EVALUATION AND IMPROVEMENT OF THE PROCUREMENT PROCESS IN CONSTRUCTION PROJECTS

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ABSTRACT

A methodology to diagnose and evaluate the procurement process for investment projects, and launch a continuous improvement was developed and applied to selected projects. A thorough literature review was carried out along with study of cases, surveys and interviews to professionals involved in this area. As a result, a methodology for diagnosis and improvement was proposed and tested in selected projects.

The results obtained show that the main problem of procurement is related to schedule delays and lack of specified quality for the project. To prevent this situation it is often necessary to dedicate important resources (money, personnel, time, etc.) to monitor and control the process. When applying the methodology to some projects, it was found that the main sources of "waste" were engineering, the system itself, the suppliers, and the policies. A great potential for improvement was detected if state of the art technologies such as, electronic mail, EDI (Electronic Data Interchange), bar codes, and other systems were applied to the procurement process. These technologies could help to eliminate the root causes for many types of wastes that were detected.

KEY WORDS

Lean construction, procurement, performance indicators, process improvement

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INTRODUCTION

The term Procurement Process is used in this paper to describe the process required to supply equipment, materials and other resources required to carry out a project. This process usually involves sub-processes such as acquisition, purchasing, logistics, monitoring, quality assurance and contract administration (Stuckhart 1995).

Currently there is a tendency to manage projects using a fast–track approach in an effort to reduce project schedule. To be able to serve the needs of these projects, the Procurement Process is subject to important pressures to be carried out in the most expedite and fluid possible manner. According to the analysis of interviews and surveys carried out during the study of the Procurement Process described in this paper (Rivas 1998), five aspects can express the relevance of Procurement:

a) Schedule pressures: the need of the project to be operative within the less possible time, avoiding excessive financial costs, minimizing project management costs, and other indirect costs.
b) Cooperation and coordination with construction: by complying with the needs of the construction schedule procurement will act to construct. Improvement of the efficiency for procuring supplies may not only result on great savings for the process itself, but also important savings on other construction resources (Business 1983).
c) High relative value: when the supplies managed by procurement represents 50%, 60%, and up to 70% of the total cost for the project, it is imperious to have a strict and permanent control of the acquisitions, having in mind the financial approach being represented by such situation.
d) Relevance of the process equipment being supplied for the performance of the project. The equipment can be of such relevance, that the operation of the project depends on its adequate performance.
e) Potential criticality of the supplies: due to precedence relationships and interrelation between different areas of the project.

This paper describes an effort to analyze the Procurement Process from a "Lean Construction" perspective (Alarcón 1997), by generating strategies to improve the procurement process in investment projects. These strategies are the result of the application of a methodology to diagnose and evaluate the procurement process in construction projects. The methodology helps to select strategies after several analysis tools have been applied to give a comprehensive view of the procurement process. The methodology was applied to study several projects being performed or under execution in Chile, obtaining important data about the current situation of the procurement process in these projects.

RESEARCH OBJECTIVES

The general objectives of the research were to generate a means to evaluate the Procurement Process, and to launch an improvement of the process involving Procurement, by applying an improvement methodology, inspired on the principles and concepts of the new production philosophy. In order to comply with the general objectives, the following specific objectives were pursued:

1. Understand the process of procurement in projects, emphasizing on process equipment.
2. Identify key variables and problems in the procurement process.
3. Determine causes of variability and problems related to information and material flow.
4. Propose performance indicators, at management level as well as operational, for the process and sub-process related to procurement.
5. Provide means for continuous process improvement and for minimizing cycle times.
6. Diagnose the current situation in Chilean projects.

RESEARCH METHODOLOGY

The research methodology was based on five elements: literature review, study of cases, casual interviews, structured interviews and surveys, and the analysis of information sources. Companies within the mining, industrial and energy areas were considered owners as well as consultants (engineering companies), and industry experts participated in the interviews. A base questionnaire was applied to 12 projects; the interviews considered 22 people from 11 companies.

The study of cases was focused on projects already performed or near the end of the project (industrial, mining, and engineering consulting companies) from which it was possible to obtain specific information regarding the procurement process. In particular, one owner company interested in the outcomes of this study provided the researchers with full access to the files of its projects. This allowed the researcher to review historical and current data of projects, particularly related to procurement, such as: purchase reports, follow-up reports, claim reports, supply reports, etc. It was also possible to interview the participants of these projects to verify, clarify or obtain information. Additionally, two cases present in the literature were analyzed (Ballard 1993, Cole 1989).

