

EXPERIENCE AND RESULTS FROM IMPLEMENTING LEAN CONSTRUCTION IN A LARGE DANISH CONTRACTING FIRM

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ABSTRACT

MT Højgaard – the largest contracting firm in Denmark – has in a number of years worked seriously with implementing Lean Construction. Lean methods have been used on more than 30 completed or ongoing construction projects. This paper takes stock of the experience and results obtained in the implementation process by presenting the main findings in our 2002 annual report on lean construction.

The outline is as follows. First, an overview of the implementation of Lean Construction in MT Højgaard is given. This implementation consists of well-known lean methods such as “last planner” and “look ahead”, but more idiosyncratic methods are also presented in this section. For instance, the introduction of a new role on the building site (the “process manager”) and an IT-tool supporting lean-planning (called “PlanLog”).

The number of lean projects performed in MT Højgaard provides an excellent opportunity for presenting aggregate data. Thus, second, the paper examines on a project level how the application of lean methods affects benchmarks such as profit (level and predictability), safety, client satisfaction and administrative costs. These preliminary data suggests that all parties can benefit from using LC. Among others, profit is increased for the main contractor as well as for the subcontractors and the workforce on the building site experiences an improvement in the working environment.

The final section briefly explores some perspectives for the use of lean in MT Højgaard. In particular the possibility of using lean ideas in the design phase is raised.

KEY WORDS:

Lean Construction, Benchmarking, safety, Lean Design

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INTRODUCTION

Lean construction (LC) has gained momentum since the ideas, thoughts, methods and tools were introduced more than a decade ago (Koskela 1992). Evidently, the LC-way of perceiving and managing the building process appeals to academics as well as people working within the construction industry. The number – and dispersion of nationality - of contributors of papers to the annual International conferences on Lean Construction (IGLC) is one sign of the growing interest. The support from the industry to the Lean Construction Institute (LCI) is another.

MT Højgaard (the largest building contractor in Denmark) has been a key player in this respect. In MT Højgaard, LC has been an integrated part of strategy for the Building Division since 2001 but embryonic lean ideas can be traced back to projects performed in the early 90s. LC principles (as explained below) have been implemented on more than 30 completed or ongoing projects and is now announced to be implemented across projects in all divisions of MT Højgaard. The challenge of a firm wide implementation of LC makes it obvious to take stock of the experiences gained in the housing division. Specifically, this paper summarises results from 2002 (the paper is based on an internal annual LC report).

The outline of the paper is as follows. First, an overview of the implementation of LC in MT Højgaards Building Division is given. Second, the results achieved by LC methods is presented and discussed. Finally, future perspectives for the use of LC in MT Højgaard are briefly considered.

IMPLEMENTATION OF LC

In 2002 LC principles were applied to 19 building projects representing approximately 40% of the total turnover in the Building Division.

The 19 projects are varied in character:

- Small and large projects. The smallest project had an turnover of 2 million euro, the largest more than 30 million euro.
- Different types of buildings: housing, offices, warehouses, stores, production facilities, refurbishment, etc.
- Projects with various degrees of complexity: from projects with simple designs and structures, plenty of space on the building site, and sufficient time to the very opposite.

The LC concept as applied in MT Højgaard consists of a set of interrelated methods and tools based on a lean understanding of project management:

- *Dynamic planning* with weekly work plans (last planner) on the meeting with the foremen and 5-weeks look-ahead plans at the site meeting.
- *Weekly evaluations* by PPC-measurement (**P**ercent **P**lanned **C**ompleted) and schemes summarising reasons for why activities are not executed as planned.

- A systematic effort at the weekly site meeting in order to ensure that the activities released by the look-ahead plan to the last planner are “sound”.⁵
- *Material Logistics*, including planning of large deliveries and a site plan.
- *Planlog*, an MS Project based planning system developed by MT Højgaard in order to support lean planning and pull-logistics.
- *The process manager*. The process manager is, in a Danish context, a new role introduced at the building site in order to facilitate bottom up planning by assisting the team work between subcontractors. Unlike the project manager, the process manager holds no formal responsibilities (or rights) with respect to economical and legal issues. Thus, the process manager can concentrate on ensuring a good collaboration with, and between, subcontractors. The process manager acts as the coach of the building site.

The application of the different LC elements on the various projects are summarised in table 1. This table also provide basis information for the different projects.

