A GENERAL FRAMEWORK FOR IMPROVEMENT OF THE CONSTRUCTION PROCESS

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Abstract

A general framework developed for construction improvement and waste reduction is presented. This framework has been successfully applied during the last three years to several construction sites in Chile, through consulting services and research studies. The approach includes a set of structured activities and tools that are performed and applied for the identification and evaluation of the problems that produce construction waste, and the causes associated to them. A second stage of the approach corresponds to the development of both short and mid-term solutions in order to act on the factors that produce these problems with the purpose of reducing or eliminating their effects. A summary of the major improvements achieved through the application of this framework is also included to show the potential of this approach.

Keywords

Construction, construction management, change management, waste reduction, productivity improvement

1. Introduction

An increasing number of Chilean construction companies are applying actions to improve their projects' performance by reducing all kinds of waste during the construction process. This trend has been progressively increasing during the last three years offering many consulting and research opportunities to the authors of this paper. During this time, a structured approach for improvement has been developed and applied with increasing success to several housing construction projects in Chile. This approach is the focus of this work and is described in the following sections.

2. A General Framework for improvement of the Construction Process

To assure the effectiveness of improvement activities it is necessary to use a structured yet flexible approach that serves as a guideline for these efforts. This structured approach has been generated from the experience obtained during the execution of several types of improvement activities in many construction sites during the last six years. All of these efforts have been directed to construction performance improvement through the reduction of waste and the elimination of non-value-adding activities.

2.1 Underlying Concepts and Background

Waste has been defined by Alarcón (1995) as "anything different from the absolute minimum amount of resources of materials, equipment, and manpower necessary to add value to the product." In general, all those activities that produce cost, direct or indirect, but do not add value or progress to the product can be called waste. Then, any improvement effort should be

focused on identifying waste in the construction process, analysing the causes that produce waste, and acting on these causes to reduce or eliminate them.

The framework for improvement is based on the construction process model described in Figure 1 (Serpell et al. 1995). According to this figure, there are three areas or elements of interest where waste can occur and improvements can be carried out:

1. **Flows, both internal and external**, which are the inputs to the conversion activities and can be classified into two groups: construction resources (materials, labour and equipment) and construction information.
2. **Conversion processes and resultant products**, which are the processes that transform the flows into completed and partially completed products.
3. **Flows and process management** which correspond to the management actions and decisions that determine the way things are done and the application of construction resources. This management is responsible for the performance of the construction process and is characterised by different styles or approaches according to companies and managers.

