On-Site Subcontractor Evaluation Method Based on Lean Principles and Partnering Practices

Sergio Maturana[1]; Luis Fernando Alarcón[2]; Pedro Gazmuri[3]; and Mladen Vrsalovic[4]

Abstract: Subcontracting has greatly increased in the construction industry. It helps shift risk from the main contractor to the subcontractor and promotes specialization. Inadequate subcontracting management, however, may result in an adversarial relationship between main contractors and their subcontractors, uncoordinated on-site execution, and disappointing quality and schedule fulfillment. New subcontractor management methods and tools are being developed and tested as part of a collaborative research project led by the Catholic University Production Management Center with the participation of the Chilean Construction Chamber and several construction companies. The experience gained by testing prototype tools and methods on selected projects enabled us to develop an on-site evaluation method based on lean principles and partnering practices. This method allows main contractors to help subcontractors improve their performance by providing them with periodic feedback. It also supports subcontractor selection based on their previous performance, which helps foster collaborative relationships with those that consistently perform well. The results of the application of the method in two case studies are discussed.

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Introduction

The development of the construction industry has resulted in a concentration on core activities by most contractors instead of integrating peripheral tasks associated with project completion. According to the Chilean Chamber of Construction, and the results of the research by the Catholic University Production Management Center (GEPUC), between 60 and 70% of the project value is being subcontracted. This significantly increases construction management complexity. However, it also gives contractors a wider range of alternatives for performing certain tasks and helps shift some risks from the main contractor to the subcontractor. The contractor usually can organize and direct subcontractors' activities. The transactional nature of this arrangement enables the contractor to effectively allocate risk outside its own organization, which helps explain why disputes and litigation are so common in this industry. It can be argued that small subcontracting firms are employees in all but name and associated benefits. Thus, while contractors assume the management role, small subcontracting firms are increasingly divorced from management decisions (Miller et al. 2001).

The deeply rooted tradition of competitive bidding in the construction industry can be destructive in the long term as the need to minimize transactional costs tends to reduce quality and client satisfaction. Since contractors enter into separate contracts with both the client and specialist subcontractors in order to fulfill the client's mandate, the margin between the price quoted to the client and the actual subcontracting cost can be seen as the contractor's reward for the effective organization and coordination of the construction process (Miller et al. 2001). This emphasis on cost competition, and the traditional adversarial customer-supplier relationship, results in frequent changes in the participating firms from one construction project to another, making collaboration between them difficult.

GEPUC is leading a collaborative research project with the participation of twelve construction firms and the Chilean Chamber of Construction. The general objective of this project is to allow firms to reach higher levels of productivity through systematic actions of research and implementation of changes in management practices. Probably the most important of these changes is the introduction of the *Last Planner* system, a production management and control system based on lean construction principles. This system helps increase the reliability of planning thereby improving performance (Ballard and Howell 1998). The plan's success at reliably forecasting what work will get accomplished by the end of the week is measured in terms of percent plan complete (PPC). Root causes for plan failure are investigated at the end of each week so they may be avoided in the future. A higher PPC leads to improved performance, not only of the production unit that executes the weekly work plan, but also of production units downstream as they can better plan when work is reliably released to them. The *Last Planner* system implemented by GEPUC resulted in a more reliable flow and a higher throughput of the production system. Increases in productivity between 7 and

[1]Professor, Dept. de Ing. Industrial y de Sistemas, Pontificia Universidad Católica de Chile, Casilla 306, Santiago 22, Chile. E-mail: smaturan@ing.puc.cl

[2]Professor, Dept. de Ing. y Gestión de la Construcción, Pontificia Universidad Católica de Chile, Casilla 306, Santiago 22, Chile.

[3]Professor, Dept. de Ing. Industrial y de Sistemas, Pontificia Universidad Católica de Chile, Casilla 306, Santiago 22, Chile. E-mail: pgazmuri@ing.puc.cl

[4]Analyst, General Motors Chile, Av. Americo Vespucio 811, Santiago, Chile. E-mail: mladen.vrsalovic@gm.com

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48% have been reported in GEPUC projects (Alarcón et al. 2005).

