

REDUCING SCHEDULE IN REPETITIVE CONSTRUCTION PROJECTS

Luis F. Alarcón¹, Cristian Betanzo² and Sven Diethelm³

ABSTRACT

This paper proposes a methodology for continuous schedule reduction in construction projects. Based on concepts and principles of Lean Construction the methodology considers actions on three stages to produce improvements and changes: (1) pre-construction, (2) execution, and (3) post-execution. The methodology suggests the application of several tools in accordance with specific needs (detected and desired) on several potential areas of improvement. The methodology was applied to the construction of Gas Stations with the following results in the implementation: reduction of 35% in schedule with respect to original company projects of the same type and 18% reduction with respect to the best schedule ever achieved in previous projects. These results were obtained in a very adverse environment for implementation, therefore, the potential reduction for future projects considers a schedule reduced 43% with respect to the best schedule result obtained during the implementation.

KEY WORDS

Lean Construction, Phase Scheduling, Work Structuring, Repetitive Construction.

¹ Professor, Universidad Católica de Chile, Escuela de Ingeniería, Casilla 306, Correo 22, Santiago, Chile, Fax : 011-562-686-4806, e-mail: lalarcon@ing.puc.cl

² Research Assistant, Universidad Católica de Chile, Escuela de Ingeniería, Casilla 306, Correo 22, Santiago, Chile, Fax : 011-562-686-4806, e-mail: cbetanzo@ing.puc.cl

³ General Manager, GEPUC, Universidad Católica de Chile, Escuela de Ingeniería, Casilla 306, Correo 22, Santiago, Chile, Fax : 011-562-686-4806, e-mail: sdiethel@ing.puc.cl

INTRODUCTION

Globalization is opening international frontiers to new business ventures. This reality also applies to the construction sector and has prompted building companies to question their methods and procedures in order to increase their competitiveness. This is the operating background for the proposed schedule reduction methodology presented in this paper. The schedule reduction methodology (Betanzo 2003) was developed as part of a research project in the Center for Excellence in Production Management at the Catholic University of Chile (GEPUC). It involves using various tools and techniques, some of them based on the Lean philosophy, in order to minimize the execution times in repetitive operations. The aim of this methodology is to provide a tool to minimize execution times in repetitive projects and use this time reduction as a competitive advantage, and gain stature and competitiveness at the international level.

The paper provides a brief background on the conceptual aspects of Lean Construction before introducing some tools used in the methodology (Alarcon 1997). A case study is used to illustrate the different steps used in the methodology and two tools considered among those with greater impact are described in more detail. Also, the performance history of the company projects of the same type is used to benchmark the reductions obtained after applying the proposed methodology.

LEAN CONSTRUCTION

Lean Construction is the application of Lean Production principles to construction. It considers three perspectives to describe the process: conversion, flow, and value generation (Koskela 2000). The difference in these visions is in the way that they conceptualize the process, in other words, the way in which they describe their aspects and properties. The conversion view is instrumental in discovering which tasks are needed in a construction undertaking; thus it is perfectly possible to realize construction projects based on this view. However, the conversion view is not especially helpful in figuring out how not to use resources unnecessarily or how to ensure that customer requirements are met in the best manner (Koskela and Huovila 1997). In short, the conversion view is effective for management, but not for improvement. In fact, this view only addresses the first of three questions that according to (Turner 1993) make up the core of project management: (1) an adequate, or sufficient, amount of work is done; (2) unnecessary work is not done; (3) the work that is done delivers the stated business purpose.

Conceptualizing the construction process as a flow lends itself to reduce waste by minimizing the time information and resources spent waiting to be used, time spent inspecting for conformance to requirements, time spent reworking to achieve conformance, and time spent moving between processes. Further, and even more important than reducing the cost and time of construction, conceptualizing the construction process as a flow of information allows coordination of interdependent flows and the integration of construction with supply and design (Ballard and Koskela 1998).

In the value generation model, the emphasis is on obtaining the customer's requirements. The improvement of construction lies in reducing loss of value that arises when not all

requisites are transmitted in the process. On the other hand, value consists of product performance and lack of defects. This value has to be evaluated from the perspective of the next customer(s) and the final customer. To prevent the loss of value it is necessary to: analyze the requirements and needs at the outset in close cooperation with the customer, use a systemized management of requirements (like the application of QFD – quality function deployment), and organize rapid iterations between all the participants who issue design and construction information (Huovila et al. 1997).