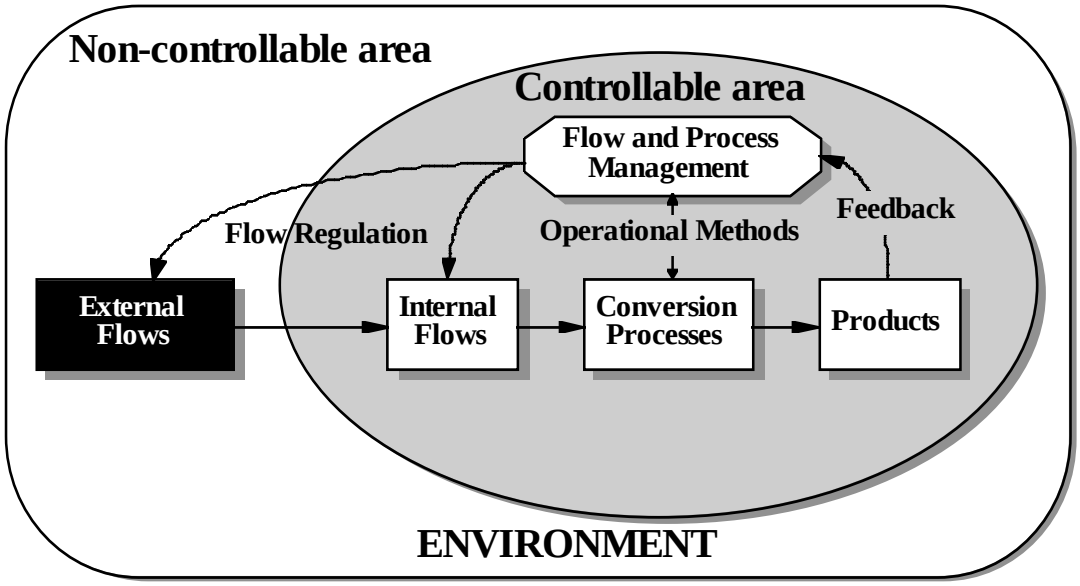

Fig. 1 Modelling of the construction process

2.2 Problem solving methodology

The general approach utilised for performance improvement was adapted from traditional problem solving methodology. General problem solving addresses a situation where what is happening is less than desirable with the aim of rectifying the situation (Straker 1995). In this case, the methodology is generally applied to an ongoing construction project that is studied for improvement. Figure 2 displays a flow diagram of the main steps included in the methodology.

As shown in the figure, the methodology has several loops to correct problems that can arise during the improvement process due to the characteristics of the particular situation (management style, labour characteristics, performance requirements, etc.). Also, after its

repeated application, the methodology provides several lessons learned that become an important source of information for future improvement processes. This is a very important feature of this structured approach.

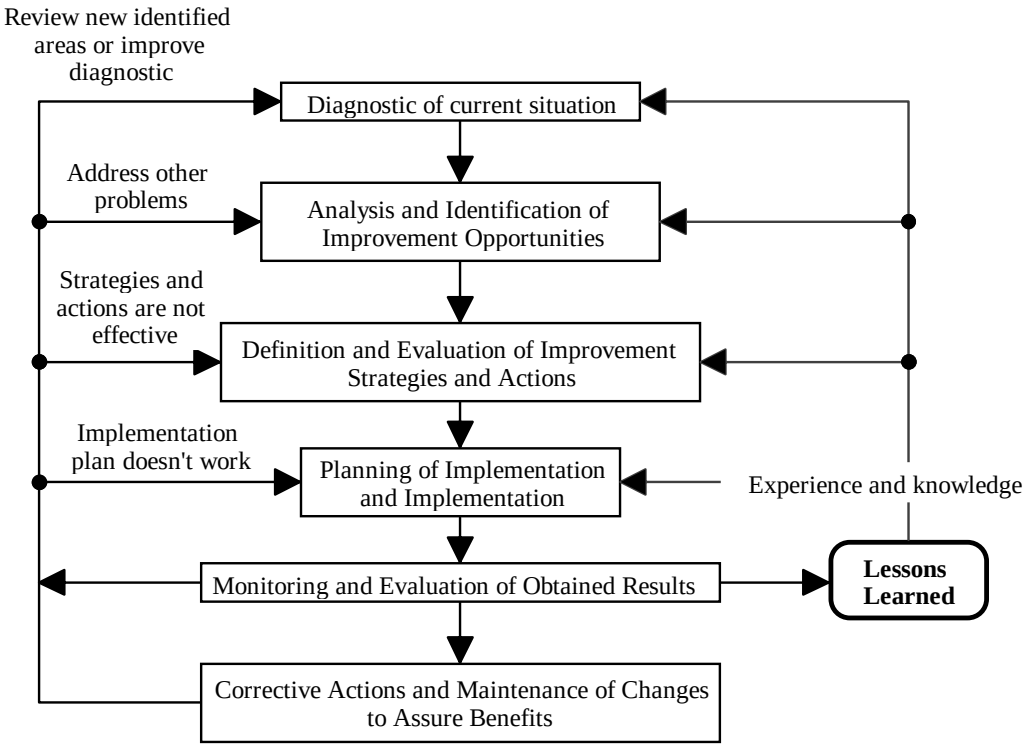

Fig. 2 Construction process improvement methodology

Diagnostic of current situation

The first step of the methodology starts with the observation, data gathering, and data processing of the construction process, i.e., resources and information flows, conversion activities and management of flows and conversion processes. The aim is to obtain the most complete and accurate picture of what is happening in the project. Several activities are carried out based on the application of many tools during this stage. The most common and effective are as follows:

1. Work Sampling: to obtain information about labour utilisation (Oglesby et al. 1989).
2. Waste Identification Survey: to obtain people's perceptions about types of waste that are occurring in the site and identification of their possible causes (Alarcón 1995).
3. Foremen Delay Survey: to identify causes of delays (Oglesby et al. 1989).
4. Processes Observation and Representation: to obtain information about construction methods, resources utilisation, processes performance and safety, etc. The idea is to map out the process to understand it in detail and to identify potential problem areas.
5. Site Layout and Temporary Facilities Study: to obtain information for studying the adequacy of the site layout and site facilities.
6. Organisation and Management Study: to evaluate the management and organisation effectiveness, considering the main functions like planning, direction, quality management, etc.

7. Labour Work Satisfaction Study: to evaluate work climate on site.
8. Study of Material Acquisition and Handling Systems: to evaluate their effectiveness and the performance of external and internal suppliers.
9. Study of Construction Equipment Utilisation: to check utilisation rates, activity levels for each piece of equipment, etc.
10. Clients' Satisfaction Survey: to obtain information of the satisfaction level of clients and to evaluate the value given by them to different product and service features.
11. Quality Survey: to obtain information on the most recurrent quality failures and problems, as well as the cost of repairing or correcting them.

After all the necessary information has been gathered, this is reviewed with the aim of achieving the following objectives:

- Obtain a clear and comprehensive understanding of every aspect related to the project construction process under study.
- Identification of waste, including non-value-adding activities.
- Identification of management and organisational deficiencies.
- Identifying possible causes of waste and deficiencies and selecting the most important ones.
- Identifying immediate (and sometimes obvious) improvement opportunities easy to implement.

If necessary, additional data gathering activities are performed to verify unclear information or detected causes that are not totally proved.

Analysis and identification of improvement opportunities

Once the identification of waste and its causes has been accomplished, the next step is to find out cost effective improvement opportunities that can be applied to reduce waste or to improve productivity. This analysis is performed using teamwork and brainstorming among the members of the team. The information is presented to the team and each member provides ideas and recommendations of potential improvements that can be applied to the construction process. The final result of this stage is a list of selected improvement opportunities, arranged according to their perceived benefit.

Definition and evaluation of improvement strategies and actions

After selecting the most promising improvement opportunities, a set of improvement strategies and actions is identified for each one, again using teamwork. Then, an initial selection is performed to reduce the number of alternative solutions. Finally, each selected improvement strategy and action is evaluated in terms of: technical feasibility, economic feasibility, time feasibility, cost of implementation, and associated benefits of its implementation. As a result of this evaluation, the feasible and most profitable strategies and actions are selected for implementation. Also, a goal is set and a performance measurement is selected for each one to be used during and after implementation, to check if the improvement goal is actually achieved.

Improvement strategies and actions defined at this stage can be classified according to the following criteria:

- Timing of implementation: short-term or mid-term implementation.
- Scope of improvement: corrective actions and/or changes of the current construction process approach. In the first case the aim is to correct deficiencies and problems that are present in the current construction process (examples: improving planning, training workers to improve the work they are doing, etc.). In the second case the idea is to change the way in which the construction process is carried out (examples: implementing a different construction method, restructuring the organisation, etc.).

Planning of implementation and implementation

The most difficult step of the improvement methodology is the implementation of the improvement strategies and actions. According to the authors' experience, the most important factor of the implementation plan is to consider the way that resistance barriers of the personnel will be overcame. Then, it is critical to ensure that implementation is understood and accepted by all the people that will be affected by the changes. Management personnel is the most critical category in this respect. Some of the typical activities considered in an implementation plan are:

- Obtaining real commitment from management.
- Communicating the plan to the personnel in the most convenient way.
- Training people on the changes to be made.
- Supporting people during implementation.
- Changing documentation.
- Analyse potential impacts of changes in other construction areas or processes.

