization with useful indicators, it is necessary to understand the relationship between data and information, as well as its limitations and potential. Data is collected in the field, in day to day operation procedures. Aggregated data, indicators and indices are information that results from aggregating and relating data, as shown in Figure 1.

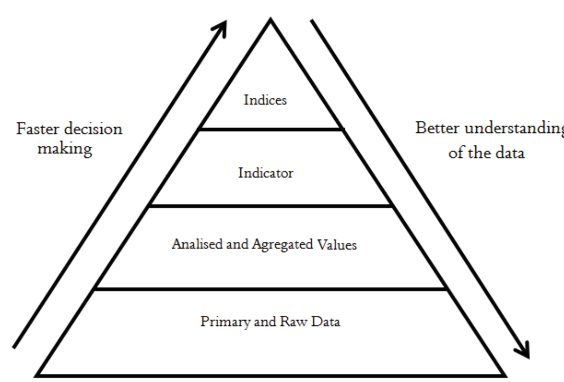

Figure 1. Data aggregation and information levels. Source: Adapted by the author from Hammond, Adriaanse, Rodenburg, Bryant and Richard (1995).

Since construction companies encounter many difficulties to manage their SCW, there is a need for a system of indicators supported by a data processing tool that would assist in monitoring the SCW, generating management information to enable the consistent evaluation of the performance of managing SCW.

The purpose of this article is to evaluate whether the indicators of a computerized software system for the monitoring and control of solid construction waste (SCW) makes the assessment of management performance possible and thereby facilitating management decisions.

Material and methods

For this study, a case study is presented, in which a Solid Construction Waste Management Software program, called SCWMS was used at two construction sites of a civil construction company in the Londrina region, in the state of Parana in the south of Brazil. The construction company is mature and consolidated.

The study was conducted at two construction sites called A and B, covering different stages of construction. As there was no previous data on SCWMS, the research at two sites allowed comparisons on the data itself and also on the perception from different engineers about the results and indicators. The system was implemented for a period of four months between May and August of 2013. The general characteristics of the sites are presented in Table 1:

There was no direct intervention by the researcher in the SCW management processes of the construction company, as adviced by Yin (2002), but new information about the SCW, generated by the Solid Construction Waste Management Software - SCWMS was presented to the company.

The results of the indicators generated during the study were discussed with the construction company team in two critical evaluation meetings and field visits. The purpose of the meetings and visits was to identify improvements, changes and provide new insights for SCW management within the team, thereby confirming, or not, the usefulness of the indicators generated by the SCWMS.

Different source documents were used, all of which could be used as proof on whether the research objective was reached or not. The sources are:

- Documents and Records in Company Archives
- Spontaneous and semi-structured interviews.
- Direct observation during field visits.

Training in the use of the SCWMS was provided to whole team participating at the construction site, including all the site engineers, environmental coordinators and stock controllers. Each one of them was given a login and password to access the SCWMS.

The SCWMS is a web application that uses an SQL Server database, and was developed in the ASP.NET language. It does not require installation on any computer and can be accessed through any device connected to the internet. Both sites had a computer with an internet connection and a printer for using the SCWMS.

The SCWMS applications were:

- Entries: Loads information about the site, waste transporters, recipients and waste itself. Each registered type waste was linked to its classification under CONAMA Resolution No. 307/2002 (Brasil, 2002), as well as its raw material, transportation and disposal costs.
- Tools: The tool available was the Waste Transport Control document, or WTC.

With the WTC tool, the system automatically generates an identification number and records the time and date. The operator specifies the waste generating department, the recipient and the Waste disposal company.

It also specifies all the waste that can be seen inside the recipient and its volume.

Segregation of waste was visually classified into three categories and this information was inserted into the WTC document. Operators were trained by the researcher to be able to classify waste objectively, reducing possible errors of evaluation.

The criteria established for each type of segregation is:

Good segregation: all waste in the recipient is of the same type.

Table 1. General characteristics of the sites in the Case Study.

Characteristics	Site A	Site B
Phase	A residential tower at the finish and closing stage	Three residential towers with several overlapping phases, from structuring to finishing
Land Area	5.800m²	10.272m²
Floors	23	19
Apartments	92	342
Construction method	Conventional system of reinforced concrete and the sealing of the masonry structure with ceramic bricks	Conventional system of reinforced concrete and the sealing of the masonry structure with ceramic bricks
Applied innovation	None	None
Staff	From 50 to 250	From 50 to 250
Duration	40 months	39 months
Percentage completed by the end of the survey	88% or 33 months	64% or 24 months

Fair segregation: possible to distinguish the presence of a dominant waste as well as presence another type of waste in a smaller amount in the recipient.