From the information gathered from these sources, and from a posterior analysis, improvement strategies were obtained and a preliminary evaluation methodology was proposed. This methodology, described in the following section, was applied to the study of two real projects to perform its validation and adaptation.

PROPOSED EVALUATION METHODOLOGY

The methodology proposed to diagnose, evaluate, and improve the procurement process comprises five phases, as shown in Figure 1. One first step is a characterization of the company, the project and procurement process, as a starting point for a formal application. Then comes a diagnosis according to pre-defined questions. The third step is to obtain some initial performance indicators to help in the detection of improvement opportunities. The next phase of evaluation, identifies "waste" from different sources, and analyses them. And last, the fifth phase is used to design the improvement strategies of the process. Each step of the evaluation methodology has been documented and structured with specific tools, surveys, diagrams, and reports. The full version of the procedures can be found in (Rivas 1998). The different steps of the proposed methodology are briefly discussed in the following sub-sections, providing some examples of the tools used to carry out specific phases.

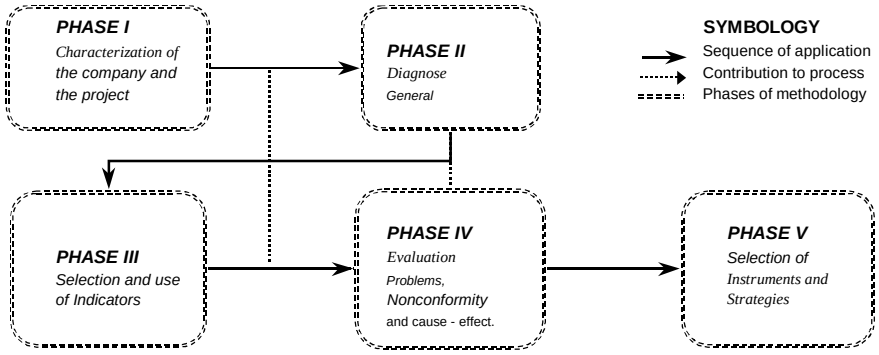

Figure 1: Phases in the Evaluation Methodology

PHASE I: CHARACTERIZATION OF COMPANY AND PROJECT

This phase seeks to characterize the company, in order to facilitate the process of problem review and later analysis within the methodology. This phase involves the characterization of the Company using pre-designed instruments to collect information about general aspects of the company, description of the way they face projects, and management of know – how, and experience within the company. The characterization of the project and procurement process requires, in addition to general aspects, a detail of the participation of the project organization on the procurement process, project policies affecting procurement, project organization, procurement organization and staffing.

The diagnosis example used in this paper does not address a specific project but it attempts a diagnosis of the procurement process in Chilean industrial projects using the information collected from several experts and multiple projects.

PHASE II: GENERAL DIAGNOSIS

In this phase, some elements of the process are checked, to detect the status of the procurement process compared with some general strategies or considerations that were found more appropriate during the current research. This stage involves analysis of the following items: procedures used, purchasing strategy, suppliers, programs, information flows, and technological instruments. This stage includes the development of an initial value stream map of the procurement process.

PHASE III: PERFORMANCE INDICATORS

Indicators are an important part of the methodology itself. They can give "signals" to management regarding how the process is performing and they can facilitate the evaluation within the methodology. Table 1 provides a list of potential indicators to serve as a starting point in selecting indicators for a specific project. These indicators were collected from the literature, interviews, surveys and case studies (Plemmons and Bell 1995, Koskela 1997, Alarcon 1997b, Rolstadas 1995). They were divided into five categories:

1. Cycle Times: for different activities within the procurement process.

2. Milestone Events indicators: they check the fulfillment of specified milestones related to the supply of equipment or materials. They make evident the non-fulfillment of the program or/and non-fulfillment of the scheduled time.
3. Management indicators: make evident problems of planning or supply itself.
4. Cost indicators: make evident situations that may result in additional expenses to the procurement area. Obtained upon delivery of supplies, may be calculated monthly.
5. Referential values: provide standards for comparison to monitor deviations within the process, and provide valuable information to create monthly reports.

