# Improving Projects Performance With Lean Construction: State Of The Art, Applicability And Impacts

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Construction projects are not often delivered on time and on budget and re-workings are usually required to satisfy customer's needs. This papers aims to present an overview of Lean Construction (LC) and how this construction philosophy tackles the aforementioned problems. The research is empirical and based on data from the literature, 7 new Case Studies built with primary data, 12 Case Studies on CLIP (Construction Lean Improvement Programme) projects, 4 semi-structured Interviews with Firms adopting LC and several interviews (face to face and email) with LC experts. The results show as LC can achieve astonishing results focusing on reducing waste caused by unpredictable work-flow, paying attention on how every single activity affects the next one and avoiding reworking considered as no valued-added activity. The paper provides three original set of results: (1) a fuzzy cognitive map of LC showing how the different elements are linked to each other; (2) a pathway for the implementation of LC; (3) a synthesis of the strengths and the weaknesses of LC merging literature review with case studies analysis. In particular (3) shows the dimensions of projects adequate for lean construction, the increase of productivity and time reduction due to LC implementation and finally the reasons moving firms to adopt LC.

## INTRODUCTION

There is an alarming number of projects failing to be delivered on time or/and within budget or/and with a satisfactory standard that require additional work and re-works. (Ashkena and Matta, 2003) refer to an astonishing number of projects failing despite the substantial amount of effort in the installation of new technologies and the adoption of new strategies. (Arbulu and Ballard, 2004) identify an additional significant problem due to the absence of an effective system in place to manage the working relationship between construction firm and its suppliers. Variability in supply and demand has an adverse effect on project management increasing cost and time delivery and decreasing project quality and safety.

One of the most interesting methodologies proposed to deal with these issues is the Lean Construction (LC). LC aims to identify and minimize wastes (Ballard and Howell, 1994) through four main elements:

- Built in quality: reduction of rework doing the right thing the first time;
- Customer focus: elimination of no value-added activities for the customer;
- Minimization of waiting: involvement of supplier in planning task;
- Creation of a continuous flow: availability of needed resources and components, when and where they are required, in a pull system.

By leveraging the LC principles it is possible to deliver better projects. This is due to the collaboration of all parties and the quality control in the construction phase through a pull control system (Juanfang and Xing, 2001).

This paper shows how LC is able to cope with the following aspects:

- Cost, Time and Quality

LC aims to reduce time and cost stressing the links between project's activities (Pinch, 2005). Following the principle of waste reduction, it aims to avoid re-working. This reduces the overall risk particularly in case of inter-related projects, where the delay of one project impact on another one, e.g. during a global exposition (Locatelli and Mancini, 2010)

- Supply System

LC puts a great effort in involving suppliers in project planning and process with the aim to minimize variability. As already demonstrated with system engineering (Locatelli et *al.* 2013) the suppliers' involvement is essential to deliver material on time at a minimum cost and maximum value for the customer. Moreover a lean local project delivery chain has clear advantages respect to a more global one (Locatelli and Mancini, 2011).

The aim of this paper is to provide a holistic view on LC (through the definition of a fuzzy cognitive map updated with recent studies on LC) and answer to these specific research questions:

1. Which projects are suitable for LC? One of the research aims is to define in what kind of projects, in terms of sector and budget are suitable for LC.
2. How can a firm implement LC? The research aims to define a standard procedure to implement the LC approach and determine how to apply lean theoretical principles.
3. Which are strengths and weaknesses of LC and its implementation? The research aims to evaluate the strengths and weaknesses of LC. Moreover the research aims to define LC impacts and benefits on the projects in terms of cost, time and quality.

The research is based on literature review, case study analysis and interviews with top-experts.

## Literature review

LC is a project management philosophy based on a set of approaches developed in production management and adapted for the project management. LC targets the objectives of a Lean Production system, maximizing value and minimizing waste (LCI, 2007).

