ENGLISH VERSION

Management system proposal for planning and controlling construction waste

Propuesta de un sistema de planificación y control de residuos en la construcción

T. Maciel *, M. Stumpf [1]**, A. Kern **

* J. M. Martins Construções e Engenharia Ltda. BRAZIL
** Universidade do Vale do Rio dos Sinos (UNISINOS). BRAZIL

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Abstract

Construction industry accounts for a significant part of the solid waste generated in urban centers. In part this is due to a lack of culture of reducing the generation or reuse of waste. This sector may improve this situation, seeking to develop management systems. The objective of this paper is to present a proposal for a management system to plan and control construction waste in small and medium sized construction firms. A case study on construction sites was performed in a building company of Novo Hamburgo, Brazil. The planning and control waste system was developed as based on the production system existing in the firm and results point to the feasibility of implementing this system.

Keywords: *Construction industry, planning and control, construction waste*

Resumen

La industria de construcción genera una parte significativa de los residuos sólidos generados en los centros urbanos. En parte esto se debe a la falta de una cultura de reducción de generación o reutilización de los residuos. Este sector puede mejorar esta situación, tratando de desarrollar sistemas de gestión. El objetivo de este trabajo es presentar una propuesta para un sistema de gestión para planificar y controlar los residuos de la construcción en pequeñas y medianas empresas de construcción. Se llevó a cabo un estudio de caso en una empresa de Novo Hamburgo, Brasil. El sistema de planeamiento y control de residuos fue desarrollado con base en el sistema de producción existente en la empresa. El sistema propuesto fue testado en las obras de la empresa y los resultados apuntan a la viabilidad de implantación del sistema.

Palabras clave: Construcción civil, planeamiento y control, residuos

1. Introduction

The construction industry generates a large amount of solid waste that, in addition to harming the environment, also produces financial losses for builders and for society as a whole (Edwards, 2010; Rocha and John 2003). In Brazil, when Resolution 307 was enacted by the National Environmental Council (CONAMA) in 2002, the industry began to work towards finding viable solutions to the problem, although progress was slow (CONAMA, 2002; Karpinski et al., 2009).

Management systems are becoming increasingly important to construction companies, especially given the economic growth of the industry. Therefore, companies are seeking systems that can provide useful information and help managers make decisions, as these decisions can make the difference in a company's efficiency in the market (Souza 2004). Management systems frequently work in isolation. Giacomello et al. (2014) have proposed integrating systems that plan and control production (PCP) with quality, health, and safety in the workplace and with environmental management systems. What is needed is a management system for waste planning and control that can work together with these management systems. Nogueira et al. (2014) state that information on waste may also be included as an environmental variable in the balanced scorecard.

The system must be clear and objective, and it must be directly linked to the company's production planning and control system in order to avoid duplication or conflicting information. This article presents a proposal for a management system to plan and control the generation, reuse, and elimination of construction waste in small and medium-sized companies. A case study was conducted with a construction company in the city of Novo Hamburgo in Brazil to apply the proposal and analyze the results.

2. Review of literature

2.1 Losses in Construction

The concept of construction losses is frequently associated only with losses in construction materials, such as cement, sand, blocks, wood, and concrete. However, according to Alarcón (2002), construction losses include any consumption of resources (materials, components, machinery, and labor) in larger quantities than the minimum needed for execution, depending on the specific project. In other words, any resources used that do not add value constitute losses. In terms of materials, the most visible loss is waste generated onsite, which is collected and removed by a container transport service. But Agopyan (2002), Formoso et

[1] Corresponding author:

Doctor en Ingeniería, Profesor del Programa de Pos Graduacao en Ingeniería Civil y del Programa de Arquitectura y Urbanismo de UNISINOS. Brazil
E-mail: mgonzalez@unisinos.br

al. (2002), and Paliari et al. (2007) also include as materials losses those that are used in excess of what becomes part of the construction, such as a layer of plaster that is thicker than what was foreseen in the project. This situation may be called an "incorporated loss."

Losses in materials occur during the useful life of a building. That is, waste is generated during the production stage of the materials and components used, as well as in the stages of building, maintaining, and demolishing a building (Karpinski et al., 2009; Patzlaff et al., 2014). Pinto (1989) has demonstrated that the Brazilian industry previously accepted loss levels in construction materials, including incorporated losses, of approximately 20% to 30% of material mass. Souza (2004) states that losses in construction declined when ISO plans and certification for quality were adopted in the industry in the 1990s.

