COST MANAGEMENT AND PRODUCTION CONTROL FOR CONSTRUCTION COMPANIES

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ABSTRACT

Construction, like other industries, has been experiencing profound changes involving both the business environment and internal organization. In this context, new cost management information that provides better understanding and helps managing increasingly turbulent and complex production processes is needed. Activity-based costing (ABC) has been suggested as the leading contender method to replace traditional cost accounting systems, due to its capability to make the processes and activities performed in the organization more transparent and observable.

This paper reports the main results of a research project which aimed to develop a cost accounting system capable of providing useful information to manage production processes in construction and devise a model that integrates this system to the Production Planning and Control process, based on the new operations management paradigm and on the ABC ideas. The study involved three case studies, a series of interviews with construction managers and the development of prototype software.

The main conclusions of this research work are that the cost information provided by the proposed management accounting system (a) makes the production processes more transparent; (b) helps to identify production inefficiencies; (c) encourages managers to introduce corrective actions; and (d) allows the evaluation of corrective actions to be undertaken. The study also indicated that the proposed model has contributed to establish systematic procedures for production control concerned not only with time management but also with cost management.

KEY WORDS

Cost management, activity-based costing, lean construction, production control.

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1. INTRODUCTION

Over the last decades, many industrial sectors have been experiencing profound changes involving both the business environment and the internal organisation. This process has been so deep and radical as to suggest that a new operations management paradigm has emerged (Bartezzaghi, 1999; Koskela, 2000). In this new competitive and turbulent environment, effective cost management information has become extremely important to drive improvement efforts (Johnson & Kaplan, 1987).

However, besides the environmental, managerial and technological changes occurred in the last thirty years, the existing traditional cost management systems are very similar to the ones that have been used since the mid Twenties (Johnson & Kaplan, 1987). In the face of all these changes, traditional cost account information has become mostly irrelevant and even dangerous for managerial purposes (Ploss, 1990). According to Johnson & Kaplan (1987), traditional management accounting information tends to be too late, too aggregated and too distorted to be relevant for production planning and control.

The failings of the traditional management accounting systems have three important consequences. Firstly, these systems cannot provide accurate product cost. Costs are distributed to products in a simplistic and arbitrary way that usually does not represent the real demand imposed by each product on the company's resources (Johnson & Kaplan, 1987). Secondly, traditional management accounting systems fail to stimulate decisions that can affect the overall production result. Managers are sometimes encouraged to accomplish short-term goals by reducing expenses with training and investment, or even produce to stock. Although effective in short term, these decisions can seriously affect future results (Goldratt & Cox, 1992). Finally, the cost management information provided by the traditional systems is of little help to managers in their effort to improve production performance. The information provided is past-oriented and too aggregated to be useful in planning and control decisions, because these systems are developed mostly to satisfy fiscal and financial needs. The lack of transparency allied with the lack of timeliness prevents the traditional cost information to help in the identification and correction of production flow inefficiencies.

Particularly in the construction industry, the inadequacy of cost accounting systems has resulted in the dissociation between the cost management and the Production Planning and Control processes. In general, construction cost control consists basically of monitoring actual performance against cost estimates and identifying variances. According to Ballard (2000), the traditional control methods based on the detection of variances appears to assume that the causes of deviation will be apparent and the appropriate corrective action obvious. As a result, the traditional cost control systems has been much more useful to manage contracts than production (Howell & Ballard, 1996; Koskela, 2000).

Since the Eighties, some alternatives for traditional cost accounting systems have been developed, aiming to regain the managerial relevance of cost information. One of these alternatives is the Activity-Based Costing (ABC) method, which has been suggested as the leading contender to replace traditional cost accounting methods due to its capability to make the processes and activities performed in an organisation transparent and observable. Over the past decades, ABC has helped many manufacturing and service organisations to improve their competitiveness by enabling them to make better decisions based on cost information.

2. BACKGROUND FOR THE RESEARCH

Construction cost control systems has been the subject of a myriad of studies. Despite their relevance in terms of both improving the cost estimate structure and integrating cost and schedule, they have hardly contributed to the integration of cost management and production control systems. Besides the fact that construction cost control systems have not changed much since the Seventies, cost management and production control are still treated independently, as separated systems.

