CONTRIBUTIONS TO THE EVALUATION OF PRODUCTION PLANNING AND CONTROL SYSTEMS IN BUILDING COMPANIES

Maurício M. S. Bernardes[1] and Carlos T. Formoso[2]

ABSTRACT

It is widely accepted that the overall performance of construction companies is largely affected by the lack of effectiveness of their production planning and control systems. Through the evaluation of such systems, one can identify the origin of existing problems and actions that can improve the performance of production systems.

The contributions presented in this article arise from a research project that had as one of its primary goals the development of a production planning and control model for small sized building companies. A set of practices underlying this model was defined in order to evaluate the effectiveness of its implementation. The identification of these practices was based on production management core concepts and principles. An indicator measuring the implementation effectiveness of the model was also proposed.

The results indicated that most successful planning and control systems in terms of implementation were those in which short term planning and control was effective and stable.

KEY WORDS

Production Planning and Control, Planning System Evaluation, Performance Measurement, Implementation

---

[1] Associate Professor, Federal University of Rio Grande do Sul, School of Architecture, Rua Sarmento Leite, nº 320, sala 504, Porto Alegre - RS, Brazil, CEP 90050-010, moreiraesilva@terra.com.br

[2] Associate Professor, Federal University of Rio Grande do Sul, PPGEC – Postgraduate Program in Civil Engineering, Av. Osvaldo Aranha, nº 99, 3º andar, Porto Alegre - RS, Brazil, CEP 90035-190, formoso@vortex.ufrgs.br

INTRODUCTION

Over the last decade, several research studies aiming to increase the effectiveness of planning and production control systems have been carried out (Alarcón 1997; Ballard and Howell 1997; Tommelein and Ballard 1997; Howell and Ballard 1997; Ballard 2000). Mostly based on case studies, these investigations have indicated that it is possible to increment production performance by developing proactive measures throughout the planning and production control process. Identifying such measures may become easier when core production management principles, practices and approaches are explicitly taken into consideration. Koskela (1992), for instance, proposed eleven principles for managing production, based on the new production management paradigm.

However, recognizing which principles, practices or approaches should be emphasized in the development of construction planning and control systems has not yet been sufficiently investigated. This is partly due to the fact that those principles, practices and approaches interact, making it difficult to understand precisely their effect on each other.

The identification of priority measures to solve problems related to the development of planning and production control systems occurs, in general, during the system's evaluation process. Spotting such problems generally requires an analysis of the performance measures adopted by the construction company. A combined analysis of these indicators allows one to identify the causes that have interfered with the execution of operational plans, compared to what had been planned.

This article aims to contribute to the evaluation of production planning and control systems, based on the identification of a set of underlying practices that can support performance improvement in construction companies. These practices have been mainly defined according to some core production management concepts and principles established in the literature (Shingo 1988; Koskela 1992; Ballard and Howell 1997; Santos 1999; Ballard 2000). The application of such practices in a number of construction companies involved in the implementation of production planning and control systems was analyzed.

This study is part of a research project that aimed to develop a production planning and control model for small sized building companies. This model contains several elements of the Last Planner Method for Production Control proposed by Ballard (2000).

UNDERLYING PRACTICES RELATED TO THE DEVELOPMENT OF PLANNING AND CONSTROL SYSTEMS

Using some production management concepts, principles and approaches established in the literature as a starting point, a group of researchers, coordinated by the first author of this paper, proposed a set of practices related to the development of production planning and control systems. Five two-hour meetings were held, and the discussion group was formed by researchers from the Building Innovation Research Unit (NORIE) from the Federal University of Rio Grande do Sul (UFRGS), Brazil. The proposed practices were considered to be the most relevant ones to support the development of planning and control systems. These could be also used as a reference for evaluating the effectiveness of implementation of such systems.