Table 1 presents the waste found among some of the materials most widely used in Brazilian construction (Agopyan et al., 1998; Pinto, 1989; Soibelman, 1993). There are significant differences among the different materials, due in part to the technology used. For example, Pinto (1989) found losses of 102% in the use of lime (more than double the amount estimated), compared to 33% losses in cement. According to that study, most of these materials were used to prepare mortar. Soibelman (1993), in contrast, found 83% losses in cement, but none with lime. However, the works studied by the latter used only cement and sand rather than lime to make mortar. That difference in specifications may partially explain the difference between Pinto's (1989) and Soibelman's (1993) data.

International studies have found materials loss in building construction. In the studies presented in Table 2, the losses represent the percentage of total waste measured at the construction sites, that is, each material's share of the total amount of material researched. The studies by Maña i Reixach et al. (2000), Pereira (2002), Costa and Ursella (2003), and Bergsdal et al. (2007) were conducted in Spain, Portugal, Italy, and Norway, respectively. Although the measurements reflect regional, technological, and even methodological differences, some similarities can still be seen, such as the high percentages of concrete, bricks, and mortar.

Table 1. *Loss of materials compared to amounts estimated for projects (Brazil)*

Materials	Pinto (1989)	Soibelman (1993)	Agopyan et al. (1998)
Steel	26%	19%	11%
Sand	39%	44%	44%
Blocks and bricks	13%	52%	13%
Lime	102%	-	36%
Cement	33%	83%	56%
Ready-mix concrete	1.5%	13%	9%

Table 2. *Percentage of materials in total losses measured*

Materials	Maña i Reixach et al. (2000)	Pereira (2002)	Costa and Ursella (2003)	Bergsdal et al. (2007)
Concrete, bricks and mortar	85.0%	58.3%	84.3%	67.2%
Metal materials	1.8%	8.3%	0.1%	3.6%
Wooden materials	11.2%	8.3%	-	14.6%
Plastics	0.2%	0.9%	-	-
Asphalt	-	10.0%	6.9%	-
Others	1.8%	14.2%	8.7%	14.6%

All things considered, these losses pose a problem to society as a whole. Some studies indicate that the amount of construction waste ranges from 230 up to 760 kg/inhabitant/year in some Brazilian cities (Pinto 2005, Rocha and John 2003). Faria et al. (2007) found that in some cities construction waste occupies 50% of the total volume at final dump sites. Klauczek and Fazolo (2006) state that two tons of waste from construction activities are picked up for every ton of household garbage collected. Studies of onsite waste generation have reported rates based on the percentage of the total generated and on the total construction surface. Dias (2013) measured waste at 20 building construction sites in the south of Brazil and calculated an average waste rate of 0.128 m^3/m^2. Teixeira (2015), studying 18 works of similar size in the same region, found an average of 0.162 m^3/m^2 of construction waste.

In Brazil, CONAMA Resolution 307/2002 established rules for disposing of civil construction waste (CCW), placing the municipal government in charge of enforcing waste disposal and implementing an integral solid waste management plan (CONAMA 2002). These regulations state that generating, shipping, and receiving companies are all responsible for waste generated. This resolution is similar to construction regulations and strategies in effect in Chile and Spain (BRE 2014, MINVU 2013, 2014; General Environmental Authority of Spain 2001). Resolution 307 classifies construction waste as follows (CONAMA 2002):

- *Category A: Waste that is reusable or recyclable as aggregates, such as bricks, concrete, mortar, blocks and bricks, roof tiles, coverings, slabs, etc.;*
- *Category B: Waste recyclable for other purposes, such as plastics, paper/cardboard, metals, glass, wood, etc.*
- *Category C: Waste for which there is as yet no technology or application allowing for economically viable recycling or recovery, such as gypsum-based products;*
- *Category D: Hazardous construction waste such as dyes, solvents, oils, or contaminated waste from demolition, remodeling, and repairs of radiological clinics and other industrial facilities; roof tiles and other items containing asbestos; and other products that pose health risks.*

According to Faria et al. (2007), appropriate CCW management strategies, in order of highest to lowest priority, are: decreasing generation of waste, reusing or recycling waste at the construction site, reusing or recycling was at another location and, as a final option, disposing of waste in duly authorized dump sites.

2.2 Production Planning and Control in Construction

The variability of conditions present in construction environments is a concept taken into account in the theory of loss-free construction. This variability stems from such factors as unforeseen events and human error, but it can also be seen as a result of uncertainty or the risk of not meeting initial cost and schedule planning (Campero and Alarcón, 1999; Koskela, 2002). Even with advances in construction, variability is still noted as a problem in the industry, including in studies conducted at worksites (Ashworth and Perera, 2015; Cabrera et al., 2015; Contreras Socarras, 2012; Campero, 2013; Cooke and Williams 2015). Therefore, tools are needed that can manage uncertainty. Dynamic planning is often proposed as an organizational strategy, dividing plans into three distinct levels of planning (Ballard and Howell, 1998; Bernardes, 2003; Laufer, 1996).

