SUPPLY CHAIN MANAGEMENT IN CONSTRUCTION – CASE STUDY OF A PORTUGUESE COMPANY

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ABSTRACT

The purpose of this paper is to present the preliminary results of the implementation of a construction supply chain management application, which is being developed in a PhD graduation project. This project was thought to overcome significant inefficiencies of the rudimentary and bureaucratic communication system of a case study company. The main result of this implementation was the design and the implementation of a web portal that allows the adequate portability to help local project managers on construction sites filling their material and equipment orders to the central warehouse. The project involved several stages, including preparatory reengineering processes conducted in the logistics sector and the implementation of a fleet management system. The web portal is being currently used by the company and there are now clear evidences that its implementation brought effective competitive gains by minimizing communication errors, improving resource usage, lowering stock levels and, most of all, by reducing the overall costs of construction projects.

KEY WORDS

supply chain management, construction logistics, information system, case study

INTRODUCTION

As market evolution drives players into a more competitive struggle, it is important for companies to improve their internal potential and minimize their internal waste. The construction industry sector is not an exception to this new market rule. Hence, managers seek ways to improve their companies and realise that it is inside the internal structure of companies that lay the more chance to have effective gains. Hence the managerial orientation for the optimization of internal supply chains offers an important competitive advantage.

The internal supply chain is related to the management and delivery of construction materials originated from several internal production plants, whereas the external supply chain is associated with the suppliers' deliveries and transportation management. So, developing and implementing an information system capable of aggregating the scattered information across several departments inside a given company will constitute an internal competitive advantage.

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This paper aims to describe the most critical reengineering processes carried out in a Portuguese construction company and to describe the development stages, main features and the results of the implementation of a new Information and Communication System (ICS), as part of a PhD project. The PhD project is entitled "Definition of a Logistics Network Model in the Construction Industry: Case Study", that is being carried out in *dst – domingos da silva teixeira*, s.a., with the main office in Braga - Portugal. The research project under development aims to elaborate a detailed analysis of the logistic system of a construction company, which includes processes of reengineering for the logistics activities by developing appropriate methodologies and tools aiming the compression of time, eliminating waste and improving the global performance of the logistics network. A more strategic objective of the research, in a socio-economical view, is to contribute to the improvement of the efficiency and competitiveness of the construction industry.

The project started with a bibliographic review and a deep analysis in the *dst* supply chain and the warehouse management rules. Later, several reengineering processes were implemented, prior to the introduction of a newly developed information system. Finally, the project addresses the impact of the information system inside the company and proposes a logistics model for the company.

The main problems found during the initial analysis of the company logistics network were similar to those described in the literature, such as the delays onsite, wastage and shortage of materials, construction site used as an storage facility (Agapiou, 1998) and not measuring and registering everything that it is possible to measure and register (Bertelsen, 1999). In particular, the company had been suffering from: (i) deficient communication between the construction site and the main office, the orders were made by phone calls and fax; (ii) at the main office, and between departments, the information was successively replicated by form papers and copied to non-standardized spreadsheets. In conclusion, the excessive bureaucracy and the deficient communication channels are extremely susceptible to induce errors in the internal supply chain, thus elevating the final cost of the construction projects.

All of the problems described above arouse the importance of the design and implementing new procedures and an adequate information and communication system, capable of providing accurate and up-to-date information across the various departments of the company.

This paper is organized as follows: the next section describes theoretical, namely the lean construction and the computer integrated construction, including the ICS. The following section presents explanation of the reengineering process conducted inside the company. The web portal and their features are presented in the continuous section. Main results are discussed and in the final section conclusions are presented.

LITERATURE REVIEW

Some bibliographic review was made, in the early stages of the project, which was the basic knowledge in the application of the current concepts. Next, it is presented some of the more

important concepts used in the development of the information system.

LEAN CONSTRUCTION

Lean construction has the "goal of better meeting customer needs while using less of everything" (Howell, 1999) or "provide a custom product exactly fit for purpose delivered instantly with no waste" (Ballard, 2007).

