

GUIDELINES FOR THE IMPROVEMENT OF DESIGN, PROCUREMENT AND INSTALLATION OF ELEVATORS USING SUPPLY CHAIN MANAGEMENT CONCEPTS

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ABSTRACT

The application of supply chain management concepts has been investigated as a possible alternative to develop solutions to some of the existing problems and to the introduction of improvements in the construction sector. This paper aims to propose guidelines to improve the process of design, procurement and installation of elevators, using supply chain management concepts. The research method was divided into three major stages. Initially, the elevator supply chain processes and their main problems were described in general terms, based on a literature review and also on interviews with architects, production managers, and experts in construction management. In the second stage, a case study on the relationship between the supply chain agents in the City of Porto Alegre was carried out, aiming to identify problems in the material and information flows. That involved interviews with elevator manufacturers and installers, visits to construction sites, the analysis of documents, and also a survey with elevator users. Finally, a number of guidelines for improving the process under investigation were proposed. Among the main conclusions of the study, there were problems related to the co-operation practices adopted, and to the lack of coordination and integration of material and information flows between agents, indicating that there is an opportunity to apply supply chain management concepts for improving the processes that were investigated.

KEYWORDS

Supply Chain Management, Processes integration, Materials and information flows, elevators

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INTRODUCTION

Much of the waste in the building industry originates outside construction sites, normally during the planning stages, and they are mainly due to managerial problems, including design failures, flaws in the planning system and ineffective material supply process (FORMOSO et al., 2002). In this context, supply chain management has been identified as an adequate conceptual framework for improving the performance of the construction sector (O'BRIEN, 1999; VRIJHOEF e KOSKELA, 2000).

According to Ballou et al. (2000), the supply chain is the set of activities related to the transformation and flow of goods and services, including the associated information flow, from the sources of raw material to the end consumer. The same authors state that the management of the supply chain comprises the integration and coordination of activities and processes through the companies in the chain.

Christopher (1999) notes that trust, commitment and willingness to share information among the members of the chain are all fundamental for the functioning of the supply chain as a set of interconnected processes. The cooperation among members diminishes individual risks and can, potentially, improve the efficiency of the logistic process, eliminating waste and unnecessary efforts. However, cooperation is an exception among the practices usually adopted in the relationships among construction companies and their suppliers (ISATTO, 1996).

According to O'Brien (1999), the construction sector has moved slowly towards the application of supply chain management, probably due to the peculiarities of its industrial context. The author maintains that very little is known about supply chain management among construction organizations. Considering this situation, Vrijhoef e Koskela (2000) proposed a set of guidelines to approach the management of construction supply chains, including evaluation, reengineering, control and continuous improvement. In the first item, they suggest that the evaluation of the supply chain is necessary not only to identify the main existing problems and waste, but also their causes. Those authors state that only in-depth knowledge of the problems in the supply chain will allow the discovery and resolution of problems.

This article presents the main results of a research study that was part of an M.Sc. dissertation (AZAMBUJA, 2002), which aimed to understand the main problems involved in the building elevator supply chain and to propose guidelines for improving its performance. The investigation was limited to three main processes, design, procurement and installation of elevators in residential buildings, considering the construction company as a focus (LAMBERT and COOPER, 2000). This study can be considered part of a wider effort carried out by the IGLC community that is concerned with understanding the problems related to the lack of integration of construction supply chains - see, for instance, Arbulu and Tommelein (2002) and Elfving et al. (2002).

The elevator supply chain was chosen for the following reasons: (a) the relatively high costs associated with the production, installation and maintenance of elevators; (b) this component is supplied as a sub-system - it means that the manufacturer provides also the design, installation and other services - and presents some characteristics that are desirable for other building components; (c) elevators are engineered-to-order products, which are

substantially customized in the delivery process - this type of product often causes trouble in the management of construction projects; and (d) there is a scarcity of research studies on this supply chain.