The resources needed to execute a work consist primarily of materials, components, labor, and machinery. The requirements for the different resources vary in terms of procurement and delivery timing, which suggests the need for implementing a hierarchy for scheduling negotiation and purchasing activities. Ballard (2000) proposed differentiating resources into three separate classes (Class 1, 2, and 3) according to scheduling needs (horizon) for procurement, and dividing planning into three levels: long, medium, and short term. These horizons and resource classes are presented in Table 3.

Table 3. *Classes of resources by planning horizon*

Class	Horizon	Concept
Class 1	Long Term	Resources that have a long procurement cycle with low repetitiveness within the cycle. The amount acquired is usually the total amount needed for the project. Examples: elevators, ceramic facade cladding.
Class 2	Medium Term	Resources with a procurement cycle of 30 days or more and a medium repetition rate within the cycle. Batches purchased are generally a portion of the total amount needed. Examples: Steel, ready-mix concrete.
Class 3	Short Term	Resources with a short procurement cycle and that are highly repetitive within the cycle. Batches purchased are generally portions of the total amount used throughout production. Examples: bricks, ceramics, mortar, cement.

Source: Ballard (2000) and Bernardes (2003)

2.2.1 Long-term planning

This is the master plan for the project, and it serves to identify the objectives and limitations of the work (Laufer 1996). The main results obtained for this planning horizon comprise the project's long-term plan (which contains the entire execution timetable) and the schedule for negotiating Class 1 resources. Purchases such as elevators must be scheduled with longer delivery times, and hiring of special equipment and organization of own labor must also be planned over the longer term (Bernardes 2003). Given the uncertainty factor, the long-term plan must not be overly detailed.

2.2.2 Medium-term planning

The medium-term plan is a second level of planning used for tactical organization. Work flows are analyzed at this stage to reduce activities that do not add value to the production process and to streamline resources. The purpose is to link the objectives set out in the long-term plan with the tasks assigned during short-term planning (Bernardes 2003).

Restrictions in the production environment are analyzed in the medium-term planning stage so that steps can be taken to eliminate them, thus increasing the reliability of short-term planning. The medium-term plan is important for scheduling the procurement of Class 2 and 3 resources (Bernardes 2003).

2.2.3 Short-term planning

The main purpose of short-term planning is to assign to the production teams work packages that have been negotiated with those in charge of task execution in order to determine the sequence, work volume, and execution schedules for each activity (Coelho 2003). Bernardes (2003) prefers short-term planning to take place in weekly cycles, generally with a horizon of up to four weeks. The activities to be carried out by the work teams are determined at this stage, and other resources are assigned.

Short-term planning produces an important factor for controlling the project works, the percentage of plans completed (PPC). The PPC is the main short-term planning indicator, represented by the ratio of the number of work packages fully completed to the total number of packages scheduled, as shown in Equation 1. The PPC must be examined, and the causes of any failure to complete planned activities must be analyzed as well (Ballard and Howell 1998).

$$PPC = \frac{\sum \text{work packages fully completed}}{\sum \text{total work packages planned}} \qquad (1)$$

The PPC may be used as a measurement of production management efficiency at the operative level (Ballard 2000). A high PPC is one that averages near 100%, while averages of 60% to 80% are considered good (Akkari et al., 2004; Bortolazza, 2006). However, given the variability in construction, it is difficult to attain a PCP of 100%. Such a high PPC is generally an indication of "soft" planning, in which easy-to-achieve tasks have been proposed when higher production goals could actually be met. Even so, assuming that quality requirements have been met, a medium-high PPC indicates a reliable production system (Ballard, 2000; Bortolazza, 2006).

3. Methodology

The proposed system was developed at a construction company from Novo Hamburgo, a city in southern Brazil. It is a medium-sized company that has worked on the local market for 24 years. It constructs seven- to ten-story buildings at a medium-high socioeconomic level, generally working on two projects simultaneously. The company has PCP systems in action at its works. This study was conducted on one of this company's projects.