A group of eight firms, of the twelve that participate in this project, focused on researching and developing new systems and tools to support subcontractor management. Prototype tools and systems were tested on selected projects managed by these firms. The method that will be presented in this paper is based on the experience gained in these tests and the application of lean principles. The research process that allowed us to arrive to the proposed method will also be described. Finally, two case studies in which the proposed method was applied will be discussed.

Literature Review

The construction industry in most countries faces fluctuating demand cycles, project-specific product demands, uncertain production conditions, and the need to combine a diverse range of specialist skills within geographically dispersed short-term project environments. Over the past 20 years, a strong growth in subcontracting has further complicated this situation through the fragmentation of the production process and an increase in construction supply chain complexity.

Lean Construction and Partnering

Partnering and lean construction have been cited as effective approaches to overcome these difficulties. Implementing them, however, may be difficult. Dainty et al. (2001) identified the following barriers to integration from the subcontractor point of view:

- Financial/cost-related issues related to competitive tendering based on price, which has developed adversarial relationships that result in serious problems with regard to payments;
- Planning/time-related issues, such as false expectations on part of the main contractor and unrealistic schedules; and
- Attitude-related issues, such as arrogant conducts, exclusion of the subcontractor from the early phases, lack of praise for good performance, poor site management practices, and lack of understanding of subcontractors' problems.

Lean construction (Ballard and Howell 1998) is a fundamentally different approach to the conventional model of project optimization on an individual activity basis. In the conventional model, the emphasis is on increasing the speed and reducing the cost of each activity. In lean construction, a reliable work flow (throughput) is more critical than individual activity speed or individual activity cost. Lean construction provides clear delivery process objectives, maximizes performance at the project level, allows product and process to be designed concurrently, and maintains production control throughout the project life (Vrijhoef et al. 2001).

Latham (1994) defines partnering as a contractual arrangement between two parties for either a specific length of time or for an indefinite time period. The parties agree to work together, in a relationship of trust, to achieve specific primary objectives by maximizing the effectiveness of each participant's resources and expertise. On the other hand, Dainty et al. (2001) define partnering as the use of integrated production teams and continued monitoring of the effect of performance improvement measures. Contractors can also become more competitive as they learn and become more experienced (Fu et al. 2003).

According to Latham (1994), the basis for partnering success is continuous improvement and the construction of long-term relationships with suppliers and subcontractors. Partnering can be based on a single project, which is called *project partnering*, or on a long-term commitment that spans several years and several projects, which is called *strategic partnering*.

Although the partnering approach has shown promising results, there are some cases in which subcontractors have considered that it did not add any value, while some main contractors have seen little benefit in forming alliances with firms that they do not regularly work with (Dainty et al. 2001). On the other hand, Kumaraswamy and Matthews (2000) showed how partnering principles can be profitably applied to the subcontractor selection process, whereas Chan et al. (2004) derived a relationship between the perception of partnering success and a set of success factors through a survey in the Hong Kong construction industry.

In order to achieve lean construction's aim of reducing waste, while simultaneously adding value to the construction process, large and small contracting firms must be able to form working relationships that effectively reduce transaction costs (Miller et al. 2001). Rahman and Kumaraswamy (2004) report on the results of a Hong Kong-based study on joint risk management, which show the importance of more relational, trust, and joint responsibility-related factors, both for selecting different parties and for building successful relational contracts.

Prequalification Methods

In recent years different project delivery systems, such as design-build, construction manager at risk, and design-bid-build with request for proposal, which require more sophisticated prequalification methods, have become more widely used (Konchar and Sanvido 1998).

Many detailed and highly developed prequalification and selection methods for contractors and subcontractors have been proposed in the literature. These methods aim to solve the problem of tendering based solely on price using different approaches, such as multicriteria utility theory models (Hatush and Skitmore 1998), cluster analysis and evidential reasoning (Sônmez et al. 2002), decision criteria (Russell and Skibniewski 1988), fuzzy set theory (Singh and Tiong 2005), linear programming (Elazouni and Metwally 2000), or performance modeling (Alarcón and Mourgues 2002). Recently Topcu (2004) proposed a multicriteria decision model for construction contractor selection in the Turkish public sector and Minchin and Smith (2005) proposed a quality-based performance rating system, which includes the quality of subcontractors' past work. All these proposals require information that is difficult to obtain for many firms, which makes them hard to implement.