Lean Construction incorporates the views of both flow and value, in contrast to the traditional vision of the conversion model. Even though each perception is analyzed separately, the construction process involves all three. In this manner, lean design “opens the doors” to modeling towards the practical application of the three perspectives in the construction process. The incorporation of new ways to ‘visualize’ the process increases the understanding and comprehension of how it works. This approach motivates the implementation of tools to integrate these frequently neglected aspects in the process; thus improving it.

APPLYING TOOLS FROM A LEAN PRODUCTION PERSPECTIVE

A variety of management tools, techniques and principles were used in the schedule reduction methodology, some of them are inspired by Lean Production principles (Freire and Alarcon 2002). They are listed on Table 1, along with the activities and the management area to which each of them is applied and the purpose and aim to be attained by each under the methodology.

It should be noted that the original applications for which these management tools or techniques were designed were adapted so as to facilitate the practical use of such tools and respond to the prevailing circumstances in the industry. All these tools were used in the case project, but two of them, described in further detail in the following paragraphs, had greater impact than the others on the results of the project discussed in the present paper: 1) phase scheduling and 2) work structuring.

PHASE SCHEDULING

Phase scheduling is a “pull” tool or technique, i.e. the project requirements “pull” the production process. It involves all participants in a project phase, generating a planning process developed by a work team and not by individuals. It aims at developing a planning process that maximizes value generation with the participation, understanding and commitment of all actors involved in a project phase (Ballard 2000a). Phase scheduling involves planning a project backwards from its date of completion to its starting point, in order to determine the sequence of the tasks to be completed. Its aim is to eliminate restrictions impeding activities and, at the same time, rule out unfounded notions about task prerequisites. Representatives of all the participants involved in a given phase of the project take part in phase scheduling, since the idea is securing reliable commitments to the new planning process. Once agreements are reached on such commitments, they are formally signed, in order to enhance their significance.

Under the time reduction methodology, this tool is used specifically in the pre-construction phase, when commitments are sought from subcontractors and project managers by inviting them to participate in decision making activities related to planning. This creates a team work environment where the participants see themselves as part of an integrated project going beyond their specific activities, and where each individual process may affect the proper progress of the rest.

Activity	Tools/Techniques	Purpose	Aim
Interviews	"5WHYs" and "5WHYs+ IHOW"	Diagnosis	- Identifying potential barriers to implementation - Obtaining general view of information flows and general assessment of the building company
Delivery and listing of background information		Diagnosis	- Obtain background information about the project - After initial study, generate basic criteria to start operations
Preconstruction meetings		Diagnosis and Planning	- Clarify aspects of project
Working meetings with persons in charge of applying methodology	Critical path method Work structuring	Planning Performance Improvement	- Searching critical path, managing time slack and potential critical paths - Study data obtained in previous operations, balance workload and resources - Involve project manager and site manager in planning and process improvements - Minimizing activities that add no value to processes, minimizing time needed to execute processes - Eliminating existing prerequisites, minimizing risk of accidents
Coordination meeting with subcontractors	Phase scheduling	Planning	- Secure commitments from subcontractors and project managers through collective planning - Promote team work, create awareness of the impact of individual actions on all participants
Permits, licensing, etc.		Planning	- Verify validity and status of permits
Drawing plans and blueprints, sheet piling		Planning	- Foresee and complete high-demand activities during first stages of project and correct topographical errors
Layout of work areas		Planning	- Proper layout of work areas may generate savings in workers' movements, eliminate need to relocate operations, and secure prompt availability of stocked materials
Obtaining feedback on site	Feedback	Planning and Control	- Check actual data against plans - Early warning of potential problems
Weekly planning meetings	Last Planner	Planning	- Control plans variability, managing interrelations, identifying cases of non compliance, increasing commitment planning, secure commitments by subcontractors
Weekly meetings with site managers	Benchmarking	Performance Improvement	- Select best practices, promote team work to solve problems on site - Secure commitments with building company
Compliance reports	Continuous improvement	Planning	- Assess variability of planning in a building project
Report on reasons of non compliance	Continuous improvement	Performance Improvement	- Identify problems encountered in order to avoid them in the future - Identify potential improvements
Report on cubing work, materials and labor	Continuous improvement	Performance Improvement	- Determine exact amount of materials to be used - Procure materials in advance - Determine human resources requirements