A practice is defined here as an activity that should be undertaken during the development and implementation of a planning and control system, contributing to improve its effectiveness. Fourteen practices were identified (see items below). Most of them are strongly related to the set of eleven principles proposed by Koskela (1992), including increasing process transparency, reducing variability, and continuous improvement.

PCP STANDARDIZATION

According to Shingo (1988), standardization is especially effective when it aims to reduce the inefficiency resulting from diversification of tasks. Koskela (1992) points out that standardization is considered a potential vehicle not only to reduce variability of the conversion and flow activities but also to establish a parameter, which should be continuously improved.

In order to standardize the managerial process, it is possible to make use of formal procedures or manuals that establish how these processes should be routinely carried out (Turner 1993). Such documents are useful to guide new employees on how to implement production planning and control systems in different projects.

PLANNING IN HIERARCHICAL LEVELS

Planning in hierarchical levels refers to the way in which production goals are related to the short, medium and long-term plans. The degree of planning details should increase as the date of execution each activity approaches. This can be seen as a way of reducing the impact of uncertainty in the production environment (Laufer and Tucker 1987). Moreover, using hierarchical levels facilitates the analysis of the repercussion of possible delays in the achievement of operational goals in the long-term plan. In this way, it is possible to give priority to measures that will avoid delays in the delivery of the project.

ANALYSIS AND QUALITATIVE EVALUATION OF PRODUCTION PROCESSES

According to Oglesby et al. (1989), the first step towards improving the performance of ongoing activities is to understand and analyze the way in which work has been developed. This can be done, for example, through weekly meetings taking place at the construction site with the presence of the production manager, and the foreman. These meetings have the purpose of identifying problems, investigating their causes, and devising ways to improve the production system (Laufer et al. 1992). Problems may be identified, at first, through a qualitative analysis of the ongoing production process.

In addition to observation, it is also possible to register how the process has been conducted, for instance by video taping or photographing. These two resources are recommended when the objective is to obtain a qualitative evaluation of the process as it is possible to document movements and postures, and interdependencies among tasks (Oglesby et al. 1989; Santos et al. 1996).

ANALYSIS OF PHYSICAL FLOWS

Alves (2000) stresses that the analysis of physical flows aims mainly to reduce the share of non value adding activities in production processes. According to that author, variations on the flow of resources is a major cause of waste in construction sites. She also proposes some measures to be taken in order to diminish the effects of such variations:

- Short-term requirements should be fulfilled in order to protect production (Ballard and Howell 1997);
- Medium-term plans can be used to remove constraints (Tommelein and Ballard 1997) in such flows;
- Long-term suppliers should guarantee quality products and on-time delivery according to the time frame requested by the company (Alves 2000);
- Time and resource buffers among the ongoing activities should be established (Howell and Ballard 1997) aiming to increase the reliability of short-term planning.

ANALYSIS OF CONSTRAINTS

Ballard (2000) proposes a screening and pulling mechanism at medium-term level, in which each work package has its constraints analyzed. These are some examples of constraint sources: unfinished design drawings, client approvals, availability of resources, and unfinished precedent work packages.

A major cause of failures in accomplishing short-term goals is the non removal of some of the above constraints (Ballard 2000). Therefore, constraint analysis allows an increase in the continuity of operations on site, and, consequently, tends to improve planning effectiveness.

USE OF VISUAL DEVICES

A visual device consists of an element intentionally designed for sharing information that is vital for the development of a task (Galsworth 1997). According to Koskela (1992), the use of such devices enables any of the company's employees to immediately identify patterns and deviations in the process. It is one of the approaches to increase process transparency.

Alves (2000) emphasizes that the use of visual devices in construction sites is essential for flow management. According to that author, the application of this practice may reduce congestion due to material, tools and equipment cluttered on the site.

FORMALIZATION OF SHORT TERM PLANNING

The formalization of short-term planning facilitates the assignment of work packages to teams and production control. This is due to the fact that the assigned tasks are made explicit on a form, in a clear and organized way.

