Case Study

Analysis of Factors Influencing Productivity Using Craftsmen Questionnaires: Case Study in a Chilean Construction Company

Rodrigo A. Rivas[1]; John D. Borcherding, Ph.D., M.ASCE[2]; Vicente González, Ph.D.[3]; and Luis F. Alarcón, Ph.D., A.M.ASCE[4]

Abstract: Improvement of productivity in construction has been a major industry challenge, given its high impact on project results. It has received increased attention from construction researchers promoting different enhancement actions, since analyzing factors affecting labor productivity is an instrumental part in this process. This paper focuses on identifying and understanding the productivity factors affecting projects in a Chilean construction company on the basis of questionnaires administered to both direct workers and midlevel employees. Analysis of the questionnaire results helped to determine organizational and managerial weaknesses and facilitated comparison of the findings with previous productivity studies. The results proved to be useful in developing recommendations for productivity improvements. The main findings indicate that the critical areas affecting construction productivity were related to materials, tools, rework, equipment, truck availability, and the workers' motivational dynamics. These results are similar to those obtained in previous studies in the United States and in Chile. Salary expectations were found to be the main reason for turnover in the studied company, which was an aspect not mentioned in previous studies. Finally, additional analyses seem to show that some factors affecting productivity are common to construction projects across boundaries, therefore validating data aggregation and the possibility of learning from experiences in different locations and even separated in time of occurrence. **DOI:** **10.1061/(ASCE)CO.1943-7862.0000274.** © *2011 American Society of Civil Engineers.*

CE Database subject headings: Case studies; Construction management; Productivity; Chile.

Author keywords: Case study; Construction productivity; Craftsmen questionnaires.

Introduction

The construction industry in Chile has been affected by globalization. Similar to what happens in other industries, the new presence of foreign construction companies in the country generates strong competition (Ramírez et al. 2004), and each company then faces increased difficulties for a position in the market.

For the past 3 years, existing mining projects in Chile have been expanded and new ones created, all of them in need of construction services that force increased competition. Prices, financial status, environmental management, quality management, safety management, project teams, and skilled labor become issues very carefully assessed when awarding jobs to contractor companies. In this context, labor productivity performance plays a key role in determining the financial success of a project (Liu and Ballard 2008). In theory, productivity is defined as output divided by input, where both output and input are usually expressed in cost. In construction, it is more often described as units of production output per personnel-hour input (Neil and Knack 1984; Thomas 2000).

Some writers have reported that labor costs account for between 30 and 50% of a project's total cost (Harmon and Cole 2006; Hanna 2001). Labor cost is regarded as one of the project components carrying the most risk (Hanna 2001). Construction labor productivity is perceived in the United States as an economic variable that has gradually declined since the 1960s (Dai et al. 2009). In Chile, labor productivity has not shown any growth, remaining constant (INE 2007) during the previous decade (1996–2006). In both countries, the evidence seems to show a behavior without substantial improvements in construction's labor performance over time. Given this scenario, identifying and implementing management actions to improve construction labor productivity is not only desirable but also necessary.

The first step in finding opportunities for improvement in labor productivity is to identify what factors are affecting it. After identifying the factors, managers can effectively act upon them to lower costs, enhance scheduling, and eventually obtain a more accurate productivity prediction when estimating construction costs (Borcherding and Alarcón 1991; Edmondson 1974). Although many factors are mentioned in the literature affecting construction labor productivity (Borcherding and Alarcón 1991; Christian and Hachey 1995; Dai et al. 2009; Sonmez and Rowings 1998; Thomas et al. 2006, among others), research in this topic has been very limited or nonexistent for the Chilean construction industry.

[1]M.Sc.E., Dept. of Civil, Architectural and Environmental Engineering, Univ. of Texas at Austin, 1 University Station C1752, Austin, TX 78712-0273; and Civil Engineer, M.S. Pontificia Universidad Católica de Chile (corresponding author). E-mail: rrivasl@hotmail.com

[2]Adjunct Professor, Dept. of Civil, Architectural and Environmental Engineering, Univ. of Texas at Austin, 1 University Station C1752, Austin, TX 78712-0273. E-mail: borch@mail.utexas.edu

[3]Lecturer, Dept. of Civil and Environmental Engineering. Faculty of Engineering, The Univ. of Auckland, Private Bag 92019, Courier Address: 3 Grafton Rd., Auckland 1142, New Zealand, 3737462. E-mail: v.gonzalez@auckland.ac.nz

[4]Head and Professor, Dept. of Construction Engineering and Management, Pontificia Universidad Católica de Chile, Casilla 306, Correo 22, Santiago, Chile. E-mail: lalarcon@ing.puc.cl

Note. This manuscript was submitted on August 4, 2009; approved on August 3, 2010; published online on August 23, 2010. Discussion period open until September 1, 2011; separate discussions must be submitted for individual papers. This paper is part of the ***Journal of Construction Engineering and Management***, Vol. 137, No. 4, April 1, 2011. ©ASCE, ISSN 0733-9364/2011/4-312–320/$25.00.

Review of Previous Studies

Determining the factors affecting labor productivity in construction has received increased attention during the past four decades, even though very little research has been carried out in the Chilean industry. Several publications have dealt with the study of factors affecting labor productivity. Researchers and practitioners have suggested different productivity factors and research approaches (Abdul Kadir et al. 2005; Borcherding et al. 1986; Borcherding and Alarcón 1991; Contractors Consultants Corporation 1981; Dai et al. 2009; Garner et al. 1979; Halligan et al. 1994; Jansma 1987; MCA 1976; O'Connor 1969; Rojas and Aramvareekul 2003; Thomas and Jansma 1985; among others).