The selection of indicators can be useful to verify if the systems being used to monitor the project provide the necessary information for managing the project. Indicators should be instruments for managing the process; they show a way of carrying out the work. In order to choose indicators for the project, there must be an identification of those supplies being most critical; this will provide some focus for the selection. Usually with the information available from the general diagnosis it is possible to identify not only critical supplies but also potential waste and waste sources, this information can be used to select indicators that could help to monitor and prevent potential problems and unnecessary waste during the project.

In our example of the Chilean reality, that involved multiple projects, the long list of indicators was confronted with the problems detected during the research. The indicators that would be most appropriate to identify some of those problems were marked with a # sign in Table 1. These marked indicators can be considered as recommended indicators for the type of industrial projects included in this research. Nevertheless, the particular project considerations are the most important for the selection because not all the indicators might be necessary or might be available for a given project. On the other hand, some particular type of indicator (which might not even be in Table 1) might be more important in some cases.

PHASE IV: EVALUATION OF THE PROCUREMENT PROCESS

The evaluation stage comprises the following steps: establishing the group of people to be interviewed; value stream maps, general and detailed; project surveys; review of performance indicators; analysis of nonconformity reports; cause – effect analysis regarding delays, costs, time cycles and others. Three tools are used below to diagnose the Chilean reality regarding procurement in projects: a survey of problems (all projects), analysis of nonconformity reports (case of industrial project) and cause-effect analysis for cycle times (all projects). Table 2 shows the most common problems grouped into four areas, they are weighted according to their frequency of occurrence in the project surveyed. The supply group is the one that shows most frequent problems, followed by the stages of the procurement process.

The example shown in Figure 2 is project specific. Nonconformity reports issued during the execution of an industrial project (62 over 14 months) were analyzed and summarized as shown in Figure 2. The problems affected mainly bulk materials as can be noticed on Figure 2 a). This type of information was usually available for most projects but it was seldom used for management purposes. Periodic reports with processed information could greatly help managers to prevent and reduce problems that can affect the procurement process.

Table 1: Potential Performance Indicators for the Procurement Process

1 CYCLE TIMES		
1.1	Cycle times for different activities of the process	#
2 EVENT INDICATORS		#
	(% fulfill program, %comply with asigned time term, field breakdown)	
2.1.1	Issue of specification of Q. R. By engineering	#
2.1.2	Procurement receives specification of Q. R.	
2.2.1	Issue of Q. R. To suppliers	
2.1.3	Delivery of Q. R. To Suppliers	
2.1.4	Reception of bids	
2.2.2	Delivery of bids for technical appraisal	
2.1.5	Appraisal of bids	#
2.2.3	Negotiation	#
2.1.6	Delivery of appraisals to bidder (or responsible in organization)	#
2.1.7	Reception from bidder (or responsible in organization)	
2.1.8	Decision and Award	
2.1.9	Notification of award	
2.2.4	Aceptance of notification of award	
2.2.5	Issue of acknowledgement letters	
2.1.10	Issue of requisition by engineering	#
2.2.6	Reception of requisition by procurement	
2.1.11	Issue of purchase order (P.O.)	#
2.2.7	Delivery of drawings for revision	#
2.2.8	Submit approved drawings	#
2.1.12	Certified approved drawings	#
2.2.9	End of material purchase for fabrication	
2.2.10	Issue of orders for sub-suppliers	
2.2.11	Supply out of fabric	
2.2.12	FOB delivery	
2.1.13	Embarkment	#
2.2.13	Arrival to port CIF	
2.2.14	Customs Clearance	
2.1.14	On site	#

Note: Q.R.: Quotation Request.P. O.: Purchase Order.
Symbol #, reflects some problems detected .