Research Methodology

In order to develop the on-site subcontractor evaluation method proposed in this paper, we first carried out a brainstorming session with two representatives of each of the 12 participating firms to detect the main problems with the subcontractors. Then we surveyed 29 subcontractors of the participating firms to have their point of view on the main contractor's management methods. Later we held a focus group session with the representatives of eight participating firms that had developed their own prequalification systems to learn from their experience. Finally, we applied the resulting subcontractor evaluation method in several projects and analyzed the results. In the next section we describe two of these applications.

Brainstorming Session

The participants agreed that there were at least two types of subcontractors: One with sufficient financial solvency, capable of solving their own problems, and another composed of small firms, which needed more support due to their limited resources and knowledge. Most of the problems mentioned in the brainstorming sessions, such as lack of training, limited financial resources, little knowledge of the required contracts, lack of planning, and unsatisfactory performance, were clearly associated with the second type of contractors. Other problems, such as little involvement in the planning process, limited integration with the main contractor, lack of formal contracts, and unenforceable contracts, applied to both types of contractors. The participants also agreed that many of these problems resulted from their own lack of long-term evaluation of subcontractors and from not taking into account the indirect costs generated by subcontractors, such as quality problems that had to be fixed after they were finished.

The participants concluded that a method for evaluating both types of subcontractors would help in reducing or eliminating many of the problems mentioned earlier. It was also concluded that the evaluation system should motivate rather than punish.

At the end of the session, 8 of the participating firms decided to implement their own prequalification systems, which they considered the best way to begin implementing a subcontractor evaluation system.

Survey

The purpose of the survey was to assess the subcontractors' opinions of the main contractor's management methods. Twenty-nine subcontractors of different specialities, such as painters, sanitary installers, HVAC, structural iron and metal, and tile installers participated.

The survey included questions related to quality of the project definition, level of collaboration and communication with the main contractor, and aspects of the work they perform, such as quality, safety, and schedule fulfillment. The results showed important differences between large and small subcontractors, where size was determined by the budget of the projects they managed and the number of workers in the firm.

All respondents agreed that the initial stages of the construction work: early establishment of schedules, information sharing, and quality and safety requirements, were important. Most respondents agreed that there was lack of planning in the execution phase of the project in those construction sites that did not have periodic planning meetings. The surveyed indicated that periodic feedback was absolutely necessary and appreciated. Some respondents considered that safety measures were extremely strict, while others considered them too lax. The survey showed that contractors in general responded quickly to doubts or problems presented by the subcontractors, but only some considered them effective.

Subcontractors also agreed that the main reasons for failing to finish on time were lack of on-site inventory and lack of space assigned for the subcontractor. They also blamed quality problems on the main contractors, for last minute changes and design problems. Most surveyed also indicated that fines or penalties indicated in the contract were seldom enforced.

The results showed that main contractors share some responsibility for these problems, especially with respect to coordination, planning, and cooperation with the subcontractor. In addition, main contractors must make a greater effort in the design stage of a project.

Focus Group

After all the firms that implemented their prequalification systems had completed them, they presented their results to the rest of the participating firms. Although the implementation of these systems differed, most shared the same methodological approach. The most sophisticated systems used database management systems, such as Access, and the simpler ones were implemented in spreadsheets. Four months later, these same firms were invited to a focus group to discuss their experience using the systems they had developed.

The main conclusion of this focus group was that none of these systems had been successful. In some cases there had been technical problems with the software, but the most prevalent problem had been obtaining the necessary data. After the project was finished, it was very difficult to get a meaningful evaluation of the subcontractors, particularly as its usefulness was not obvious for the on-site manager. Why bother if the project had ended? The large amount of information required by many of these systems complicated things even further by making them more time consuming and difficult to use. After some discussion, it became clear to the participants that the best approach would be to implement a well-designed on-site evaluation system that could be used to both improve subcontractor management during the construction, and for obtaining data for selecting subcontractors in future projects.