According to Borcherding et al. (1986), the five major categories of unproductive time that produce labor productivity losses are waiting or idle, traveling, working slowly, doing ineffective work, and doing rework. Borcherding and Alarcón (1991) have suggested several categories of factors and subfactors affecting productivity (Table 1).

A number of academic research efforts have been performed in the construction industry with in-depth studies on several of the productivity factors and subfactors shown in Table 1. For instance, Thomas and Jansma (1985) analyzed productivity losses over nuclear projects related to an accelerated schedule focusing on staffing levels, in which they proposed a methodology to estimate the productivity loss related to this issue. Hanna et al. (2007) examined the effects of overstaffing on labor productivity on mechanical and sheet metal projects losses through a survey of various contractors, developing statistical analysis of the survey results to find out a quantitative relationship between overstaffing and labor productivity. Similar research on electrical and mechanical projects was developed by Gunduz (2004), in which overstaffing effects on labor productivity were studied. The National Electrical Contractors (NECA) carried out experiments to quantify the effects of weather conditions, such as humidity and temperature, on labor productivity (NECA 1974). Thomas et al. (1999) studied the effect of material delivery practices and unfavorable winter weather situations on labor performance using structural steel erection projects. Hanna et al. (1999) studied the impact of change orders on labor productivity, developing statistical models from mechanical trade data, which allowed quantitative explaining and predicting this relationship. Hanna et al. (2005) investigated the schedule acceleration problem, studying the consequences of overtime over labor efficiency through statistical analysis of production data from electrical and mechanical trades. Hanna et al. (2008) also analyzed the schedule acceleration issue by using qualitative and quantitative project data from diverse specialty trades, such as mechanical and sheet metal contractors, and focusing on the effect of shift work on labor productivity. A research study analyzing the effects of timing changes over labor productivity over a wide range of projects was conducted by Ibbs (2005). The impact of management practices as related to reliability on labor productivity planning has been also studied as a relevant factor (González et al. 2008; Liu and Ballard 2008).

Although much research has been done on labor productivity, there is a lack of detailed research on the factors affecting labor productivity in construction projects in Chile. Even though a number of actions and initiatives have been developed to enhance labor productivity in construction projects (Alarcón and Calderón 2003; Alarcón et al. 2008; Grillo et al. 2003; among others), little effort has been made to systematically identify and classify labor productivity factors.

Table 1. Factors and Subfactors Affecting Labor Productivity (Adapted from Borcherding and Alarcón 1991)

Main factor	Subfactors
Schedule acceleration	(1) Overcrowding and/or overmanning
	(2) Peak craft level and single craft population
	(3) Scheduled overtime
Poor coordination	(4) Stacking of trades
	(5) Concurrent operations
Changes	(6) Reassignment of manpower
	(7) Deterioration of learning curves
	(8) Ripple effect
	(9) Engineering errors and omissions
Resources and site management	(10) Site conditions and organization
	(11) Materials and tools availability
	(12) Material handling space
	(13) Site access
	(14) Interference
	(15) Poor lighting and housekeeping
	(16) The size and dispersion of tasks
	(17) Methods and equipment
	(18) Size of a crew
Management characteristics	(19) Management control or project team
	(20) Dilution of Supervision
Project characteristics	(21) Project size
	(22) Work types
	(23) Beneficial occupancy
	(24) Joint occupancy
	(25) Fast track
	(26) Subcontract
Labor and morale	(27) Quality of craftsmanship
	(28) Quality control and quality assurance practices
	(29) Absenteeism
	(30) Craft turnover
	(31) Fatigue
	(32) Morale
	(33) Wages
Project location and external conditions	(34) Economical activity or availability of skilled labor
	(35) Commuting time
	(36) Support community size
	(37) Weather
	(38) Population differences

Research Methodology

This paper reports on a case study conducted to explore the main factors affecting labor productivity. Mining projects are analyzed to find potential root reasons for these factors, as well as quantifying lost work time in the Chilean construction industry. In general, the mining sector in Chile is a very competitive market that outsources many of its productive operations to construction companies. Questionnaires administered to craftsmen were used to capture perceptions of project personnel regarding productivity issues because a good understanding of the factors influencing productivity can be obtained from the workforce's viewpoint. This approach can lead to improved management and allocation of material and labor resources (Dai et al. 2009).

J. Constr. Eng. Manage., 2011, 137(4): 312-320

The main objective of this research was to explore the factors in Chilean construction projects that decrease labor productivity or prevent its improvement. This work consisted of the case study strategy and making use of information gathered from three mining projects that illustrate particular characteristics of the factors affecting labor productivity. A secondary objective was to compare these productivity factors with previous studies, with the aim of analyzing potential patterns and trends across projects and countries, as well as obtaining a more in-depth understanding about factors affecting productivity in construction.

Case study research is a strategy often used in project management. In general, case studies are the preferred strategy in dealing with "how" and "why" questions, when the investigator has little control over events, and when the focus is on a contemporary phenomenon within some real-life context (Yin 1994). Craftsmen questionnaires were selected as instruments for collecting information because of their simplicity and the confidence coming from validation in previous research in U.S. Department of Energy (DOE) projects (Garner et al. 1979). A good understanding of the factors affecting labor productivity can be obtained through the viewpoint of those directly related with on-site production in construction projects. This can also enable site managers to make decisions more effectively to improve labor productivity (Dai et al. 2009).