SUPPLY CHAIN MANAGEMENT

Supply chain management (SCM) is a multidisciplinary research area, involving ideas from marketing, strategy, industrial economics and production management. It is not the aim of this article to present an in-depth review of all concepts involved. Instead, it is limited to some key ideas that are relevant for the scope of the investigation on the elevator supply chain:

AGENT INVOLVEMENT IN THE EARLY STAGES OF THE ENTERPRISE

The involvement of designers and suppliers in the initial stages of a project can lead to a dramatic reduction in a product's development cycle time, also facilitating the coordination of the purchasing and engineering functions by contractors. Savings in time and costs associated with the function of purchasing can be re-directed to the management of suppliers.

PARTNERSHIP

A long-term commitment between two organizations based on trust, dedication and common goals, as well as on a mutual knowledge of individual expectations and values is necessary. The search for efficiency improvement, lower costs, more innovation and continuous improvements of products and services are among the goals of a partnership

SHARING AND MONITORING INFORMATION

Effective supply chain integration depends on the willingness of participants to share information, particularly those related to demand, stock availability and production planning (CHRISTOPHER, 1999). As for the monitoring of information, it is not necessary that all members have access to the same information. However, members must have the information needed at hand in order to improve the management of their interfaces in the chain (COOPER e ELLRAM, 1993).

COORDINATED PLANNING

Traditionally, planning among the chain members is focused on the transaction and on short-term relationships. In supply chain management, planning moves beyond the two-chain model, i.e. it should involve more than a pair of members (COOPER e ELLRAM, 1993).

RAPID SYSTEM RESPONSE AND EFFECTIVE MANAGEMENT OF THE DEMAND

The presence of large amounts of stock throughout the chain can be attributed to three main variability sources. The first is inherent to the production process, the second is associated with the suppliers and the last is due to the variability in the demand (DAVIS, 1993). The latter has its origin in the irregular pattern of orders and, therefore, places demand management in a critical position. Demand management must balance the requests of clients

against the ability of suppliers to provide the resources. Production processes must be flexible in order to maintain the ability to respond to market fluctuations. Just-in-time processing of orders, prioritization of production according to delivery, and changes in the production flow can all reduce the cycle-time considerably, improving the quality of client response. An effective system can, for example, inform data directly from the selling point, reducing uncertainties and smoothing out flows through the chain.

RESEARCH METHOD

This research study encompassed three main stages:

EXPLORATORY INTERVIEWS

Initially, the processes were analyzed in general terms, based on interviews with six architects, six engineers and five experts in construction management (academics and consultants). The relationships among designers, construction companies, and elevator manufacturers were investigated from the point of view of these construction professionals. The main problems that resulted from the lack of supply chain integration were identified.

CASE STUDY

A case study on the elevator supply chain in the City of Porto Alegre was carried out. In this stage, some additional sources of evidence were used: focused interviews, direct observation, document analysis and a survey with a sample of end users.

The focused interviews provided a counterpoint to the previous interviews. Fifteen people from the supply side were interviewed: nine managers from manufacturing companies, four of them responsible for the installation of elevators, three from the sales department and two branch managers; and six managers from outsourced companies who were responsible for the assembly of elevators on site.

Direct observation was undertaken through visits to ten building sites. During these visits the pre-installation and installation processes were observed, mapped and documented by using photographs.

Complementing the information from the building sites and from the interviews, several documents were analyzed: technical specifications, check lists used to evaluate site conditions, production drawings (provided by the producers), technical catalogs, and purchase contracts.

Finally, a questionnaire was applied to a sample of end-users of residential elevators in Porto Alegre. A total of 192 users participated in the survey, from a total of 72 buildings. Collected data were instrumental in identifying opportunities for improvement in the elevator supply chain, from its conception to its final use.

PROPOSAL OF GUIDELINES

Based on the data collected, which were mostly qualitative, a set of guidelines for improving the elevator design, procurement, installation processes was proposed. Finally, all the conclusions of the study were handed to the participants in the form of reports.