Finally, it was decided that, based on these experiences, GEPUC would develop a new method to replace the traditional tendering based solely on price, which would require less information, and less effort from the users than the existing systems. This method is described next.

Proposed Method for Subcontractor Evaluation

Subcontractor evaluation can play an important role during a construction project. During the execution of the project it can provide feedback to the subcontractors to help them improve their productivity. Previous evaluations can also help select better subcontractors for a new project. Over time it may promote collaboration with those subcontractors that consistently perform well. These subcontractors can get involved from the design phase in the project, as suggested by the partnering approach.

The proposed evaluation method allows different evaluation criteria, supports periodic evaluations, includes dialogue instances, and visualization and dissemination tools to promote communication between the subcontractors and the main contractor. It also supports the evaluation of suppliers. We describe next each of these points.

Evaluation Criteria

To improve productivity it is necessary to monitor the performance of all relevant dimensions of the construction site. A subcontractor management system should allow evaluating subcontractors on a number of different dimensions or criteria based on a framework for performance measurement. Improvement measures are used infrequently and they aim to find current performance level and improvement potential, whereas monitoring measures are used for screening and controlling operations continuously (Wegelius-Lehtonen 2001). When choosing the criteria, the main contractor should cover only areas that have, or may have, a direct effect on performance. The criteria can be only as specific as the culture allows. When a construction firm lacks a strong measurement culture, which is mostly the case in Chile, it is difficult to apply objective measures.

When there is a strong measurement culture, the evaluation system designer must maintain independence among the criteria. This facilitates the detection of root problems, which makes it easier to determine corrective actions and promotes a proactive attitude. In the proposed method, main contractors choose the evaluation criteria to be used based on the measurement culture of their firm.

Periodic Evaluations

Subcontractors should be subject to periodic and timely evaluations. If subcontractors are only evaluated when the project ends, they can only improve in a future project. However, if subcontractors are uncertain about working in future projects with the same main contractor, they are less likely to solve the problems detected in the evaluation. Periodic evaluations during the project allow subcontractors to improve their performance by giving them adequate feedback.

The evaluation period should correspond to the production planning time frame. In the cases that were studied, which all used the *Last Planner* system, the evaluations were weekly, the same as the planning meetings.

Dialogue Instances

Periodic instances for dialogue, where evaluations can be openly discussed, are needed to improve communication and coordination between main contractors and subcontractors. Dialogue (communication for cooperation) among the participants fosters continuous improvement on critical issues. Rewards should also be considered for motivating fulfillment and excellent performance. For example, the performance assessment scoring system of public housing construction in Hong Kong failed in achieving its goals mainly because it lacked rewards and praise (Tam et al. 2000). Praising the best performer is an easy way to promote competition among subcontractors.

Using the weekly planning meetings as dialogue instances improved the learning process that takes place in these meetings that gather in the same room all the people directly overseeing the work at the construction site (Last Planners), including foremen, subcontractors, supervisors, and main suppliers. During these meetings learning takes place in different ways: causes for noncompletion are examined, corrective actions are taken, and subcontractors' performances are evaluated and communicated according to all selected criteria, including PPC performance. The proposed method promotes the participation of all the subcontractors in the formulation of the weekly plan so they can specify their restrictions to meet the schedule. If the main contractor can help lift these restrictions, on-site productivity is improved.

Visualization and Dissemination Tools

Having a good tool for showing the evaluations is important. This tool should serve as a reminder and as a dissemination tool among the workers. It should promote competition among the subcontractors and allow prompt reaction to bad evaluations. It should also stimulate a proactive attitude towards future performance evaluations and it must be easy to "read" or interpret. Evaluations that are not easily understood tend to be ignored. The evaluation must also be conducted by knowledgeable people who have good information of what goes on at the work site.