The implementation of this practice requires the presence of the foreman during the preparation of the plans, as suggested by Ballard and Howell (1997), since he usually has an overall view of undergoing tasks on site.

Another fundamental aspect related to this practice refers to the easiness of analyzing the collected data. In this case, once there is a precise record of the problems that interferes in the execution of assignments, it becomes easier to identify the effects of the decisions taken to correct deviations from the plans.

DETAILED SPECIFICATION OF TASKS

A task whose specification has been poorly detailed may result in activities that are inadequate to the client's requirements, causing rework and further interference in the subsequent tasks. A well detailed specification reduces the chances of failure by lack of information and, therefore, increases the understanding on the way a task should be executed, facilitating the control of the work packages.

PROGRAMMING OF WORKABLE BACKLOG

Programming a workable backlog provides a contingency plan at the short-term planning level. This may reduce, at least partly, the negative effects of uncertainty within the production environment (Ballard and Howell 1997). If any interference occurs in the work flow on site, the affected teams could be relocated to other tasks in order to reduce unproductive time.

SHARED DECISION MAKING

Shared decision making tends to encourage the employees to identify possible ways of improving the production system performance, as well as diminishing the incidence of rework and interference among production teams. It also tends to increase the commitment to the planned goals.

After implementing the decisions, the employees who have taken part in the discussions are usually able to learn from the results. Consequently, discussion meetings become more frequent, the communication among participants increases, and, therefore, the work of different teams tend to be more synchronized (Laufer et al. 1992).

USE OF PPC AND IDENTIFICATION OF THE CAUSES OF PROBLEMS

The use of the PPC (Percentage of Plans Completed) and the identification of the causes for not completing work packages are two key elements in the Last Planner Method of Production Control (Ballard 2000). Both of them can be used to improve the performance of production planning and control systems, by supporting the process of learning from existing problems in the production system. As a result, variability in the production system is reduced.

USE OF PERFORMANCE INDICATORS

Performance measurement provides the necessary data and facts for process control, and makes it possible to establish challenging and feasible goals (Lantelme and Formoso 2000). By using measurements to evaluate the performance of production systems, it is possible to establish standards that, if implemented, may improve the quality of information available for decision making (Alarcón 1997).

The use of indicators for measuring the performance of both managerial and production processes supports the evaluation of production planning and control effectiveness (Oliveira 1999). The use of performance indicators may bring into view some production attributes, which, normally, would not be explicit. In addition, monitoring a set of indicators allows those employees responsible for decision making to take part in the learning process that can lead to a continuous improvement of the production system (Chiesa et al. 1996).

CORRECTIVE ACTIONS BASED ON THE CAUSES OF PROBLEMS

As the problems that cause the non completion of short-term tasks are identified, corrective actions should be carried out in order to eliminate or minimize the incidence of such problems. These actions are crucial not only to reduce the PPC variability but also to establish a knowledge base for those responsible for the production of short-term plans.

In the first cycles of execution of a production process, when there is not a precise knowledge on the capacity of the work teams, it is possible to reduce the load of a task to a lower level than the planned average rhythm (Ballard 1999). This attitude may facilitate the identification of improvements in the work flows or, at least, indicate the availability of additional resources that will make the production rhythm accomplish the plan.

MEETINGS TO INFORMATION DIFFUSION

These meetings aim to disseminate information related to changes on how the work has been carried out, and also to existing problems concerning the execution of the work, within the week the work is due. Such meetings may involve the same participants who were involved in short-term planning, and can be called by team leaders, foremen, or site engineer.

Through these meetings, it becomes easier to achieve the desired results as the participants are clearly informed about what has to be done and the sources of problems that should be tackled so that the execution of the established goals is not compromised.