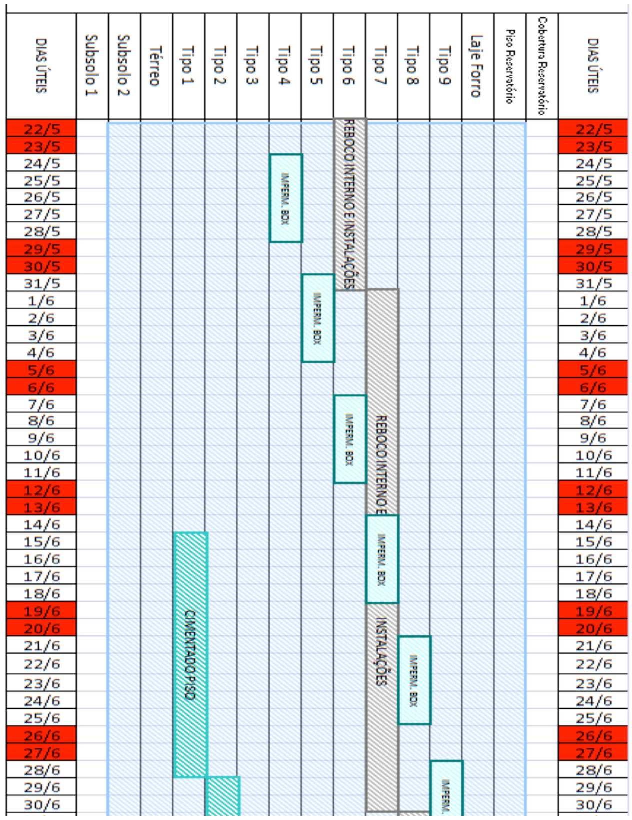
The project chosen was an apartment building with finishing that is standard for upper middle class homes. The building has two- and three-bedroom apartments with two parking places each, built with a conventional construction method (a reinforced concrete structure with masonry walls of ceramic brick. It is an eight-story building of approximately 5,000 square meters. After the project was selected, the PCP study was conducted, detailing the system and identifying the tools used at the different planning stages. Construction of the building was scheduled to take a total of 25 months. A proposal was then developed for a waste planning and control (WPC) system using the characteristics of the construction company's PCP system and testing it on the project being studied. The proposed system handles the waste generated during construction. The study does not cover waste generated in the use, maintenance, and demolition of the building.

3.1 Planning and control of production at the project

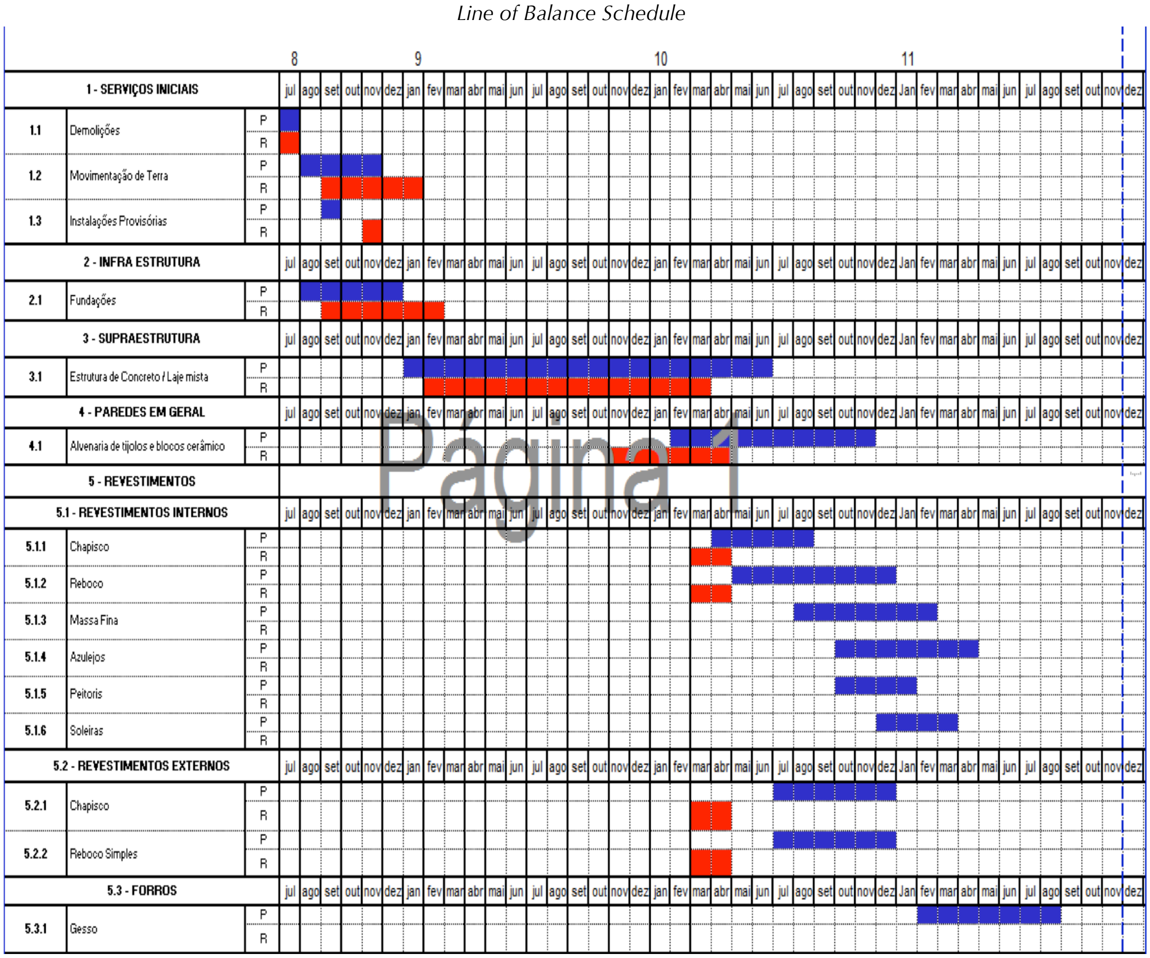
The system being studied, used at the project to plan and control production, is based on the three stages of planning. Each planning horizon uses different tools as described below. The PCP system was developed by the company's management and employees and has been used for over four years to the satisfaction of the employees. It is considered fully integrated into the company's routine activities.