LC takes the five principles of Lean Production (Value, Value Stream, Flow, Pull and Perfection) and applies them to construction industry to minimize waste (Picchi and Granja, 2004). Lean thinking applied to construction can be summarized in: waste elimination; Improving reliability; Creating continuous flow in a pull system; Meet the customer's need; Involvement of workers at every level; Involvement of supplier and client in the project process; Built in quality; Continuous improvement; Knowledge sharing.

Table 1 shows the main differences between LC and usual construction techniques. The main effort of lean thinking is in reducing the high variability that affects projects through a more reliable workflow of materials, information and equipment mainly through the Last Planner System (Thomas *et al.*, 2003). Moreover, LC is not aimed to optimize the project activity by activity but optimize the overall project considering how every single activity affects the next (Howell, 1999).

The LC includes a set of tools, most of them presented by (Salem *et al.*, 2005). The most relevant are (with related focused reference): Last Planner (Neil, 2003), Visualization (Hall, 1986), (Highways Agency, 2010), Daily Huddle Meeting (Highways Agency, 2010), 5s Processes: (Ballard and Howell, 1994), Fail Safe for Quality and Safety "Poka-Yoke" (Bertelsen, 2004), Target Value Design (Howell *et al.*, 2007). In particular, "Poka-Yoke (Shingo, 1985) means 'mistake-proofing' or more literally avoiding (yokeru) inadvertent errors (poka). Ideally, poka-yokes ensure that proper conditions exist before actually executing a process step, preventing defects from occurring in the first place. Where this is not possible, poka-yokes perform a detective function, eliminating defects in the process as early as possible. Poka-yoke can be used wherever something can go wrong

| Traditional Construction | | Lean Construction |
|---|---|---|
| Uses the same activity centered approach used in mass production and project management | ▶ | Defines a clear set of objectives for delivery process |
| Aims to optimize the project activity by activity and identifies customer value in design | ▶ | Aims at maximizing performance to the customer at the project level |
| Breaks the project into pieces and puts them in a logical sequence focusing on each activity | ▶ | Designs concurrently product and process |
| Considers control as monitoring each activity against its schedule and budget projections | ▶ | Applies production control throughout the entire project life |

Table 1. **Difference between traditional construction and L**

or an error can be made. It is a technique, a tool that can be applied to any type of process in manufacturing, service or construction industry. It copes with several types of errors, including: Processing error, Setup error, Missing part, Improper part/item, Operations error and Measurement error, errors in machine adjustment, test measurement or dimensions of a part coming in from a supplier.

## Methodology

The methodology employed in this research is based on the following steps:

1. Initial literature review to define the state of the art of LC
2. First set case studies analysis of projects adopting LC principles
3. Interviews with experts to discuss the findings
4. Second literature review focused on the critical aspects emerged from the previous steps
5. Second group of case studies analysis
6. Interviews with experts
7. Definition of the Fuzzy cognitive maps (see section 4)
8. Final validation with experts.

In summary the research is based on the following data:

- 7 Case Studies built with primary data;
- 12 Case Studies on CLIP (Construction Lean Improvement Programme) projects;
- Firms Interviews conducted using a semi-structured questionnaire;
- Several interviews (face to face and email) with a LC experts.

The case studies are based both on primary and secondary data. The authors built the case studies following the guidelines from (Yin, 2009). The number of cases analyzed is consistent with the concept of "Theoretical saturation" presented in (Eisenhardt, 1989).

Regarding the interviews, the authors discussed the salient aspects of LC with a semi-structured questionnaire. The authors interviewed professionals working for construction companies and a consultant expert of implementation of LC in construction companies. Furthermore, the authors interviewed 4 firms applying LC in their projects. This highlighted the aspects considered most critical by the senior managers. A final interview to a lean expert mentoring firms in developing LC in their projects, provided a summative view about how construction firms might move in the initial phases and how they might solve initial problems. By integrating firms and expert interviews, it has been possible to picture an holistic view of LC.