3 MANAGEMENT INDICATORS		
3.1	Frequency of days of delay/in advance, regarding target	
3.2	Number of cases w/lack of supply on planned date for use in construction	#
3.3	Number of changes in specifications	
3.4	Number of change orders	#
3.5	Number of urgent dispatches	#
3.6	% of air transport	
3.7	Number of changes to air transport	#
3.8	Amount of supplies with reception problems	#
3.9	Cases with problems of reception, under and over deductible insurance	
3.10	Cases where goods were not shipped	
3.11	Damage on transport	
3.12	Number of Bills of lading (B. L.) rejected by period	#
3.13	Days of difference between gross and fine reception	#
4 COST INDICATORS		
4.1	Number of drops to ground/month (ship)	
4.2	Number of days in warehouse (customs) / delivery (aircraft)	
4.3	Number of days in customs / delivery	#
4.4	Number of rules 1 proceeded / Number of rules 1 possible	#
4.5	Number of fiscal credits proceeded / Number of possible fiscal credits	#
4.6	Number of (days spent) corrections, repairs	
4.7	Number of special transports / period and accumulated	
4.8	Time until release of container, for container at job site	#
5 REFERENTIAL VALUES		
5.1	Amount of Q. R.'s issued / period and accumulated	
5.2	Amount of P. O.'s issued / period and accumulated	
5.3	Amount of Change orders issued / period and accumulated	#
5.4	Amounts involved in orders / period and accumulated	
5.5	Embarkments by period (general and detail)	
5.6	Embarkments in transit by period (general and detail)	#
5.7	Amount of money in embarkments by periods	#
5.8	Gross receptions performed	#
5.9	Fine receptions performed	#
5.10	% advance engineering (verification correlation engineering-procurement)	
5.11	Domestic purchases / import purchases	#
5.12	Number of supplies according to criticality level (relationship industry - events)	#
5.13	Amount of inspection by order	
5.14	Final amount of supply /budgeted amount	

Cause-effect diagrams were used to analyze three basic aspects within the procurement process, these were cycle times, costs, and delays (associated to variability). These diagrams helped to synthesize the main causes related to waste in the procurement process for these three aspects. Figure 3 shows one example that summarizes the causes of long procurement cycle times. The analysis of this type of diagram can help managers to focus on specific issues to introduce improvements in the process, for instance, in the example diagram it is apparent that by introducing changes in technologies and procedures improvements in systems could help to reduce cycle times.

The information obtained from the different tools provides a comprehensive view of the procurement process performance, strengths and weaknesses. This information is also used to

systematically design improvement strategies as explained in the following phase. Some general conclusions obtained about the Chilean projects are discussed later in the paper.

Table 2: Main Problems Detected in Chilean Projects

AREA	SUB AREA	DESCRIPTION	Weight
Supply	TRUSSES (fabrication)	Delays on delivery of supplies	7
Supply	*EQUIPMENT*	Medium size equipment with delayed request, negotiate due to forced time term	5
Supply	*EQUIPMENT*	Spend more time to replace or repair equipment parts by sub suppliers	5
Supply	*EQUIPMENT*	Need for scheduled inspection, have same technical level as suppliers	4
Supply	*EQUIPMENT*	Equipment poorly designed, does not meet technical requirements, excess of confidence	3
Supply	*EQUIPMENT*	Closing and fusion problems, reorganization of suppliers	3
Supply	BULK MATERIAL	Generally, critical route for projects	3
Supply	BULK MATERIAL	Lack of experience or trained personnel for design, delays, replacements	3
Supply	BULK MATERIAL	Too wide variety when designing, more standardization	3
Procur. Proc	ACTUATION & FOLLOW-UP	Desinformation or lack of clarity from people on site regarding reception	4
Procur. Proc	WAREHOUSE & RECEPCTIO	Need to plan orders for easier management in warehouse	4
Procur. Proc	*QUOTATION APPLICATION*	Delay due to lack of information from engineering	3
Procur. Proc	NEGOTIATION	Too many obstacles and clauses delay negotiations	3
Procur. Proc	*TRANSP. & LOGISTIC*	Late purchase makes system expensive, with air freight and urgent procedures	3
Procur. Proc	WAREHOUSE & RECEPCTIO	Poor explanation about items, coming more automized supply than in description	3
Procur. Proc	WAREHOUSE & RECEPCTIO	Waiting time for gross reception	3
Project	PROGR. & PLANNING	Delays from engineering	4
Project	PROGR. & PLANNING	Programming forces change for air freight	4
Project	ENGINEERING	Delays on issueing specifications for quotations	3
Project	PROGR. & PLANNING	Programming forces to cut normal time terms for supplies	3
Project	PROGR. & PLANNING	Lack of forward thinking, late verification that there is no time left	3
Project	PROGR. & PLANNING	Delay on informing supplier	3
External	*SUPPLIER*	Need for scheduled inspection, have same technical level as suppliers	4
External	*SUPPLIER*	Lack of clarity from supplier market, recent study	3
External	*SUPPLIER*	Do not meet requirements	3
System	*PROCEDURES*	Too many obstacles and clauses delay negotiations	3