3.1.1 Long-term planning

Long-term planning consists of a general plan for the entire project with two methods of presentation: a Gantt chart and a line of balance schedule. The main goal is to organize the purchase of Class 1 materials and to hire subcontracting teams. The long-term plan is reassessed at bimonthly meetings attended by the key players: the company manager, the engineer in charge of the project, the foreman, the apprentice (a civil engineering student), the main contractor, and a representative for each subcontractor. The purpose of the meeting is to assess whether the objectives are being reached, make scheduling changes, and set medium- and short-term horizons. Figure 1 shows examples of the instruments used.



Line of Balance Schedule



Gantt Chart

Figure 1. *Long-term planning – Examples of balance line schedule and gantt chart*

3.1.2 Medium-term planning

Medium-term planning works with four- to five-week periods that are reviewed in weekly planning meetings attended by the engineer, foreman, apprentice, and contractor representatives. Figure 2 presents the model used. The goal of medium-term planning is to organize resources and management limitations.

3.1.3 Short-term planning

Short-term planning involves assigning the different areas of work to the teams (a group of a few workers) on a weekly basis. The plans are reviewed daily by the foreman and the apprentice. The weekly planning sheet (Figure 3) is filled out at the weekly planning meeting attended by the engineer, foreman, apprentice, and contractor representatives. The purpose of this sheet is to determine the activities to be carried out by each team and subsequently to calculate the PPC. If the work is not completed according to plan, the sheet has a specific field for identifying the problem (the last column in Figure 3).

3.2 Proposal and testing of the waste planning and control system (WPC)

The proposal and the application of the waste planning and control system discussed in this paper are both presented at the same time. The WPC system proposed is to be implemented together with the PCP in the practical application of small and medium-sized companies' construction works. Similar to Giacomello et al. (2014), long- medium-, and short-term tools are used. Based on the PCP, the proposed WPC was divided into different planning horizons. Each of these planning stages has different monitoring tools. A success indicator was also proposed for waste management.

3.2.1 Waste planning and control – long term

The first stage of waste planning and control consists of establishing a "mini classification center" basically composed of crates or containers large enough to classify waste and with enough room for trucks to maneuver. The size of the containers is determined according to the needs of the company, and records are kept of their use, as shown in Table 4. This table is to be completed and placed by the corresponding container. In addition, each container must be identified with a sign large enough to be read at a reasonable distance, from 10 meters away, for example, to help guide the employees.