The following research stages were defined to achieve the goals of this paper: (1) a literature review was carried out on the factors influencing productivity, survey studies, and case study research; (2) several mining projects of a Chilean general contractor were selected and constituted the case study; (3) a questionnaire was prepared, based on the DOE survey (Garner et al. 1979), modifying some of its questions to fit the analysis context (Appendix, Fig. 1 shows an example of the survey questions); (4) specific project personnel were selected, consisting of midlevel managers and craftsmen-level employees directly related with on-site operations; (5) collected information from surveys was analyzed to determine the main factors affecting labor productivity (using different ranking approaches), the perception of lost time in construction operations, possible reasons for problems in projects, and demotivators and motivators in the labor work; and (6) the main case study findings were compared with results of previous studies.

This research was exploratory in nature, rather than explanatory; whereas there is no evidence about the issues investigated in the local construction industry, it is instrumental to propose further improvement actions.

Determining Productivity Factors in the Case Study

The company analyzed is a medium-sized general contractor in Chile. Its projects are generally located in the central and northern parts of Chile. The company specializes in earth movement, heavy construction, industrial construction, and some industrial building construction. The firm maintains a diverse base of clients that include mining outfits, cellulose mills, power plants, water treatment centers, public infrastructure projects, water supply companies, and private investors.

The company utilizes a low percentage of subcontractors and owns some heavy construction equipment. Its annual invoiced volume is around \$50 million. The company employs 150 full-time people on contracts, and 1,000 to 1,400 people contracted on a project basis.

The company works typically on four to eight projects concurrently, with a range from \$1 million to \$20 million. In some cases, it works on joint ventures with other construction companies to accommodate abnormal objective markets according to specific project requirements or work capital requirements.

The company has been working under ISO 9001 and ISO 14001 for several years. In safety, it has maintained good performance compared with the national average and works according to international standards dictated by mining companies in Chile. Recently, it obtained OHSAS 18001 certification.

For conducting the research, three out of eight existing projects were chosen, at different locations and with different features, as shown in Table 2, which lists various project aspects such as safety performance, project duration, contract type, and price.

Survey Questionnaires

The data for this study were the results of 28 questionnaires administered to 19 direct workers (foremen, craftsmen, and helpers) and nine midlevel employees (administrative, warehouse, quality control, and field supervisors) working on the projects. Tables 3 and 4 describe the type of work and specialty of every person surveyed. Tables 5 and 6 describe questionnaire characteristics (number and type of questions), targeting specific project information as well as problems and motivation data.

The data provided important information on the current status of the company's projects and provided insight for identification of key factors affecting productivity, along with possible actions for improvement. The results of this research reflect the opinions of the people interviewed, who are directly associated with on-site work; and therefore this information is instrumental toward identifying labor productivity factors at the project operation level.

Survey Results Analysis

After processing the information from the questionnaires, some clear trends were observed with respect to the main factors influencing craft productivity, as summarized in Tables 7 and 8. Table 7 identifies the major factors by simply comparing the total affirmative answers in each influence item (see the first question in Fig. 1), Table 8 defines a relative index (RI) to state a ranking of the most relevant influence items (calculation details included in Table 8). Accordingly, the main factors identified were materials, rework, equipment and trucks, tools, and rework. These results are consistent with those obtained in previous research in Chile that identified causes for not completing weekly plans in projects (Alarcón and Calderon 2003).

The perception of hours lost per week per person is presented in Table 9 (second question in Fig. 1). The total hours lost per week per worker is a rather high 32.44 h, without including rework. Table 9 indicates that the lost time for the first four factors—materials, tools, design interpretation and equipment, and trucks—represents 59% of the total waiting time.

Considering that the employees work 45–50 h per week (including extra hours—see Note B in Table 2), 32.44 h lost represent 65% to 72% of the workweek, indicating a very high percentage of lost time. However, this does not mean that the workers work only 28% to 35% of the time, but instead, points to the potential effect that management and/or the client could have on the cumulative work time. If direct personnel perceptions are analyzed, they indicated 26.35 lost hours, representing 53–58% of the workweek.

By comparing the results per project, there exists a minimum amount of hours lost that all employees (direct and midlevel) perceive as caused by management (e.g., contractor project manager, field superintendent, among others) and/or the client (e.g., owner, project manager), involving the influence of their decisions/actions and supporting organization. At least 40% (19 h of every 45 to 50 h) of weekly work hours (Table 9) was attributed to management

J. Constr. Eng. Manage., 2011, 137(4): 312-320

Table 2. Projects of the Research

Project #	1	2	3
Name	El Torito	Water pumped Guardia Tunnel	Pipes and pool for cooper concentrated
Owner	Mining company 1	Mining company 2	Mining company 2
Location	V Region, Chile	IV Region, Chile	IV Region, Chile
Main Works	Earth movement, civil works, vertical excavation, channel	10.5 km steel pipe line, 1.2 HDPE pipeline, civil works, electrical, instrumentation	Earth movement, civil works, HDPE pipelines
Duration (months)	12.2	4.0	5.0
Total direct (WH)[a]	125,300	62,000	57,000
People (D/I)[a]	164 (124/40)	104 (78/26)	75 (55/20)
% completed	59%	48%	92%
Total $ (MM dollars)	6.6	3	3.2
Status (schedule)	On schedule	Late	On schedule
Status (cost)	Below estimated	Within cost	Within cost
Work system[b]	M–F: 5dw × 2dnw/9 h[a]	10dw × 4dnw/8.5 h[a]	10dw × 4dnw/8.5 h[a]
Contract type	Unit price	Unit price	Unit price
Accidents	5 without lost time 0 lost time	0 without lost time 0 lost time	0 without lost time 0 lost time
Turnover	17%	33%	13%
Survey people (D/ML)[a]	15 (10/5)	8 (6/2)	5 (3/2)

[a]Key: WH = work hours; D = direct; I = indirect; MM = million; M–F = Monday to Friday; dw = days working; dnw = days nonworking; ML = medium level.
[b]In general, an average of 5 extra hours per week can be considered in these weekly work systems (total 45–50 h), according to project personnel perceptions.