From a managerial point-of-view, the effort to develop, implement and operate a cost system is justifiable only when the cost information provides effective support for decision making (Johnson & Kaplan, 1987; Krieger, 1997).

Activity-Based Costing has been increasingly adopted in many industrial and service firms as a method to improve cost management in complex production systems. Despite some similarities to the cost centre method or other traditional costing methods (Horngren & Foster, 1990), the underlying philosophy of ABC is considerably different. ABC is a costing system that is based on the idea that activities consume resources and product/services consume activities.

The method is basically a two-stage approach for allocating indirect costs to products based on cost drivers of various levels. In the first stage, resource costs (labour, equipment and power) are assigned to those activities performed in the organisation. During the second stage, activities costs are assigned to the cost objects based on selected cost drivers (e.g., machine set-up, quality inspection and material handling activities), which express a causal relation between the activity demand and the cost object considered. Besides the fact that ABC permits to directly trace manufacturing costs to products, it is possible to determine the costs related to objects different from products, e.g., product family, services and clients.

However, the main contribution of ABC to the operations management area is the process view incorporated by the method. The information produced by ABC cost systems can increase process transparency, providing guidance to identify non-value-adding activities and take the necessary corrective actions (Kaplan & Cooper, 1995).

Notwithstanding the benefits of its application, ABC presents some drawbacks when compared to traditional cost systems. Perhaps, the most important one is the larger amount of data usually needed in ABC systems. Indeed, according to some authors (Krieger, 1997; Cokins, 1999), the excessive level of detail is a major cause of unsuccessful ABC implementations. This problem can be even worse when one considers unstable and complex production processes, such as those observed in the construction industry.

Despite its wide utilisation in manufacturing companies and its capability to increase the transparency of production processes, ABC has been poorly discussed in the construction literature. The few existing studies usually restrict the discussion of ABC concepts to academic applications (Maxwell et al., 1998). Therefore, there is a clear need to discuss the use of ABC concepts and principles in the construction environment. As other manufacturing concepts and practices transferred to construction, ABC has to be translated and adapted (Lillrank, 1995).

3. AN APPLICATION OF ACTIVITY-BASED CONCEPT IN THE CONSTRUCTION INDUSTRY

This paper suggests an integrated model of cost management and production control for construction companies, which is strongly based on concepts related to production planning and control proposed by Laufer & Tucker (1987) and Ballard & Howell (1998). In this model, four subprocesses are identified: the preparation, the production planning and control process itself, the evaluation process and, finally, the cost management system.

The information generated by the cost system is introduced into two different control cycles (*figure* 1) - one is continuous and the other is intermittent. The first is a continuous feedback for long and medium term planning. The aim is to encourage a process of continuous improvement to happen, enabling the managers to identify and correct problems in real time. In the intermittent cycle, cost information is used in the planning evaluation process, aiming to improve the production planning and control process and support decisions to be taken in future projects.

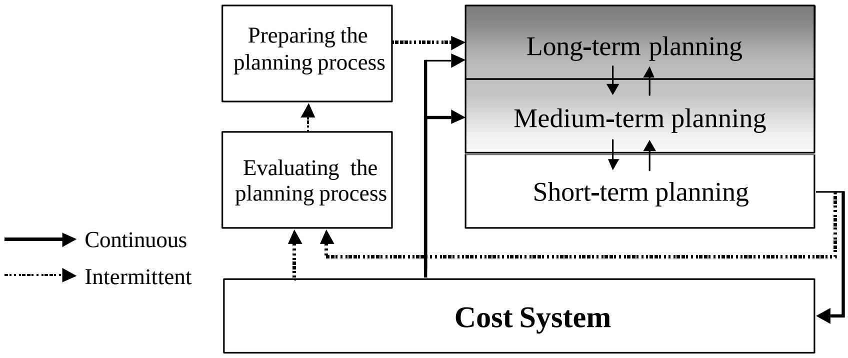

Figure 1: An Integrated model for cost management and production control in construction companies.