Monitoring and evaluation of obtained results

This stage is used to determine the results obtained from implementation, using selected performance measures for each improvement action. The focus at this stage is to review the actual improvements achieved by the implementation, the difficulties faced during implementation, and the reasons that precluded improvement or reduced the expected gains. Decisions should be made at this stage based on the results obtained and the analysis of the implementation process. Some of these decisions are to apply corrective actions to the implementation process, to loop back to a previous stage to review the improvement methodology, to stop the improvement process due to its failure, or to wrap up a successful implementation by adopting best practices and other learned lessons.

Corrective actions and maintenance of changes to assure benefits

According to the results obtained in the previous stage, corrective actions considered necessary to make the implementation more effective are adopted in this stage. A second aim of this stage is to assure the maintenance of the implemented changes, to assure the short and long-term benefits expected from them. This aspect is critical in the Chilean construction industry due to the low educational level of the majority of the workers and to the fact that most of them learnt their trade from practice. Then, there is a strong tendency to return to their traditional construction methods when time passes by if no follow-up measures are

taken. This is true even though the improved methods are easier or require less physical effort (Ghio et al. 1996).

Figure 3 is an attempt to summarise the methodology and the different activities performed in each step as described above.

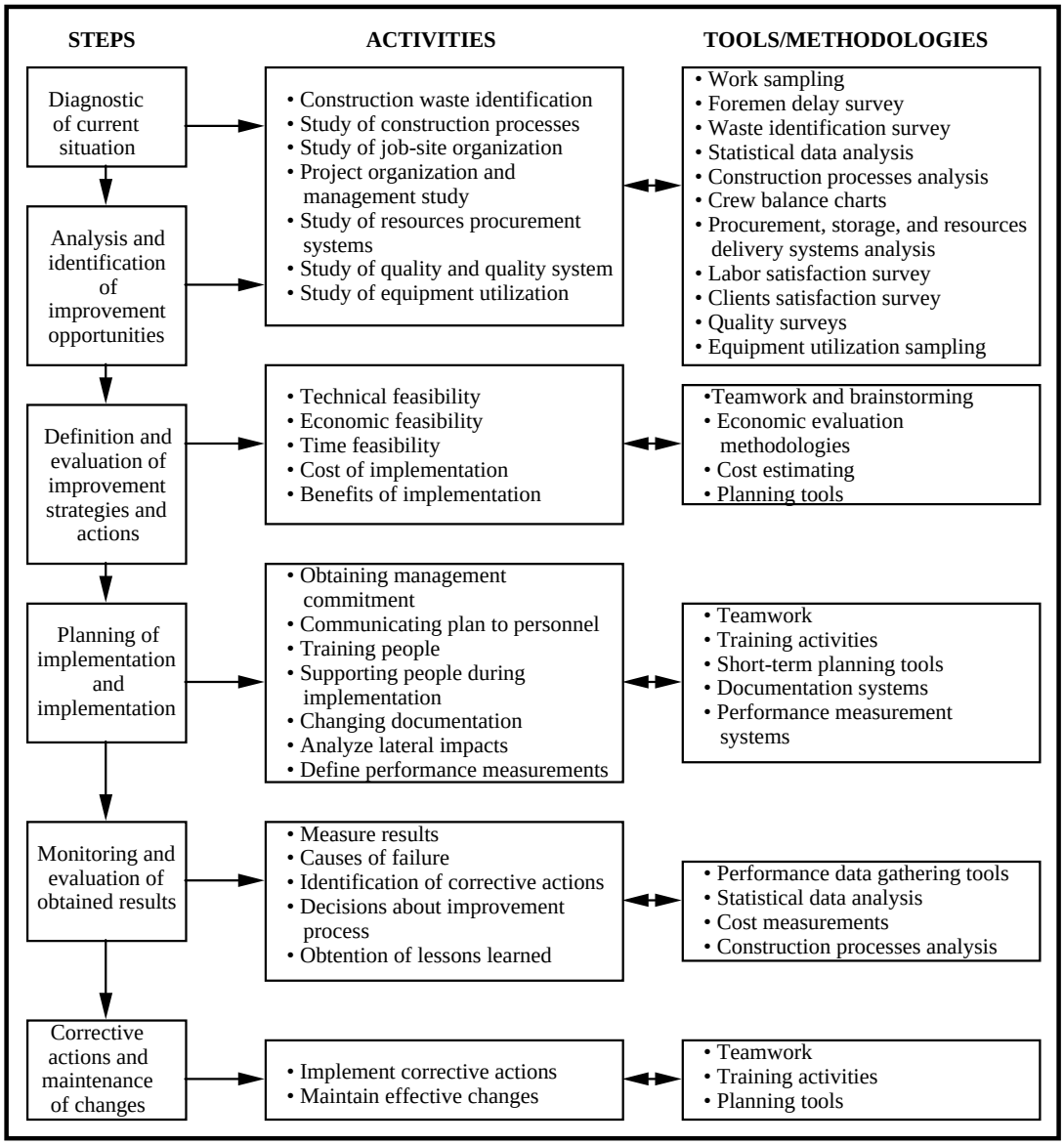

Fig. 3 Summary of the improvement methodology (adapted from Ghio et al. 1996)

The methodology of improvement just described represents a systematic attempt to organise the implementation of performance improvement processes in construction projects. However, this methodology should be flexible and adaptable to the specific needs of each construction project situation. To obtain effective results and successful implementation it is also necessary to develop a synergistic relationship with management and supervisory personnel of the construction project.

According to the authors' experience, working in a team approach with the project team is a requirement to obtain good results. If this condition is not achieved, the improvement process is continuously hindered by lack of trust, bad attitudes, lack of commitment and other negative situations.