In the following sections, it will be described how the supply chain efficiency was improved and, simultaneously, how the usages of the resources, both material and human, were reduced. By developing and implementing some reengineering processes, the concept of lean thinking was implemented inside the company, in a new customized ICS.

In order to achieve lean, it is necessary to identify a "clear set of objectives for the delivery process, aimed at maximizing performance for the customer at the project level, concurrent design of product and process and the application of production control throughout the life of the product from design to delivery" (Howell, 1999).

Another interesting lean construction concept is the "small wins" that Vrijhoef introduced when he said "one small win begets another and that the change propagates through snowballing" (Vrijhoef et al. 2001).

In the last sections of the paper, it will be related and discussed the fact that the overall improvement of the company' supply chain has been gathering numerous small gains at different organizational levels and departments, rather than an off-on great improvement at any specific point of the supply chain. However, a common infrastructure makes possible all those small wins: the new ICS.

COMPUTER INTEGRATED CONSTRUCTION

The concept of Computer Integrated Construction (CIC) is derived from the computer integrated manufacturing, where the application of information technologies was expanding the manufacturing capabilities. Basically, CIC is the integration of corporate strategy, management, computer systems, and information technology throughout the project's entire life cycle and across different business functions (Jung et al. 1999).

The main issue in CIC is the integration of several computing applications used in a construction project, such as computer aided design, engineering analysis, production planning and facilities management. This kind of integration is accomplished via automated digital data transfer between applications (Björk, 1994).

An interesting example of an integrated automation system, for construction industry, is MITOS - multi-phase integrated automation system (Kanoglu et al. 2004).

The most important feature in CIC is, obviously, the adequate Information and Communication System (ICS) that can assist the users in their tasks and maintain the key factors in close observation.

The development of a CIC system in the company is beyond the scope of the project, but it is a straightforward aim for further development, as it will be discussed in the last section. The conceptual structure of ICS was thought to allow its future integration an easy task.

INFORMATION AND COMMUNICATION SYSTEMS

A common difficulty in engineering companies is achieving effective communication between different disciplines or departments in house (Arbulu et al. 2002).

Information Technologies (ITs) in construction can serve various kinds of processes, such as production support, for instance, management of production (including management of costs), material administration and trade of products for building (Brandon et al. 1995). Making use of the latest ITs to support construction projects it is now a common practice among the several research projects that have been developed along previous years. A recent example is the use of cellular phones to assist and share information between the foreman and the engineers (Nakagawa, 2006). This proved to be very successful in the online transmission of information.

More recently, Tarantilis et al. (2008) identified the importance of a web system to help several business areas, namely, construction industry. This system was tested in more than 40 companies in Greece, in areas such as construction, education, production, insurance and finance. This system is used in several areas, such as office automation, customer relationship management, supply chain management, human resources management, equipment management and quality management.

Many Internet and traditionally-based electronic commerce (e-commerce) companies, whether focused on business-to-business (B2B) or business-to-consumer (B2C) markets, have come to realise that easy access to information and communication and the delivery of their products or services are important drivers in developing market competitiveness. To support electronic logistics (e-logistics) and reverse e-logistics it is necessary to maintain this competitiveness (Sarkis et al. 2004). The use of an internet-based portal adds portability to the ICS, giving users the ability to access (view & edit) the information from construction sites as well as from anywhere else, including from the company intranet. Beyond their portability, internet-based systems for information management are intended to extract and filter information from a large amount of information in a database (Kopanaki et al. 2001).

REENGINEERING PROCESSES

Before introducing the information system it was necessary to carry out some reengineering processes of the logistics activities. The analysis and restructuring of the processes were the starting point for the implementation of the new information and communication system and their completion was a crucial start for the new improvements to come.

WAREHOUSE RESTRUCTURING AND AUTOMATION

The most important reengineering process was perhaps the complete restructuring of the main headquarters warehouse, in order to allow a more efficient storage and handling of products and equipments (a significant percentage of the total requirements of the company pass through this facility).