## The LC Fuzzy Cognitive Map

A Fuzzy Cognitive Map is a graph that shows the degree of causal relationship among concepts of the map. It can be used to compute the "strength of impact" of these elements (Kosko, 1986). Figure 1 presents one of the main results of this research: a fuzzy cognitive map on LC. This output comes from the analysis of integrated data of literature review, construction firms' interviews and case studies. It is the result of a progressive approach ended with its validation between May and November 2011 by lean experts and 3 authors of references cited in this paper as Ballard, Howell and Koskela. Arrows indicate which elements influence which other while the "plus" and "minus" signs show the positive and negative correlation and its intensity. The main elements and relationships are discussed right after.

Stakeholders involvement: LC is based on the *supplier involvement* in order to achieve on time delivery of information and materials to project sites. LC leads to *customer involvement* in order to develop the project in a better way i.e. it is possible to understand the real needs and to reveal the consequences of the wishes (Ballard and Zabelle, 2000). The lean idea is (1) to provide to the customers exactly what they need; (2) to accomplish this goal without waste, focusing on *customer value* (Ballard, 2007). A key aspect is to involve the stakeholders to learn lessons useful for future projects and avoid repeating the same mistakes twice (Locatelli and Mancini, 2012). An important feature of LC is *sharing knowledge*. LC promotes information sharing at every level (Sacks *et al.*, 2010).