Bad segregation: It is not possible to distinguish a specific type waste in the recipients, due to a high level of mixing. If there was hazardous waste present (as defined by CONAMA Resolution No. 307/2002) (Brasil, 2002) in any quantity, the waste was also classified as bad segregation.

Indicators System

Using the records and the SCWMS tools, indicators were designed and applied to express the Solid Construction Waste Management performance. These indicators can be used at all levels of the organization. Indicators used were:

Indicators of Waste Generated

- Volume of Waste: the sum of the volume of all waste generated in a given period. It can also be calculated for each type of waste identified as predominant in recipient. It is expressed in m^3.

- Waste height (cm): an indicator that relates the volume of waste generated per total built area, or m^3 (generated) m^{-2} (built). It allows a parameterized comparison of waste generation from different sites. It is expressed in centimeters (cm)

Equation 1: Waste Height Indicator Calculation

$$Waste\ height\ (cm) = \frac{Waste\ Volume\ (m^3)}{Built\ Area\ (m^2)} \times 100 \qquad (1)$$

Cost indicators

- For cost of raw material, the total is calculated using the cost of the construction raw material which has become waste, times the quantity generated. Only the predominant waste in the recipient, which was selected at the time of filling out of the WTC document, was used in the calculation. It is an estimate of the cost of Construction Waste Material.

- Cost of transport: the total is calculated using the amount of waste generated times the cost of transportation for this waste.

- Cost of disposal: The total is calculated using the amount of waste generated times the cost of disposal of this waste.

- Total cost of the Waste Management: This is the sum of the costs of wasted raw materials, plus the transportation and disposal cost of that waste.

- Cost per square meter built: This is the ratio between the total cost of waste management and the total built area. It allows a parameterized comparison of waste generation from different sites. It is expressed in R$ m^{-2}.

Waste segregation Quality Indicators

-Waste Segregation Quality represents the total number of recipients divided into the level of segregation quality, classified as Good, Fair or Poor.

-Waste Segregation Quality Indicator (WSQI): a weight is assigned to each type of evaluation, 3 for good, 2 for Fair and 1 for Poor. The indicator is the weighted average of all evaluations performed over a period considering the weight of each type of waste. Equation 01 shows the calculation of WSQI.

The end result is dimensionless, and values closer to three (3) indicate a better segregation of waste, while values closer to one (1) indicates poor segregation of waste.

Equation 2: Calculation of Segregation Quality Indicator

$$WSQI = \frac{(3\ x\ \Sigma\ Good) + (2\ x\ \Sigma Fair) + (1\ x\ \Sigma Bad)}{(\Sigma Good) + (\Sigma Fair) + (\Sigma Bad)} \qquad (2)$$

General indicators of Waste Management

-Waste Management Effectiveness Index (WMEI): This is the ratio of the target set for the indicator and the results reached for generation, cost and segregation of waste. A WMEI equal to 1 indicate that the target was met, WMEI results above 1 indicates that the target was overshot and below 1 that the target was not met.

Effectiveness indicators are grouped to create a single indicator which represent the global the quality of management of solid waste, and is called the Waste Quality Management Quality Index, or WQMI.

-Waste management Quality Index (WQMI) represents the average of the three WMEI and summarizes the overall result of waste management relative to the targets set by the company.

Results and discussion

In the period the SCWMS was used, between May and August of 2013, 98 Waste Transport Control documents were created at site A and 131 WTC documents at site B.

The first indicator analyzed in Table 2 was the volume of waste generated by waste type (m^3). For site A, it was predominantly the generation of mortar and concrete waste, 351 and 85 m^3, respectively. Among the waste classified at site A, there were also bricks, but only 5 m^3.

For site B, predominantly soil was generated, at about 360 m³, followed by concrete, at 271 m³. Mortar registered at 50 m³ and was much lower in comparison with the land/soil and concrete. Ceramic tile waste were also generated in large quantities at site B, about 75 m³.

Table 2. Breakdown of waste generation of site A and B in volume (m³) per type of waste generated.

Waste	Volume Generated per Type of Waste — Volume (m³) Site A	Site B
Mortar	351	50
Concrete	85	271
Gravel	-	20
Blocks	-	15
Iron	20	5
Brick	5	25
Land / Soil	20	363
Construction Tailings	5	5
Plastic film	15	-
Hard Plastic	20	3
Paperboard	35	49
Plaster	40	25
Non-ferrous materials	-	20
Ceramic tiling	-	75

First, it can be noted that site A generated lots more mortar and concrete waste than site B. This result was evaluated in field assessments and it was found that waste operators have difficulty distinguishing between the two types of waste. Site B generated 75 m³ ceramic tiling waste, while site A did not generate waste of this type.