As part of the reengineering process, the interior warehouse was divided in four separated sections, with two for the more dangerous and fragile products and two for the more

expensive and complex equipments. The external area, of about 18.000m^2, was divided in 33 sections, where the products are stored according to their weight and rotation. It was also necessary to develop several procedures for the usage of the warehouse and to create supporting documents to register the information in a systematic manner.

The restructuring of the warehouse allowed more effective receiving and expediting of materials and equipments. The products are all tagged with bar codes in order to accelerate the expediting, especially in the documents preparation. This new procedure allows knowing, with accuracy, the real quantities and location of all the products in the warehouse. The information is automatically and continuously updated into the ICS and made available at the construction site users.

FLEET MANAGEMENT BY NEW ITS

In parallel with the implementation of the web portal, a fleet management system was also implemented. An analysis was made to several solutions (Pinho et al. 2006) and after the test and implementation phase, the system was implemented in 60 vehicles. The system is composed of a Global Positioning System (GPS) unit and the communication is made through a General Packet Radio Service (GPRS) modem that connects to the central offices, which allows the real time visual tool for control. This system registers the speed, geographical coordinates, driver identification and several other parameters, allowing monitoring, statistical analyses including cost estimation.

WEB PORTAL

In order to optimize the company information flow, a web portal was developed as part of the ongoing project of reengineering the logistics network of the company.

The web portal was developed using open source languages, PHP and JavaScript, and a MySQL database. The web portal is the front-end of the internal ICS of the company, as shown in Figure 1.

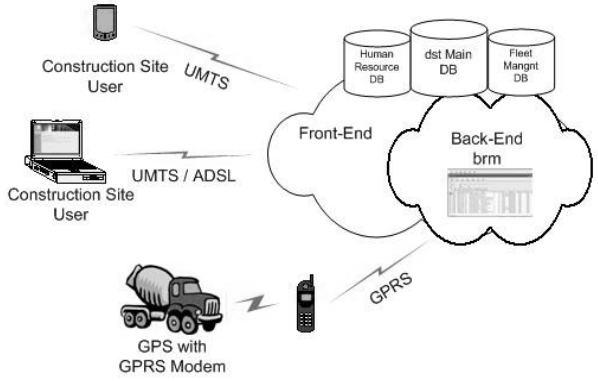

Figure 1: *dst* client/server architecture

Integrated in the ICS, the web portal is an essential tool for engineers to improve their communication with the central office. A survey conducted to the *dst* web portal users showed that 90% of the respondents said that the web portal was useful or very useful. All the information used is stored in the main database of the company, which provides all users with the same information, without any errors or misinterpretation, since the information introduced and visualised in the web portal is the same information used by the main program used in the company intranet.

The main characteristics of the portal were developed in order to correspond to the user's needs inside the company's supply chain, so that the information could be available at anytime and anywhere. Many of the features were implement for "outside" use only, since they do not exist in the internal ICS. The online fleet tracking system is an example of the implementation only available in the web portal. Next, the implemented features are explained in more detail.

WORKFORCE MANAGEMENT

This feature is used to help engineers introduce their work times (the company has an access and time control system using PDA devices, but in case of system fault, the web portal can substitute the system for all the employees).

This feature is also used to distribute the engineers' total time cost per all the construction sites in which they worked during a period, allowing a more accurate distribution of cost in the several construction projects.

REQUESTS MANAGEMENT

The materials, equipments and transportation are requested through the web portal and the processing is made inside the company, in *back-end*. This allows the construction site users to see, in real time, the status of their requests. This feature even allows the construction site users to update existing information, since the ICS informs the central coordination users of the current change in the status. This can help the construction site managers to plan their tasks according to the deliver plan established. This feature is also integrated with the fleet management tool, so that the construction site user can access the information regarding the location of their cargo.

FUEL MANAGEMENT

The feature *Fuel Management* is used to introduce the fuel supplying of all the equipments that work in the construction site (owned, rented and sub-contractors equipments). This allows a more accurate management of the equipments, thus giving the managers a more effective management of the construction project, allowing choosing the more adequate equipment to perform the several tasks of the projects' activities.