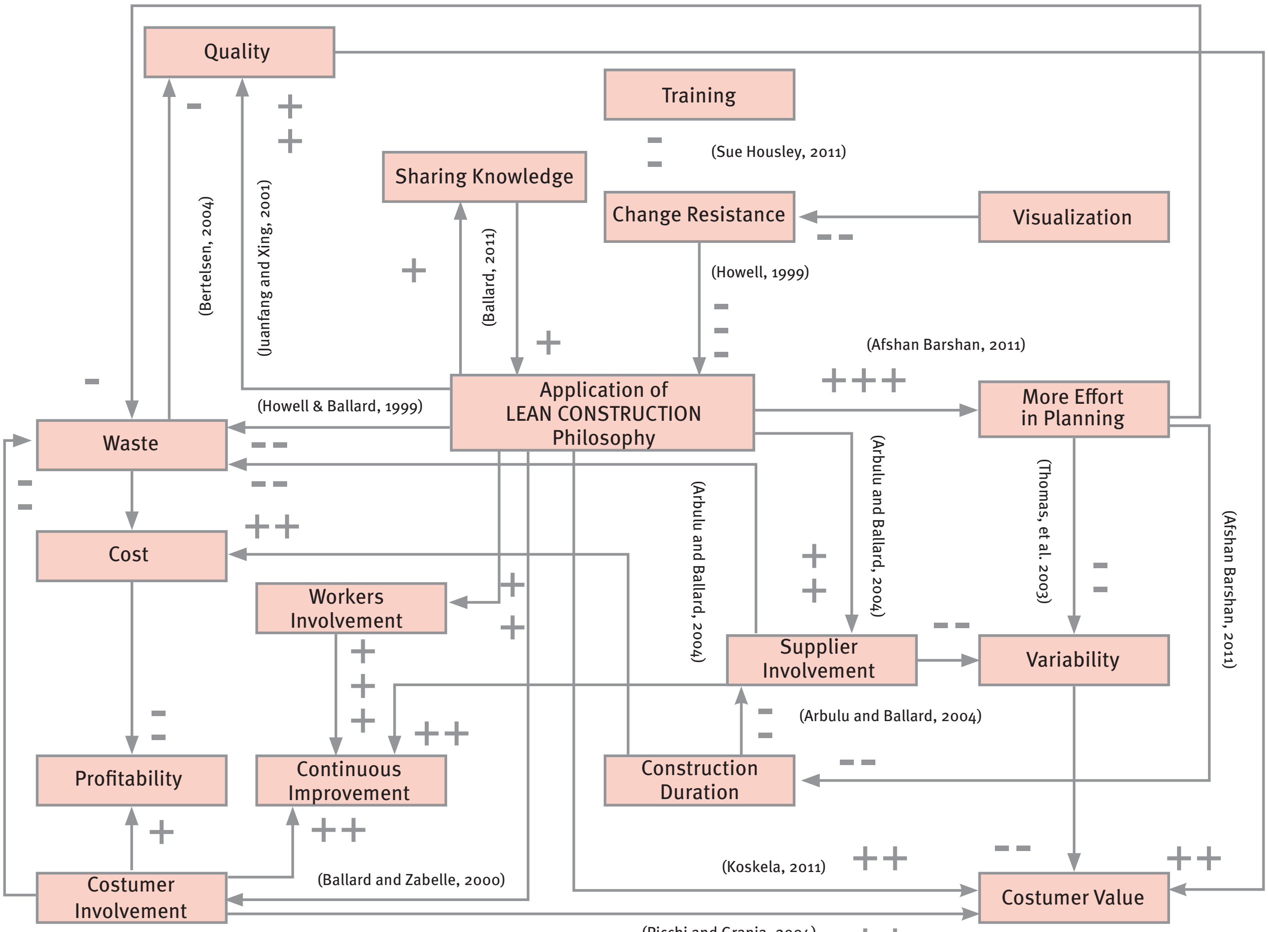


Figure 1. **Fuzzy Cognitive Map of LC.**

Change Resistance: LC has often to face "change resistance" from most of the stakeholders involved (Howell, 1999). People generally stand out against changes of their operational practices and this prevents the application of the *LC philosophy*.

Training: In order to fight *change resistance* a deep training of the stakeholders involved is necessary. In this way it is possible to let them understand the lean principles and increase workers motivation.

Visualization: The visualization of the achieved benefits and the project progress represents a good way to persuade workers to embrace lean philosophy and overcome *resistance*. Visualization can be increased, for example, through the use of displays placed at construction site, organizing stand-up meetings and use of CEDAC (Cause and Effect Diagram with the Addition of Cards).

Workers Involvement: Improvements in performance cannot be achieved just through the application of lean principles or tools, without a simultaneous strain for a lean culture. Indeed, it is necessary to involve and motivate workers at every level to reach lean benefits (Höök and Stehn, 2008). CEDAC is one of the lean tools that strives workers involvement with the aim to reach a *continuous improvement* of the process. It promotes the collection of employees' suggestions for the problem setting and problem solving.

Supplier Involvement: The inclusion of the suppliers in the planning process fosters the reduction of material lead times and inventories, promotes the on time delivery of information and materials to projects site reducing the *variability* linked to the supply system (Arbulu and Ballard, 2004). Moreover, establishing a trust and lasting relationships with suppliers introduces more reliability in the process also on terms of quality supply (Ruuska et al. 2011). The improvements of suppliers relationships affect directly on the construction duration. Better suppliers'relationships decrease the lead-time, inventories and the need of quality inspection of material. Thanks to a closer relationships and collaboration with suppliers, it is possible to identify problems, find together solutions, introduce changes in the project process and create a system that leads to a continuous improvement.

More Effort in Planning: More effort in planning, through the Last Planner technique, promotes a smooth workflow and decreases the *variability* in the process. A more accurate planning allows easier management of the project especially during small crises. Moreover a major effort in planning, focused on coordination and commitment, allows the reduction of waiting and so the reduction of *construction duration*. Improving coordination and detailing planning allows the reduction of *waste* in terms of waiting for information and materials, space used by inventories and unnecessary transportation.

Variability: A more reliable process in terms of time and quality increases customer satisfaction and therefore *customer value*.

Construction Duration: A reduction of the construction time decreases, other things being equal, project costs because the necessary human resources and equipment are used for less time and because it is less likely to penalties due to delays in delivery.

Quality: Improving project quality, without additional cost, increases *customer value*.