PHASE V: INSTRUMENTS AND STRATEGIES FOR IMPROVEMENT

During this phase there is a search for appropriate solutions to reduce or eliminate waste detected in the process. It involves the following stages: generation of instruments and strategies, setting of priorities for the instruments proposed, and implementation of strategies and instruments for improvement. Instruments are specific tools, technologies, actions or simple methods. The strategies for improvement are compounds of instruments.

To facilitate the generation stage, a collection of potential instruments or actions was generated from a brainstorming process performed with the interviewed and from the literature reviewed (Plemmons and Bell 1995, Stuckhart 1995, Ballard 1993, Beverley 1994, Houston 1996, Bell and McCullough 1988, O'Brien 1997). The list shown in Table 3 is suggested for initial screening in generating improvement actions for a given project; the instruments were organized according to the area where the improvement is needed.

An adaptation of the "House of Quality" is proposed (Akao 1997) to select the instruments that are more effective in eliminating or reducing "waste." The House of Quality, shown schematically in Figure 4, is a matrix that spreads the requirements or needs on the rows (WHAT), and the technical answers satisfying such requirements, on the rows (HOW). The inputs of rows (WHAT) are proposed strategies or instruments selected from Table 3 after a preliminary screening process. To compose a strategy, it is necessary to carry out a preliminary verification of the relation between the proposed instruments, for possible implementation. On one side, their potential interaction must be checked, either positive (when complementing and/or reinforcing), or negative (excluding or contradictory); preliminary strategies for improvement can be formulated to be introduced in the columns of the matrix of Figure 4.

