APPLICABILITY OF LOGISTICS MANAGEMENT IN LEAN CONSTRUCTION: A CASE STUDY APPROACH IN BRAZILIAN BUILDING COMPANIES

Fred Borges da Silva[1] and Francisco Ferreira Cardoso[2]

ABSTRACT

Logistics management concepts and tools currently have a great value for several business sectors that are searching for productivity and competitiveness improvement, providing costs reduction and better customer satisfaction. With that purpose they are trying to promote a better integration between internal and external actors who support logistics activities.

This paper reports on three case studies undertaken as part of a Master Research program, which has the main objective of investigating how logistics concepts and tools are being applied to the Brazilian building construction sector.

As a conclusion, guidelines are presented in order to improve logistics efficiency and effectiveness in the building production process. These guidelines are based on positive and negative experiences of some construction companies presented briefly in three case studies and on experiences of companies from other sectors of the economy.

KEY WORDS

Logistics, supply chain, supply logistics, site logistics, lean construction, Brazil.

[1] Civil Engineer, M. Eng. Candidate, Civil Construction Engineering Department, Escola Politécnica, Universidade de São Paulo, fred@pcc.usp.br

[2] Professor Dr., Civil Construction Engineering Department, Escola Politécnica, Universidade de São Paulo, fcardoso@pcc.usp.br

INTRODUCTION

Increasing competition among Brazilian building companies has led them to develop new strategies focused on production aspects of construction. They are giving more importance to constructive rationalization, quality management systems, labor productivity, and material loss studies. In this new context, logistics improvement also becomes an important element for building companies wishing to develop competitive advantage.

This paper discusses how logistics concepts and management tools can be applied to building construction in order to achieve competitive advantage. It also attempts to demonstrate the validity of these concepts and tools and to identify general guidelines for logistics management improvement through case studies developed in three Brazilian companies.

This discussion gains a particular interest if the new production philosophy concept is taken into account. Production process is understood here not only as a sequence of conversion activities (conversion model) but also as a flow process of materials and information and as a process that generates value for customers. As Koskela (1992) states, "production is a flow of material and information from raw material to the end product. In this flow, the material is processed (converted), it is inspected, it is waiting or it is moving... processing represents the conversion aspect of production; inspect, moving and waiting represent the flow aspect of production".

From this concept, it can be deduced that in a production process, competitive advantage can not only come from improving efficiency in conversion activities, but also from reducing waiting time, storage, moving and inspection processes. All these activities are inherent to a logistic process.

The Council of Logistics Management (CLM 1992) gives the most recent definition of logistics as "the process of planning, implementing, and controlling the efficient, effective flow and storage of goods, services, and related information from point-of-origin to point-of-consumption for the purpose of conforming to customer requirements."

In construction terms, logistics can be understood as a multidisciplinary process that seeks to guarantee at right time, cost and quality:

- material supply, storage, processing and handling;
- manpower supply;
- schedule control;
- site infrastructure and equipment location;
- site physical flow management;
- management of information related to all physical and services flow.

This is achieved through planning, organizational, directing and controlling activities before and during the construction works.

Logistics functions in a construction firm can be divided into supply logistics and site logistics (Figure1.)

Supply logistics are related to activities that are cyclic in the production process. These activities are basically: supply resources (materials, equipment and manpower) specification, supply planning, acquisition of resources, transport to site and delivery, and storage control.

Site logistics are related to physical flow planning, organizing, directing and controlling on-site. This means, management of handling systems, safety equipment, site layout, definition of activity sequence and resolution of interference among production teams activities on-site.

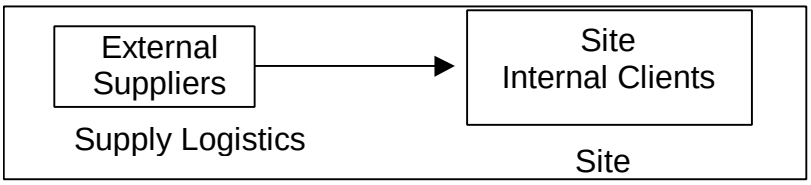

Figure 1: Logistics functions

The main objectives of a logistics system are to maximize customer service level and to minimize total cost in its activities. In other words, the objectives are to generate value to the customer and to reduce cost in the production process.

Customer service level can be measured on external relations between a construction company and its final clients, on external relations between a construction company and its suppliers, and on internal relations between a company and its internal clients on-site.