Waste: A reduction of waste leads decrease the project costs because no value added activities are eliminated. "Reworking" in lean thinking means waste. The effort spent in eliminating waste leads also to better *quality*. For instance the lean tools, called *poka-yoke* devices, alerts for potential defects avoiding unnecessary reworking (Dos Santos and Powell, 1999).

Cost: It is evident that a reduction of cost impacts directly on *profitability*. Even considering the initial cost of setting up the LC implementation investment, the overall economic result is usually positive.

Customers Involvement: Including customers during project definition and design phase leads to *waste* reduction. It is possible to focus on the real customers' needs and to show immediately the impact of customers' wishes. Customers involvement allow the reduction of reworking and adjustments during the construction. Thanks to a closer relationship and collaboration with customers in the early stages, it is possible to identify some problems and find together solutions, introduce changes in the project processes and create a system that leads to a *continuous improvement*.

The application of lean principles or tools, without a simultaneous strain for a lean culture, does not lead to any results or benefits (Höök and Stehn, 2008). In order to reach improvement sin performance, LC aims to involve the stakeholders through some lean tools, such as Visualization Management and Daily Huddle Meeting (Salem *et al.,* 2006). LC promotes the supplier involvement in order to achieve on time information and materials to project sites. Moreover LC leads to customer involvement in order to (1) understand the real needs, (2) explicit the consequences of the wishes, (3) develop the project in a better way and (4) provide exactly what they need.

## Results Answers to Research Questions

The answers to the research questions comes from the sources presented in the methodology section, i.e. literature review, the interviews with the firms and expert and the analysis of 19 case studies.

1. Which projects are suitable to for LC?

Fig. 2 (a) and (b) presents the results from the aforementioned 19 case studies of LC applications. They analyses the dimension of Budget vs. Time Saving and Budget vs. Productivity Increases (there are less than 19 points because these analyses were not available for all the case studies). The graphs clearly show as the LC can be applied to a wide range a projects with budget spanning from less than 1 million of $ to multi-billions $. Therefore,

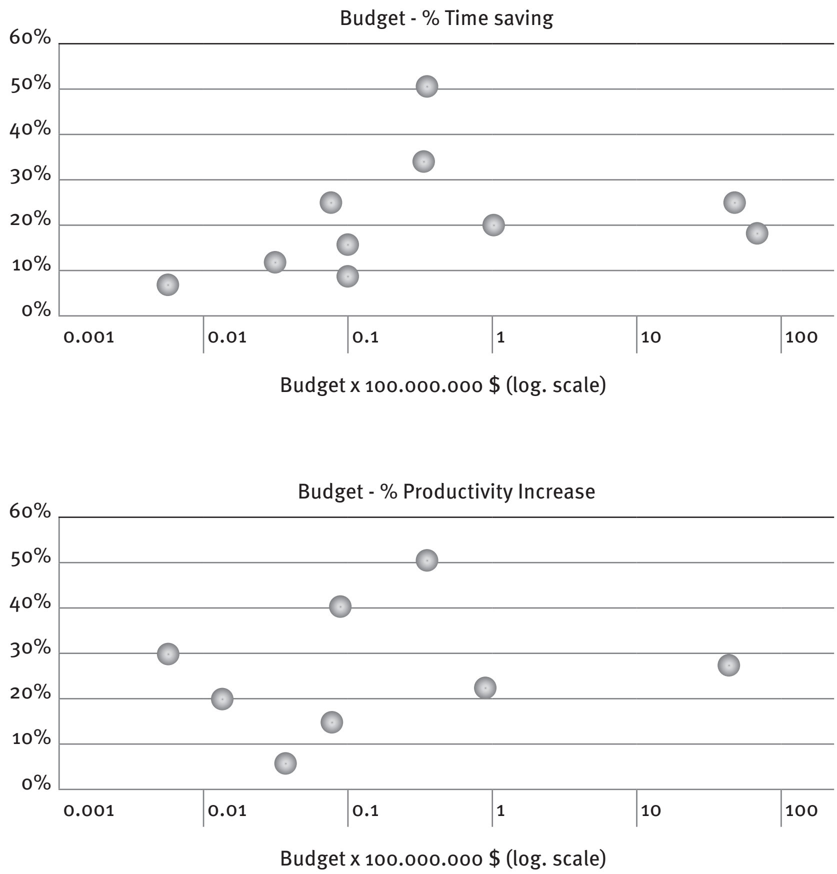


Figure 2. **(a) and (b) show how the LC can be applied to a wide range of projects**