The amount of soil waste generated at site A was lower compared to site B. This was due to the early stage of site B at one of the towers, which required greater earth movement and excavation.

Figure 2 shows the monthly total of the Generated Waste Height indicator in cm during the study period and the cumulative result for the same period for site A. The indicator ranged between about 0.40 and 0.60 cm per month, adding up to approximately 1.70 cm over the period.

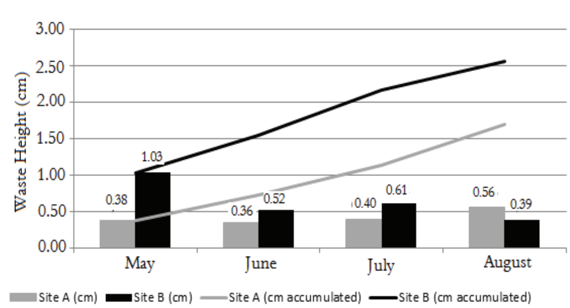

Figure 2. Comparison between A and B works of monthly generated construction waste height (cm).

For site B (Figure 2) the monthly variation was between 0.40 and 1.00 cm, adding up at the end of the period to approximately 2.50 cm. It can be noted that in May the generation of waste was clearly much higher than the other months. This was due to the great movement of land / soil during this period, as discussed above.

Table 3 presents the results of site A for the costs calculated for each type of material, considering the following three aspects: raw materials cost, transportation cost and disposal cost.

The total cost of waste management for site A was R$ 83,551.71. Much of the cost was generated in the loss of raw materials, R$ 66,145.80, while the disposal and transportation costs was less than R$ 9,500.00. Most of the cost of raw material waste was caused by the loss of mortar and concrete. The cost of disposal was impacted more by gypsum waste since it must be allocated to a specific company for disposal, at a higher cost. Thus, for site A, approximately 75% of the cost came from mortar and concrete waste. The gypsum disposal corresponds to 13.89% of the costs.

Table 3 also shows that for site B, the most significant costs for raw material waste was concrete, at R$ 33,139.35, followed by ceramic tiling, at R$ 9,480.90 and mortar, at R$ 7,468.85.

As for the waste disposal, the highest cost was of gypsum waste, R$ 4,470.50, due to its high cost of discarding. Soil also showed high cost relative to other waste, due to the large volume generated, and not because of its cost as a raw material.

Finally, the total waste management costs in the period was R$ 91,668.02, with the most significant portion of this amount being the cost of raw materials, R$ 67,356.05, similar to what happened at site A. The highest waste cost was concrete, at 43.10%, ceramic tiles, at 12.67%, plaster, at 10.22% and land / soil, at 7.91%.

Figure 3 shows the comparison in growth index between site A and B. Site A presented a monthly variation of between approximately R$ 0.50 m^{-2} and R$ 1.00 m^{-2}, adding up at the end of the period to R$ 2.48 m^{-2}. Site B presented a monthly variation between approximately R$ 0.40 m^{-2} and R$ 1.00 m^{-2}, totaling at the end of the period at about R$ 2.50 m^{-2}.

Comparing site A and B, it appears that both had significant variations in the period but the final results for R$ m^{-2} tended towards the same value of approximately R$ 2.50 m^{-2}.

Despite the significant difference in the Waste Height Indicator (cm), the difference in the Cost Indicator (R$ m^{-2}) is very low between the sites.

Table 3. Cost Report results of waste management by type of waste from site A.