In the first case (relations: company-final client), service level or customer satisfaction, can be measured by the company's capacity of accomplishing the period of execution with expected quality and budget. In the second (relations: company-suppliers) and third case (internal relations), service level is determined by the company's capacity of providing resources to internal agents on site at the right time and place, attaining the correct specification.

Total cost concept is based on the fact that some actions that aim to reduce an individual logistics activity cost may cause an increase in others activity costs (Lambert and Stock 1993). Therefore, there is a conflict in logistics costs. For example, freight cost can be minimized by acquisition in higher quantities, but this will probably cause an increase in storage and stock costs.

Total cost analysis should always be associated to service level analysis. It is a trade-off analysis, because an increasing on service level will generate an increasing in the total cost. For this reason, it is necessary to build up different scenarios before deciding which solution will be adopted. Given these concepts, the case studies will be presented and some tools for logistics management that were found in bibliographical references and during the casework.

CASE STUDIES GENERAL PRESENTATION

Three case studies were conducted in order to identify: (1) general difficulties in logistics management process; (2) new visions, methods and tools that are being applied on building companies; (3) the opportunity of using these visions, methods and tools in building companies.

The companies were chosen randomly because it did not matter if they were passing by a logistics intervention. The initial hypothesis was that new visions, methods and tools in order to improve logistics efficiency are somehow being implemented in any of them, although not necessarily in a systemic way. Based on these companies' experiences and on theoretical background, general logistics management guidelines can be proposed.

Observations were made in internal ambit of the companies, what means, it was done a diagnosis research focused in their logistics management process and it was not taken into account an analysis of external influences.

Due to the brief space for this discussion, the tools used to collect data in these companies will not be detailed here, but they are mentioned in Table 1.

Table 1: Aspects analyzed in the case studies

	Observed and analyzed aspects	Sources and tools
Politics and Procedures	-Competitive and production strategy; -Relationship with suppliers; -Strategic objectives and actions; -Performance indicators.	-Interview with a company's director; -Questionnaire for company's characterization. -Questionnaire for material flow characterization; -Interview with resident engineers. -Interview with supply managers; -Analysis of information exchange documents. -Observation on building sites.
Logistics Organization and Coordination	-Responsibilities of actors; -Decision of logistics coordination responsibilities; -Key moments for decision making in the process; -Collective decision making process.	
Supply Management	-Acquisition process; -Decentralized X centralized purchase; -Supply plan; -Storage management.	
Site Layout and Material Handling	-Site layout planning procedures; -Production planning and site preparation; -Main equipment for internal transport in building sites (decision process); -Responsibilities in transport activities;	
Logistics Information Management	-Documents used to record information; -Information available for decision making. -Velocity of data processing; -Duplicity of information ; -Communication vehicles.	

The first company, that is called here "**X**", acts as an entrepreneur and a general contractor of residential and commercial buildings in a specific district of São Paulo City. As an entrepreneur, it usually establishes an "administration contract" with final clients who pay a certain percentage for conception service and project administration / execution.

The production process rationalization strategy used by this firm is focused on the improvement of traditional constructive techniques and on the improvement of labors work conditions. The company also uses its in-house labor to execute its production. Competitive advantage outcome from cost reduction due to a high control of construction techniques. In order to achieve its strategic objectives, this company is now developing an internal Quality Management System based on ISO 9000 criteria.

Some key points for logistics efficiency improvement identified in this company are:

- Strategic politics for suppliers relationship definition;
- Site layout planning considering the different site phases;
- Agents roles and responsibilities definition in site logistics activities;
- Duplicity elimination and velocity increasing in data processing and information exchange.

The second company, that is called here "**Y**", acts only as a general contractor in "cooperative systems" project. Usually they are huge projects with six or more buildings with long term execution. These buildings are all located in São Paulo's metropolitan area.

Its production process rationalization strategy can be characterized by a widely subcontracting practice and it seeks a vertical disintegration of production process. In this case the company concentrates efforts on developing management techniques to obtain reduction costs and competitive advantage.

Some key points for logistics efficiency improvement identified in this company are:

- Logistics coordination function definition;
- General procedures for acquisition process definition;
- Supply plans elaboration;
- Duplicity elimination and velocity increasing in data processing and information exchange.

The third company, that is called here "**Z**", acts as an entrepreneur and a general contractor of residential buildings mainly in São Paulo. It has bigger revenues than the others do and all units are commercialized through direct financing with the company.