PROCESS OVERVIEW

The simplified current state map shown in Figure 1 is based on the exploratory interviews that were conducted with architects, building companies and elevator's manufacturers, as well as on direct observation. The main stages of the process are design, procurement, fabrication, installation and maintenance. The process steps on the map do not represent a specific project, but rather a typical industry practice. Figure 1 represents the sequence of activities involved in the process, and the main problems identified in the study.

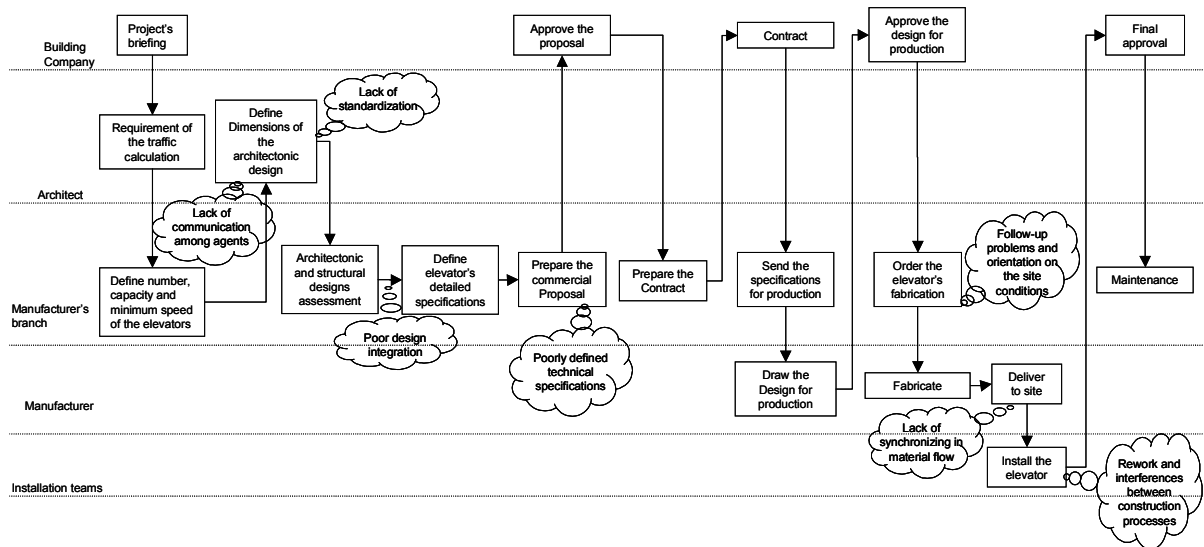


Figure 1: Current State Map of elevator's supply chain

DESIGN PROCESS

The conception of the elevator subsystem starts by calculating its traffic, based on existing standards (ABNT, 1983). Traffic calculation determines the number of elevators, the elevator capacity (number of passengers) and its minimum speed, so that the system meets the building demand. Based on these parameters, the architect can develop the component design, using criteria established in the catalogs that are provided by producers.

PROCUREMENT PROCESS

Since the elevator is a very expensive item in a residential building project, its procurement starts several months (typically from ten to twelve months) before its installation on site. The construction company usually commissions the elevator after the beginning of the construction stage, and pays for it in installments, so that its cost is fully financed before it is manufactured.

The establishment of partnerships involving elevator producers and construction companies is not common practice - it usually happens only when either the developers or the construction company is fairly large and several units are purchased per year. For that reason, the procurement process is characterized by intense negotiations in which the buyer

tries to reduce the acquisition price. Sometimes a competitive bidding is undertaken among the three main manufacturers that operate in the Brazilian market.

Once the producer has been selected, a complex process of detailing technical specifications and delivery horizons starts. Technical specifications are based on the architectural plan and the producer's catalogs.

Excessive bargaining allied to the complexities that are inherent to the elevator design and installation often makes the procurement process relatively long and costly for the construction companies.