the investment on LC application should always be included in the R&D budget of a project. Since one of the main difficulty in LC implementation is the resistance to change, a delay in the starting phase of the construction must be considered in order to adequately share the LC principles among the stakeholders involved. Regardless the size the adoption of LC causes a time saving of about 20%-30%, and an increased productivity of the same order of magnitude.

Figure 3 deeps the analysis showing the reasons for the adoption of LC, as reported in the 19 case studies. Reduction of Waste, development of better relationships with the customer and more reliability in cost and schedule estimations are the most important benefits. Figure 3 summarises the most relevant incentives for adopting LC. “Reduction of waste”, “Better relationships” and “Reliability” are the three most important.

**2.** How can a firm implement LC?

The adoption of LC is not always easy since the main barriers in adopting the LC are:

- It can be undervalued since it might be seen as a common sense; for this reason workers' effort in its application will not be enough;
- It seem to be counter-intuitive since it is focused on the work-flow and not on time and cost;
- Lean thinking is born as a manufacturing approach and it might be hard to prove that it is suitable also in the construction industry;

The case studies and experts' interviews show as the implementation of LC often requires an investment of less than 100.000€. Considered the typical turnaround of construction companies is evident as this investment is a tiny portion of the budget available. Consequently, the main challenge for implementing the LC is not the cost itself, but the resistance to change from the workers involved. The measures to overcome the resistance are:

- Training: it can include lean seminars, guides development, examples of real experiences in LC implementation, support of an external consultant with experience in the field of LC. Fig. 4 summarizes time, techniques and tools necessary to achieve this goal;
- Kaizen week: the Japanese word Kaizen means “continuous improvement”. Kaizen involves every employee. Everyone is encouraged to come up with small improvement suggestions on a regular basis. In most cases, these are not ideas for major changes. Kaizen is based on making little changes on a regular basis: always improving productivity, safety and effectiveness while reducing waste. The “Kaizen week” is a week where the firms, supported by a Kaizen expert, start to introduce (or strengths) the Kaizen philosophy is its daily work. During this week changes and improvements are made applying lean principles. This might show and prove the possible and potential benefits of the LC application in a short time;
- Visualization: the project progress and the benefits need to be showed during weekly meetings and on the visual displays placed at construction site.

An example of possible holistic approach is shown in Fig. 5. After the agreement with the top management about implementing LC the first step would be to create a multidisciplinary project team. This would be essential since no one have the holistic knowledge of the workflow required to deliver an high quality project to the customer. Before starting the project the team members need to attend one or more seminars to ensure they were familiar with Lean Principles. The seminars are also required to overcome any potential reticence that team members might have towards the implementation of

