

# **METHOD FOR WASTE CONTROL IN THE BUILDING INDUSTRY**

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## **ABSTRACT**

The paper presents the preliminary results of an ongoing research project which aims to develop a method for controlling waste on building sites. The main focus of the method is to establish waste control procedures as part of site management on a routine basis, using a pull learning approach and emphasising the principle of process transparency by using qualitative and quantitative data collection techniques. The study also intends to make some contributions for the consolidation of the Lean Construction theory, through the application of some of its principles in practice.

A classification for waste in the construction industry is proposed, based on previous studies concerning waste measurement. Based on that classification, a protocol for data collection was developed and applied in case studies carried out in three different Brazilian building companies.

One of the main conclusions of the paper is concerned with the need to integrate waste control into the production planning and control process.

## **KEY WORDS**

Building industry, learning, waste control

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## **INTRODUCTION**

Waste in the construction industry has been the subject of several research projects around the world in recent years. Some of them have focused on the environmental damage that results from the generation of material waste. Wyatt (1978) stressed the consequences of high levels of waste in both reducing the future availability of materials and energy, and creating unnecessary demands on the transportation system. The Hong Kong Polytechnic and the Hong Kong Construction Association Ltd. (1993) conducted a research on construction waste aimed to reduce the generation of waste at source, and to proposed alternative methods for treatment of construction waste in order to reduce the demand for final disposal areas. Brossik and Brouwers (1996) conducted a research project in The Netherlands, concerned with the measurement and prevention of construction waste, regarding sustainability requirements stated by Dutch environmental policies.

On the other hand, there have been a number of studies mostly concerned with the economic aspect of waste in the construction industry. In the UK, Skoyles (1976) developed one of the most extensive studies on this theme. The author monitored material waste in 114 building sites, concluding that there is a considerable amount of waste that can be avoided by adopting relatively simple prevention procedures. In addition, storage and handling were pointed out as major causes of waste. Most of the problems concerning waste on building sites are related to flaws in the management system, and have very little to do with the lack of qualification of workers. Furthermore, waste is usually caused by a combination of events, and not due to an isolated factor (Skoyles 1976).

In Brazil, a number of surveys on material waste have also been developed in recent years. Pinto (1989) developed a study based on one site only, pointing out for the fact that indirect waste (materials unnecessarily incorporated in the building) can be higher than direct waste (rubbish that should be disposed in other areas).

The first research project on construction waste developed at the Federal University of Rio Grande do Sul (UFRGS) started in April 1992. The main objective of that study was to analyse the main causes of material waste in the building industry in order to propose guidelines for controlling it in small sized firms. Seven building materials were monitored in five different sites during a period ranging from five to six months. Soibelman (1993) presents a detailed description of this study.

More recently, a much more ambitious research project on material waste measurement was developed for the Brazilian construction industry. It was a two year study, co-ordinated by the Brazilian Institute for Technology and Quality in Construction (ITQC), involving 15 universities (including UFRGS) and more than one hundred building sites (Agopyan et al. 1998). Eighteen materials had their waste monitored by using a data collection method similar to that applied in the study carried out by Soibelman (1993).

The main conclusions drawn from those two studies are:

- The waste of building materials is far higher than the nominal figures assumed by the companies in their cost estimates.

- There is a very high variability of waste indices from site to site. Furthermore, similar sites might present different levels of wastes for the same material. This indicates that a considerable portion of this wastage can be avoided.
- Some company do not seem to be concerned about material waste, since they do not apply relatively simple procedures to avoid waste on site. None of them had a well-defined material management policy, neither a systematic control of material usage.
- The lack of knowledge was an important cause of waste. Most building firms did not know the amount of waste they had before the development of the study.
- As in the work of Skoyles (1976), most causes of waste are related to flaws in the management system, and have very little to do with the lack of qualification and motivation of workers. Also, waste is usually the result of a combination of factors, rather than originated by an isolated incident.
- A significant portion of waste is caused by problems which occur in stages that precede production, such as inadequate design, lack of planning, flaws in the material supply system, etc.

Despite the importance of those previous studies in terms of both highlighting the importance of waste management and identifying the causes of waste, their contribution for establishing waste control systems has been relatively small for the reasons presented below:

- Most studies tend to focus on the waste of materials, which is only one of the resources involved in the construction process. This seems to be related to the fact that most studies are based on the conversion model, in which material losses are considered to be synonymous of waste.
- Data collection is usually very expensive, involving a large team of researchers, including people who are heavily involved in monitoring the work on site. Consequently, the procedures used for controlling waste in research studies are not easily adapted in real time production control systems.
- The results of such surveys take a long time to be produced, usually after the work being monitored has finished. This limits the impact of those studies in terms of corrective action.
- There is relatively little involvement of people from the company in both data collection and analysis, since most waste control procedures are external to the organisation. As a result, the learning process in the company resulting from those studies tend to be very limited.