Table 1. Activities, tools and techniques applied in the Methodology

WORK STRUCTURING

The main object of work structuring is to give shape to the design process of a given project by organizing its tasks in the design engineering, supply chain and resource areas, and by concerting efforts in order to create a faster and more reliable work flow; all this would add to the value of the output delivered to the client. In other words, work structuring is a production system design, is a technique of seeing and reconsidering what work must be done and who will be best suited to do the work and when (Tsao and Tommelein 2001) (Tsao et al 2000) (Ballard et al 2001).

As a production system design, work structuring involves several steps. The following stages should be adhered to or kept in mind:

Design flow:

- Identifying requirements;
- Integrating requirements into a design criterion;
- Selecting concepts, systems and technologies to be used;
- Determining the design, suppliers of materials and features of assembly processes;
- Choosing components and materials;
- Integrating components into systems and these systems into other systems through the use of detailed engineering techniques allowing for an easy completion of this process;

Supply flow:

- Creating a detailed design;
- Stocking materials;
- Manufacturing components;
- Creating partial assembly modules;
- Transport to assembly plant;

Work front structuring:

- Defining the process as a series of operations connected in a repetitive work flow or linked by a short lead time;
- Using buffers or control mechanisms to monitor the work flow among processes;
- Assigning tasks to people having the required capacities and skills.

The work structuring methodology was used mainly to improve processes during the stage prior to the execution of the project. Processes were redesigned in order to minimize losses and cut down unnecessary steps or activities that added no value to the final output. At the same time, the aim was to eliminate all unproven rules and premises usually followed by the building company in the performance of its activities.

The application of the work structuring methodology also brings benefits not always easy to quantify, for instance in connection with the safety of workers and the streamlining of work sequences. A case in point is the use of prefabricated components or the pre-assembly of components on the ground prior to their hoisting.

SCHEDULE REDUCTION METHODOLOGY

The methodology was divided into a series of activities, each with a specific function. Table 1 shows the activities covered by each application, the tool or technique used in each case, and the aim of each activity.

APPLICATION CASE

The methodology was applied in a construction company active in the construction of Gas Stations. This company had a long term contract with one owner to build many stations over a period of three years. Since these stations are alike, the building operations are repetitive; thus, the methodology is applicable.

The previous history of projects was valuable to establish benchmarks for comparison. It should be mentioned that in different projects different work schedules were used, which prevented direct comparisons. Therefore, all project durations were converted to days with 10 working hours.

Gas Station projects comprise two sectors, considered as separate projects, whose only common feature is the date when work will start. One sector is called “parking and canopy area” and covers parking areas, fuel tanks and fuel distribution areas, plus the structure above them (canopy), and green areas. The other sector covers the service building, which includes cafeteria, toilets, kitchen, office, etc, plus an annex for storage, garbage collection and pickup, bathrooms and locker rooms for the staff. The methodology was applied to a project comprising both sectors.

Situation prevailing before implementation

According to the company experience, the construction of the first Gas Stations, about two years earlier, took 78 days for the service building and 70 days for the parking and canopy area. Subsequently, on the basis of experience, schedule reduction efforts were developed with target deadlines of 52 days for the service building and 48 days for the parking and canopy area. A Gantt Chart with the above targets was used for the project built immediately before the application of this reduction methodology. Nevertheless, the actual execution schedule were 62 days for the service building and 60 days for the parking and canopy area (Figure 3).

No control procedures were in place, no management tools were used and no actual scheduling took place. In fact, since the Gantt chart had been developed at headquarters with no participation of site staff, many deadlines were unrealistic.