Project:	*Data:*						*Engineer:*									*Foreman:*								
Work Teams and Packages	*Week 1*						*Week 2*						*Week 3*						*Week 4*					
Team 1: (names of workers)	*S*	*T*	*Q*	*Q*	*S*	*S*	*S*	*T*	*Q*	*Q*	*S*	*S*	*S*	*T*	*Q*	*Q*	*S*	*S*	*S*	*T*	*Q*	*Q*	*S*	*S*
Team 2: (names of workers)																								
Team 3: (names of workers)																								

Figure 2. *Medium-term Planning Sheet*

Work:		*Week:*	*Engineer:*						*Foreman:*	
Team	*Work Package*	*Activities*	*S*	*T*	*Q*	*Q*	*S*	*S*	*PPC (%)*	*Problems*
		Planned								
		Completed								
		Planned								
		Completed								
		Planned								
		Completed								
		Planned								
		Completed								

Figure 3. *Weekly planning sheet*

***Table 4.** Container use sheet (example)*

Item handled		*Situation at site*
Type of waste		*Masonry waste*
Category per Res. 307		*A*
Volume of container		*6m³*
Volume generated daily		*1m³*
Reuse onsite?		*Yes, partially*
Final destination		*Municipal landfill*
Waste handling and transport		*The employee in charge must arrange regular pickup with the container transport company (duly licensed) to prevent excess waste accumulation at the worksite.*
Responsible for pickup and transport	*Employee*	*Apprentice*
	Offsite	*Company X*

Long-term waste planning and control considers the main construction stages set out in the long-term work schedule. There must be an action plan for each step, developed prior to execution (as in Table 5).

The study covered some of the services in the project. This paper presents the data on the waste generated in the masonry work. This stage took nine of the 25 total months needed for construction, and it started in the third month of work. Amounts were measured every 15 days. The volume of loss predicted was based on the 8% masonry loss included in the initial estimate, a common value for the region. The total volume of loss expected was calculated at 46 m^3.

Masonry waste contains mixed pieces of brick and mortar, material that is difficult to reuse or recycle. The waste would be used to fill holes at the site rather than purchase sand for this purpose, as originally planned for the project.

***Table 5.** Action plan for long-term activities (example: masonry)*

Long-term Plan		*Situation at site*	
Activity		*Masonry*	
Dates	*Start*	*March 1*	
	Finish	*December 1*	
Type of waste		*Mortar, ceramic brick, concrete*	
Estimated volume		*46m³*	
Onsite transport		*Crane*	
Usable onsite?		*Yes, partially*	
Onsite Use			
Volume reused		*16m³*	
Purpose		*Fill*	
Reuse procedure		*Waste from this activity can be reused to fill in holes in outside areas*	
Responsible for reuse	*Employee*	*Project engineer / Foreman*	
	Offsite	*None*	
Leftover waste			
Remaining volume		*30m³*	
Final destination		*Municipal landfill*	
Method of transport		*Container truck (5 loads of 6 m³)*	
Transport procedure		*The leftover waste will be taken from where it was generated directly to the collection point (a location previously determined and with room to handle the material). The containers will be replaced as they are filled and taken to the final destination.*	
Responsible for transport	*Employee*	*Apprentice:*	*Date:*
	Offsite	*Company:*	*Supporting document:*

3.2.2 Waste planning and control – medium term

As in the PCP, medium-term waste planning is a tool for studying any limitations that keep the system from functioning properly. This assessment takes place in weekly meetings held along with the PCP meetings. Table 6 is filled out during the meetings. The worksheet covers one month and is updated weekly.

Table 6 is to be filled out with the volume of waste expected each week. After checking for restrictions, the cell is filled in with "OK" (no restrictions) or "X" (restrictions present). Any limitations found must be briefly described, as well as the steps to be taken to free up each activity.

3.2.3 Waste planning and control – short term

As in the PCP, the short-term planning for waste that is expected to be generated is organized on a weekly basis, together with planning the work packets. The plans are brought in by the foreman and the apprentice and are reviewed in the weekly planning meeting attended by the same participants indicated in point 3.1.3.

Also proposed is an indicator for how well the WPC system is functioning, termed "percentage of waste control plans 100% complete (PWCPC) as indicated in Equation 2. The proposed PWCPC is similar to the PPC. However, in order not to overload the team responsible for planning and operating the system, the PWCPC is calculated every 15 days. The data are presented at the weekly short-term planning meeting on alternate weeks.

$$PPCRC = \frac{\sum \text{Waste control packets 100\% complete}}{\sum \text{Total waste control packets planned}} \quad \textbf{(2)}$$

In order to collect the necessary data, an employee must keep a daily record of the volume of material discarded or reused onsite. This table must contain a short, objective description to facilitate understanding of the issue. Table 7 has specific fields for recording the circumstances that resulted in the failure to complete the planned activities, if such is the case. This data is used to obtain the PWCPC, a percentage calculated by dividing the volume of waste actually measured by the volume predicted. The predicted amount is determined in the medium-term planning process (Table 3). Table 7 below presents the information for the third 15-day period. Farther below, Figure 4 presents the amounts measured throughout the project's masonry works.