The adopted production process rationalization strategy is characterized by the firm's capacity of financing the units directly to the final client. To make that possible, the company must maximize periods of construction and minimize operations on site. It is also necessary to be very efficient and effective in budget development and control as well as in production planning and controlling. To achieve this strategy and reduce costs, company **Z** has also standardized lots of constructive solutions for their building projects and minimized the number of material and component suppliers.

The main key points for logistics efficiency improvement identified in this company are:

- Process integration with suppliers increase;
- Information vehicles improvement including Electronic Data Exchange (EDI) implementation;
- Interference reduction among subcontractors and agents roles and responsibilities definition in site logistics activities.

Although the three companies have different strategies and different challenges for logistics improvement, it was possible to notice that in all of them some philosophies, methods and tools for logistics management are somehow being used.

LOGISTICS MANAGEMENT

SUPPLY LOGISTICS MANAGEMENT

Supply function is currently pointed as being responsible for production process delays and stops, because a lack of material can impede the accomplishment of an activity, causing productivity loss (Picchi 1993).

But recently, the "Quality Movement" and, in a certain way, the diffusion of Just In Time (JIT) principles among Brazilian building companies have been influencing positively the supply logistics process.

Quality Movement has been involving hundreds of companies in the very different Brazilian States. Actually it consists basically on the diffusion and implementation of Quality Management Systems in these firms. These systems, based on ISO 9000 series, can help supply logistics improvement, particularly, through a standardization of procedures, that are in fact operational tools, like: (1) specifications and purchase orders; (2) suppliers selection and qualification; (3) material quality assurance; (4) materials and components deliveries inspection; (5) criteria for divergences solution in the relationships between the company and suppliers.

This vision is especially present on company **X**, which has been developing an internal quality program. Up to now, not all procedures were implemented, but the company argues that it is already possible to observe a reduction on material unconformity and loss.

Just In Time is a philosophy that can be traduced as a synchronized flow production system without stock. Large materials and components stocks (including finished services waiting for a sequential job) usually hide problems like: (1) non punctuality in materials and components deliveries; (2) inability of the suppliers of doing deliveries in small lots; (3) inability in foreseeing with accuracy the periods of activities execution; (4) problems in production teams planning and productivity rates appropriation; (5) lack of knowledge of materials and components loss rates.

This philosophy is based on the principle that no activity should start in a system until it is necessary. In the same way, no material or product should arrive on a processing site without being necessary to that moment. So, the demand should pull the production flow. Some management practices that are associated to JIT philosophy are (Fullmann et al. 1989): (1) defects elimination; (2) self quality control and immediate feedback information; (3) waiting time between activities reduction; (4) material handling volumes reduction; (5) transparency by visual control; (6) Kanban system adoption; (7) adjustment of suppliers to the same ideas.

None of the three companies studied (**X**, **Y, Z)** adopt JIT systems. But most of management practices mentioned above are in the scope of their production strategy objectives in order to reduce stocks. So it is possible to identify JIT philosophy influence in their current practice.

One of the main barriers to JIT systems adoption in material supply relies on the factor that the traditional constructive system adopted by these companies does not permit a regular furnishing practice for all kinds of materials and components. But some alternatives can be applied like prefabrication of components out of site and creation of unit packages systems.

Akintoye (1995) points out that in an analysis of JIT system implementation in construction companies many factors should be taken into account, like: production planning; process and product designs; the relationship with suppliers; sources of supply; education and training.

Another strategic vision for logistics development is related to Supply Chain Management, which is the company's capacity to manage the supply chain and integrate its processes with them. From this point of view, cost reduction and material / component quality improvement actions should be taken since raw materials production, in order to integrate suppliers to production process.

According to Merli (1990), some challenges to the evolution of a relationship between a company and its suppliers are: to establish long term and stable relations; to limit the number

of suppliers; do not to change suppliers frequently; to establish a global qualification system; to evaluate suppliers by total costs; to collaborate with suppliers to make their products more reliable, and less expensive.

Evaluating the companies studied, Company **Z** was the only one that has already developed long term relations with suppliers. Ninety percent of their suppliers are exclusive partners in their building projects. Before a building project conception start, all these material suppliers are already defined. Company **X** is not in the same stage but it has developed a partnership with two of its suppliers. Company **Y** has not established any partnership. But it is important to point out that a lot of things is still to be done in these partnering experiences, because an exclusive relationship does not mean (in these cases) an intervention in the supplier production process in order optimize it.

From an operational point of view, another important aspect for supply logistics management efficiency is the production planning, which includes supply plans. Some authors (Ballard and Howell1998) (Colas et al. 1997) have argued that production plans can be divided in three different levels.