Pre-construction stage

First, coordination meetings were held with the building company to determine how work would proceed and to ask for their help in the implementation of the methodology. Second, a review was made of the Gantt chart prepared by the company and the general background of the project. A completed project was visited. Subsequently, working meetings with the person in charge of implementation were held. In these meetings the first Gantt chart was revised and processes were improved in order to cut down execution times. In this context, first the duration of tasks was reviewed and then new construction systems were proposed to reduce times through work restructuring. A case in point was the use of prefabricated foundations, previously made on site (Figure 1). This meant saving 5 days of execution time; at the same time, the activity was taken off the critical path, and fewer workers had to be assigned to it. Another example was the canopy, which used to be assembled overhead. This required waiting until the supporting pillars had been put up. As a result, the area under the canopy could not be used because of the required scaffolding, the assembling was slow because it was done overhead, and the risk of accidents was high.

In a previous project the building company had assembled only the skeleton of the canopy on the ground and then hoisted it, so a significant amount of work had been done overhead. This time, work structuring entailed assembling the whole canopy on the ground, including the lighting fixtures, while parallel activities were going on in the area. Thus, when the supporting columns were put up, the canopy was hoisted to its final position (Figure 2). Almost 8 days were saved, the risk of accidents decreased significantly, the task was taken off the critical path, and it was possible to perform parallel tasks in the area which would eventually be covered by the canopy.

Each activity listed in the Gantt chart was assigned labor and machinery resources. The possibility of minimizing execution times through labor-intensive methods was considered. Once the first stage of the Gantt chart was completed, the prospective site manager joined the discussions. He participated in the review and amendment of the plans. He was invited to join the meetings in order to secure from him a firmer commitment to the planning exercise.



Figure 1. Prefabricated Foundations

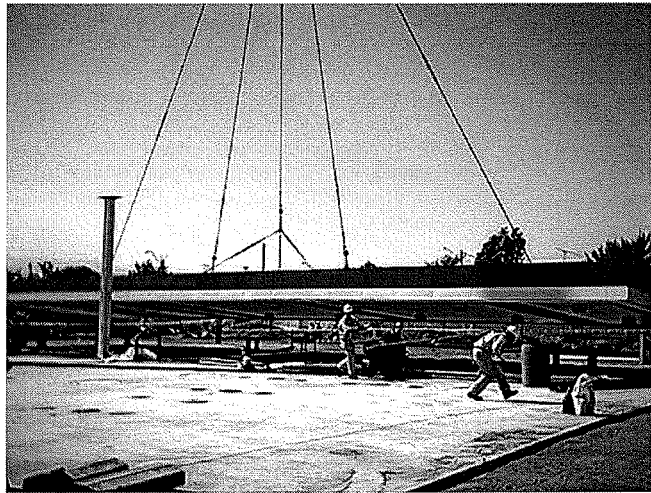


Figure 2. Hoisting Canopy assembled on ground

Coordination meetings with subcontractors followed. The Gantt chart was reviewed backwards from the end to the beginning of the project. Prerequisites were established so that each participant could complete their tasks. Subsequently, participants were asked to fill out a “commitment agreement”, where the prerequisites of their tasks were listed, and to submit it two days before the next meeting. On the basis of this information the “General Commitment” (Table 3) was formulated and handed out to all participants. It listed the activities assigned to each person, dates of completion, tasks ready to proceed and the names of the persons in charge of each activity. The “General Commitment” was signed by all participants, who also were given copies of the document.

Execution stage

Once the project was initiated, it was necessary to follow up the progress of the plans, so as to assess on site the sequence and duration of tasks and the resources used. This information was collected and collated daily by an agent not linked to the building company so as to ensure its objectivity. Process analysis was applied to a critical activity. A similar activity was followed up by specialized staff from SPG S.A. (Productivity and Management Systems, Inc).

Plans for weekly meetings were adhered to only in part, since they took place only when the researcher exerted pressure in that respect. This led to the loss of a significant part of the information needed for the proper application of the methodology.