***Table 6.** Restrictions predicted, action needed (example)*

Activity Planned	Masonry			
Restrictions in…	Week 1	Week 2	Week 3	Week 4
Volume generated	$1.3m^3$	$1.3m^3$	$1.3m^3$	$1.3m^3$
Classification system	Ok	Ok	Ok	Ok
Onsite transport	Ok	Ok	Ok	Ok
Offsite transport	X	X	X	X
Destination	Ok	Ok	Ok	Ok
Container	Ok	Ok	Ok	Ok
Other	Ok	Ok	Ok	Ok
Describe restriction	Offsite transport – the company in charge of this activity was removed from the database because it did not submit transport licenses by the deadline.			
Action needed	Contract with new company for offsite waste transport.			

***Table 7.** Percentage of waste control plans (example for third 15-day period)*

SHORT TERM PLAN	*SITUATION AT SITE*	
Activity	*Masonry*	
Category per Res. 307	*A*	
Volume expected (15 days)	*2.6 m³*	
Expected reuse (in 15 days)	*0.94 m³*	*Where: fill in holes at back of site*
ONSITE MEASUREMENT RESULTS		
Volume of waste generated	*3.0 m³*	
Volume of waste reused	*0.5 m³*	*Where: fill in holes at back of site*
PWCPC – Volume of waste generated *PWCPC – Volume of waste reused*	*3.0 / 2.6 = 115.4%* *0.5 / 0.94 = 53.2%*	
REASONS		
Volume of waste generated	*A larger-than-expected amount was generated as the masonry team's activity exceeded that planned for the project (a larger-than-expected area of masonry was produced).*	
Volume of waste reused	*The amount of waste expected was not reused because the disposal area was still in use, awaiting the retaining wall along the side of the property.*	

A constant of 2.6 m^3 was used for the ten 15-day periods, as the information available did not indicate that the amount would vary during the periods. It was decided to use the waste to fill a hole of approximately 16 m^3 at the back of the property. The initial plan for reuse was based on a volume of 1 m^3 per 15-day period. Based on the number of wheelbarrows used at the site, a volume of 0.94 m^3 was used in order to have a set number of loads (eight, in this case), which made it easier to verify the amount. At the end of the period, a smaller amount was projected to finish filling the hole (Figure 4-b).

Table 7 shows that the data collected at the worksite differed from those predicted. The volume collected was 3.0 m^3, higher than the volume of 2.6 m^3 planned. Therefore, the waste generation PWCPC in this case would be calculated at 115.4%. The reuse rate planned was not reached, as the actual volume was 0.5 m^3, a little more than half of what was predicted. Therefore, the PWCPC rate for waste reuse is 53.2%.

Figure 4 presents the data for the entire period of masonry works at the project. The red lines represent the volumes planned, while the blue lines are those measured onsite. The graph of waste generated (Figure 4-a) shows that the volumes were not constant, but that they varied throughout the period. When waste reuse was assessed, two separate stages were found. The hole was filled more quickly than planned at the beginning of the works (with reuse of up to 1.75 m^3 in the second half of March), and then volumes dropped below what was planned (about 50% of what was expected in the following 15-day periods. The quality rates of PWCPC planning are presented in Figure 4-c. Waste generation is higher than expected in some 15-day periods, with a PWCPC of over 100%, but it is below expectations in others. The average was calculated at 107.1%. The PWCPC reuse rate was under 75% in several 15-day periods, with an average of 80.7%.