ABC was chosen as the conceptual basis of the proposed system for its capability to provide a better understanding about the processes and the activities performed, as well as for its affinity with the new operations management ideas.

There are two basic groups of resources that are involved in production: those that perform the work - named *production resources* - and those that are the object of work - typically materials. Production resources are those that can add value to the products. Considering that the cost management of materials is an issue much discussed in literature, this paper focuses on the application of ABC to the management of production resources.

Construction production processes tend to be extremely variable. This variability involves not only that caused by manual labour, but also the variability of the process configuration itself. In such a context, the use of a classical ABC structure would demand too many activities, overburdening the cost system.

For that reason, a different cost allocation structure was proposed. As shown in *figure* 2, activities were decomposed into tasks and operations. Resources are consumed by operations and the operations are demanded by different tasks. Differently from typical ABC structures, a restricted set of operations is employed to describe and analyse any construction production process. However, in practice, some resources, such as employees or subcontractors, are typically assigned to tasks. For such resources, cost assignment is made upstream, i.e., from tasks to operations.

One of the main challenges in the application of the proposed cost allocation model is the definition of an adequate set of operations. Firstly, the conceptual difference between process and operation must be observed (Shingo, 1988). Briefly, process refers to the material flow and operations refers to the human and the equipment flow. The cost system presented in this work is focused on the operations axis, i.e. the subjects that perform the work.

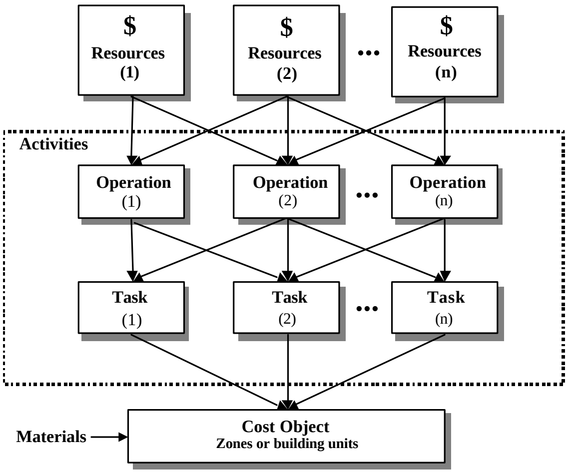

Figure 2: Cost Allocation Model - adapted from ABC.

Secondly, the existence of different process types should be recognised (Shingo, 1988). Despite the fact that any process - essential, contributory or preparation, and post-adjustment (*figure* 3) - consists of the same categories of activities - waiting, inspection, moving and processing - the nature and the purpose of an operation differ considerably in each of those process types.

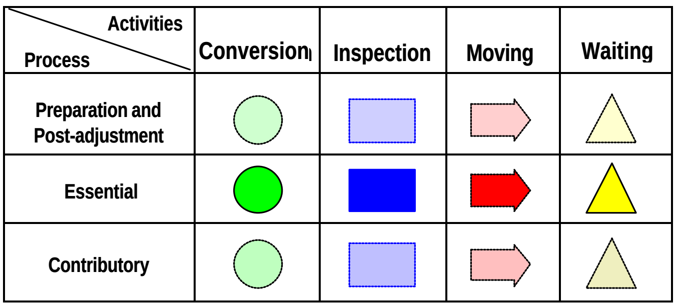

Figure 3: Classification of processes (adapted from Shingo (1988)).

In this study, essential processes were defined as those that add a permanent component or prefabricate a permanent component to the owner-specified facility (Pregenzer et al., 1999). Clearly, the definition of what is essential or contributory could be different depending on who classifies the process: owner, contractor, subcontractor or layman. Preparation, post-adjustment and contributory tasks are necessary for the execution of essential activities, but do not directly add a permanent component to the facility, i.e. do not directly add value for the owner. For example, using current methods, formwork must be built for a concrete column to be cast, but the construction of the formwork itself does not add a permanent component to facility and, therefore, does not add value for the owner.