Application of the Subcontractor Evaluation Method

The application of the proposed method can be summarized in the following steps:

1. The main contractor selects the valuation criteria on a number of different dimensions that may affect subcontractors' performance. The criteria should be as objective as the measurement culture of the firm allows. The criteria should also be the same for all the firm's projects in order to allow comparisons between them.
2. Establish periodic and timely evaluations. The evaluation period should correspond to the production planning time frame, which is a week when the *Last Planner* system is used. It is also important to keep track of the evolution of the evaluations to see whether they are improving or not.
3. Institute periodic dialogue instances between subcontractors and the main contractor in which evaluation results can be discussed and good performances praised. This can be a learning experience for both the subcontractors and the main contractor. As many subcontractors and suppliers as possible should be invited and meetings should be scheduled on a fixed day of the week that is convenient for all attendees. Participants should include subcontractors, main suppliers, foremen, supervisors, and the site manager representing the main contractor. Besides communicating and discussing the evaluations, these meetings can also be used to praise good performers and identify corrective actions that may be required.
4. Provide feedback to the subcontractors using a visualization and dissemination tool. The subcontractors' electronic panel system (SEP) is used for helping visualize the evaluation results and for storing them during the project execution. The system was developed by the GEPUC team using Microsoft EXCEL and programmed in Microsoft VISUAL BASIC FOR APPLICATIONS. We used the "expressions" evaluation system, which had three mood states: *happy*, *indifferent*, and *sad*. *Happy* indicates that the contractor was satisfied with the subcontractor's performance with respect to the dimension being evaluated, whereas *sad* indicates that the performance was unsatisfactory. Otherwise, the evaluation was *indifferent*. Each mood has an associated graphical representation and a color in SEP. The graphical representation is a face with the appropriate expression and the associated color is green, yellow, and red, for *happy*, *indifferent*, and *sad*, respectively. The expression evaluations also have a numeric equivalent: 100 corresponds to *happy*, 50 to *indifferent*, and 0 to *sad*. The main advantage of this evaluation system is its simplicity, which facilitated both the evaluation by the main contractor and the interpretation by the subcontractors. Fig. 1 shows an example of how subcontractors' evaluations for a given week, as well as their PPC, could be displayed in a work site. Our experience showed that displaying the evaluations in a large panel placed on a highly visible place in the site was very effective.

Once the project ends, it is important to store the evaluations so that they can be used when selecting subcontractors for a future project. The firm should consolidate the information in a central database for this purpose. The SEP system could be also be used for this purpose.

Construction Firm				Site:	
Firm	Quality	Schedule fulfillment	Safety	Cleanliness	PPC
Painter 1	🙂	🙂	🙂	😐	63
Painter 2	☹	😐	🙂	😐	78
HVAC 1	🙂	🙂	🙂	🙂	100
Metal 1	🙂	😐	🙂	😐	80
Tiles 1	☹	☹	🙂	☹	73
Sanitary 1	🙂	😐	🙂	😐	88
Supplier 1	☹	☹	😐	😐	54

Good 🙂 Regular 😐 Bad ☹

Fig. 1. Example of a subcontractor evaluation panel at a work site

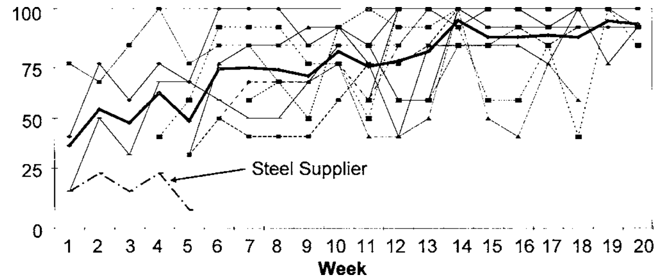

Fig. 2. Weekly average evaluation of the subcontractors in the sports center case study

Discussion of the Proposed Method

The experience of using the proposed subcontractor evaluation method was well evaluated by the project team. It worked very well in most of the projects; there were no failures, only some implementation problems, which provided valuable lessons. One of the issues that turned out to be very important was the visibility of the dissemination tool. A project in which the subcontractor evaluation panel was less visible (inside an office) had much less improvement of the subcontractors' performances during the project than when it was highly visible (at the entrance of the site). Also the attendance of as many subcontractors and suppliers as possible to the planning meetings proved to be important. Otherwise the dialogue instance lost effectiveness.