Table 3. Surveyed Workers by Type of Work

Type of work	Activity	Number	Total number
Direct	Helper	1	19
	Foreman	5	
	Craftsman	13	
Indirect medium level	Administrative	1	9
	Warehouse	3	
	Quality	1	
	Supervisor	4	
Total			28

Table 4. Surveyed Workers by Specialty or Area

Specialty	Type of work	Number	Total number
Warehouse	Indirect medium level	3	3
Quality control	Indirect medium level	2	2
Earth movement	Direct	2	2
Civil works	Direct	13	17
	Indirect medium level	4	
Piping	Direct	4	4
Total			28

Table 5. Questionnaire Characteristics: Project Information

Topics	Number of questions	People interviewed
General	7	Top project management
Contract	8	
Personnel	7	
Resources	6	
Safety	2	
Total	30	

Table 6. Questionnaire Characteristics: Problems and Motivation Information

Topics	Number of questions	People interviewed
Personal data	7	Direct and medium indirect level project employees
Rework	4	
Materials	4	
Tools	6	
Equipment and trucks	4	
Crew interference	5	
Overstaffing	4	
Instructions	4	
Quality control	4	
Design and engineering information	4	
Turnover	3	
Absenteeism	3	
Summary	5	
Motivation	3	
Total	60	

support of the workforce. However, looking at the direct personnel's perceptions of lost work hours in Table 9, the minimum amount of hours lost that the direct workers perceive as caused by management and/or client is at least 15% (7 h of every 45 to 50 h) of weekly work hours. They indicated that critical problematic areas common to every project are materials, tools, and instructions; other problems are project-specific. These calculations are based on the minimum and maximum levels for the total average hours lost per worker per person and are shown in Table 9, comparing the results of the three projects (see comparison columns).

In determining the causes of problems, the workers interviewed stated possible reasons for each of them.

J. Constr. Eng. Manage., 2011, 137(4): 312-320

Table 7. Main Factors Influencing Craft Productivity

Sample size total: 28; direct: 19; midlevel: 9	Total affirmative responses			Percentage (affirmative responses/sample size) × 100		
Influence	Total	Midlevel	Direct	Total	Midlevel	Direct
Materials	21	8	13	75%	89%	68%
Rework	16	6	10	57%	67%	53%
Equipment and trucks	15	6	9	54%	67%	47%
Tools	15	5	10	54%	56%	53%
Interference	9	4	5	36%	44%	26%
Instructions	9	4	5	36%	44%	26%
Design interpretation	7	5	2	29%	56%	11%
Inspections	6	3	3	25%	33%	16%
Absenteeism	5	2	3	18%	22%	16%
Overcrowded work areas	4	2	2	18%	22%	11%
Turnover	4	2	2	18%	22%	11%

Table 8. Ranking of Factors Influencing Craft Productivity

Sample size total: 28; direct: 19; midlevel: 9	Points (p.) total rank order 1st: 3 p./2nd: 2 p./3rd: 1 p.			Relative index (RI) number of points/(3*sample size)		
Problem area	Total points rank	Midlevel points rank	Direct points rank	Total RI	Midlevel RI	Direct RI
Rework	21	8	13	0.25	0.3	0.23
Materials	39	10	29	0.46	0.37	0.51
Tools	24	8	16	0.29	0.3	0.28
Equipment and trucks	19	6	13	0.23	0.22	0.23
Other crews not finished	5		5	0.06	0	0.09
Waiting for instructions	2	2		0.02	0.07	
Waiting for quality control	2		2	0.02	0	0.04
Waiting for design interpretation/ engineering information	8	5	3	0.10	0.19	0.05
Turnover	6	2	4	0.07	0.07	0.07
Absenteeism	9	1	8	0.11	0.04	0.14
Parking and access roads	1		1	0.01	0	0.02
Quality of work	5	3	1	0.06	0.11	0.02
Quality of supervisors	1	1		0.01	0.04	0
Safety	4	2	2	0.05	0.07	0.04

1. *Materials:* Workers attributed the primary cause of material-related problems to the lack of on-time delivery from the central warehouse; the second cause is the lack of materials available before work starts; the third is the issue of materials being far from the work areas; and the fourth is excessive paperwork. Workers also indicated that there was insufficient equipment to move materials, possibly from the field lacking logistics or support review.
2. *Tools:* The main reason stated for tool problems was an insufficient number of tools for the people in the field. Second, tools were unavailable when required, broken when needed, and not replaced when broken. The participants also indicated that the tool room was too far from the work area or that it operates inefficiently. Only one person stated that people did not take care of the tools. Some of the problematic tools were electric saws, electric generators, grinders, drills, picks, shovels, pike poles, gas (oxyacetylene), radios, electrical extensions, and electric hammers. Some of the problematic consumables were solder, lumber, metallic tape, concrete consumables, gasoline, safety tape, tape measures, saw blades, drill bits, safety shoes, hardhats, and safety signals.
3. *Equipment and trucks:* The main reason for this type of problem concerned the availability of sufficient trucks in the field, especially for moving materials or tools. The workers consider the process to get equipment or trucks too long and lacking coordination for getting what is necessary when required.
4. *Rework:* Workers indicated that the primary cause of rework was related to change orders made by clients; the secondary cause was design errors or lack of project definition. Only 20% of the causes for rework were linked to field errors or misunderstandings.
5. *Interference among crews:* Even though it was not considered a major problem, the reasons given were small work areas, excessive numbers of people assigned to an area, and lack of coordination between crews.
6. *Overcrowded work areas:* Even though it was not considered a major problem, the reasons given were lack of coordination among supervisors and lack of detailed planning among crews.
7. *Waiting for instructions:* Workers assigned equal roles to engineering, central office, supervisors, and clients as the causes of delay of instructions, although this factor was of minor importance.