The following set of operations was defined for the proposed cost system:

- *Processing*: a conversion operation that intersects an essential process. It is a conversion activity that adds a permanent component or prefabricates a permanent component of the owner specified facility, e.g. pouring concrete on slabs, bricklaying, electrical wire installation. Only processing may add value to the final product from the owner point of view;
- *Pre-processing*: a conversion operation that intersects a contributory process, which is a prerequisite of an essential process. Pre-processing operations are considered to be non-value adding, because it does not add a permanent component to the final product, e.g., formwork construction, and scaffolding assembling;
- *Post-processing*: also a conversion process that intersects a contributory process, which, in this case, is subsequent to an essential process, e.g. formwork and scaffolding disassembling;
- *Moving:* an operation in which any material is moved. This operation may belong to either essential or contributory processes;
- *Cleaning*: an operation dedicated to remove rubbish and waste materials from workstations or from construction sites. It belongs to preparation and post-adjustment processes;
- *Adjustments and corrections*: a conversion operation related to both the correction of defects (rework) and the adjustments required by the different production methods;
- *Travelling*: an operation in which a workman travels from one point to another. This operation does not belong to any process, i.e., it does not intersect any material flow;
- *Waiting*: it corresponds to those idle times caused by inclement weather, production disruptions or physiological needs. Like travelling, it does not belong to any process.

This set of eight operations has been specifically proposed for this study, considering its objectives and the resources available. In other studies, a different set could be suggested, depending on the cost-benefit analysis of data collection and processing.

3.1 DATA GATHERING AND ANALYSIS

Despite the fact that it is possible to collect data on site, the perception of managers and employees was used in this study to evaluate the intensity which each operation is demanded by each different task. This decision was made due to the difficulty of incorporating objective methods, such as work sampling and work study, in small and medium sized construction companies as systematic procedures for measuring the time spent performing each operation. Moreover, the relative short duration of several construction tasks would imply in the need of making a great number of observations during a very short period of time – sometimes about half a day – in order to get statistical validity.

According to Drucker (1995), it is necessary to rely on assessment and judgement rather than on direct measurement when objective measures are nearly impossible to obtain. Furthermore, perception has been successfully used with such purpose in several cases of ABC implementation (Brimson, 1991). Although the use of perception is a limitation of this study, objective measures might be used when the processes are reasonably stable and the proper resources are available. In such situations, objective time measurements can also be used to validate data collected through the perception-based measurement.

In general terms, the procedure adopted in this study consisted of measuring the total amount of resources spent in each task (total man-hour) and then determining the intensity that each task demanded from each operation. The time demanded by each operation was evaluated by the managers and the foremen through the assignment of an index (0 to 10) which express the relative intensity of each operation.

To illustrate the data gathering and analysis process, consider the example provided in table 1. The table represents a daily register of the tasks performed in a construction site. Each line in the table corresponds to a specific task, defined as a unique combination of an ***action*** (e.g. casting, assembling or digging) to be performed on ***a physical element*** (e.g. beams, columns, windows or pipes), located in ***a zone*** (e.g. a building, a level, an apartment, or a room). For each task, the total cost is given by the multiplication of labour cost per hour and the task duration. For example, assuming that each worker (JJ) cost $40,00 per hour, the task of "pouring concrete on the 14th floor's slab" costed $160,00

Table 1: Cost System Input Data - Example

		Task				Operations				
Date	**ID (Name)**	**Action**	**Element**	**Zone**	**Duration (h)**	**Processing**	**Pre-processing**	**Post-processing**	**Moving**	**Waiting**
Mar-01	JJ	pouring concrete	slab	14th floor	4	6	4	2	10	8
					Total cost share (TCS)	6/30	4/30	2/30	10/30	8/30
					Operation total cost ($160 x TCS)	$32,00	$21,33	$10,67	$53,33	$42,67

The second step consists of distributing the task cost among the set of operations considered. For every tasks an intensity index is assigned to each operation based on the perception of managers and employees. Accordingly to the assigned index, a share of the task cost is allocated to each operation

Finally, the cost assignment to cost objects depends on how these are defined. A cost object might be defined as an element, as a zone, or as a combination of both element and zone. Once defined the cost object, the costs of all those tasks that match the cost object definition are summed up to determine its total cost.