Those reasons reflect a major limitation of such a kind of study, which refers to the fact that it offers little opportunity to build continuous improvement into processes. Koskela (1992) points out some key factors such as focus on measurable and actionable improvement, people involvement and learning that must be balanced in order to implement the new production philosophy. More reliable and faster information flow are also required when shortening production cycle time. Unfortunately, little attention has been paid on these aspects in those studies.

A critical analysis of past experience led to the proposition by UFRGS of another research project on waste management. This study aims to develop a method for controlling waste on building sites, following three main guidelines: (a) short cycles of production control; (b) broad concept of waste, based on the new production philosophy; (c) involvement of the companies in a pull learning process.

## CONCEPT OF WASTE

According to the new production philosophy, waste should be understood as any inefficiency that results in the use of equipment, materials, labour, or capital in larger quantities than those considered as necessary in the production of a building. Waste includes both the incidence of material losses and the execution of unnecessary work, which generate additional costs but do not add value to the product (Koskela 1992). Therefore, waste should be defined as any losses produced by activities that generate direct or indirect costs but do not add any value to the product from the point of view of the client.

Besides a clear understanding of the general concept of waste, it is helpful to use a classification of waste in different categories, in order to understand the wide range of possible corrective actions related to its prevention.

Regarding the possibility to control the incidence of waste, this study admits that there is an acceptable level of waste, which can only be reduced through a significant change in the level of technological development. Thus, waste can be classified in *unavoidable waste* (or natural waste), in which the investment necessary to its reduction is higher than the economy produced, and *avoidable waste*, when the cost of waste is significantly higher than the cost to prevent it. The percentage of unavoidable waste in each process depends on the company and on the particular site, since it is related to the level of technological development.

Waste can also be classified according to its origin, i.e. the stage that the main root cause is related to. Although waste is usually identified during the production stage, it can be originated by processes that precede production, such as materials manufacturing, training of human resources, design, materials supply, and planning.

The main classification of waste proposed in this study is by its nature, since it helps managers to understand the different forms of waste, why they occur and how to act in order to avoid them. The following classification resulted from a study developed at UFRGS, based on Shingo's seven wastes (Shingo, 1989) and on the analysis of some Brazilian building sites:

- **Overproduction:** related to the production of a quantity greater than required or earlier than necessary. This may cause waste of materials, man-hours or equipment usage. It usually produces inventories of unfinished products or even their total loss, in the case of materials that can deteriorate. An example of this kind of waste is the overproduction of mortar that cannot be used on time.
- **Substitution:** is monetary waste caused by the substitution of a material by a more expensive one (with an unnecessary better performance); the execution of simple tasks by an over-qualified worker; or the use of highly sophisticated equipment where a much simpler one would be enough.

- **Waiting time:** related to the idle time caused by lack of synchronisation and levelling of material flows, and pace of work by different groups or equipments. One example is the idle time caused by the lack of material or by lack of work place available for a gang.
- **Transportation:** concerned with the internal movement of materials on site. Excessive handling, the use of inadequate equipment or bad conditions of pathways can cause this kind of waste. It is usually related to poor layout, and the lack of planning of material flows. Its main consequences are: waste of man hours, waste of energy, waste of space on site, and the possibility of material waste during transportation.
- **Processing:** related to the nature of the processing (conversion) activity, which could only be avoided by changing the construction technology. For instance, a percentage of mortar is usually wasted when a ceiling is being plastered.
- **Inventories:** related to excessive or unnecessary inventories which lead to material waste (by deterioration, losses due to inadequate stock conditions on site, robbery, vandalism), and monetary losses due to the capital that is tied up. It might be a result of lack of resource planning or uncertainty on the estimation of quantities.
- **Movement:** concerned with unnecessary or inefficient movements made by workers during their job. This might be caused by inadequate equipment, ineffective work methods, or poor arrangement of the working place.
- **Production of defective products:** it occurs when the final or intermediate product does not fit the quality specifications. This may lead to rework or to the incorporation of unnecessary materials to the building (indirect waste), such as the excessive thickness of plastering. It can be caused by a wide range of reasons: poor design and specification, lack of planning and control, poor qualification of the team work, lack of integration between design and production, etc.
- **Others:** waste of any nature different from the previous ones, such as burglary, vandalism, inclement weather, accidents, etc.

## **OVERVIEW OF RESEARCH PROJECT**

The study has been developed in partnership with a private industry funding agency, named *Serviço de Apoio às Micro e Pequenas Empresas* from the State of Rio Grande do Sul (SEBRAE/RS), which supports development projects for small businesses. The main objective of the study is to devise a method for controlling waste which can be used by small sized building firms, using concepts and principles from the new production philosophy.