J. Constr. Eng. Manage., 2011, 137(4): 312-320

Table 9. Perception of Average Hours Lost per Worker per Person per Week in Each Project

Sample size total: 28; direct: 19; midlevel: 9	Survey perception																	
	Average hours lost per worker per week												Comparison					
	Total average delay by			Project 1 average delay by			Project 2 average delay by			Project 3 average delay by			Total comparison of each project			Direct comparison of each project		
Problem areas	Total	Direct	Midlevel	Total	Direct	Midlevel	Total	Direct	Midlevel	Total	Direct	Midlevel	Max	Min	Differ	Max	Min	Differ
Materials	5.30	4.25	7.41	4.30	3.60	6.00	5.20	3.30	9.00	6.90	6.70	7.20	6.90	4.30	2.60	6.70	3.30	3.40
Tools	5.29	4.90	6.25	6.70	7.00	6.00	4.00	2.70	8.00	4.50	4.30	1.00	6.70	4.00	2.70	7.00	2.70	4.30
Design interpretation	4.40	4.00	4.40	3.70	4.00	3.50	4.00	0.00	4.00	5.50	0.00	5.50	5.50	3.70	1.80	4.00	0.00	4.00
Equipment and trucks	4.20	4.20	4.20	4.30	4.60	3.50	3.00	3.00	3.00	3.70	0.00	5.50	4.30	3.00	1.30	4.60	0.00	4.60
Interference	4.00	4.50	3.33	5.70	6.00	5.00	3.30	3.00	1.00	1.00	0.00	1.00	5.70	1.00	4.70	6.00	0.00	6.00
Overcrowed work areas	3.50	1.00	6.00	0.00	0.00	0.00	1.00	1.00	0.00	6.00	0.00	6.00	6.00	0.00	6.00	1.00	0.00	1.00
Inspections	3.00	2.00	4.00	3.00	3.00	0.00	1.50	1.00	2.00	6.00	0.00	6.00	6.00	1.50	4.50	3.00	0.00	3.00
Instructions	2.75	1.50	4.00	2.00	2.00	1.00	1.50	1.00	2.00	4.30	1.00	6.00	4.30	1.50	2.80	2.00	1.00	1.00
Others																		
Total	32.44	26.35	39.59	29.70	30.20	25.00	23.50	15.00	29.00	37.90	12.00	38.20	45.40	19.00	26.40	34.30	7.00	27.30
Rework	3.69	4.11	2.75	3.63	4.00	3.00	4.00	4.00	0.00	3.75	4.30	2.00	4.00	3.63	0.37	4.30	4.00	0.30

8. *Waiting for inspections:* Workers indicated that the main reasons for inspection delays were inspector incompetence, lack of preplanning of quality control, not notifying quality control in advance, and difficulty understanding drawings and specifications.
9. *Design interpretation and additional engineer information:* The workforce indicated the reasons were poor drawings and specifications, engineers unfamiliar with field conditions, and indecision.
10. *Turnover:* Salary (better salary offers or salary expectations) was the most important reason indicated by the workers for high turnover in the company; other reasons were personal problems, preference for working close to home, lack of incentives, short-term contracts, better work system, and supervisor treatment.
11. *Absenteeism:* A wide range of reasons was cited for not working during the shift. Those include sickness, fatigue, alcoholism, personal problems, and time for personal activities. This last reason is relevant in a Monday to Friday (M–F) workweek system, because a significant portion of the employees lived out of the work area and needed personal time.
12. *Supervision ratio:* Another important aspect was the worker-supervisor ratio. There is no fixed rule in other regions, such as American union regulations concerning the supervision ratio. It depends on the specialty and the opinion of the high-level supervision. A ratio of 10 to 12 workers per foreman is expected, and 20 to 30 workers (two or three crews) per supervisor. It was indicated in the survey that the foreman supervised a crew of five to 16 people, with an average of nine people in the crew. For supervisors (a field-trained person with a wealth of experience and no formal studies), the range of people is 13 to 36, with an average crew size of 23.
13. *Motivation:* The study registered the motivators and demotivators affecting the employees, but it was generally related to the company more than to the project, which has been separated into direct workers and midlevel employees in the following categories:

- *Direct work employee demotivators:* (1) doing work of other specialties; (2) lack of coordination; (3) lack of materials; (4) requirement to do rework of their own work; (5) lack of solutions to problems; (6) problems with trucks; (7) problems with equipment; (8) lack of safety; (9) short-term contracts (because the project is short or divided into many contracts); (10) unfair work assignments: one group may perform the work of another specialty group, but it may feel that there is no reciprocation (i.e., other groups do not perform their work); (11) doing cleanup; and (12) lack of electricity (equipment in the field).
- *Midlevel indirect work employee demotivators:* (1) lack of collaboration; (2) lack of communication with project personnel and the client; (3) lack of commitment; (4) lack of confidence; (5) lack of worker recognition; (6) lack of equipment; (7) lack of materials; and (8) working with unqualified employees in key positions.
- *Direct work employee motivators:* (1) possibility to become foreman or craftsperson in the company; (2) good treatment of employees in general; (3) good treatment of employees by high-level supervision (superintendent, area engineer, project manager); (4) trying to maintain employees on the project until completion; (5) good communication with foremen, supervisors, chiefs; (6) support among crews; (7) companionship between workers; (8) having a career in the company; (9) coordination of the work; (10) planning of the work; (11) motivated supervisors; (12) recognition of the work of every individual; (13) having materials to work with; and (14) work safety and good working spirit.
- *Midlevel indirect work employee motivators:* (1) good relations with coworkers; (2) forming work teams; (3) work meetings; (4) maintaining work teams; (5) client trust in the company; (6) working with well-prepared employees; (7) communication; and (8) having career opportunities for every company employee.

J. Constr. Eng. Manage., 2011, 137(4): 312-320

Table 10. Comparison of Productivity Factors

USA Research (Garner et al. 1979)		Chilean Case Study (2008)		USA research (Dai et al. 2009)	
Ranking[a]	Productivity factor[b]	Ranking[a]	Productivity factor[b]	Ranking[a]	Productivity factor[b]
1	Materials	1	Materials	1	Tools
2	Tools	2	Tools	2	Materials
2	Rework	3	Equipment and trucks	3	Engineering drawing management
3	Waiting for quality control	3	Rework	4	Equipment
4	Quality of supervisors	4	Absenteeism	5	Supervisor direction

[a]Represents the relative ranking for productivity factors according to the specific ranking procedure of each research. Two repeated ranking positions characterize factor with the same score.

[b]Every productivity factor has an associated score according to the specific ranking procedure. The relative importance of each factor is estimated as the ratio between individual scores and the total score for all the factors. Thus, those productivity factors with a cumulative importance $\geq 70\%$ were selected.

Comparing Chilean Case Study with United States Productivity Studies

To gain insight and a better understanding of factors affecting labor productivity, the findings of the case study in this paper were compared with results of previous studies in the United States. The writers acknowledge that comparing research from different countries with different survey approaches and samples sizes in different time periods is a hard and sometimes fruitless effort, although it may not be rigorous from a statistical viewpoint. Also, statistical inferences are not possible given these differences. However, comparing the major issues and findings across different studies may allow outlining potential patterns and trends in obtaining an overview of the productivity factors identified in the case study.

The Chilean case study is compared with two United States construction studies. The first one is the emblematic DOE study developed in the 1970s about productivity problems and their causes in nuclear power plant projects, which was developed with a methodology similar to this study by collecting approximately 1,200 questionnaires about craft workers' perceptions (Garner et al. 1979). The second one is a nationwide survey involving nearly 2,000 craft workers, in which the relative impact of several productivity factors was quantified according to the workers' perceptions (Dai et al. 2009). Unlike the aforementioned surveys, Dai et al. (2009) state rankings of productivity factors based on Likert scales, obtaining a more detailed description of respondents' perceptions. Nevertheless, the latter allows stating a productivity factors classification comparable with the other studies.

The DOE study and this case study used midlevel employees and craft workers' perceptions while Dai et al. (2009) uses only craft workers' perceptions. The Chilean case study and the DOE's survey (Garner et al. 1979) use the RI to calculate the ranking of productivity factors, in which craft workers' perceptions determine their impact level (as shown in Table 8). Meanwhile, Dai et al. (2009) apply a severity index (SI) to estimate the impact of factors affecting labor productivity, in which craft workers' perceptions are captured by means of the Likert scale. To make a consistent comparison, only craft workers' perceptions are considered in the productivity factors shown in Table 10.

There are obvious similarities among these studies: (1) the three studies present similarities in the first two productivity factors, i.e., materials and tools; (2) research compiled by this Chilean case study and Garner et al. (1979) have closer similarities in these productivity factors, being in the same priority order; (3) studies by Garner et al. (1979) and Dai et al. (2009) have the supervisor issue among the most important productivity factors; and 4) this Chilean case study has three of the five top factors in common with each of the United States studies. These are materials, tools, and rework with the DOE study; and materials, tools, and equipment with the Dai et al. (2009) study.

It is remarkable that two studies in the United States developed in two periods spanning 30 years (Dai et al. 2009; Garner et al. 1979) show similar patterns in productivity factors. This reason may explain in part why productivity in construction has progressively declined during previous decades in spite of the academy and industry efforts to improve performance in construction projects. Additionally, the writers suggest that productivity has failed to improve on many projects in the United States as well as in Chile as a result of ineffective crew-level planning. Accordingly, few projects show much commitment to this level of planning so far.

In brief, the fact that the Chilean case study identified similar productivity factors could be a sign that detrimental factors that affect productivity are common to construction projects across boundaries and that there is an opportunity to learn from different experiences distant in time and location.

Summary and Conclusions

An exploratory analysis of the main factors affecting labor productivity in projects of a case study company was addressed. Questionnaires applied to direct and midlevel project personnel provided a useful method for understanding many of the project productivity problems.

The main productivity factors identified were materials, tools, equipment, trucks, and rework, which also represent the productivity factors with higher influence in the work-time losses. In other words, these are the factors that have higher incidence of lost time doing nonproductive activities. The main possible reasons for each factor affecting performance of labor productivity as perceived by project personnel were studied.