Table 2. General Commitment Chart

Name of participant in meeting:		PM	
Position or function in organization:		Project professional	
Specific activity, task or contract in project:		Project Manager	
What must I do?	When should I do it?	What for?	Whom am I doing it for?
Secure access for crane	Day 16	To put main beam in place	Contractor W
Hoisting plan	Day 17	To assemble canopy	Contractor W
Clear assembly area	Day 17	To assemble canopy	Contractor W
Secure electric power	Day 18	To assemble canopy	Contractor W
Sink steel armatures	Day 19	To install perimeter lighting	Contractor Y
Pour concrete in armatures	Day 19	To install wiring for perimeter lighting	Contractor Y
Paint and inputs	Day 19	To apply anticorrosive paint	Contractor W
Layout and placement	Day 19	To place lampposts	Contractor W
Pour foundation concrete	Day 19	To put up lampposts	PM
Put up building firewall	Day 20	To install lighting ducts in building	Contractor Y
Pour concrete for MID foundation	Day 22	To place MID anchoring and armature	Contractor W
Paint and inputs	Day 22	To apply polyurethane paint	Contractor W
Secure licensed scaffolding	Day 23	To place top blocks on walls	Contractor W
<p>Contractor Y Contractor W Contractor X Professional Project Manager Building company Supervisor</p>			

Post-execution stage

Once the building project was completed and feedback was compiled, optimal Gantt charts were developed for the service building (execution: 29 days) and for the parking and canopy area (execution: 23 days). The resulting schedules represent best case scenarios and constitute the new targets to be met (Figure 3).

Barriers encountered during implementation

The main barriers faced during the implementation was resistance to change from some members of the organization. Project managers did not think the new methods would be very useful. They maintained that their impact would be negligible, even though they later acknowledged they had helped them to organize work and improve planning. Executives were informed of shortcomings observed in previous projects and of possible corrective measures, but no proper responses were forthcoming.

Another critical area was the supply of materials to the site. Project managers criticized harshly the management of the Procurement Department, and said it did not purchase or

deliver materials on time, thus causing serious delays. In the case of some important items, there had been delays of nearly 20 days. This mismanagement caused unpredictability and uncertainty as to the delivery of materials. This, in turn, undermined any realistic planning, since the commitments agreed to in the weekly meetings had become unattainable.

Implementation results

The achievements attained in the implementation of the methodology are shown in Figure 3, which illustrates the execution times of several projects. The theoretical times stated in the Gantt charts submitted by the company are also included, as are those in the initial chart, developed on the basis of the one submitted by the building company, and those in the “optimal” chart, formulated after working with the initial chart and the data collected on site; this “optimal” chart represents the new targets to be met.

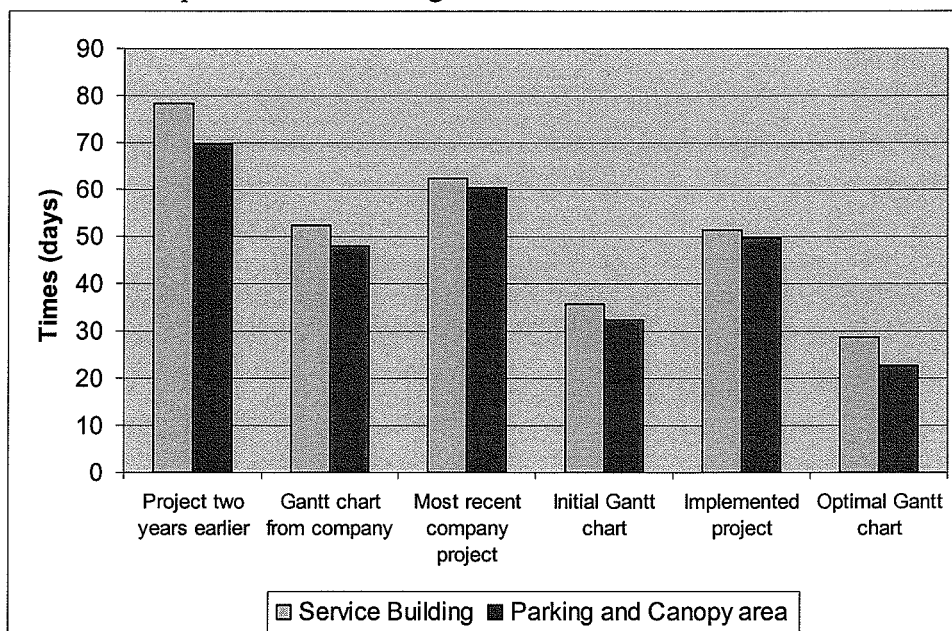


Figure 3. Evolution of Schedule Reduction

In a project built by the company two years before, 78 and 70 days were needed for the service building and the parking and canopy area, respectively. Improvements made by the company shortened the execution times to 62 and 60 days. The new methodology reduced such times 18 per cent, to 51 and 50 days, in spite of delays due to the late delivery of materials for critical items and the lack of commitment of some participants in the project. Even though it is difficult to assess the total delay this caused, it is fair to conclude it amounted to 10 to 15 days for the project as a whole. This illustrates the efficiency of the methodology and the potential benefits to be obtained when it is properly applied.