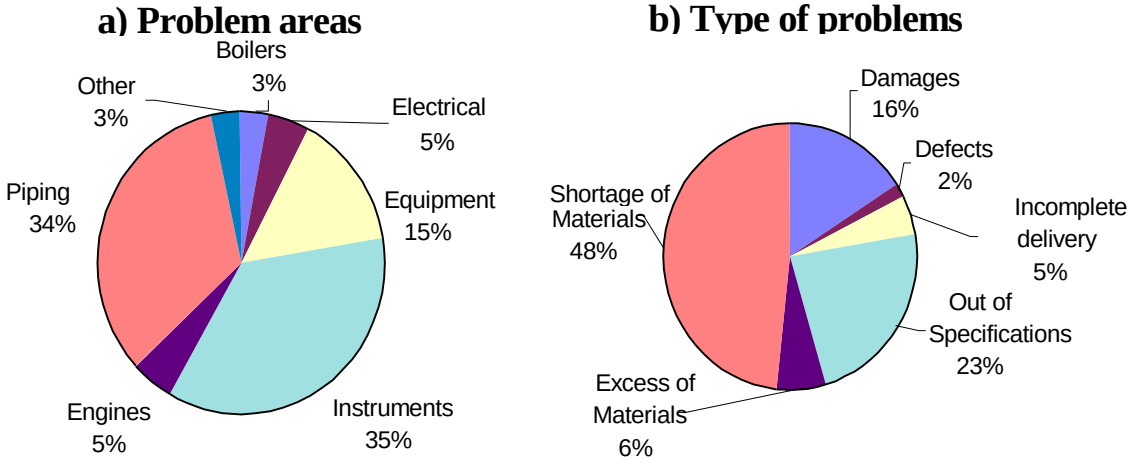

Figure 2: Non-conformities at Reception in an Industrial Project

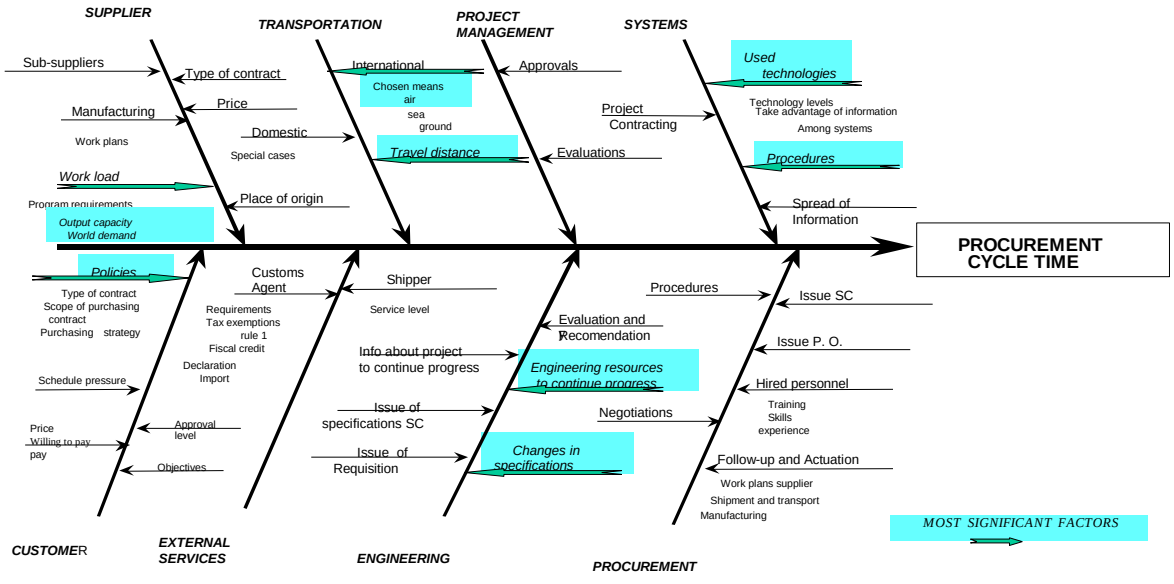

Figure 3: Cause-Effect Diagram for Long Cycle Times

The inputs for columns (HOW), can be obtained from the analysis instruments used in Phase IV of the methodology: (a) a priority list of problems and waste detected upon evaluation, (b) nonconformity reports of the project (quantified), and (c) an analysis of the causes of the main problems and nonconformity. The matrix is then completed indicating how the technical answers (rows) contribute to reduce or eliminate the waste shown on the rows. The result is a ranking of the importance of the instruments, considering the diverse interactions, registered on the last rows.

This analysis can be made separately for each of the results of the analysis instruments (a, b and c). It is quite possible that a different priority for each type of input can be obtained. Consolidation of the analysis should consider quantitative as well as qualitative consideration to select the improvement strategies, for instance, information from non-conformity reports can be more critical or more reliable than information from the causal analysis and could be given more importance in setting priorities to alternative strategies.

FINDINGS ABOUT CHILEAN PROJECTS

From analysis of information obtained from the different sources (interviews, surveys, case studies, and overall analysis) used in this research it was observed that:

- Each Owner presents a project organization adapted to its own reality, varying from company to company, and even, from one project to another. This has special relevance since it affects procurement and the way to face it.
- The problems present on procurement are of different types and origins. The most frequent problems detected were: delay at delivery, delay on ordering, repair and replacement at job site (equipment), poorly planned inspections (equipment supplier), lack of information on site about arrival for some supplies, delays on engineering (programming) and frequent changes to air transportation to make faster deliveries (programming), among others.
- The problem of procurement is basically related to delays (to comply with the requested time for the project, supply, or service) and lack of quality (specified for the project). It is common to request extra resources (capital, personnel, time, etc.) in order to avoid or overcome delays.
- The main sources for the problems detected were the system itself (forms and procedures to carry out things), Engineering (delays, errors, etc.), company policies, and the suppliers.
- Analyzing the value stream of the procurement process of an industrial project, only 18% of the activities were found to be value adding.
- Traditional systems (telephone, fax, and mail) are widely used; however, there was a low proportion of projects using modern IT to manage the procurement process.

When applying the procedure described in Figure 4 to the multiple projects under study it was found that the strategies with highest potential were Information Technology strategies, including the implementation of technologies such as, electronic mail, EDI (Electronic Data Interchange), bar codes, and other systems. These technologies were the most effective to eliminate the root causes for many types of wastes that were detected, according to the above procedure. These results, however, can not be generalized because they might vary for

specific projects where those technologies have been already implemented and where different sources of waste could be detected.