A comparison among the Chilean case study and previous studies in the United States indicated that there is seemingly a pattern in the most relevant productivity factors such as materials, tools, and equipment. These factors have remained unchanged for the last 30 years in the United States construction industry and also appear in developing countries, such as the one in this case study. This evidence is not conclusive because of limitations in the analysis, but it is an invitation to develop more sound management actions from practitioners and researchers to overcome common productivity problems that remain today in different times and locations.

J. Constr. Eng. Manage., 2011, 137(4): 312-320

In general, there was a high potential for productivity improvement in the analyzed projects that focused on detailed crew-level planning. The first improvement stage was the identification and classification of factors affecting labor productivity, which has allowed the writers to define critical areas where improvement actions could be implemented. Moreover, the project personnel interviewed defined not only the detrimental productivity factors but also personnel motivators and demotivators.

One of the main benefits of the findings of this study is that they promoted management initiative. On the basis of these results, the company initiated a program to improve operational crew-level planning that has produced important results in the short term. If the study had not been conducted, the company may have ignored more detailed production planning and control.

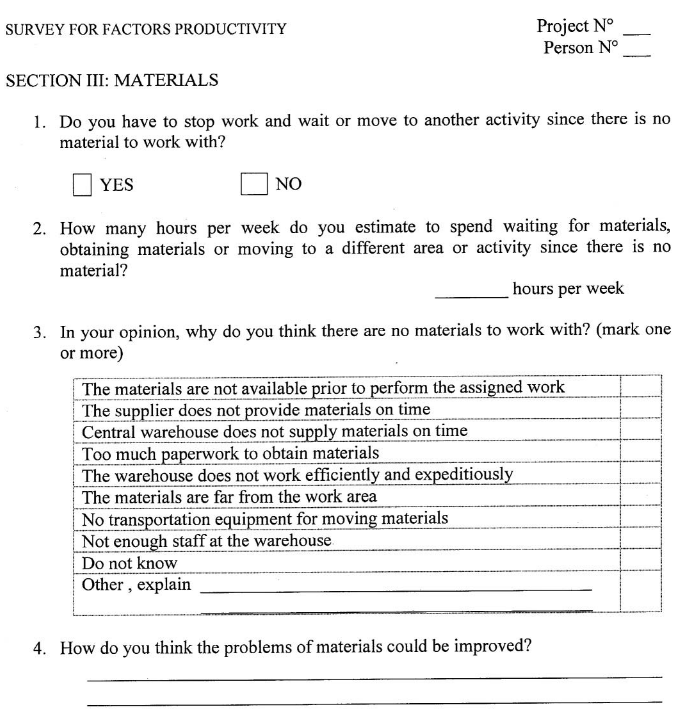
This paper addressed a first initiative for exploring productivity factors that can be easily addressed in local projects. The writers believe that this type of study can be applied in other types of construction companies/projects to attempt to improve the current performance in the Chilean construction industry.

Acknowledgments

The writers gratefully acknowledge the important contributions to this research provided by Carlos Solis, Senior Manager at Incolur, Chile (www.incolur.cl). The same recognition is extended to the workers and project managers (Mr. Gonzolo Gomez and Mr. Oscar Portugal) of the three projects involved in this study. Finally, to the company, which generously supports such initiatives as it strives for excellence and continuous improvement.

Appendix. Example of Survey Questions

Survey questions capture perceptions of project personnel about several factors influencing labor productivity performance, addressing factors from rework to absenteeism, involving project general information, rating of project problems, and labor demotivators and motivators. Fig. 1 shows an example of the type of questions in the research survey.



SURVEY FOR FACTORS PRODUCTIVITY

Project N° ___
Person N° ___

SECTION III: MATERIALS

1. Do you have to stop work and wait or move to another activity since there is no material to work with?

☐ YES ☐ NO

2. How many hours per week do you estimate to spend waiting for materials, obtaining materials or moving to a different area or activity since there is no material?

_______ hours per week

3. In your opinion, why do you think there are no materials to work with? (mark one or more)

The materials are not available prior to perform the assigned work	
The supplier does not provide materials on time	
Central warehouse does not supply materials on time	
Too much paperwork to obtain materials	
The warehouse does not work efficiently and expeditiously	
The materials are far from the work area	
No transportation equipment for moving materials	
Not enough staff at the warehouse	
Do not know	
Other , explain ______________	

4. How do you think the problems of materials could be improved?

____

Fig. 1. Example of survey questions: material analysis

References

Abdul Kadir, M. R., Lee, W. P., Jaafar, M. S., Sapuan, S. M., and Ali, A. A. A. (2005). "Factors affecting construction labour productivity for Malaysian residential projects." *Struct. Surv.*, 23(1), 42–54.

Alarcón, L. F., and Calderón, R. (2003). "Implementing lean production strategies in construction companies." *Proc., Construction Research Congress, Winds of Change: Integration and Innovation of Construction*, ASCE, Reston, VA.

Alarcón, L. F., Diethelm, S., Rojo, O., and Calderón, R. (2008). "Assessing the impacts of implementing lean construction." *Rev. Ing. Constr.*, 23(1), 26–33.

Borcherding, J. D., and Alarcón, L. F. (1991). "Quantitative effects on construction productivity." *Constr. Lawyer (Am. Bar Assoc.)*, 11(1), 36–48.

Borcherding, J. D., Palmeter, S. B., and Jansma, G. L. (1986). "Work force management programs for increased productivity and quality work." EEI Construction Committee Spring Meeting, 4–9.

Christian, J., and Hachey, D. (1995). "Effects of delay times on production rates in construction." *J. Constr. Eng. Manage.*, 121(1), 20–26.

Contractors Consultant Corporation. (1981). "The productivity survey." Island Park, NY.