Despite the difficulties encountered to apply the methodology correctly, results were generally satisfactory, especially since this was the first such experience for the construction company. Even the project manager acknowledged that the scheduling exercise had allowed him to better organize and plan the work.

Adhering to the steps proposed in the methodology not only cut down the time needed but also improved the living conditions of workers, since it eliminated the need for overtime, night shifts, weekend shifts, etc. This allowed them to spend more time with their families. Another advantage is that normal working hours, with no pressure to absorb backlog, reduced the number of accidents.

CONCLUSIONS

The application of the proposed methodology to the projects discussed brought about significant and systematic reductions in execution times and showed that continuous performance improvement is feasible. The expected results were attained, even in the face of many difficulties. A reduction of 35% in schedule was achieved with respect to original company projects of the same type developed two years before and 18% reduction with respect to the best schedule ever achieved in previous projects. The post execution analysis identified a potential reduction for future projects of 43% with respect to the improved duration obtained during the implementation,

The proposed methodology is conducive to rapid results, especially in relation to commitments and performance improvement. This is important, since these achievements encourage new advances. However, to be able to obtain all the gains from this type of methodology it is necessary to obtain commitment from the project team designing an strategy that includes this aspect as a primary driver of the implementation.

There is always room for improvement, but the first requirement is the availability of measurements to compare results and determine whether the measures taken have been effective. This is why, in order to implement this methodology or introduce any other performance improvement, it is essential to establish methods or formulae to collect, measure and control data.

ACKNOWLEDGEMENTS

The authors acknowledge SPG, GEPUC and M&M project team for their support and help in carrying out this work. They also acknowledge FONDEF project DOI1004 for funding to this research. The authors thank Mr. Walter Pizarro for the time and support in editing the paper.

REFERENCES

- Alarcon, L. (editor) (1997). *Lean Construction*. A.A. Balkema, Rotterdam, The Netherlands, 497 pp
- Ballard, G. and Howell, G. (1998). "Shielding Production: An Essential Step in Production Control". *Journal of Construction Engineering and Management*, ASCE, 124 (1) 11-17.
- Ballard, G. and Koskela, L. (1998). "On the Agenda of Design Management". *Proc. 6th Annual Lean Construction Conference*. Guarujá, Brazil, 13-15 August.
- Ballard, G. 2000a, Phase Scheduling, LCI White Paper <http://www.leanconstruction.org/>
- Ballard, G., Koskela, L., Howell, G. and Zabelle, T, 2001, Production System Design: Work Structuring Revisited, LCI White Paper <http://www.leanconstruction.org/>

- Betanzo, C. 2003, Metodología de reducción de plazos en obras repetitivas. Pontificia Universidad Católica de Chile, Facultad de Ingeniería, Santiago, Chile.
- Freire, J., Alarcón, L.F. (2002) Achieving a Lean Design Process: An Improvement Methodology. *ASCE Journal of Construction Engineering and Management*, 128(3), 248-256.
- Huovila, P., Koskela, L. and Lautanala, M. (1997). "Fast or Concurrent: The Art of Getting Construction Improved". *Lean Construction*. Alarcón, L.F. (ed.), A.A. Balkema, Rotterdam, The Netherlands, 143-159.
- Koskela, L. 2000, An Exploration Towards a Production Theory and its Application to Construction. *VTT Publication 408*. VTT Building Technology, Espoo, Finland 2000.
- Tsao, C., Tommelein, I., Swanlund, E., Howell, G. (2000) Case Study for work structuring: Installation of metal door frames, *8th annual conference of the International Group for Lean Construction*, Brighton, U.K.
- Tsao, C.C.Y. and Tommelein, I.D. (2001). "Integrated Product-Process Development by a Light Fixture Manufacturer." IGLC-9, August 6-8, Singapore.
- Turner, J.R. (1993). *The Handbook of Project-Based Management*. McGraw-Hill, London. 540 p.