This feature has also an update page for the fuel tanks stock management, where it is possible to introduce robberies, reading errors and the refuelling.

DOCUMENTS MANAGEMENT

The *Documents Management* feature allows the construction site users to introduce the supplier's documents, which automatically update the construction site stock. This feature also allows performing documents

validation, since all the documents must be validated in order to pay the supplier. Alongside it is also possible to print some results reports for the accounting perspective.

STOCKS MANAGEMENT

The *Stocks Management* feature is extremely important for costs management. This feature allows the stock management of the construction site to be performed, through which is possible to carry out material consumptions, associated with the activities. Also, in this feature, is also possible to introduce the material waste and perform material inventory correction.

According to the several security polices, it is also possible to see the main warehouse headquarters stocks, available online and in real time. This is a very important feature because it allows the construction site managers the possibility to consult the materials available in stock, before they perform the request.

Another important aspect in this feature is the possibility to perform stock counting in the construction sites, allowing a more accurate management of the stocks available.

FLEET MANAGEMENT

The *Fleet Management* feature (Figure 2) is an appendix to the requests management, since it provides real time information about the vehicles that are circulating with the specific cargo for that request. This feature is integrated with fleet management software, using Global Positioning System (GPS). This was also made so that the fleet manager could also access their vehicles information without having to be physically in their desk.

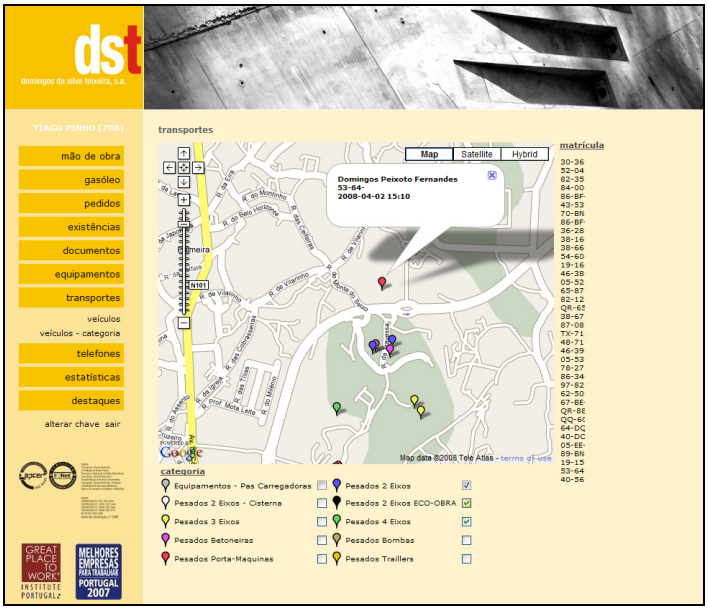

Figure 2: *dst* fleet management

The information is graphically displayed in online maps provided by Google®. Depending on the security level, some of the construction site users can also have access to this feature. This is helpful for the users that are in a tight schedule and are expecting urgent deliveries, so they can see were their allocated resources are located.

IMPLEMENTATION RESULTS AND DISCUSSION

The current project is a conjunction of small wins that had a significant impact in the way people work. The users were used to handle paper-based information; now, they deal with accurate digital information. They were used to making several copies of the documents to send by fax, to deliver by hand or inform by telephone calls; now, they only have to insert the information once in the computerized database. The new system thus overcomes several deficiencies of the previous manual system: low reliability in passing the information, error-prone procedures, out of date information, low diffusion speed and difficulty in addressing responsibility of editing.

The other impact of the misunderstanding in communication was the (implicit) adoption of excessively high security levels for on-site stocks as a means to avoid shortages. As a snowball, such stock order policies from all the work sites usually created serious impact in the warehouse management itself, inducing high oscillations on stock levels and frequent creation of obsoletes, most of them originated from unused material returned by work sites. Obviously, these problems also had a huge impact in the time consumption of all the elements of the supply chain, since now they have time to effectively "manage" the construction project, since the time consumption of all the human resources allocated to these tasks was enormous. Now, the information and its responsible are clearly identified, so that there are virtually no mistakes in the communication.