In a first level, it should be done an initial global plan, establishing general budget and schedule, activities sequencing and resources forecasting. In a second level a more detailed plan (a three or four week plan) is made adjusting the schedule resources forecasting. In a third level, a commitment plan of what should be done and how much resource will be consumed in each day of one or two week period, this plan is what really permits that the demand to "pull" up the production.

The case studies showed that this plan in the third level (commitment plan) is the one that the companies have much more difficulties in accomplishing. Mostly because they have a culture of using planning methods to push production and also because building production process involves lots of uncertainties what makes this attempt a little bit hard to be successful.

SITE LOGISTICS MANAGEMENT

Some tools that can be used to aid site logistics management are commented here associated to "site preparation phase", site layout planning, handling systems studies, "design for production" and checklists.

Site Preparation Phase

It can be defined as a stage of the production process dedicated to preview in advance, before site activities start, the potential problems that can happen during the project execution. Some objectives of this stage are: to review site conditions and design descriptions, to study and to validate technical solutions, to develop detailed production plans, to preview interference between actors. As a result of this period of reflection, a collection of plans and documents must synthesize made decisions.

The adoption of this stage as well as a methodological tool to organize decision process in the production process is an excellent opportunity for logistics planning and organizing, especially site logistics. In this way, unilateral decisions made by any element of a production team during service execution can be avoided. It also seeks to lessen interface problems among internal agents, because it consists of several meetings where take part all agents in

order to make decisions. And the same team that has participate of this "site preparation phase" elaboration can form afterwards a "logistics pole" to coordinate all established plans.

In this "preparation team" the main subcontractors and suppliers, resident and planning engineers, designers, foreman and any other agent judged important to the process should be called to participate. The resident engineer should coordinate the process (this is not a rule).

This preparation phase is not very common in projects developed by Brazilian building companies and in none case studies was possible to verify an operational tool like the described above. However, Company **X** is interested in developing a methodological tool based in a sequence of meetings involving all agents. And in Company Z, the resident engineer prepares an operational plan in a period of one month, just after some designs are already developed, in which he presents necessary site equipment, general site organization and an initial site layout sheet. This plan is discussed with other experienced engineers before it is approved.

Site Layout Planning

Ferreira (1998) defines site layout planning as a "service which is a part of construction process responsible for the decision of size, shape and location of working areas, which can be fixed or temporary, and also for the decision of circulation routes on site, which are necessary for the development of support and execution operations, during each project phase with an integrated and evolutionary approach, respecting production design, offering safety, health conditions and motivation for workers, and permitting service execution in a rationalized manner."

So layout planning is much more than to only identify necessary space and to produce layout sheets, it should also define activities sequence and conflicts, it should modify if necessary, constructive methods, tasks duration, etc. Some factors that influence site layout elaboration are general production schedule, available period for execution, constructive system and methods, available equipment, space demand and availability.

The greatest defect found on the case studies in site layout plans of case studies relies on its inability of previewing different situations to the different project stage.

Handling Systems Studies

Handling systems study is an activity of site layout planning, but it is highlighted here due to its importance in production flow optimization. A handling system study should consider strategic material characteristics (weight, geometry, etc.), available alternatives, technical and economical feasibility.

Some operational tools that can be used to help an analysis of different alternatives are process flow chart, labor productivity studies and cycle time studies of handling systems. Process flow chart is a very useful tool to identify all the stages a material (or group of materials) passes from site delivery to its application. Labor productivity and cycle time studies are useful for a correct dimensioning of equipment capacity.

Design for Production

Another helpful tool for site logistics management is what it has been called in Brazil, designs for production. Melhado (1994) defines it as "a group of design elements concurrently elaborated with definite product design, defining the arrangement and sequence of production

activities, equipment utilization, building site planning and evolution, and other information linked to the resources and characteristics of a construction company".

It complements the design information of building parts that can be considered critical for its quality achievement, like formwork, partition walls, floor detailing, external rendering and waterproofing. Design for production has been increasingly used in building construction as it could be observed in case studies. All the companies (**X, Y** and **Z**) are using them. Company **Y**, for example, uses formwork, partition walls and external rendering designs for production.

Checklists for Site Conditions Control

A checklist itself is a very interesting management tool for site logistics diagnosis and control and also to help decision making process in site layout planning. So these checklists have a double function: to control site logistic performance and to aid site layout planning.

For the several analyzed requirements of a checklist can be attributed a punctuation system to facilitate a comparative evaluation between different projects (Saurin 1997).