Dai, J., Goodrum, P. M., and Maloney, W. F. (2009). "Construction craft workers' perceptions of the factors affecting their productivity." *J. Constr. Eng. Manage.*, 135(3), 217–226.

Edmondson, C. H. (1974). "You can predict construction labor productivity." *Hydrocarbon Process.*, 53, 167–180.

Garner, D. F., Borcherding, J. D., and Samelson, N. M. (1979). "Factors influencing the motivation and productivity of craftsmen and foremen on large construction projects." *U.S. Dept. of Energy (DOE)*, *Contract EQ-78-G-01-6333*, Vol. II, Dept. of Civil Engineering, Univ. of Texas at Austin, Austin, TX.

González, V., Alarcón, L. F., and Mundaca, F. (2008a). "Investigating the relationship between planning reliability and project performance." *Prod. Plann. Control*, 19(5), 461–474.

Grillo, A., Muñoz, R., García, F., and Herrera, R. (2003). "Indicadores de Desempeño Sectorial y Línea Base 2002." *Bit, la Revista Técnica de la Construcción*, 10(31) 22–25.

Gunduz, M. (2004). "A quantitative approach for evaluation of negative impact of overmanning on electrical and mechanical projects." *Build. Environ.*, 39, 581–587.

Halligan, D. W., Demsetz, L. A., Brown, J. D., and Pace, C. B. (1994). "Action-response models and loss of productivity in construction." *J. Constr. Eng. Manage.*, 120(1), 47–64.

Hanna, A. S. (2001). "Quantifying the impact of change orders on electrical and mechanical labor productivity." *Research Rep. No. 158-11*, Construction Industry Institute, Austin, TX.

Hanna, A. S., Chang, C. K., Lackney, J. A., and Sullivan, K. T. (2007). "Impact of overmanning on mechanical and sheet metal labor productivity." *J. Constr. Eng. Manage.*, 133(1), 22–28.

Hanna, A. S., Chang, C. K., Sullivan, K. T., and Lackney, J. A. (2008). "Impact of shift work on labor productivity for labor intensive contractor." *J. Constr. Eng. Manage.*, 134(3), 197–204.

Hanna, A. S., Russell, J. S., and Vandenberg, P. J. (1999). "The impact of change orders on mechanical construction labour efficiency." *Constr. Manage. Econ.*, 17(6), 721–730.

Hanna, A. S., Taylor, C. S., and Sullivan, K. T. (2005). "Impact of extended overtime on construction labor productivity." *J. Constr. Eng. Manage.*, 131(6), 734–739.

Harmon, K. M., and Cole, B. (2006). "Loss of productivity studies–Current uses and misuses." *Constr. Briefs.*, 8(1), 1–19.

Ibbs, W. (2005). "Impact of change's timing on labor productivity." *J. Constr. Eng. Manage.*, 131(11), 1219–1223.

Instituto Nacional de Estadísticas (INE). (2007). "Macroeconomía del Empleo." ⟨www.ine.cl/canales/menu/boletines/enfoques/2007/pdf/macroeconomia.pdf⟩ (Jan. 10, 2010).

J. Constr. Eng. Manage., 2011, 137(4): 312-320

Jansma, G. L. (1987). “A methodology for making construction productivity comparisons.” Ph.D. dissertation, Univ. of Texas at Austin, Austin, TX.

Liu, M., and Ballard, G. (2008). “Improving labor productivity through production control.” *Proc., 11th Annual Conf. of Int. Group for Lean Construction*, Manchester, UK.

Mechanical Contractors Association of America (MCA). (1976). “Outline of standards for change orders in the construction industry.” Rockville, MD.

National Electrical Contractors Association (NECA). (1974). “The effect of temperature on productivity.” *Rep. No. 5072*, Washington, DC.

Neil, J. M., and Knack, L. E. (1984). “Predicting productivity.” *AACE Trans., Paper U-3*, Transaction American Association of Cost Engineers (AACE), Morgantown, WV.

O’Connor, L. V. (1969). “Overcoming the problems of construction scheduling on large central station boilers.” *Proc., American Power Conf.*, 31, 518–528, Chicago.

Ramírez, R. R., Alarcón, L. F., and Knights, P. (2004). “Benchmarking system for evaluating management practices in the construction industry.” *J. Manage. Eng.*, 20(3), 110–117.

Rojas, E. M., and Aramvareekul, P. (2003). “Labor productivity drivers and opportunities in the construction industry.” *J. Manage. Eng.*, 19(2), 78–82.

Sonmez, R., and Rowings, J. E. (1998). “Construction labor productivity modeling with neural networks.” *J. Constr. Eng. Manage.*, 124(6), 498–504.

Thomas, H. R. (2000). “Principles of construction labor productivity measurement and processing.” *Research Rep. No 2K14*, Pennsylvania Transportation Institute, University Park, PA.

Thomas, H. R., and Jansma, G. L. (1985). “Quantifying construction productivity losses associated with and accelerated schedule.” *Final rep. prepared for Burns and Roe*, Oradell, NJ.

Thomas, H. R., Riley, D. R., and Sanvido, V. E. (1999). “Loss of labor productivity due to delivery methods and weather.” *J. Constr. Eng. Manage.*, 125(1), 39–46.

Thomas, H. R., Riley, D. R., and Sinha, S. K. (2006). “Fundamental principles for avoiding congested work areas—A case study.” *Pract. Period. Struct. Des. Constr.*, 11(4), 197–205.

Yin, R. (1994). *Case study research, design and methods*, Sage Publications, Thousand Oaks, CA.

J. Constr. Eng. Manage., 2011, 137(4): 312-320