METHOD FOR EVALUATING PLANNING AND CONTROL SYSTEMS

The proposed evaluation method is based on the subjective verification of whether these practices have been fully or partially adopted by a construction company. This evaluation can be carried out through semi-structured interviews and also through direct observation in the company's office. Each practice receives a weight that corresponds to the degree in which it is used. The weights are assigned according to the following criteria:

- Weight 1.0: a practice is being largely used in the company;
- Weight 0.5: a practice is being partially used in the company. This is assigned when the company applies some elements of the practice. For example, the practice named “shared decision making in the production control system” requires a discussion about the goals of the operational plan. In order to reach a consensus it is necessary to hold a meeting involving representatives of production teams. However, if the meeting between the foreman, the engineer and the team leader is held separately, it is still possible to assume that there is some kind of participation, but the practice is considered to be partially implemented;
- Weight 0.0: a non-implemented practice or a practice that was implemented but not based on the elements of the model. In this case, there is no evidence of the application of the practice in the company's planning and control system.

An indicator has been created in order to analyze the use of the practices, named the "effectiveness of implementation". This indicator is calculated by summing the weights assigned to each practice and, then, dividing the result by 14 (number of practices considered). Finally, the result is multiplied by 100 so that the indicator is presented as a percentage. The combined analysis of this indicator with the PPC helps the identification of measures to improve the effectiveness of the production planning and control system.

CASE STUDIES IN BRAZILIAN CONSTRUCTION COMPANYS

The proposed evaluation method was used to assess the production planning and control systems of seven construction companies. These companies are located in Porto Alegre, Canoas and Santa Maria, in the State of Rio Grande do Sul, Brazil. Six of the companies are mostly involved in the development and construction of residential and commercial buildings (companies A to F), while other one has as its main market the construction and refurbishment of industrial buildings and hospitals (Company G).

All companies have been involved in the development of a production planning and control model, in partnership with the Building Innovation Research Unit at UFRGS. The first stage of the research (named Stage I) study involved the development of planning and control systems in each of those companies. Companies A to F began to develop their systems in July 1996 and finalized in December 1998. Company G started in February 1999 and continued until September of the same year. Based on those seven case studies the model was proposed. The second stage of the empirical study (named Stage II) started in May 2000. Each of those companies had its planning and control system evaluated using the method described above - based on that an evaluation of the model was carried out. Data collection involved interviews with managers, direct observation, and the collection of performance indicators.

EFFECTIVENESS OF IMPLEMENTATION

The weights assigned to each practice are shown in Table 1. It is possible to notice that the effectiveness of the implementation is less than 50 % in all companies, except for company G.

The strategy adopted for implementing the planning and control systems had a strong influence on the application of different practices. For instance, short-term planning was usually the first stage of implementation. For that reason, some practices related to that planning level were implemented more intensively than others. The practices that were introduced in the project during the last few months of Stage I did not have the same degree of success. This is the case of practices # 3, 4, 5 and 6 (Table 1).

Table1: A summary of the evaluation of practices' usage in the companies

PRACTICES	COMPANY						
	A	B	C	D	E	F	G
1. Planning and control process standardization	1.0	1.0	0.5	0.5	0.0	0.5	0.5
2. Planning and control Hierarchization	1.0	1.0	1.0	0.5	0.0	0.5	1.0
3. Analysis and qualitative evaluation of processes	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4. Analysis of physical flows	0.0	0.0	0.0	0.0	0.0	0.0	0.5
5. Constraint analysis	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6. Use of visual devices	0.0	0.0	0.0	0.0	0.0	0.0	1.0
7. Formalization of short term planning	1.0	0.5	0.5	0.0	0.0	0.5	0.5
8. Detailed specification of tasks	1.0	0.5	0.5	0.5	0.0	0.5	0.5
9. Programming of workable backlog	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10. Shared decision making	0.5	0.5	0.5	0.0	0.0	0.0	0.5
11. Use of PPC and identification of the causes of problems	1.0	1.0	0.5	0.0	0.0	0.5	1.0
12. Use of performances indicators	0.0	0.0	0.0	0.0	0.0	0.0	0.5
13. Corrective actions based on the	0.5	0.0	0.0	0.0	0.0	0.0	0.5