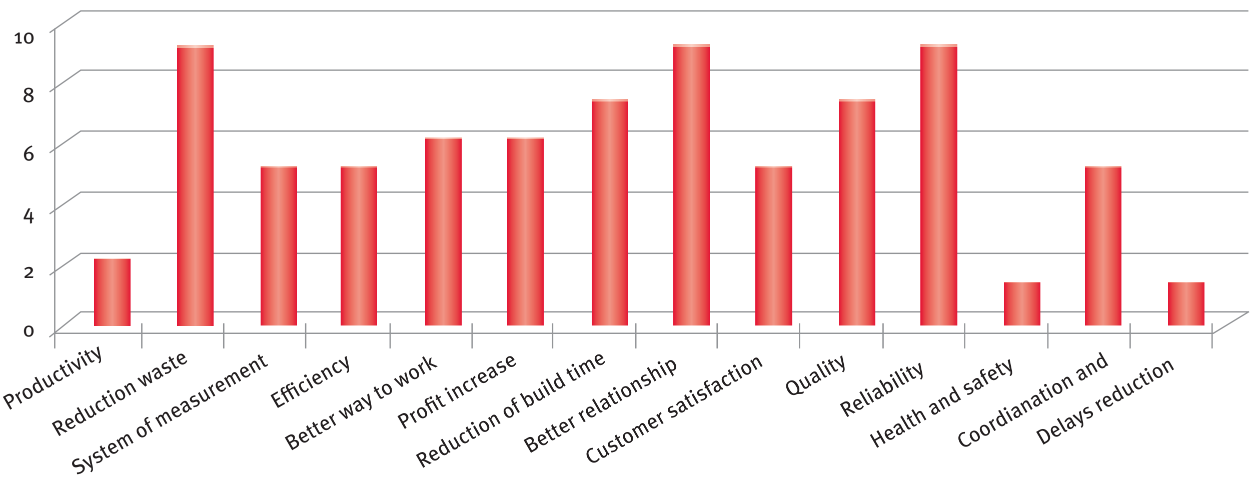


**Figure 3 Incentives for adopting LC**

| Phase | Pathway | Parties Involved |
|---|---|---|
| Preparation | Persuasion of Top Mamagement ↓ | Top Management |
| | Interdisciplinary Project Team Definition ↓ | Project Team Members |
| | Training/Seminars ↓ Collaboration with a Lean Consultant ↓ | Project Team Members and Workers |
| | Aims Definition ↓ | Project Team Members |
| Implementation | Work Observation and Data Collection ↓ | Workers |
| | Brainstorming to Define Improvement Activities ↓ Weekly Meeting / Visual Display to take Process under Control and show the Benefits ↓ | Project Team Members and Workers |
| Continuous Improvement | Results Analysis and Knowledge Consolidation | Top Management Project Team Members and Workers |

Figure 4. **Time, techniques and tools used to persuade and train the three hierarchical levels**

Lean Strategies. Each project requires at least an external consultant i.e. an expert in the field of LC with prior experience of the implementation of LC in real-life projects. The role of this consultant would be to give guidance to the team during the planning phase and continued help and support during the implementation phase. During the initial meeting between the team and the consultant, all project aims and time scales would have been agreed.

Because of the essential requirement of colleting several types of data throughout the life of the project, it would also be necessary for the consultant to promote the need for on-going analysis and evaluation and provide training in the techniques required. On-going monitoring and evaluation would include the analysis of the effectiveness of methodologies employed, the efficiency of processes and the quantities of waste generated. Analysis and evaluation would need to inform subsequent work on an on-going basis to ensure the optimisation of workflows and procedures. This would be achieved by designing, and then continually refining a current state process map. The project team would need to meet weekly to ensure the implementation was effective as possible.

Visual displays need to be placed at construction site to allow workers to see how the project is progressing throughout the various stages.

Research has indicated that the majority of firms have firstly chosen to implement LC in a single pilot project. Seen the benefits on to the pilot project they often decide to expand the approach to the other projects in the portfolio. Another approach has been to firstly use a pilot business unit, and then apply LC to the other units.