One aspect that needs more work is the evaluation of suppliers. In all the projects that evaluated one or more suppliers, their performance was poor and there was no improvement during the project.

Another important finding was that the proposed method was relatively easy to use and well received, both by the main contractors and the subcontractors. However, the method has to be customized to a certain degree to take into account the culture of each firm. It also has to be able to change as the firm evolves.

A computer system to support the evaluation is necessary to manage all the relevant data and compute the weekly evaluations. The SEP system developed by the GEPUC team greatly facilitated these tasks. It also has analysis tools and generates useful graphs, some of which are shown later. The system, however, has to be very flexible in order to be effective. It must be able to be customized together with the method.

An aspect that was not possible to study was the use of previous evaluations in the selection of subcontractors and suppliers. However, this could be one of the most important applications of the proposed method. The SEP system included some features to support the use of previous evaluations in the subcontractor selection process.

Case Studies

The case studies that will be described next were selected from the eight projects initially implemented by GEPUC. As the *Last Planner* system was used in all these projects, the required weekly planning meeting was used as the instance for discussion in the proposed method.

Sports Center Case Study

This project involved the construction of two buildings: A single floor gymnasium and a two-floor administration building for a sports center. The total surface of the buildings was approximately 3,000 m^2. The project was finished on time in five months. Subcontractors performed 51% of the project.

The criteria used to evaluate the subcontractors were: quality, safety, tidiness and cleanliness, supervision, administrative procedures, and commitment. The on-site administration decided to evaluate only those subcontractors that worked at the site for 3 or more weeks, which reduced the number of evaluated subcontractors to 17, including a steel supplier.

Several important subcontractors were invited to participate in the *Last Planner* weekly planning meetings even before they began to work on the site, which facilitated their insertion in the project. The evaluation was usually conducted by the site supervisors, the site manager, the foremen, and those in charge of safety. The dissemination tool was a 2 by 1.5 m panel similar to that shown in Fig. 1, which was placed at a highly visible place at the site entrance where everybody, including workers and visitors, could see the evaluations and the PPC.

Data Analysis

Fig. 2 shows the weekly average evaluation of the subcontractors generated by the SEP computer system. The slim lines, which in the computer system are in different colors, correspond to the subcontractors' weekly evaluations. The thicker line is the average obtained by all the subcontractors in each week. The evaluation of each subcontractor was computed as the weighted average of the evaluation of each attribute. The subcontractors were given the evaluations of each attribute and its weight.

The average evaluation obtained by all the subcontractors shows an ascending trend during the project. It increased from around 50 in the first few weeks to an average evaluation of almost 90 at the end of the project. Fig. 2 also shows that the steel supplier had a very low evaluation, with no improvement during the project. This could be explained by the low level of commitment of a firm that did not participate directly at the work site.

Fig. 2 also shows an important variability in the evaluation of each subcontractor. Fig. 3 shows that the difference between average evaluations from one week compared to the week before tends to diminish as the project progresses. This reduction of variability during project execution is an indication of the success of the subcontractor evaluation method. Toward the end of the project, subcontractors' evaluations were good and varied very little.

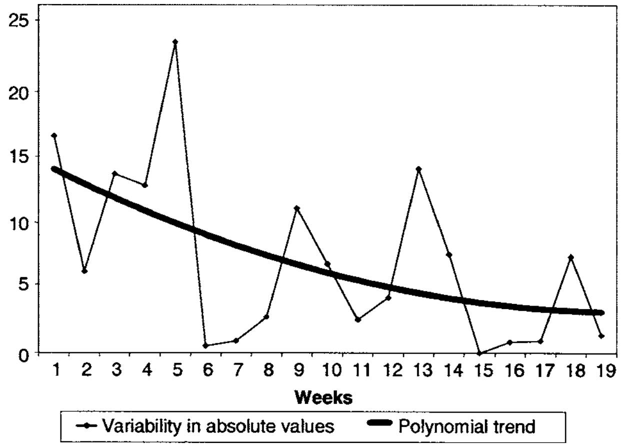

Fig. 3. Weekly evaluation variability of subcontractors in the sports center case study