The application of this methodology can be extensive and detailed or limited and global depending on the goals defined for the improvement process and the characteristics of the construction process. In our experience in four housing projects with construction rates of 150 to 300 houses a year, we have spent two to three months for the diagnostic stage and around a year when implementation and follow-up of some major improvement actions were included. In fact, the goal should be to prepare the project personnel to sustain a continuous improvement process considering the multiple possibilities of improvement that can be found in construction projects.

3. Improvement Actions

As explained before, improvement actions or recommendations can be classified according to the timing and duration of their implementation and to the scope of improvement.

Short-term improvement actions take advantage of improvement opportunities which can be achieved easily with low effort and low economic investment. These improvement actions require the involvement of few people and a short time for implementation (1 to 3 months). Some of them can be implemented almost immediately, for example, providing a mobile site materials and tools storage system or establishing adequate transportation routes to reduce transportation and travelling time.

Short-term actions can provide important improvement benefits to construction projects. Most of the construction projects in Chile offer many of these opportunities due to technological limitations and lack of a construction engineering function on site, especially in the housing construction sector. Generally, most of these short-term actions are limited to minor changes to correct the way in which things are currently done.

Mid-term recommendations require more analysis, planning, and design for their actual implementation. Typically, these actions require deeper changes and the benefits of introducing these changes are usually not obvious (Ghio et al. 1996). In most of the cases, these actions require a significant development effort, a longer implementation time and their scope includes the use of innovative construction methods, new planning and control strategies, new technology, new management systems, etc. Mid-term actions may require considerable initial investments and, consequently, should be well evaluated and well planned before implementing them to assure the effectiveness of the changes.

A summary of some improvement actions which have been recently applied or suggested to three extended housing construction projects is shown in this section as an example. Table 1 summarises these actions.