PRE-INSTALLATION PROCESS

The pre-installation process encompasses activities ranging from commissioning the elevator to its delivery to the building site. It includes the making of production drawings, the definition of fabrication and delivery dates, and the installation of some elements that establish the interface between the elevator and the building, such as rails and doorframes.

INSTALLATION PROCESS

The installation process has two major stages. The first is essentially mechanical, involving the assembly of the elevator. It is mostly characterized by intense transportation. Large subsystem components are pieced together in the engine room and shaft. The second stage corresponds to the installation and connection of the electronic components, final assembly of the cabin and electronic testing.

The installation process has a high level of interference with other ongoing processes in the building site (structure, electrical services, finishes). Therefore, the installation lead-time depends fundamentally on the effectiveness of coordination among installers and the site management. During the case study, reported installation lead times varied from fourteen to ninety days. On some sites, elevator components stayed dismantled on site for fairly long periods, waiting for installation.

CRITICAL ANALYSIS OF PROCESSES

DESIGN PROCESS

Lack of standardization among producers

Besides the number of elevators, traffic calculation establishes some basic parameters for the product, such as its capacity and minimum speed that are standardized among manufacturers. However, the basic dimensions of the elevator, such as the minimum length and width of the shaft (Table 1), the height of the engine room and of the last stopping point vary greatly among producers. Such variety in building options, dimensions, shapes of normal and special access doors introduces difficulties in the selection of the best technology in the design stage.

Among the possible consequences of inadequate decision-making during the conception of this sub-system is the increase in acquisition and usage costs. The first one occurs during the purchase of the product, in case design dimensions need to be modified. According to an expert on vertical transport, each miscalculated dimension can generate an increase of up to

10% in the final price of the elevator. The usage costs appear in the wear and tear of misconceived parts, which operate beyond their capacity, demanding constant maintenance.

If there is a partnership between the construction company and the elevator manufacturer, design becomes much simpler, since the architect can work directly from the dimensions provided in the producer's catalog. In other words, if the elevator manufacturer is selected prior to design, the subsystem can be engineered considering the manufacturer's standard products. If the design is developed first and then all three producers bid, there is high probability that design changes will be required.

Table 1: Minimum measures for the shaft in conventional elevators (in mm)

Minimum measures for the shaft (speeds from 45 to 105 m/min)						
Capacity	Producer A	Producer B	Producer C	Producer A	Producer B	Producer C
	Lateral opening doors			Central opening doors		
6 people	1600 x 1650 1550 x 1550	1540 x 1440 1600 x 1590	1600 x 1580 1700 x 1580	1850 x 1750 1750 x 1400	1540 x 1440 1780 x 1550	1560 x 1680
8 people	1650 x 1800 1600 x 1700	1540 x 1650 1560 x 2020 1620 x 1800 1680 x 1770 1760 x 1720	1600 x 1750 1700 x 1750 1600 x 1950 1700 x 1950	1850 x 1900 1750 x 1650	1540 x 1650 1780 x 1770 1780 x 1670	1560 x 1890 1780 x 1730

Lack of communication among architects, contractors and producers in the conception of the elevator

Often, not enough information is exchanged between the construction company, the architect, and the elevator producers during the design phase. Most architects are not fully aware of producer's requirements on dimensioning and of the construction company's needs. Half of the architects interviewed admitted not to exchange information with producers during the scheme design stage, particularly in the case of small residential buildings, in which elevator traffic and technical problems are considered to be fairly simple. It is not uncommon for architects to use outdated catalogs or define the elevator dimensions based on their practical experience.

The consequences of such neglect are similar to the ones mentioned earlier. It tends to increase both acquisition and maintenance costs.

Poor design integration

Normally, the elevator design is carried out by the producer after its selection and commissioning by the building company. Therefore, during the building design phase some important information about the elevator design may not be available to structural designers or electrical engineers, such as the weight of the traction machine that is necessary for the design of the slab upon which the machine will rest, and the positioning and size of trap-doors. This might result either in the lack of integration between sub-systems (for instance, elevator and structural sub-systems) or in design re-work.