Lessons Learned

The main lessons learned in this case study were the following:

1. Keep track of PPC. Although the subcontractors' fulfillment of the commitments acquired in the planning meeting was measured by the weekly PPC indicator of the *Last Planner* system, it was difficult to visualize the improvement. This was solved by monitoring the evolution of the PPC of each subcontractor during the project.
2. Promote a measuring culture to monitor subcontractors' performances. For example, subcontractors' productivities could be measured using customized indicators for each specialist.
3. Importance of the dissemination tool. Having the panel in a highly visible place had a great impact, not only on the workers at the work site, but also on visitors. The work site manager reported several instances in which visitors from other sites noticed a subcontractor that worked at their site that was poorly evaluated in the panel. This had a clear impact on that subcontractor's reputation.
4. Importance of including the subcontractors in the weekly planning meetings. The work site manager reported that including the subcontractor in the weekly planning meetings greatly reduced the uncertainty in the project execution.
5. Importance of integrating suppliers. In this case study, the only supplier that was evaluated did not improve its performance. A possible explanation is that the supplier had little connection with the work site. One way to improve this is to deliver periodic reports directly to the supplier's senior management.
6. Hand out customized weekly reports to subcontractors. This report not only gives them valuable feedback to help them improve their performance, it also gives them official information they can use to promote their services.

Apartment Building Case Study

This project comprised the construction of an apartment building in downtown Santiago. The total built surface was around 2,500 m^2, including 7 stories over the ground and 2 underground floors for parking. The project took almost a year to complete. The criteria selected for evaluations were: schedule fulfillment, quality, safety, and tidiness and cleanliness.

Initially only a few critical subcontractors, of the 11, were invited to participate in the *Last Planner* weekly planning meetings. After several months, more subcontractors were included in the meetings, but the attendance never reached 100%. The planning meetings were frequently rescheduled and almost never started on time, although this tended to improve as the project execution advanced. The visualization tool was again a 2 by 1.5 m panel in a highly visible place.

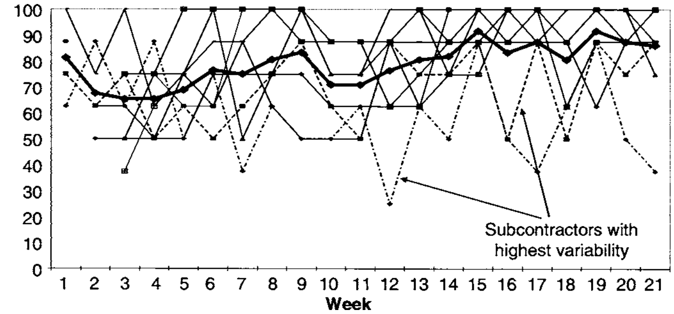

Fig. 4. Weekly average evaluation of the subcontractors in the apartment building case study

Data Analysis

Fig. 4 shows the weekly average evaluation of the subcontractors, where the slim lines correspond to each of the eleven subcontractors' weekly evaluations and the thicker line is the average obtained by all the subcontractors in each week. The evaluations shown in this figure correspond to the primary phase of construction. After this stage was finished, the firm changed its evaluation system to a more objective one.

Overall, the subcontractors' average evaluations increased from 67.5 points in the first weeks, to 88.5 at the end of the primary phase of construction. Although the initial evaluation was relatively high, it was based on very little information. Note also the fall in the evaluation in the middle of the project, and the renewed increase in productivity that continued until the end of this phase. This coincided with a refinement of the system, an increase in the commitment of the professionals working on-site, and a few phone calls from the central office to support the implementation of the method. Fig. 4 also shows that two subcontractors, shown in dashed lines, exhibited a high variability through the entire evaluation period. The rest of the subcontractors (over 80%) reduced the variability of their evaluations as the project progressed.