Company **Z** has developed a detailed checklist for logistic control in which there are more than a hundred items monitored, related to site conditions. The foreman or resident engineer periodically (once a month) verifies site organization based on this checklist. The evaluation permits an immediate correction of mistakes and it implies in rewards for production teams.

LOGISTICS INFORMATION FLOW MANAGEMENT

An information system involves the definition of a way to send, receive and record information in an organization. The information system is the one that promotes internal relationship of several subsystems of a firm. And also promotes external data and information exchange. It can be classified as a system for operations support (when the information assembled are routine procedures for current tasks) or a system for decision making support (when it assembles information destined to aid a decision process).

An efficient information system is the one that is able to appropriately use data resources transmission, receiving and recording of a firm. On the other hand, an effective information system is the one that is able to supply the different internal systems with correct information at a correct time. Barton (1989) mentions some symptoms of weaknesses in information systems efficiency and efficacy: moroseness in data processing and transmission, incomplete information transmission, information duplicity and high costs of information acquisition.

Some general principles for an information system implementation are: (1) analysis of information needs; (2) integration of information needs; (3) elaboration of an appropriate information system design; (4) selection of equipment and software; (5) gradual implementation with constant evaluation. So before adopting complex computational tools it is necessary to adjust the information system.

GUIDELINES FOR LOGISTICS IMPROVEMENT

Facing all challenges pointed out above to develop logistics management and using the case studies experiences and theoretical background, some general guidelines are proposed as follows. These guidelines are organized in three different levels: strategic, structural, and operational. Although the companies have different production rationalization strategies it is believed that this proposition is valid for all of them.

STRATEGIC LEVEL

Some strategic guidelines for logistics improvement are:

- Decision of customer service level desired, what means, desired stock levels and acquisition request attendance time;
- Decision of logistics goals to be reached in short, middle and long time and performance indicators for them;
- Decision of relationship politics with suppliers, seeking supply chain process integration and partnering.

These strategic guidelines are general logistics management politics and procedures for decision making. The firm must understand what is logistics and must establish clear objectives to control its performance.

In the studied cases, company **Z** was the only one that has promoted strategic interventions. With a high level of standardization in architectural solutions it has established specific materials and components brands that should be used in all their projects. After that, it has established an average for production periods and long term relationships with many suppliers. These strategic decisions has permitted time reductions in request cycles attendance, in the stock levels, and in the amount of information exchanged with suppliers.

But surely, this partnering politic adopted was possible due to the fact that company **Z** simultaneously runs a wide number of similar projects. It was possible to bargain prices with suppliers and also to have a scale economy. Maybe it would not be possible for the other two companies (**X** and **Y**) to use the same politic but it is perfectly possible for them to establish different goals to achieve cost reduction and better logistic performance.

STRUCTURAL LEVEL

Structural level guidelines are related to structural organization of firms through a systemic view. Some of them are:

- Determination of agents' responsibilities in logistics process, especially the logistics coordination responsible. Here it is suggested two ways to structure logistics within a company's organization. He firms can opt to develop a new administrative function that will be responsible to coordinate these activities or can create a “logistic pole”, which consists of a collective forum involving multiple agents for logistics coordination.
- Definition of an information system design and a mechanism for information exchange among actors of logistic process. Firms must seek in a later future to implement tools, which will permit information exchange in “real time”.
- Definition of a general procedure for purchase practice (centralized or decentralized).

Regarding the studied companies, company **X** is the one that is much more worried with this kind of changes implementation. The company is rethinking its organizational structure and it is trying to adapt administrative functions to a new reality. Due to Quality Management System implementation, company **X** is also seeking to define precisely the responsibilities of each function.

Companies **X** and **Y** already have a culture of using periodic meetings for information exchange among actors. But in company **Y** these meetings have a purpose of experience exchange. Considering their culture it would easier for them (**X** and **Y**) to adopt the "logistics pole" system than a creation of a new logistics function. In a different way, in company **Z** due to its size and structure it would be easier to create a new logistics function.

OPERATIONAL LEVEL

In an operational level it is necessary at least to develop the following guidelines:

- Definition of critical materials for physical flow rationalization;
- Elaboration of supply plans considering the three hierarchical levels of planning. It should be developed a general initial plan, an intermediate plan for a shorter period and a commitment plan in a weekly basis for daily activities;
- Elaboration of site layout planning considering technical and economical feasibility of several internal transport alternatives for handling materials and previewing different arrangements for the different site phases;
- Planning of vertical transport equipment use in a daily schedule;
- Elaboration of designs for production for critical services;
- Incorporation of constructive system changes seeking to let them more rationalized or industrialized.