causes of problems							
14. Meetings for information diffusion	0.5	0.0	0.5	0.0	0.5	0.0	0.5
TOTAL	6.5	4.5	4.0	1.5	0.5	2.5	7.0
Effectiveness of implementation	46.4%	32.1%	28.7%	10.7%	3.5%	17.8%	50.0%
Average PPC for the best project	80.3%	97.8%	82.1%	66.2%	-	50.3%	69.8%
PPC Coefficient of Variability (CV) for the best project	18.0%	4.1%	15.6%	39.4%	-	21.9%	6.2%
Notes: Weight 1.0 – fully implemented Weight 0.5 – partially implemented Weight 0.0 – not implemented							

Some practices that had been effectively implemented in Stage I were not observed during the Stage II in any of the companies (practices 9,12 e 13). This can be explained mainly by the fact that some site managers did not perceive the utility of such practices. This indicates that it is necessary to give more emphasis to them during the training process. Simulations and practical exemplification also may help.

According to Table 1, the higher is the effectiveness of implementation the higher tends to be the PPC. The only exception was company B, which had a very high average PPC (97.8%), low variability in the PPC (CV = 4.1%), and a relatively low effectiveness of implementation (32.1%). However, in that company short-term plans were insufficiently detailed and that no constraint analysis was carried out. Based on that and also on direct observation, the authors concluded that the results of the PPC indicator were distorted, probably because the site engineer wanted to impress top management.

PPC AND VARIABILITY

Despite the problems already mentioned and the relatively low percentiles of effectiveness of implementation, in general the implementation process was fairly successful in most companies. This can be observed in Figure 1, which compares the average PPC and the coefficient of variability (CV) in all construction sites where the production planning and control systems were implemented. Projects investigated in both Stage I and Stage II projects were included in the analysis. Each graph corresponds to the projects related to one specific construction company (A to F). No data is presented for company E, since the practice "standardization of short term planning" was not properly implemented in there.

Figure 1 indicates that the projects in Stage II in general had a higher PCP and lower PPC variability when compared to projects in Stage I. All projects investigated in companies A, B and C during Stage II indicated an improvement of PPC if compared to the previous stage. In both companies G and F there was a small decrease in the PPC indicator, but there was some kind of improvement in the planning and control effectiveness, since the PPC variability has decreased.

Finally, company D was the one that had the worst results among all companies. No significant improvement of PPC was observed from Stage I to Stage II. In all projects the PPC coefficient of variation was relatively high. The effectiveness of implementation in this company was only 10.7%.