4. CASE STUDIES

The study involved three case studies in which the proposed system was implemented. The first two cases - the refurbishment of a hospital building (Case A) and the construction of a steel mill plant building (Case B) - were carried out in the same company between December 1999 and May 2000. Case C - a library building - was carried out by a different construction company, between May and September 2000.

4.1 CASE STUDY A - HOSPITAL

This was a highly complex project, since the refurbishment was carried out without interrupting hospital activities. That introduced several restrictions both for material and work flow. The workforce employed in this project was mainly subcontracted, but a number of employees hired by the general contractor was also kept on site to perform specific tasks such as bricklaying and cleaning.

Case A provided the necessary conditions for investigating cost management of both direct and sub-contracted labour. Those procedures described in section 3 were applied in both cost system modules. The only difference was that for direct labour cost control was focused on each workman, while for subcontracted labour the data referred to each gang.

The data was collected on a daily basis, while the cost information reports were generated on a monthly basis. The cost management information was obtained following the procedures presented in section 3, in which, after determining the cost of each task, the cost was allocated among the set of operations based on the intensity index assigned to each operation.

The implementation of the proposed cost system in case A resulted in the identification of several losses that would not otherwise have been identified, as well as stimulated the site manager to take corrective action. The most important conclusions are presented below:

- determination of the cleaning costs: more than 18% of the contractor's workforce cost was spent in cleaning operations. In fact, this evidence has encouraged the site manager to prioritise improvements that reduce the need of cleaning. Moreover, new work procedures for subcontracted teams were established, in which they should be responsible for cleaning each workstation after they finish work;
- guidance to improve subcontractor's production processes: more than 27% of the workforce cost for a specific subcontractor was spent in moving operations (*figure 4*). As a result, some corrective actions were introduced: prioritisation of improvements that reduce the need of moving operations; discussion and reflection about alternatives for the existing process configuration; utilisation of cost information for planning other services to be performed in the same place; price negotiation between the subcontractor and the general contractor based on the expected cost reduction related to the implementation of the suggested improvements.

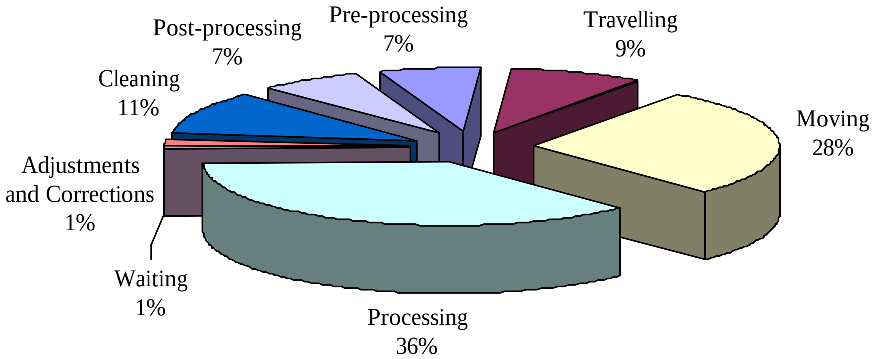

Figure 4: The cost distribution among operations - the case of a subcontractor.

4.2 Case Study B - Steel Mill Plant

In this case study, the focus was on the construction of a building for sheltering a set of ventilators and filters inside a steel mill plant. . Instead of being the general contractor, the construction company was contracted only to build equipment bases, foundation consoles and beams. In this project, the company employed only direct labour - about 30 employees.

Data collection indicated that there was some distortions on the cost percentage assigned to some operations: from one hand, "waiting" and "correction" were too small, and "processing" operations were often too large, on the other hand. This was probably caused by the fact that the interviewees have had the conversion model in their minds. Nevertheless, the cost information provided were effective in terms of supporting decision making. The realisation that moving costs were between 8 and 15% (*figure 5*), after some reflection and discussion, for example, supported the decision of moving the carpentry workshop. Although it has already been located in a building destined for all the steel mill plant's subcontractors, the cost reduction expectation was large enough to encourage the site manager to negotiate with the steel company a new location for the workshop and, then to build a new facility.