Despite the inexistence of quantitative performance indicators, there are several sources of evidence that the SC is indeed much more efficient since the introduction of the new tools: clear economical gains obtained by having visibly lower inventory levels and fluctuations, lower obsolete materials and returns. Also, more accurate information on stock levels has introduced a new perspective in the purchasing department in terms of global volume and lead times contract deals. The company's supply chain is now a more stable, reliable and flexible chain.

The fuel consumption feature of the web portal was another important addition to the ICS, since it has controlled a big portion of the equipments related cost. Many of the fuel consumption deviations can be now more easily detected and adequate corrective measures can be also rapidly implemented.

All these implementations have only one purpose: minimizing the internal waste. That can be the excessive stocks on construction sites and in the warehouse, or the wrong materials requested due to lack of reliable and fast communications. The usage of equipments was improved, as well as their management become clearer. All the improvements corroborated the aiming of lean construction principle: making it

possible to perform more and better tasks from the same or less resources.

Another important aspect in the implementation of an ICS of the type created and implemented in here is that it allows a more accurate management of the construction projects. While, in the past, the cost of a given construction project would take months to estimate, now the same task can be performed with increased accuracy in a matter of days. It is expected that this capability will have an important impact in the management and coordination of construction projects in the near future.

In the final part of the project, a survey was conducted to evaluate the impact of the web portal in the company. The results show clearly that the web portal was an important help to the users to perform their tasks, since 90% of the responds were that the web portal was useful or very useful. Moreover, the results show that more than 95% of the responses were that the web portal is a useful or very useful to the company. Related with the workload, the opinions are more divided, 10% said that have more work, 25% the same amount of work and 43% said that the web portal has reduced the amount of work, 23% did not have an opinion.

CONCLUSIONS AND FUTURE WORK

At the early stages of the project, the majority of company managers were sceptic about the possibility of creating and implementing an alternative, automatic, practical and successful ICS for construction site management. Most of their reluctance was due to their natural fear in having to making use of something very different to the system they have been working with for decades (the "fear of change"). After the first reengineering processes, the main consensus was that the workload had increased, and that the older work methods were better. During the implementation of the information system, namely the web portal, the users started to address the problem in a more constructive way, beginning to give suggestions and improvement opinions.

Along the time, users progressively become more conscientious of the benefits of what the information system could offer to their own work: more reliable and faster information and, most of all, more comfort on doing their work. This concept of lean thinking (users do more and better with the same amount of resources) has become part of users' thinking perspective, since they started to submit new ideas and improvements.

This research project developed reengineering processes to the logistics activities within the company, restructuring the main warehouse, in terms of the distribution of the products and equipments and the standardization of information inside the ICS. Also, it has developed procedures for reception and expedition of materials and equipments. This allowed the correct control of all the resources and allowed the implementation of the ICS in the main warehouse. Along with this implementation, other projects were develop and integrated with the main ICS, namely the fleet management system, using GPS technology. Now, the main systems are integrated and working in all the *dst* construction sites with high performance.

A future development of the ICS is planned to integrate a dynamic project management module, where the

activities will be linked together in a way that any change made in a given plan version of any given project can easily be reflected in all the others construction site plans. Along with the automatic reallocation of resources, the dynamic project management module can easily introduce other data for updating any relevant coordination information at the central supply chain management level.

Other important development consists of incorporating suitable tools for enabling suppliers and subcontractors' integration in the ICS. The access to internal information regarding the construction projects, the purchase orders and the construction site stock are some of the information that will be made available to the suppliers. The tasks assigned and the workloads are some of the information that will be made available to the equipments subcontractors. This kind of integration will be preceded by a detailed analysis of the supplier and the subcontractor, in order to determine the potential growth for the company.

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