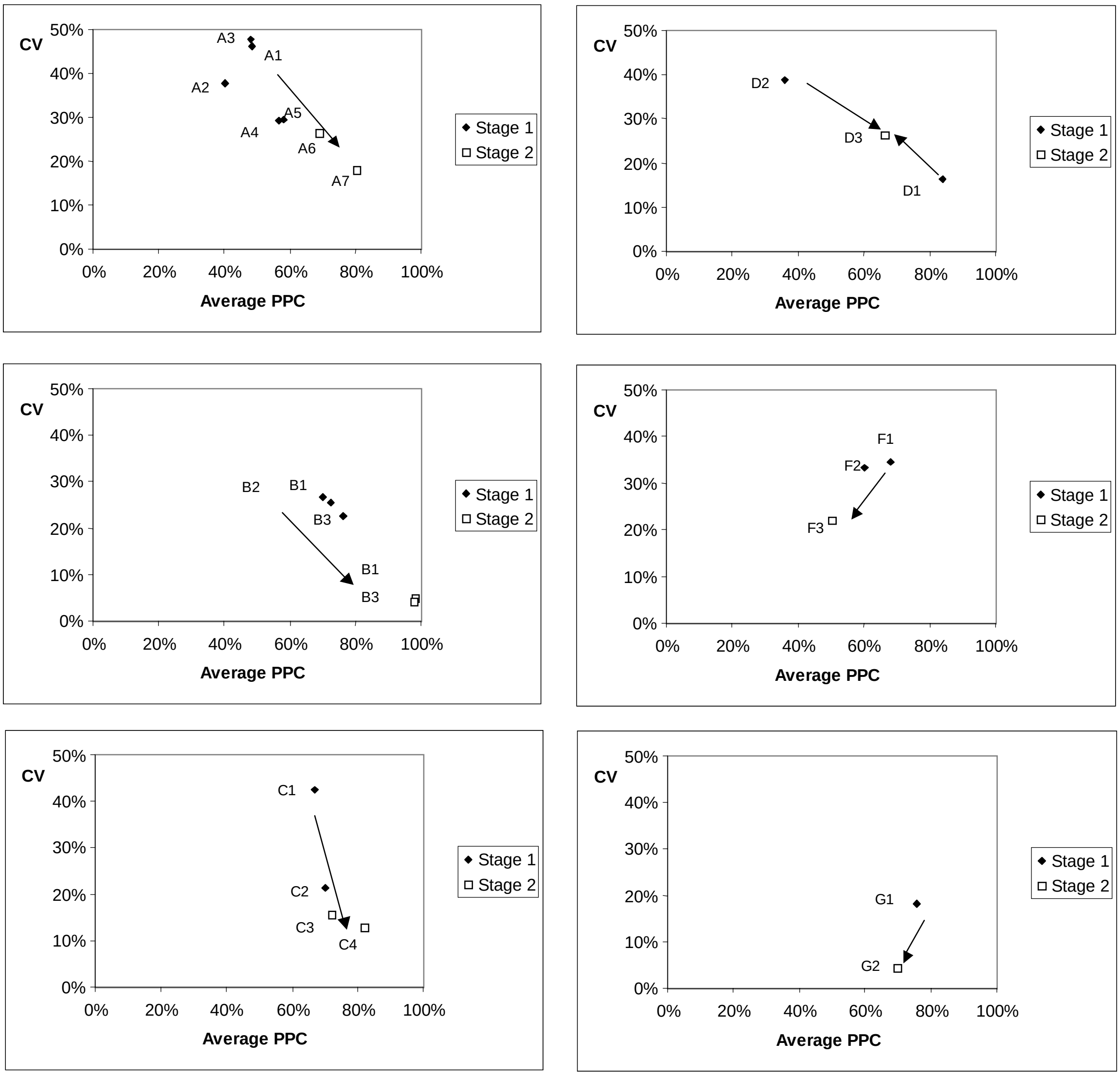

Figure 1: Average PPC and PPC Coefficient of Variability (CV) for all projects analyzed in Stage I and Stage II (companies A, B, C, D, F and G)

CONCLUSIONS

This paper proposes a fairly simple way to evaluate the effectiveness of production planning and control system implementation, using a number of practices that can be related to production management core concepts and principles. It does not intend provide a definitive list of necessary practices for all planning and control systems in the construction industry. Future work should address the need to identify other practices, considering the evolution of leading companies. Whichever modification is made in the set of practices this should be related to a pertinent theoretical framework, since this facilitates learning.

Some of the analyses presented indicate ways to evaluate the success of planning and control systems, using a relatively small number of indicators: PPC, PPC coefficient of variability, and effectiveness of implementation.

ACKNOWLEDGEMETS

We thank Finep – *Financiadora de Estudos e Projetos* (Financing Agency for Studies and Projects), *Habitare* Program, for sponsoring this research study.

REFERENCES

Alarcón, L. (1997). The importance of research to develop lean construction. In: Seminário Internacional sobre Lean Construction, 2, 20-21 Out., 1997. São Paulo. Proceedings... São Paulo: [s.n.], 1997.