Types of Waste	Cost Analyses							
	Site A				Site B			
	Raw material	Transport	Disposal	Total	Raw material	Transport	Disposal	Total
Mortar	R$ 42,531.40	R$ 5,700.00	R$ 2,786.54	R$ 51,017.94	R$ 7,468.95	R$ 1,000.00	R$ 489.35	R$ 8,958.30
Blocks	R$ 0.00	R$ 0.00	R$ 0.00	R$ 0.00	R$ 1,875.00	R$ 200.00	R$ 142.50	R$ 2,247.50
Gravel	R$ 0.00	R$ 0.00	R$ 0.00	R$ 0.00	R$ 0.00	R$ 400.00	R$ 207.77	R$ 607,77
Concrete	R$ 12,061.10	R$ 1,100.00	R$ 790.21	R$ 13,951.31	R$ 33,139.75	R$ 4,200.00	R$ 2,17.23	R$ 39,510,.8
Iron	R$ 600,00	R$ 0.00	R$ 0.00	R$ 600.00	R$ 150,00	R$ 0.00	R$ 0.0	R$ 150.00
Plaster	R$ 5,362.10	R$ 800.00	R$ 5,440.45	R$ 11,602.55	R$ 4,402.20	R$ 500.00	R$ 4,470.55	R$ 9,372.75
Non ferrous metals	R$ 0,00	R$ 0.00	R$ 0.00	R$ 0.00	R$ 3,,160.00	R$ 0.00	R$ 0.00	R$ 3,160.00
Paperboard	R$ 2,310.00	R$ 0.00	R$ 0.00	R$ 2,310.00	R$ 3,234.00	R$ 0.00	R$ 0.00	R$ 3,234.00
Hard Plastic	R$ 286.00	R$ 0.00	R$ 0.00	R$ 286.00	R$ 42.90	R$ 0.00	R$ 0.00	R$ 42.90
Construction Tailings	R$ 0.00	R$ 100.00	R$ 27.27	R$ 127.27	R$ 0.00	R$ 100.00	R$ 55.01	R$ 155.01
Ceramic tiles	R$ 0.00	R$ 0.00	R$ 0.00	R$ 0.00	R$ 9,480.90	R$ 1,500.00	R$ 818.81	R$ 11,799.71
Land/Soil	R$ 0.00	R$ 300.00	R$ 190.00	R$ 490.00	R$ 0.00	R$ 3,800.00	R$ 3,446.98	R$ 7,246.98
Brick	R$ 1,015.20	R$ 100.00	R$ 71.44	R$ 1,186.64	R$ 4,402.35	R$ 500.00	R$ 309.80	R$ 5.212,15
Film Plastic	R$ 1,980.00	R$ 0.00	R$ 0.00	R$ 1,980.00	R$ 0,00	R$ 0.00	R$ 0,00	R$ 0,00
Total	R$ 66,145.80	R$ 8,100.00	R$ 9,305.91	R$ 83,551.71	R$ 67,356.05	R$ 12,200.00	R$ 12,112.00	R$ 91,668.05

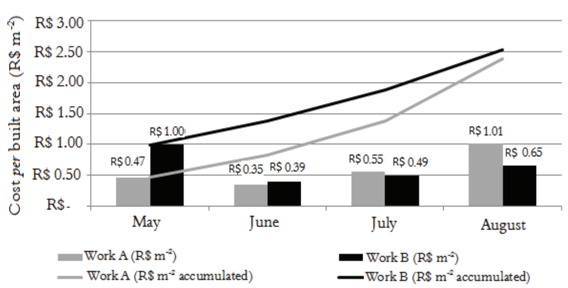

Figure 3. Comparison of growth of the R$ m^{-2} indicator between sites A and B between May and August of 2013.

All recipients from site A and B were evaluated visually for quality of segregation, following the criteria established in the methodology chapter.

With the amount of assessed recipients, the Waste Segregation Quality Indicator (WSQI) was calculated. Table 4 presents the monthly results of sites A and B.

Table 4. Summary of Waste Segregation Quality Indicator in recipients and results of WSQI of site A and B.

Period	Waste Segregation Quality Indicator							
	Site A				Site B			
	Evaluation value			WSQI	Evaluation value			WSQI
	Good	Fair	Bad		Good	Fair	Bad	
May	19		1	2.9	5	35	6	1.98
June	17	1	2	2.75	9	7	11	1.93
July	24	1		2.96	26	4		2.87
August	19	11	1	2.58	21	2	1	2.83
Total for the Period	79	13	4	2.78	61	48	18	2.34

It appears that at site A the results remained stable over the period, with a final value of 2.78. Site B, had bad ratings in May and June, and better results in the months of July and August, culminating in a fair result in the period, equal to 2.34.

Efficacy indicators compare the results obtained with the desired result or goal. Because the research was limited in scope as well as time, neither of the sites created formal goals for waste management. For this reason the achieved goals are compared to simulated goals that were created specifically for this research. In addition, the comparison was made only for site A.

This simulation was then used to discuss the indicators with the construction staff and test the possibility of setting targets linked to these indicators in future projects.

Three scenarios were simulated and are presented in Table 5. The first scenario was with results above the target, the second scenario with results exactly on target and the third scenario with results below the target. The simulation was performed only with the results obtained from the sites in the period between May and August of 2013.