Table 1. Summary of selected improvement actions

Construction Project	Improvement Opportunities	Improvement actions
Low-income housing project with a total of	• **Inefficient use of manpower**	• **Reduction of waiting time by improving materials acquisition system**

324 units.	• **Poor operational planning** • **Lack and low quality of resources** • **Lack of management support systems** • **Inefficiencies in construction methods (concrete work, masonry work)** • **Quality problems** • **Complaints by clients regarding repairing servicing time**	• **Implementation of a short-term planning system** • **Improvements of construction methods and reduction of construction crews** • **Implementation of a quality assurance system** • **Reduction of cycle time of servicing by increasing response capacity**
Mid-income housing project with a total of 30 units	• **Waiting time due to lack of equipment and interferences** • **Inefficient use of manpower** • **Inefficiencies in construction methods (formwork, concrete work)**	• **Implementation of last planner concepts in a micro-planning system** • **Reduction of construction crew sizes** • **Provide more efficient tools for formworking** • **Use light-weight concrete and pre-fabrication of some concrete elements**
Mid-income housing project with a total of 2000 units	• **High level of transportation time** • **Overmanning of crews** • **Inefficient use of manpower** • **High level of reworking time** • **Poor operational planning** • **Inadequate construction method**	• **Improve site layout and reduce transportation time making resources more accessible to workers** • **Reduce personnel in excess** • **Balance crews and improve operational planning** • **Train personnel** • **Implement operational planning system** • **Change construction method by changing masonry-based structure to a concrete structure**

4. Results Obtained

Many significant results have been obtained on several construction projects from the application of this improvement methodology. The most important results are described in the following sections.

4.1 Direct Benefits

Table 2 shows a summary of selected direct and expected benefits obtained from the same projects considered above.

Table 2. Summary of selected direct and expected benefits

Construction Project	Selected Direct and Expected Benefits
Low-income housing project with a total of 324 units. (3 months of research time)	• 10% increase of productive labour time • 40% increase in productivity of concreting crews • Improved construction methods • Reduction of rework
Mid-income housing project with a total of 30 units (2 months of research time)	• Reduction of wasted time • Increase of productivity through a better balance between construction operations • Reduction of construction major cycle time
Mid-income housing project with a total of 2000 units (1 year of research time)	• 25% increase of productive labour time • Reduction of housing units construction costs • 70% reduction of clients' complaints due to low quality of product

4.2 Indirect Benefits

The application of the structured improvement methodology provides additional benefits both to the construction company and site and to the researchers. First, after the initial fear that improvement actions produces in the people, the involvement of the construction personnel in

improvement activities stimulates teamwork and facilitates continuous improvement. Construction workers and supervisors become more conscious of their contribution to the general performance of the project, supplying new ideas and recommendations.

Second, management becomes more aware of the importance of its role with regard to the feasibility and effectiveness of the improvement process. They realise that they should become the champions of the process because in this way the rest of the people develop trust and commitment on what is being done and achieved. It is interesting to note here that many construction managers that have participated in improvement processes have incorporated the concept of continuous improvement in their management style, permanently pushing for new ideas and improvements.

Third, the experiences, lessons learned, and implemented improvements have been incorporated into normal procedures and methods of many companies, a fact that has produced an accelerated change of the Chilean construction technology during the last 5 years. Also, this experience has been documented and published by researchers to make it available for other construction companies and projects. Additionally, it has helped researchers when undertaking new construction improvement processes.

5. Conclusions

A structured framework for improvement of the construction process has been presented. This methodology has been very effective in achieving significant improvements in several construction projects. The framework has been developed from repeated experiences of supporting construction companies and projects in their improvement efforts.

The use of a structured framework which provides systematic information gathering about the construction process and a sequence of logical steps, based on a general problem solving approach, increase the potential of a successful improvement project. Also this approach allows repeatability and reliability of improvement efforts that can be fed back with experiences and lessons learned from previous projects.

In addition to the framework used for improvement, there are some requirements that are necessary for achieving good results. One of them is obtaining commitment of all the people involved in any improvement effort. Without their support and participation it is not possible to achieve improvements. A second important requirement is to carefully plan the implementation of improvement actions. This stage is by far the most difficult and complex and should be seriously studied.

Within the framework it is very important to select the appropriate tools and methods to carry out the improvement activities. Experience plays a very important role in this respect.

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