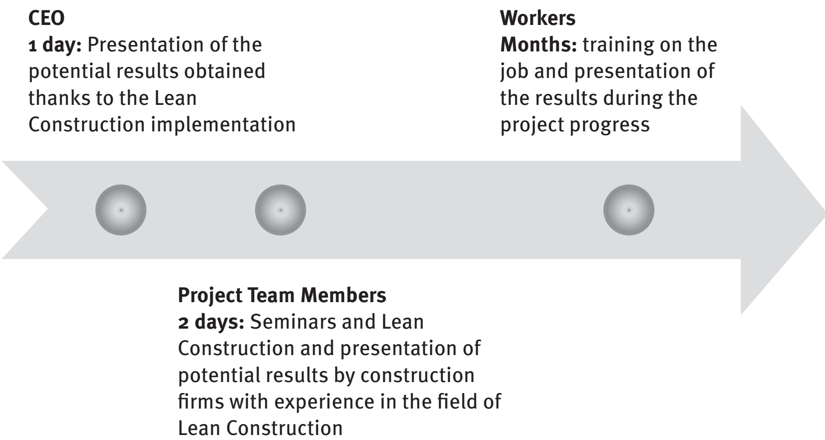


Figure. 5 **Proposed pathway for the implementation of LC**

3. Which are strength and weaknesses of LC and its implementation?

   LC strengths and weaknesses are summarizes in Table 2.

## Conclusions: how LC can improve project management.

The most common benefits of LC are a shorter delivery time and a higher project performance, because:

- The Productivity of the workforce increases (e.g. thanks to Poka-Yoke devices);
- There is a better coordination and communication with suppliers;
- There is a minimization of re-working following the lean principles "Do the right thing at the beginning";
- There is a minimization of no value-added activities focusing on the real customer's needs.

To exploit the benefits reached with LC implementation, it is possible to follow a process based on five steps:

| | | REFERENCES |
|---|---|---|
| STRENGTHS | Minimization of reworking | (Ballard, 2007), (CLIP, 2003), (Dos Santos and Powell, 1999), (Pinch, 2005),(Salem et al. 2006). |
| | Increased project reliability | (Arbulu and Ballard, 2004),(Ballard, 2003),(Ballard et al., 1996), (Howell G. A., 1999),(Lantelme and Formoso, 1999),(Salem et al., 2005), (Thomas et al., 2003). |
| | Projects are completed within budget | (Arbulu and Ballard), (Ballard, 2003), (Brady et al., 2006), (CLIP, 2003),(Conte, 2002),(Dos Santos and Powell, 1999), (Juanfang and Xing, 2011), (Pasternack, 2008), (Picchi and Granja, 2004), (Pinch, 2005), (Salem and Zimmer, 2005), (Thomas et al., 2003) |
| | Increased workers motivation and satisfaction | (CLIP, 2003) |
| | Good organized way of work | (CLIP, 2003) |
| | Positive feedback on the basis of trials | (CLIP, 2003) |
| | Fewer instances of conflict between all parties involved | (CLIP, 2003), (Pasternack, 2008) |
| | Promotion of greater degree of creative thinking and innovation | (CLIP, 2003) |
| WEAKNESSES | Challenge to widespread the culture | (CLIP, 2003), (Howell G. A., 1999) |
| | Need to overcome initial resistance | (CLIP, 2003), (Howell G. A., 1999) |
| | Associated training costs | (CLIP, 2003) |

Table 2. **Strengths and weakness of LC application**

1. Definition of indicators that are relevant for workers and establishing the values of the existing operational standards. The indicators need to be as simple as possible so that everyone at construction site can understand them.
2. Planning the benefits: all potential benefits should be considered and estimated in a realistic way;
3. Measuring the benefits: during the project the benefits forecast should be reviewed and updated and evidence to support benefits should be captured;
4. Realising the benefits: the actual benefits achieved should be recorded;
5. Analysing and reporting the benefits: a short and simple benefits report should be released monthly.

The main result of the paper is the formal clustering of LC benefits through the definition of a LC Fuzzy Cognitive Mape. The merging of formal academic results, real case studies (with primary and secondary data) and interviews to international experts brings to the conclusion that the most important investment for a LC strategy implementation is in the team members' training (possibly with the support of external consultants with experience in LC field). Investing in LC might be very profitable because with small investments it is possible to strongly increase the probability to deliver projects on time avoiding penalties and minimizing costs linked to waste. Investment required to introduce LC is generally under €100.000 and the return of the investment is generally much higher.

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