A multi-case study approach has been used in this research project, involving three different construction firms. This has enabled comparisons between different organisation environments, creating an interesting opportunity for analysing the implementation of the method.

Two of the companies are both developers and builders, being mainly involved in residential and commercial building projects. The third company tends to work mostly as

contractors for private clients, such as hospitals, manufacturing industries, etc. All of them are relatively small organisations, which means that their sites are usually managed by a civil engineer and a foreman, usually supported by an undergraduate trainee, who is responsible for data collection on site. Both site managers and trainees are involved in each building site on a part time basis.

The fact that all firms had previous experience on data collection was considered to be a positive factor, since it was expected that this study would introduce little additional effort for gathering the data required to control productivity and waste.

A protocol was developed for data collection, involving the application of quantitative and qualitative techniques. The main focus of this protocol was to strengthen the continuous improvement aspect of waste control on site. Based on that, the following guidelines were established:

- Feedback from the site must be as much transparent as possible and the people directly involved in the process being analysed must be the first ones to see the results. As a consequence, those people could learn from their own experiences and commit themselves to the reduction of waste in the process;
- Feedback must be quick and flexible enough so as to motivate people and to make feasible the intervention in the process before it finishes. Whatever the data collected it must be useful for improving the process, avoiding further waste; and
- Identification of problems must be followed by the proposal of solutions. The method must have simple and flexible tools in order to allow the identification of solutions to a relatively wide range of problems.

Based on these guidelines, the method was expected to be pro-active, allowing the processes to be controlled during the life span of the production process, and enabling the company to be involved in a learning process in which the information was pulled by the company, rather than pushed by researchers.

This research project gives priority to process improvement, in spite of considering processes and operations as a system. This strategy was taken due to the need of enabling construction managers and workers to deal with process control and improvement. In addition, the proposed method emphasises learning how to learn from process control in order to encourage the learning process to happen in the whole system.

The framework backbone is the learning process involved in data collection and analysis and the discussion about both causes of waste and possible corrective actions. For that reason, one of the essential steps of the method are discussions involving the “owners of the process”, i.e. the ones responsible for the process and the site being analysed, aiming to motivate them to reflect on their work. As each company was responsible for some data collection, one of the main criteria for choosing data collection tools of the protocol was simplicity and transparency.

## **DESCRIPTION OF METHOD**

The companies were selected in August 98, and the data collection stage was carried out from September 98 to February 99. Processes monitored were: bricklaying, concrete pouring,

plastering, and ceramic tiling on walls and floors. The definition of the processes to be monitored was an element of concern. Since the study would demand observations for at least three to four months for each process, the duration of each one should be long enough in order to allow a considerable number of control cycles. Thus, considering that the monitoring would be made in a weekly basis, and also the need of repetition to enable the learning process, the research group decided to take into consideration only those processes with duration not shorter than three months.

In each company, a preliminary meeting was held with the company managers in order to present the objectives of the study and the protocol to be used as well as to define the production process to be monitored. Afterwards, some directions were given to the person in charge of data collection on the behalf of the company (usually a civil engineer undergraduate trainee). These directions were related to the definition of the control cycle, measurement criteria and the organisation and presentation of the data to be collected.

The company was responsible for collecting of data related to the productivity of workers and the usage of materials as well as for elaborating charts in order to represent process variability. The basic tool used for data collection was the production chart, from which the company gets information about the output of each activity. Data about the usage of materials and man-hours spent in the process are collected through a resource usage chart. In addition to the production and resource usage charts, a periodical inventory survey is necessary to monitor the amount of materials stored on site, and identify the origins of it. A foreman or trainee collects all data by at the beginning of each monitoring cycle. From that, the productivity and waste rates are calculated.

The researchers were responsible for auditing the building site monthly in order to collect further information that could help the analysis of causes and the identification nature of the waste detected. The tools used in the audit were a check-list about site conditions, flow chart, process charts, documentatiob of processes through photographs and video tape, and also some additional indicators related to each specific process (for example, plastering thickness). A brief description of the data collection tools used by the companies and by the research team is respectively presented in Table 1 and Table 2 bellow.

Table 1: Monitoring Tools

<b>Tool</b>	<b>Purpose</b>	<b>Who is in charge</b>
Production chart	Measure the output of each activity during the week or within the production cycle	Trainee
Resource usage chart	Monitor the usage of materials and the amount of man- hour spent in the process in each the control cycle (weekly basis)	Foreman or trainee
Inventory files	Monitor the physical quantity of inventories in each cycle (weekly basis).	Foreman
Control charts: productivity, production and waste rates	Quantify and show the variability of productivity, production and waste rates during each cycle.	Engineer or trainee

These tools were selected considering the need to make visible all kinds of waste described in Section 2. However, the protocol does not intend to quantify the relative importance of each one of the categories (possibility of control, origin, and nature).