In this project there were two molding subcontractors with quite different performances. The results shown in Fig. 5, which was generated by SEP, indicate that molding subcontractor 2 had a higher average evaluation than subcontractor 1 (73.75 versus 58.92). The evaluations also show that subcontractor 2 consistently improved, while subcontractor 1 had such a high variability that it is impossible to discern any trend.

Lessons Learned

The main lessons learned in this case study were:

1. Importance of maintaining a fixed day for the planning meetings. At the beginning the meetings constantly changed from one day to another. This caused the attendance to drop, which deteriorated the communication between the main contractor and the subcontractor. When the problem was detected it was solved by setting a fixed day for the meeting. This had an almost immediate effect on the evaluations.
2. Importance of keeping track of the evaluations. This allows

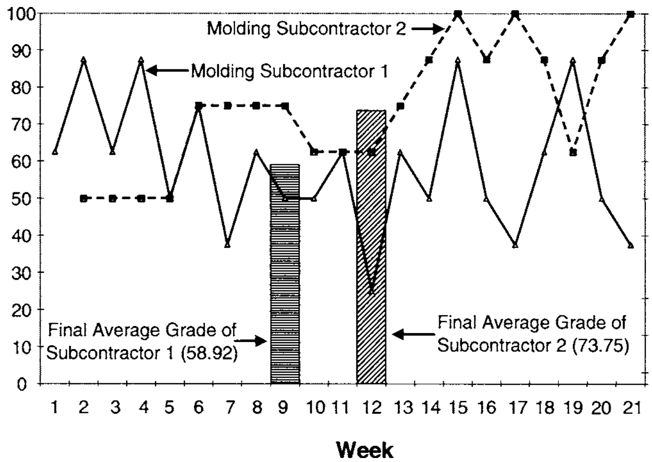

Fig. 5. Comparison of two subcontractors of the same specialty in the apartment building case study

the comparison of subcontractors of the same specialty to determine which is the best one.

Conclusions

From the experience gained using the method in different projects, it was concluded that, in order to successfully implement it, main contractors must be rigorous, persevering, and fair. Rigorous so the evaluations are taken into account, persevering to overcome cultural barriers, and fair to avoid unnecessary conflicts with the subcontractors.

Interviews with subcontractors' employee firms and project managers allowed us to conclude that the evaluation method was regarded as reliable, accurate, and useful. Reliable because it helped resolve many disputes, accurate because it proved to be a good indicator of what was going on, and useful because it helped the subcontractors' supervisors to monitor their workers on-site performance.

In future work we are considering improving the implementation of the method to allow it to collect more data to better support a prequalification system. It would also be of great value to study whether the productivity of projects that rely on such a system is better than those that do not.

If the proposed method is successfully implemented in many construction firms, it can help change the widespread practice of selecting subcontractors based solely on price. The method supports an interlinked relationship between on-site management and the preselection/selection system. Furthermore, a selection/evaluation system based on this method should help improve subcontractor performance, thus improving the main contractor's overall performance. It can also help identify critical areas for subcontractor performance improvement. Finally, it can also be used to generate a database with subcontractors' performances, which can be used to benchmark them.

The traditional construction firm is being replaced by firms with strong technical offices capable of generating winning proposals and managerial teams capable of successfully managing small or medium subcontracting firms, which can handle 80, 90, or even 100% of the processes at the work site. The main contractor is becoming an intermediary who must manage subcontractors to satisfy the client's demands, at the least possible cost.

The proposed method allows for the implementation of an on-site evaluation system that should help reduce subcontractor-generated uncertainty, give feedback to the subcontractors, increase knowledge of subcontractors' performances, improve on-site performances, and coordinate efforts to develop collaborative work among subcontractors and the main contractor.

Currently the writers are developing a common, objective, and standardized evaluation method, which will allow information to be shared among main contractors. SEP, the prototype system that supports this method, is also being improved and will be integrated into the *Last Planner* system developed by GEPUC. This will result in a powerful tool that will help improve construction firms' productivity.

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