PROCUREMENT AND PRE-INSTALLATION PROCESSES

Poorly defined technical specifications

Salespeople often cannot define all technical specifications for a product when working together with the buyers, generating incomplete or wrong orders to the producer.

There are several possible causes for this problem: (a) salespeople make errors in transforming the desires of the buyer into technical specifications of the product; (b) as the elevator is part of a larger product, a complete order cannot be generated before all interfaces with other building sub-systems are specified; (c) sales teams are usually outsourced and they get a commission on each order, which may cause a degradation in the quality of the operation, since this is not fully controlled by the producer; (d) architectural designs often have to be changed later due to requirements from local authorities when the complete design is submitted for approval.

Omissions or mistakes in the elevator specifications during sales may cause waste during the pre-installation and installation processes. The producer needs sales information to prepare production and installation drawings. If the information provided by the sales team is not adequate, there might be a delay in the delivery of the design, or it may be necessary to alter product specifications, resulting in cost changes after the deal has been made.

Follow-up problems and orientation on the site conditions

A large percentage of installation problems originate from flaws in the on-site follow-up services, carried out by the pre-installation teams. These teams work for the producers and their role is to provide guidance during pre-installation. For instance, the plumb survey needs to be carried out before the fabrication of the elevator, since it provides the real dimensions found on site. If the plumb survey is not carried out early enough, fabrication will follow the specifications provided by the buyer. If there is a significant difference between site and design dimensions, this might require rework in the shaft, for example. Therefore, one should stress the importance of providing the tolerances accepted by the producers during the execution of the building, mainly in relation to the structure and walls.

The interdependence between the installation and the pre-installation processes is aggravated by the lack of knowledge about installation requirements by the site management. Therefore, the quality of service provided by the producer in the pre-installation phase is considered a critical point in the successful installation of the elevator.

INSTALLATION PROCESS

Site conditions to begin assembly

According to the installation supervisors who were interviewed, the most serious problem is synchronizing the arrival of the elevator on site with the completion of all technical specifications necessary to begin installation. They state that the problem could be minimized if the building companies followed the contractual deadlines, e.g. delivery of the engine room and shaft well in ready-to-assemble conditions.

According to Luhtala et al. (1994), the relatively long fabrication lead-time (4 to 9 weeks) is another possible source of problems. A shorter fabrication lead-time would help synchronization for the client (construction company), providing trustworthy information on the real conditions for the beginning of assembly. Nowadays, it is common for producers to require confirmation of the conditions of engine room and shaft from the clients two months before the delivery of the product. This period of time is considered too long by the construction companies that need to get the installation out of their way in order to avoid interference with other activities on the building site. Improvements in the anticipation of real site conditions would also reduce uncertainty associated with installation demands, facilitating the scheduling of installation teams, i.e. an optimization in the planning of installation capacity by the producer.

The result of planning and control problems is the widespread presence of inventories on building sites, although producers attempt to adopt procedures that postpone the fabrication of materials up to the moment when the site presents the right conditions for installation.

Rework caused by mistakes in the design or pre-installation processes

Normally rework is a consequence of the lack of integration between the elevator and other building sub-systems or flaws in the pre-installation service provided by the supplier, as mentioned earlier.

The rework in the slab of the engine room is a common problem in elevator installation. Often the assemblers need to break the slab of the engine room during installation, due to structural design or execution errors (Figure 2).