Differently from the other levels mentioned before, that imply on general changes in company structure or strategy, the solutions adopted in an operational level maybe different for each project. None of the studied companies follows all guidelines mentioned above. But some operational tools are being used with success in all of them. For example:

- Only company **Z** elaborates a site layout planning for all project phases even though in some projects that does not happen;
- In company **X** it is made a daily schedule of vertical transport using;
- All companies are using with success the design for production tool, mostly for partition walls, external rendering and floor detailing;
- None of them are using a commitment production or supply plan in a weekly basis, but in company Z, all purchase request are made in the very beginning of first site phase, and in company X, a monthly supply plan is prepared by each resident engineer to brake out purchase process.

CONCLUSION

This paper aimed to initiate a discussion about the current opportunity of studying logistics applied to building construction, and to briefly describe some concepts and management tools that can be applied to logistics improvement.

General guidelines then were presented based on three middle size Brazilian building companies' experiences and on a theoretical reflection about the theme. As it was foreseen in the initial hypothesis, in all studied companies it was possible to identify positive and negative experiences in logistics management. The most relevant positive experiences found in one or more of them have been gathered in the general guidelines. On the other hand, the negative

experiences showed potential changes in logistics management in order to be more effective and efficient, so they also have helped to develop some of the presented guidelines.

Although all the presented guidelines together were not tested as a completion in one company this does not invalidate these statements as a starting point for future intervention practices in building companies and future researches. Certainly, much more topics can be presented and tested in different situations what demonstrates the importance and complexity of this theme that needs much discussion in order to help improving lean thinking.

REFERENCES

Akintoye, A. (1995). "Just In Time Application and Implementation for Building Material Management." *Construction Management and Economics*, 13, 105-113.

Barton, P. et al. (1985). .*Information System in Construction Management - Principles and Applications*. Mitchell's Professional Library, Bitsford Academic and Educ., London.

Ballard, G. and Howell, G. (1998). "Shielding Production: Essential Step in Production Control." *Journal of Construction Engineering and Management*, Jan/Feb, 11-17.

Cardoso, F.F. (1996). *Stratégies d'Entreprises et Nouvelles Formes de Rationalisation de la Production dans le Bâtiment au Brésil et en France.* (*Entrepreneurial Strategies and New Formes of Production Rationalization in the Brazilian and French Building Sector.*) Doct. Diss. Paris: École Nat. des Ponts et Chaussées.

CLM (1992). *What It's All About*. Oak Brook, IL: Council of Logistics Management.

Colas, R. et al. (1997). *Pour Une Logistique des Chantiers. (In Favor of a Better Site Logistics.)* Collection Recherche. Paris: Plan Construction et Architecture.

Ferreira, E.A. (1998). *Metodologia para Elaboração do Projeto do Canteiro de Obras de Edifício (Methodology for Site Layout Planning in Building Construction)*. Doctoral Thesis. São Paulo: EPUSP.

Fullmann, C et al. (1989). *(MRP + JIT/KANBAN), OPT & GDR*. Série Qualidade e Produtividade do IMAN. São Paulo: IMAN.

Koskela, L. (1992). *Application of the New Production Philosophy to Construction*. Technical Report 72, CIFE, Stanford Univ., CA, September, 75 pp.

Lambert, D. M; and Stock, J. R. (1993). *Strategic Logistics Management*, Irwin, 862 pp.

Melhado, S.B. (1994). *Qualidade do Projeto na Construção de Edifícios: Aplicação ao Caso das Empresas de Incorporação e Construção. (Design Quality within Building Construction applied to entrepreneur and building company cases)*. Doct. Diss., São Paulo: EPUSP, 294 pp.

Merli, G. (1990). *Co-makership: A Nova Estratégia para os Suprimentos. (Co-makership: New Supply Strategy).* Rio de Janeiro: Quality mark, 249 pp.

Picchi, F. A. (1993). *Sistemas da Qualidade: Uso em Empresas de Construção de Edifícios. (Quality Management Systems in Building Construction Firms.)* Doct. Diss., São Paulo: EPUSP, 436 pp.

Saurin, T. (1997). A. *Método para Diagnóstico e Diretrizes para Planejamento de Canteiros de Obras de Edificações. (A Diagnosis Method and Guidelines for Building Site Planning*) M. Thesis, Porto Alegre: UFRGS, 171 pp.