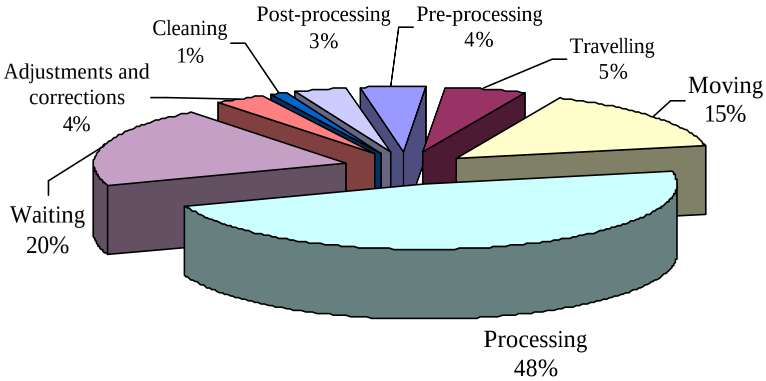

Figure 5: Direct labour cost distribution (2[md] control cycle) - Steel Mill Plant's Case.

4.3 Case Study C - Library

The building had four floors, and the structure consisted of cast in place reinforced concrete columns and waffle concrete slabs. Both internal and external walls were brick. The project was initially scheduled to be finished in six months. Most of the tasks observed in case study C were related to structure erection and bricklaying.

All labour was subcontracted - approximately twenty people were involved in the construction of the structure and brickwalls, all of them hired by the same subcontractor.

Compared to the previous case studies, a more in depth investigation was carried out in this case due to: (a) a greater emphasis was put on training people for the implementation of the system, (b) cost information was combined with other process management tools, such as process diagrams, and (c) a prototype software to support data collection and processing was implemented.

The data collection and analysis procedures employed in this case study followed the same procedures described on section 3. However, based on the Case A and Case B, some minor changes were implemented. Firstly, while the data related to task definition was had still being collected daily, the operations evaluation begun to be made in weekly meetings involving the construction manager, the main subcontractor, the foreman and the researchers. In those meetings, the production processes employed for each task were discussed and the intensity indexes were then assigned to each operation. Secondly, the cost reports were provided on a fortnightly basis, allowing a faster feedback and a larger number of corrective cycles.

The implementation of the cost system in case C was successful, and a number of corrective actions were introduced:

- concrete supplying service evaluation: a relatively large share of subcontractor's labour was spent on slab casting tasks. Such operations were basically caused by the huge variability in the concrete supplying service. As shown in *figure* 6, concrete supplying delays increased the costs of both waiting operation and the task itself in periods 2 and 4. This evidence has encouraged an intense discussion about the possibility of replacing the supplier. However, based on the expectation of cost reduction, the company decided to maintain the same supplier. Thus, cost information was used to support decisions on process improvement;

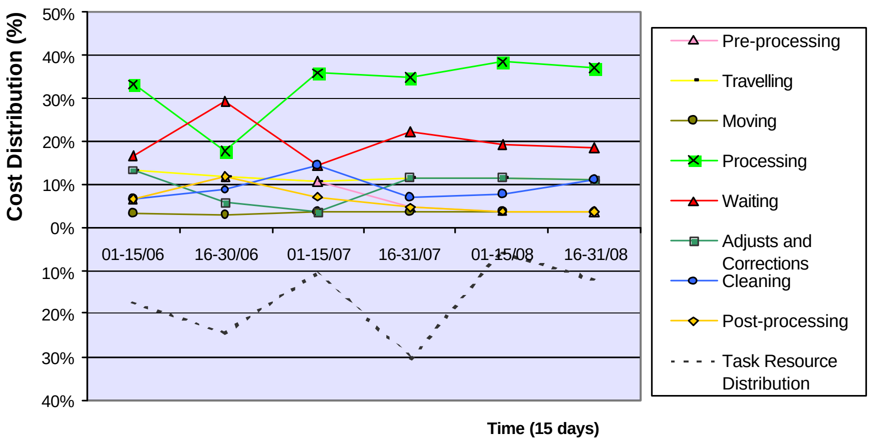

Figure 6: Temporal evolution of cost distribution - concrete supplying.