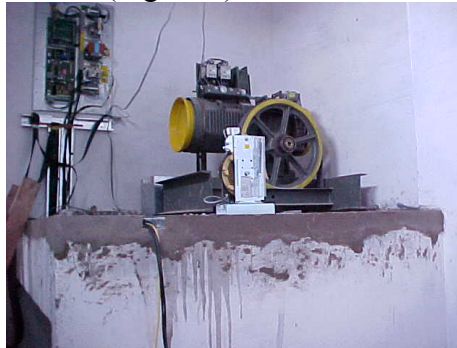


Figure 2: Rework at the engine room slab

Another frequent problem is the mistaken placement or the non-execution of structural hooks for the lifting of the traction machine. The same error occurs for trap doors allowing the passage of the machine and providing entrance to the engine room. This problem arises from insufficient detailing at the design stage. Ideally the structural designer should include the trapdoors and hooks in the design. However, this cannot be done because elevator specifications are rarely available at that stage. A possible solution would be to carry out the structural detail design later - such detailing could be pulled by the complete definition of specifications and measurements of elevator components.

Interference between the installation process and other processes on site

The elevator installation process is intrinsically related to the execution of the structure, walls, electrical services, and finishes.

According to some of the interviewees, these are the main interfaces that should be given attention on site: installation of elevator door frames, walls in the shaft's front face, and wall and floor finishes in the corridor. The timing for placement of the doorframes is very important, since it affects the conclusion of all finishes on a given floor. Normally, the installation of such frames is necessary before building walls, floor screed, walls and floor finishes, and painting. As the internal spaces of the apartments are finished before the corridor, this causes much moving for some crews, adding non-value adding activities.

An alternative solution for this problem would be to install both the elevator doorframes and the ordinary doorframes at the same time. This would require a change in the pre-installation process on the part of the producer. This task would have to be carried out earlier than it is usually done.

GUIDELINES FOR PROCESS IMPROVEMENT

In this section, the set of guidelines for improving the elevator design, procurement, and installation processes is briefly presented:

GREATER INVOLVEMENT OF AGENTS IN THE DESIGN STAGE THROUGH THE FORMATION OF MULTIFUNCTIONAL TEAMS

Engineers, architects, and producers should work together in the design of the elevator and on the interfaces with other sub-systems. It is necessary to improve communication between them and also to define their role in product development more clearly.

TECHNOLOGICAL SELECTION AT DESIGN STAGE

The selection of the product to be used should occur at the design stage, since both acquisition and maintenance costs can be reduced. In this respect, the establishment of partnerships between construction companies and their designers and elevator manufacturers plays an important role, since it would bring more interaction among the different agents in the early design stages. In the case of small construction companies, partnership arrangements could be established between the association of contractors and the producers, since the market is dominated by very large multi-national companies.

INCORPORATE USERS' FEEDBACK INTO THE PROCESSES OF NEW PRODUCT DEVELOPMENT AND SUPPLIER SELECTION

The results from user satisfaction surveys should provide feedback for new product development, indicating possible alternatives for improvement. The investigation with final users carried out in this study indicated that the producers lacked information about the users' perception of their products and services. The degree of satisfaction among end-users could be improved if elevators had safer and faster escape mechanisms in case of breakdowns; if

the communication system between users and the external environment of an elevator was improved; and if product warranty period was extended.

GREATER INTEGRATION AMONG ELEVATOR SUPPLIERS AND THE SITE MANAGEMENT DURING PRE-INSTALLATION

Integration at this stage should focus on the anticipation of problems in the installation phase, particularly in terms of avoiding rework. Such integration could be achieved through agreements among pre-installation and site management teams, and should contemplate documentation and information such as deadlines for the production drawings, identification of constraints to the installation process, guidance to the installation process and to the placement of doorframes. Those measures would facilitate the scheduling of the installation teams on site.

IMPROVING INFORMATION EXCHANGE AMONG SITE MANAGEMENT, BRANCHES, AND PRODUCERS

The branches (or sales team) should pass to the producing plant correct and complete information about the contract, and on the site situation before pre-installation. The latter includes the plumb survey (a document that contains the precise measures of the building), possible changes in the production drawings, and the deadline for the beginning of installation. When this information is not properly delivered, fabrication is hampered, delays in the delivery of production drawings may occur, and the lack of synchronization between production and delivery on site appears, resulting in inventories either in the factory or on site. According to Holzemer et al. (2000), synchronization among production, delivery of subsystems on site, and other on-going activities on site is fundamental to reducing waste and production costs. This of course requires also improvement in the reliability of site activities.