Table 5. Simulated results for Quality of Waste Management Index.

Scenario 1- Above the target - Site A				
Indicator	Final result	Goal	QWMI	WMEI
Generation (cm)	1.7	1.75	1.03	
Cost (R$ m^{-2})	2.38	2.4	1.01	1.03
WSQI	2.78	2.7	1.05	
Scenario 2- On target - Site A				
Indicator	Final result	Goal	QWMI	WMEI
Generation (cm)	1.7	1.7	1	
Cost (R$ m^{-2})	2.38	2.38	1	1
WSQI	2.78	2.78	1	
Scenario 3 - Below target - Site A				
Indicator	Final Result	Goal	QWMI	WMEI
Generation (cm)	1.7	1.5	0.88	
Cost (R$ m^{-2})	2.38	1.5	0.63	0.83
WSQI	2.78	2.8	0.99	

In Scenario 1, in which all indicators surpass the goals, the WMEI values are all above 1. In scenario 2, the indicators reach exactly the goals and the WMEI values are all equal to 1. In Scenario 3, the goals are not achieved for any indicator and the WMEI values are all less than 1. The Quality of Waste Management Index (QWMI) gives an overall value for the result of the waste management effort.

To discuss the results of each site with the team assigned to the site, two critical evaluation meetings for the SCWMS results were held. In these meetings the usefulness and the possible application of indicators generated by the system were discussed.

In presenting the indicators generated by SCWMS all participants indicated that they understood the meaning of each indicator. The Generated Waste Height (cm), Cost per built area (R$ m^{-2}) and Waste Segregation Quality Indicators (WSQI) were accepted by the participants as useful and understandable indicators to measure and understand the company's waste management.

Regarding of waste generation and cost information, the construction team demonstrated that they had no knowledge of the actual volumes and costs involved in managing waste. They indicated surprise at the high cost of wasted raw material.

These costs were interpreted as a result of inefficient processes and construction technologies which cause a direct reduction of the company's profitability. Hence, the team agreed on the importance of this indicator.

The distortion caused by the soil dirt waste on the indicators results was also discussed. It was argued that the soil waste should be considered separately. The reasoning was that it is not part of the building's construction process, since it does not depend on the engineer and his team's performance but on terrain features, which lies outside their control.

On the high generation of ceramic tiling waste on site B, it was found that over the period considered, a bigger amount than normal was generated due to the finishing of the bathrooms and quality control work.

In the discussion on the evaluation of waste management performance, everyone agreed that there was a lack of well defined and measurable goals and targets for the waste management of their sites.

The wide range of generated waste and costs in the short period studied highlights the need to study the construction of a building from beginning to end in order to develop strategies and goals for managing waste.

According to the resident engineers, the system of indicators helped bring focus to the waste management, because it brought clear analytical criteria, which allows the taking of timely actions to improve waste management performance.

Discussing the segregation indicators in the recipients, all participants agreed that the visual assessment of segregation is subjective and cannot bring real results. Therefore other tools for evaluating the quality of segregation should be created. However, evaluating the quality of segregation was seen as fundamental requirement for managing waste.

Throughout the research process, when the information was made available to the staff of the construction company, spontaneous steps were taken by the construction teams in attempting to improve the waste management. In none of the meetings and visits the investigator directed or requested any specific action to improve the management of waste.

The team agreed that the new information about waste management have led to questions about aspects of work that were not previously asked. Engineers reported to have spent some time on the waste managementand that was not previously devoted to this activity.

Conclusion

The application of the Solid Construction Waste Management System - SCWMS - generated indicators that reflected both quantitatively and qualitatively on the relevant aspects of waste management of a site. This allows the performance to be evaluated and it facilitates management decisions.

The Generated Waste Height (cm), cost per built area (R$ m^{-2}) and Waste Segregation Quality Indicators (WSQI) are parameters of waste management, and allowed the comparison of results between the two sites studied. In addition, it made it possible to define waste and create measurable targets for waste management, which could then be represented by the Waste Management Effectiveness Indicator (WMEI);

The Waste Management Quality Index (WMQI) blended different aspects of waste management into an index which reflects the goals and results for waste management of each site. This index was easily understood by the construction team and agreed on as a possible way to facilitate waste management.

The information generated by SCWMS aided management decisions and actions to improve waste management, as demonstrated by several improvement actions that were voluntarily undertaken as a result of the new information gathered. Therefore, the indicators tested are effective and can lead to improvements of waste management to the civil construction industry, specifically reducing costs and risks of this activity.

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