Table 3: Potential Instruments for Improvement

Nmr	AREA	PROPOSED INSTRUMENTS
1	system	Internal electronic mail
2	system	External electronic mail
3	system	EDI (traditional and/or owner)
4	system	Integrated systems, data bases
5	system	CAD 3D
6	system	Bar codes, automized identification
7	system	Filter for stabilization of performed purchases and to be performed
8	system	Differential control for supply
9	system	Clear procedures and regulations
10	organization	Transfer channels of know-how within the company
11	organization	Training and "comissioning" of procedures and systems
12	organization	Experience, capacity and preparation of procurement personnel
13	programming	Program adequate time terms
14	programming	Engineering must comply with time terms; apply resources
15	programming	Include float of security
16	programming	proactive attitude
17	project areas	Apply a competent and valueable engineering
18	project areas	Clearly know equipment and supplies to purchase (which is the objective market)
19	project areas	Specification check lists
20	project areas	Standarize design where posible
21	project areas	Team work, work having the interests of the project in mind
22	services to project	Adequate inspection, general preparation, technical knowledge at supplier level
23	services to project	Simplify and subcontract to accelerate
24	purchase arrangement	Prenegotiations, time terms and conditions with supplier (s)
25	purchase arrangement	Avoid innecesary changes
26	purchase arrangement	Purchase in order to facilitate reception, contracts, and follow-up
27	traffic and proceedings	Leasing of services
28	traffic and proceedings	Preestablished prices for freight, services
29	follow-up arrangement	Follow-up of targets internal to the project
30	follow-up arrangement	Follow-up of targets external to the project
31	follow-up arrangement	Follow-up activities of the supplier (emphasizing on drawings)
32	supplier	Check up systems, quality asurance, ISO
33	supplier	Previous experience, suppliers historial
34	supplier	Study of the market of suppliers, "picture" of the supplier
35	supplier	Tight contact with supplier (s)
36	supplier	Promote joint ventures domestic / foreigners