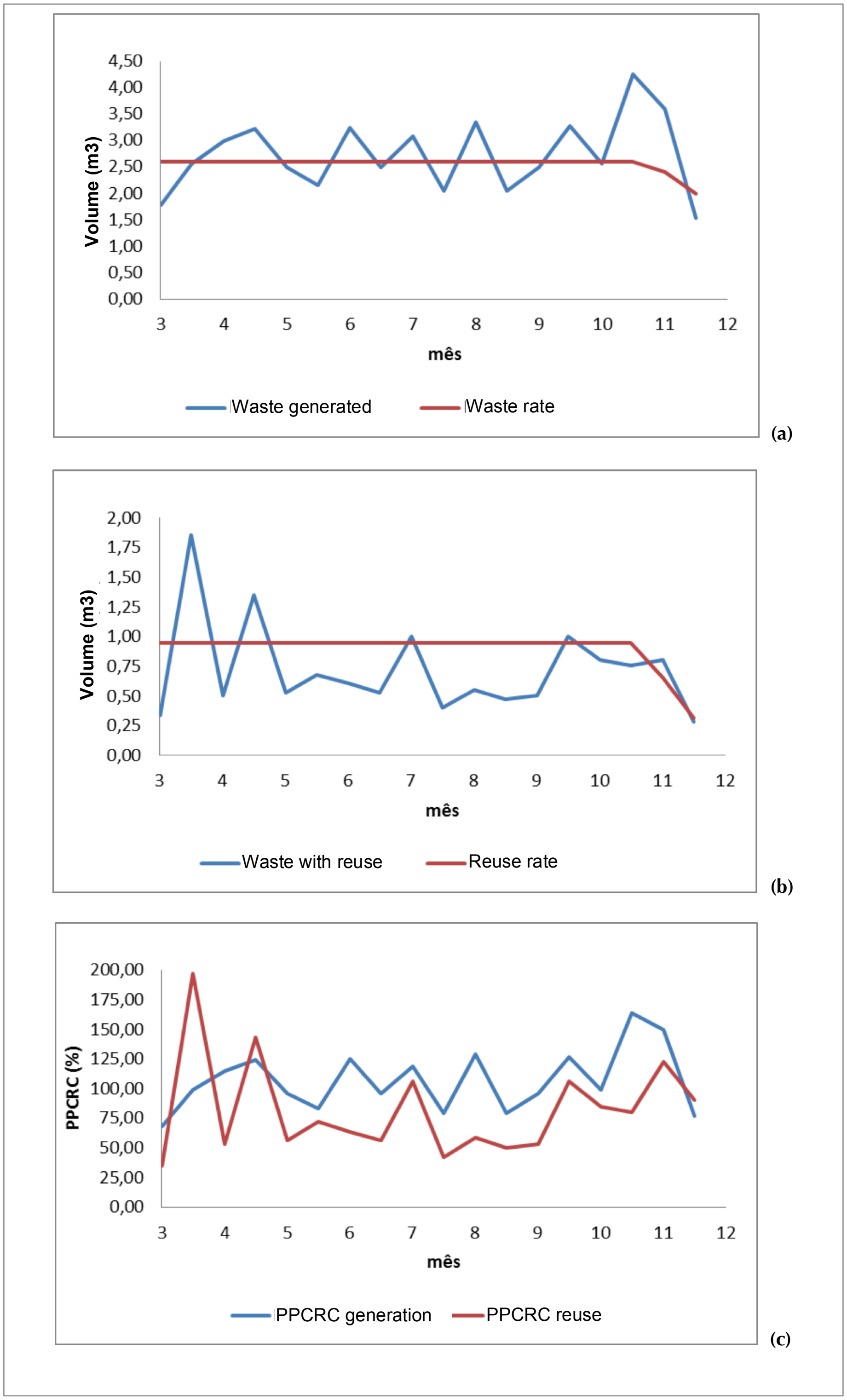


Figure 4. *Waste Measurements and PPCRC – masonry*

4. Discussion and final considerations

The WPC system uses a number of charts and tables that serve as tools for planning and controlling the generation, reuse, and disposal of waste. These tables have been based on the PCP project, and their purpose is to integrate the different control horizons used in planning (long, medium, and short term).

CONAMA Resolution 307/2002 requires that cities implement integrated civil construction waste management plans, so the cities, in turn, must require that large waste generators submit waste generation plans. Waste being transported must be documented with transport manifests indicating the types and quanities of CCW; documentation can be handled by the company generating the waste or the transport company. The long- and medium-term WPC plans can be used to draw up these manifests.

Onsite observations found that Table 5 is essential to the system as a whole because it records the long-term estimates of waste volumes to be generated. Therefore, these tables must be filled out by those administrating the WPC system and then assessed by the other professionals involved. The behavior observed in those working with the system reflected their satisfaction with the techniques proposed and used in this project, both in terms of its applicability and the importance of waste management.

Waste measurement and PWCPC calculations indicated that actual situations failed to meet expectations. PWCPC generation averaged over 107%, indicating higher waste generation than planned. In addition, reuse PWCPC averaged around 81%, almost 20% lower than expected, representing a reuse volume of some 3 m^3 less than planned. The construction industry consumes a large amount of natural resources and generates a significant amount of waste and environmental harm. Management systems are becoming more and more important for construction companies, and even for the financial wellbeing of the industry. This paper proposes and studies a waste management system that helps small and medium-sized companies plan and control the generation, reuse, and disposal of waste. The system proposed is based on planning stages and uses an indicator to assess completed waste management plans. The conclusion reached is that the study demonstrates that the waste management and control system is viable for the industry studied.

5. Acknolwledgements

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