The company sends the data collected and charts to the research team on a weekly basis. Based on these elements and on the audit data, the research team produce a short monthly report presenting an evaluation of the process, using waste indicators (mean and variation) and a global analysis of the site. It also presents a comparison of the results achieved with existing benchmarks. Visual devices like diagrams, charts and photos are used in these reports in order to improve process transparency.

Table 2: Audit Tools

Tool	Purpose
Site and process evaluation check-list	Aimed to provide a brief evaluation about site and processes performance. It enables a qualitative evaluation of the process and work environment, also pointing out improvement opportunities.
Process chart	Used for registering improvements in the process, regarding the flow of raw material and components.
Videotapes and photos	Enable the process and the work environment to be documented in order to improve transparency for the people involved in the improvement of the process.
Additional indicators: (such as plastering thickness, concrete slab thickness)	Provide additional quantitative data, aiming to identify the nature of waste.

The purpose of the report is to show the main problems identified every month, in a visible way and induce a “problem-solving” attitude among the company personnel. Therefore, the research group intentionally omit any conclusions about existing problems and its possible solutions in the report.

One week after sending the report to the company, a meeting is settled with the ‘owners of the process’, which usually includes production and planning managers and the trainee responsible for data collection. The purpose of this meeting is to encourage the learning process to be performed through the analysis of the information presented in the report. One core guideline for this meeting is that the owners of the process are the most able people to identify and solve the existing problems. The role of the researchers at the meeting is to help them to reflect about the data (questioning and presenting additional data collected at the audit) and to stimulate reflection and discussion. The meeting should result in a clearer understanding of the process, a broader view of the causes and origins of waste, and a selection of corrective actions to prevent waste in the following control cycle.

## DISCUSSION

One of the most significant findings about the implementation of the method was the shallow perception of the managers about the variability in production and productivity rates. During the meetings that followed the audits they were surprised about such variations. Nevertheless,



this fact pointed out a lack of transparency on the data regularly collected on site. This fact indicates an opportunity to improve the competence of the personnel in charge of data collection in terms of objectives, the purpose of the study and what would be the consequences of waste so they can be committed to data collection and continuous improvement of the process. They should also be able to use visual devices to present data.

In some cases some of the variation in production rates was not due to the process variability but instead to the way data was collected. In such cases, site managers decided to consider only completed packs of work when measuring production, for example completed walls (for bricklaying and plastering) or compartments (fixing tiles on walls or floors). The control based on events is easy to be done, since measurements result from counting completed packs (or elements produced). Each pack is defined and quantified before the activity starts. However, the use of this type of control can often lead to the exclusion of uncompleted packs in the week when they are carried out, and the inclusion of them in the week in which they are finished. Mistakes in the interpretation of data may occur when mixing 'event-driven control' and 'period-driven control' (in this case, weekly measurement).

On the other hand, managers were not much concerned about the determination of the level of wastage. They usually compared the average productivity obtained from data collection against the productivity rate used for cost estimating. As a consequence, in many occasions productivity was higher than expected and no questioning was made about the origins of such high performance. This attitude indicates an implicit concept of waste as the surplus of resources, referred to a standard rate. Furthermore, this attitude does not contribute to the learning process because it does not challenge the company to improve its performance.

Another issue that was pointed out during the audits was the kind of control used by the site managers. They were mostly concerned with verifying (acting after the facts) rather than monitoring (acting during the facts). Howell and Ballard (1998) named this attitude of focusing only on the results of production as '*construction management activity or contract centred*' practice. This explains to a certain extent why data collection efforts do not always result in continuous improvement.

The poor definition of the scope of measurement and the use of indicators that monitor the process as a whole impose limitations on the search for the real causes of deviations. It became clear during the research development that there is a need to clearly define the position of monitoring activities along the process, concerning both material and workflow, in order to identify the origins of deviations.

Finally, the site managers also understood that many of the difficulties in terms of process control are related to the fact that waste control is not fully integrated to the production and control process. Usually, construction plans deal with resource allocation and milestones, but fail for not being used for controlling material and workflow.

## **FINAL COMMENTS**

This paper presents an ongoing research project aimed to provide small-sized building companies with a method for controlling waste in building sites. It describes the first stage of

the research project comprising the design of the method and an initial application in three Brazilian small-sized building companies.

The main conclusions of the study so far are presented below:

- The lack of perception from managers of variability in production and productivity rates;
- The need of a prior definition of the type of control to be used (event-driven or period-driven);
- The lack of integration of waste control with the planning and control process, and the need for not only verifying but also monitoring the efficiency of construction processes.
- In the next stage of this project the research team intends to integrate the described tools with short and medium term production planning, through the use and discussion of data on work flows and material flows in production planning meetings.

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