Alves, T. (2000). Diretrizes para a Gestão dos Fluxos Físicos em Canteiros de Obras: Proposta Baseada em Estudo de Caso [*Guidelines for managing physical flows in building sites: proposal based on a case study]*. Postgraduate Program in Civil Engineering, Federal University of Rio Grande do Sul, 2000. M.Sc. Dissertation.

Ballard, G. and Howell, G. (1998). Shielding Production: An Essential Step in Production Control. Journal of Construction Engineering and Management, ASCE, 124 (1): pp. 18-24, Jan.

Ballard, G. (1999). Improving work flow reliability. In: Annual Conference of the International Group for Lean Construction, 7., 1999, Berkeley, CA. Proceedings... University of California. p. 275-286.

Ballard, G. (2000). The Last Planner System of Production Control. Birmingham: School of Civil Engineering, Faculty of Engineering, University of Birmingham.. Ph.D. Thesis.

Chiesa, V.; Coughlan, P. and Voss, C. (1996). Development of a Technical Innovation Audit. Journal of Product Innovation Management, v. 13, p. 105-136. New York: Elsevier Science Inc.

Galsworth, G. (1997). Visual Systems. Harnessing the Power of a Visual Workplace. United States: Amacon.

Howell, G. and Ballard, G. (1997). Implementing Lean Construction: Reducing Inflow Variation. In: Alarcón, L. (Ed.). Lean Construction. Rotterdam: A.A. Balkema. p 93-100.

Koskela L. (1997). Application of the New Production Philosophy to Construction. Technical Report, Filand: CIFE.

Formoso, C.T. and Lantelme, E.M.V. (2000). A performance measurement system for construction companies in brazil. International Project Management Journal. Finland, V. 6 (1), p.54-60.

Laufer, A. and Tucker, R. L. (1987). Is construction planning really doing its job ? A critical examination of focus, role and process. Construction Management and Economics, London, United States, n. 5, p. 243-266.

Laufer, A.; Howell, G. and Yehiel, R. (1992). Three modes of short-term construction planning. Construction Management and Economics, v.10, p. 249-262.

Oglesby, C.; Parker, H. and Howell, G. (1989). Productivity Improvement in Construction. United States: McGraw-Hill Inc.

Oliveira, K.(1999). Desenvolvimento e implementação de um sistema de indicadores no processo de planejamento e controle da produção: Proposta baseada em estudo de caso

[*Development and implementation of a performance measurement system for the production planning and control process: proposal based on a case study*]. Porto Alegre: Postgraduate Program in Civil Engineering, Federal University of Rio Grande do Sul. M.Sc. Dissertation.

Santos A. (1999). Application of Production Management Flow Principles in Construction Sites. Salford: University of Salford. Ph.D. Thesis.

Santos, A.; Formoso, C.T. and Hinks, J. (1996). Method of intervention on the flow of materials in building processes. In: International Conference on Lean Construction, 4th, Birmingham, UK, 26 a 27 ago. 1996. Proceedings**.** Birmingham, University of Birmingham, Dept. of Civil Engineering.

Saurin, T. (1997). Método para diagnóstico e diretrizes para planejamento de canteiro de obra de edificações [*Method for diagnosing and guidelines for planning building sites*]. Porto Alegre: Postgraduate Program in Civil Engineering, Federal University of Rio Grande do Sul. M.Sc. Thesis.

Shingo S. (1988). Non-stock production. UK: Productivity Press.

Tommelein, I.; Ballard, G. (1997). Look-Ahead Planning: Screening and Pulling. In: Seminário Internacional sobre Lean Construction, 2, 20-21 Out., 1997. São Paulo. Proceedings... São Paulo: [s.n.], 1997.

Turner, R. (1993). The Handbook of Project-Based Management. England: McGraw-Hill Book Company Europe.