REDUCTION OF FABRICATION LEAD-TIME

The reduction in fabrication lead-time can improve demand forecast (construction sites ready for installation) and, therefore, improve the scheduling of raw material purchase and the production of a component by the producer. This is due to the reduction in alterations in contractual deadlines and in the scheduling of assembly teams (reduction of uncertainty). The improvements resulting from a shorter lead-time can only be achieved if the construction company is committed to the prerequisites needed for the beginning of the installation process. Clear definition of responsibilities among the parties is important to effectively solve interface problems. The adoption of partnerships among the agents would accelerate the introduction of mechanisms of obligation and trust in the chain, playing a key role in lead-time reduction.

IMPROVEMENTS IN PHYSICAL FLOW PLANNING OF BOTH ASSEMBLERS AND CONSTRUCTION COMPANY

Several installation problems are caused by the lack of planning of physical flows at the building site, i.e. the flow of people and materials. This type of planning must be undertaken in the pre-installation period, involving both the site management and assemblers. This

requires the elevator installation process to be well defined, as well as its interactions with other construction processes. For example, the definition of the inventory area is important for the efficiency of the installation process, and must be established in advance because of the difficulties in transporting heavy material. Besides, the poor positioning of inventories may affect the execution of other activities on site (Figure 3).



Figure 3: Stock of tracks interrupting the work flow at the site

COORDINATION OF TEAMS AND EQUIPMENT BY THE PRODUCER

The coordination of equipment and labor supply to the building site, together with the delivery of the assembly parts, is fundamental to the achievement of synchronization between the installation process and any ongoing activity on the site (HOLZEMER et al., 2000). Therefore, the producer should integrate its outsourced assembly teams in the planning of installation activities on different sites. The producer must plan its own capacity so that the installation teams are used efficiently, and, at the same time, delays and unnecessary interruptions of the work on site are avoided, since this can increase the time span between the order and the delivery of the product (lead-time).

CONCLUSIONS

This study has confirmed that there are several opportunities for improvement in the building elevator supply chain, which can be considered one of the most developed in the residential building market in Brazil. Most of the problems are in the interfaces between agents, mostly due to lack of communication, coordination and role definition. They strongly affect the elevator installation process and other processes on site, but originate in the design, procurement and pre-installation processes prior to the work on site.

The majority of problems are associated with managerial issues, such as ineffective information flows, lack of cooperation and poor coordination of the supply chain agents. One of the main problems is the lack of synchronization in the flow of materials between the producer and the activities in the building site, caused mainly by flaws in the communication between the installation teams, the manufacturing plant and the building site. As a consequence much waste was observed on site in terms of inventories and unproductive time among installation teams, and re-work. These problems could be avoided through the introduction of formal methods to coordinate planning and control of activities on site.

Regarding the production planning and control on site, the benefits of stabilizing the production process on site were clearly seen as supply chain management concepts were more effectively implemented. If the production system is not reliable, suppliers cannot effectively plan on-site delivery of materials, or coordinate the work of installation teams.

Finally, this work has indicated that the agents in the supply chain lack knowledge about end-users' expectations and degree of satisfaction. For instance, architects do not have a feedback on possible flaws in the sub-system design; installation problems are frequently solved by outsourced installation companies and do not reach the subsystem producer. End-users are rarely asked about the performance of the subsystem or the quality of customer servicing. The implementation of systematic mechanisms to provide feedback must be investigated in the future, in order to improve the performance of the supply chain as a whole, from product development to final usage and maintenance.

The lack of integration in the process studied presents a strong case for the application of supply chain management concepts as a source of improvement in the elevator supply chain.

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