- column casting process modification: the combined use of process diagram and cost report analysis enabled the managers not only to identify the losses but also to estimate its economic impact. The evidence of large cost of moving operations in the column casting process led the company to buy a new piece of equipment, enabling the crane to directly discharge the concrete inside the formwork. As shown in *figure* 7, this process modification immediately reduced the percentage of resources spent in moving operations. However, the crane was not tall enough to deliver materials at the top floor of the building, since its use had not been initially planned. Therefore, the same manual process needed to be used again, increasing the percentage of resources spent in moving operations (*figure* 7);

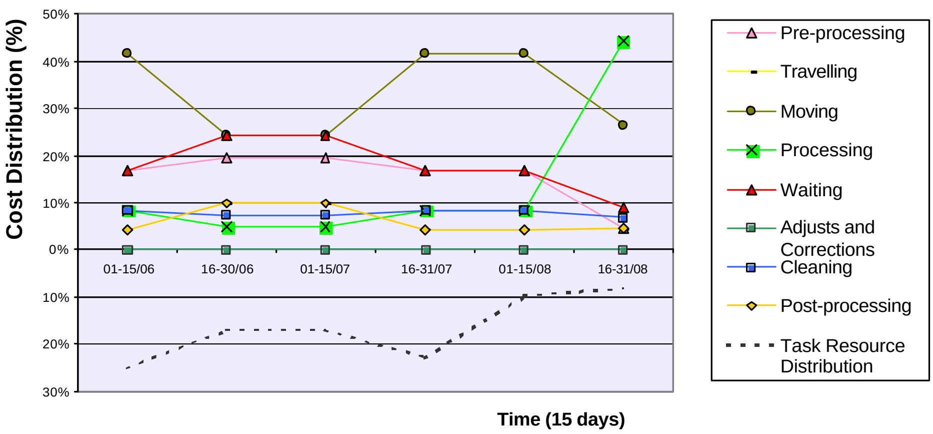

Figure 7: Temporal evolution of cost distribution - column casting

- <u>formwork assembling process evaluation and modification</u>: formwork assembling was identified as the most expensive task in the structure erection phase. Furthermore, the cost report analysis indicated that at least 20% of the resources traced to this task were spent in adjustment and correction operations. Such finding had provoked an intense discussion among the directors, the site manager, the foreman and the structural designers. The difficulty to adjust the borders of the slab formwork and the need of rectifying the slab wood formwork near the columns were identified as the main causes for these operations. Due to the structural designer's participation, a series of incremental improvements were implemented resulting in a gradual decrease in the adjustment and correction costs.

5. CONCLUSIONS

This paper reports the main results of a research project which investigated the application of ABC concepts to improve process transparency in construction cost control. A cost allocation model was suggested aiming to translate and adapt the method for the construction industry context. The need to integrate the cost management information in the production planning and control process was also stressed. Three case studies were carried out, in which the proposed cost system was successfully implemented.

The main contributions of this paper are presented below:

- The proposed cost system has demonstrated the capability of providing relevant information for production management. Its implementation has increased production processes transparency, making visible important aspects usually neglected by traditional cost systems. The cost information encouraged discussion and reflection about the way production process are managed and performed. In this way, it helped to identify production inefficiencies, as well as to evaluate the corrective actions that were undertaken. The great benefit of the proposed cost system, when compared with operational analysis techniques such as first run studies, work sampling and craftworker questionnaires is that it enables to quantify and evaluate processes costs distribution in a systematic way. The proposed system can be continuously operated by the construction companies, allowing them not only to identify but also to quantify waste, so that corrective actions can be properly evaluated before hand in terms of cost.;
- the adoption of ABC concepts in the construction industry demands the translation and adaptation of such concepts in order to create a manageable cost system. The cost allocation model suggested in this paper uses "operations" as the main unit for process analysis. Instead of hundreds of activities, a restricted set of operations, which incorporates the flow and value views by differentiating the value adding from the non-value adding operations, is employed to describe and analyse any production process;
- the integration of cost information in the production planning and control process is essential so that systematic procedures for production control concerned not only with time but also with costs can be established.

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