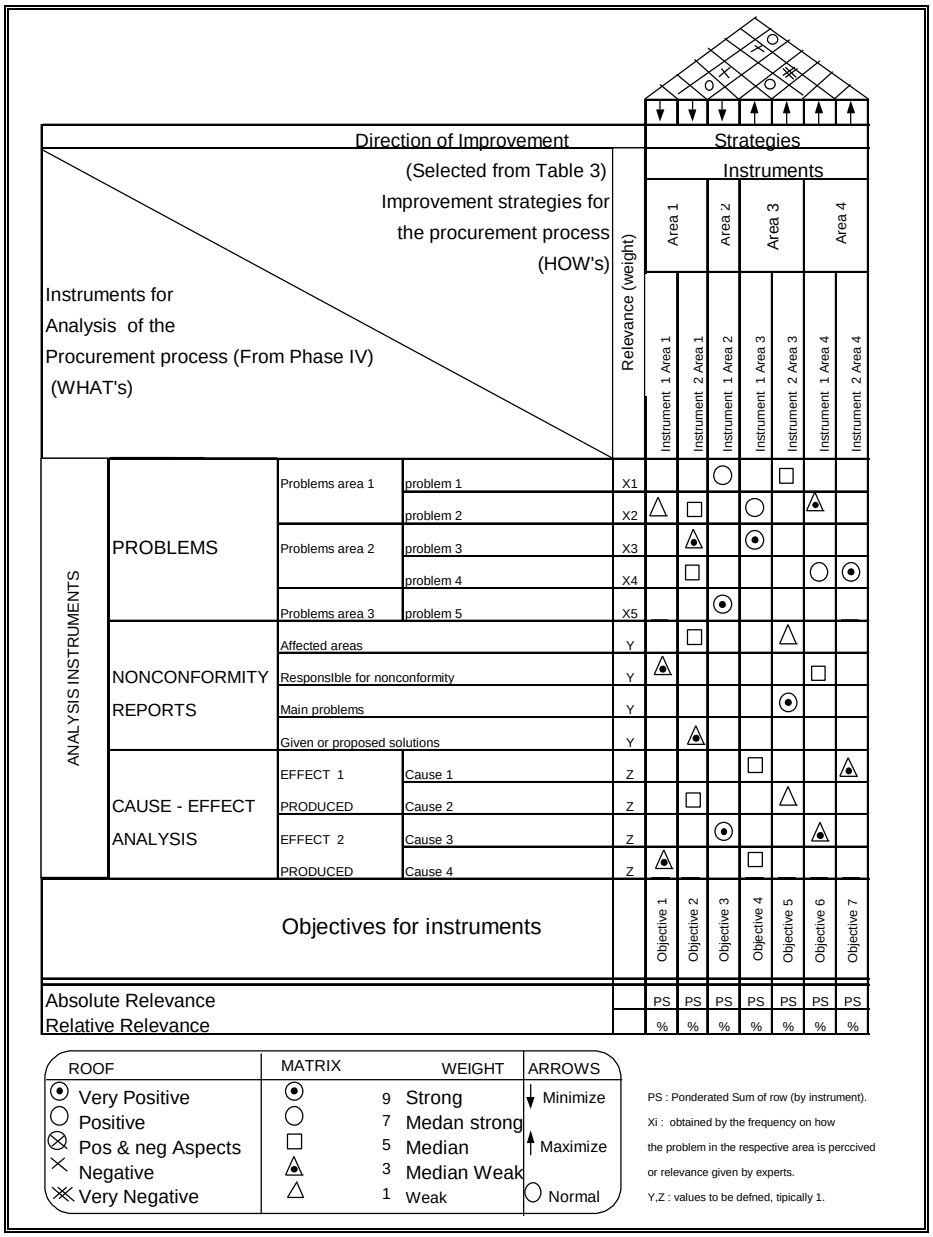

Figure 4: Selecting Improvement Instruments and Actions

CONCLUSIONS

Traditional project management systems do not offer a clear view, in global terms, regarding how the procurement process is being developed because the criteria used to control the process is usually too general. This research proposes several instruments to better understand procurement process performance. They are summarized in a methodology that provides guidelines for diagnosis, evaluation, and improvement of the procurement process. If a particular organization is frequently involved in new projects, it is recommended to apply

the methodology to the company in general, in order to work over the backgrounds and experience of the company. The use of performance indicators for the procurement process is recommended, since they complement the work of traditional systems for management of the procurement process, introducing concepts for continuous improvement and instruments of easy visualization. This research identified key areas of the procurement process that are currently failing in Chilean Projects. The analysis of this information is not exhausted in this paper and it can help to design procurement strategies for new projects.

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REFERENCES

Akao, Y. (ed.)(1990). *Quality Function Deployment***.** Product. Press, Cambridge, MA, USA.

Alarcón, L. (ed.)(1997). *Lean Construction*. A.A. Balkema, Rotterdam, The Netherlands, 497 pp.

Alarcón, L. (1997b). "Modeling Waste and Performance in Construction." In Alarcón L. (ed.), 51-66.

Cole, V. (1989). *Oakland Project (Class Syllabus)*. Department of Civil Engineering, University of California, Berkeley.

Ballard, G. (1997). "Lean Construction and EPC Performance Improvement." *Lean Construction*, In Alarcón L. (ed.), 79-92.

Bell, L. and McCullough, B. (1988). *Bar Coding applications in construction.* Source Document 33. Construction Industry Institute (CII).

Beverley, A. (1994). **"**Electronic communication in the building industry." *PMI 25th Ann. Seminar/Symposium*. October 17-19, Vancouver, Canada, 310-316.

The Business Roundtable (1983). More Construction for the Money: Summary of the Construction Industry Cost Effectiveness Project**.**

Houston, C. (1996). *Management of Project Procurement*. The McGraw-Hill Companies. College Custom Series. USA, 533 pp.

Koskela, L. (1997). "Lean production in Construction." In Alarcon L. (ed.), 1-10.

O'Brien, W.J. (1995) **"**Construction supply – chains: Case study, integrated cost and performance analysis." In Alarcon L. (ed.), 187-222.

Plemmons, J., and Bell, L. (1995). "Measuring Effectiveness for the Materials Management Process". *Journal of Management in Engineering*. November/December pp. 26-32.

Rivas, R. (1998). *A Methodology for the Evaluation and Improvement of the Procurement Process in Construction Projects***.** M.S. Thesis, School of Engrg., Pontificia Universidad Católica de Chile.

Rolstadas, A. (1995). *Performance Management. A Business Process Benchmarking Approach*. Chapman & Hall, London.

Stukhart, G. (1995). *Construction Materials Management*. Marcel Dekker, Inc. USA. 328 pp.