Table 1: Project application of LC methods, Building Division 2002

Project	Project characteristics				Period of building	Lean Construction elements used							
	Type of project	Turnover (mil. €)				Last planner / "foremen meeting"	Causes to "not performed as planned"	PPC	5 week Look Ahead	List of Pittfalls for sound activities	Logistics (on paper)	Logistics with PlanLog	
		5>	5-10	10-15									15<
1	Housing		X			15.5.02-01.06.03	X			x			
2	Housing		X			1.1.02-01.11.03	X			x	x	x	
3	Offices, shops and cinemas		X			15.11.02-31.10.03	X	X	x	x	x	(x)	
4	Housing		X			06.04.02-15.06.03	X	X	x	x	x		X
5	Offices, warehouse and production facilities			X		Kick Off 10.04.03							
6	Offices				X	21.01.02-04.07.03	X	X		x	x	x	/
7	Offices, production facilities			X		01.08.02-01.08.03	X			x	e	x	
8	Housing				X	01.03.02-01.02.04	X	X		x	x	x	
9	Hotel and parking facilities			X		01.10.02-21.04-04	(x)			x	(x)	x	X
10	Nursing home	X				30.10.02-28.11.03	X	X					
11	Nursing home	X				25.11.02-31.01.04	X	X					
12	Housing		X			01.12.02-21.03.03	X			x		(x)	
13	Housing	X				11.11.02-28.11.03	X						

⁵ More precisely, we work with seven flows that have to be managed as part of ensuring sound activities: information, materials, manpower, equipment, completion of previous activity, an accessible building site and external conditions (for instance approvals from local authorities).

14	Housing	X			15.04.02-28.02.03	X	X	x			(x)	
15	Offices			X	01.01.01-01.08.02	X	X	x	x	x	(x)	(X)
16	Offices			X	01.07.01-31.08.02	X	X	x				
17	Offices			X	05.12.01-10.03.03	X	X	x	x	x		X
18	Housing, shops	X			01.01.02-13.03.03	X			x			
19	Refurbishment (housing)		X		01.11.02-01.02.03	X				x		(x)

e=expected

LC Kick Offs have been held at the beginning of each project in order to introduce LC methods and tools – and not the least the fundamental thinking of LC – to the project management and to subcontractors.⁶

IMPLEMENTATION OF LC AT THE FIRM LEVEL

Besides the above project specific activities, a number of initiatives have been taken in order to implement LC at MT Højgaard:

- In 2001 and 2002, approximately 500 employees have attended a one-day introduction course to LC theory and methods.
- A selected group of approximately 40 project and process managers have attended a one-day course "process management and team work at the building site". This course is tailored to facilitate the job of process managers as it focuses on Human Resource Management aspects of project management.
- Education on the building sites in the planning software "PlanLog". Version 3.0 of this software has been launched in 2002.
- Workshops between process managers. At these meetings process managers exchange experience, problems, and solutions as experienced on their respective projects.
- A 3-person staff – mainly working with LC – assist in the development and implementation of the concept.
- In 2002, MT Højgaard joined LCI and has taken part in this network by participation in conferences, personal contacts, etc.
- Participation in the informal Danish network for LC.

⁶ The agenda for these kick-offs is as follow. First, sub-contractors and project management reflect on the typical barriers to efficient production at the building site. Second, internal LC consultants give a presentation to the basic principles of lean construction followed by a more practical introduction to the last planner system. This section is concluded by a joint discussion on if and how the barriers to efficient production outlined in the beginning of the kick-off are actually solved by the proposed lean approach. Finally, we play the game of parades in order to illustrate the importance of an even workflow.

LC RESULTS

The crucial question is of course if the application of LC improves on the building process. In order to assess the impact of LC, projects that have used LC tools have been benchmarked with projects in the Building Division not using LC tools. This section presents the data we have been able to collect at the present stage. As only a limited number of LC projects have been completed, the data are preliminary.

CUSTOMER SATISFACTION

Table 2: displays customer satisfaction for projects with and without LC.⁷

Table 2: Customer satisfaction

Customer satisfaction (1=lowest 5=highest)	Satisfaction with project
LC projects (21 obs.)	3,8
Not LC projects (59 obs)	3,6

As seen, the average score in Customer Satisfaction is slightly better for the 21 LC projects than for projects not using the LC methodology.

The rather narrow difference is not surprising when taking into account that LC in its present form in MT Højgaard is a concept targeted at the production on site and as such does not involve the client. However, it is worth mentioning that the only 5,0 in customer satisfaction (the highest obtainable grade) was given to a project that is considered to be a successful LC-project (as LC in this project was used by a group of subcontractors who had also used the concept on an earlier, and closely related, project).

LC AND PROFIT

LCs impact on the level and predictability (i.e. deviation from budget) of net profit⁸ at the project level is shown in figure 1.

The data should be read with utmost care as only 3 LC projects (and 13 non LC projects) were completed in 2002.

⁷ Measured by a standard questionnaire with 11 questions on client satisfaction with MT Højgaards handling of the entire process from tender to final delivery. Answers are given on five-point likert scale. The questionnaire is filled in by the client or the client representative towards the end of the building process.

⁸ "Net profit" = "Dækningsgrad 2 (DG2)" in Danish, that is MT Højgaards profit on Main or Design and Build projects after all project management costs have been deducted.

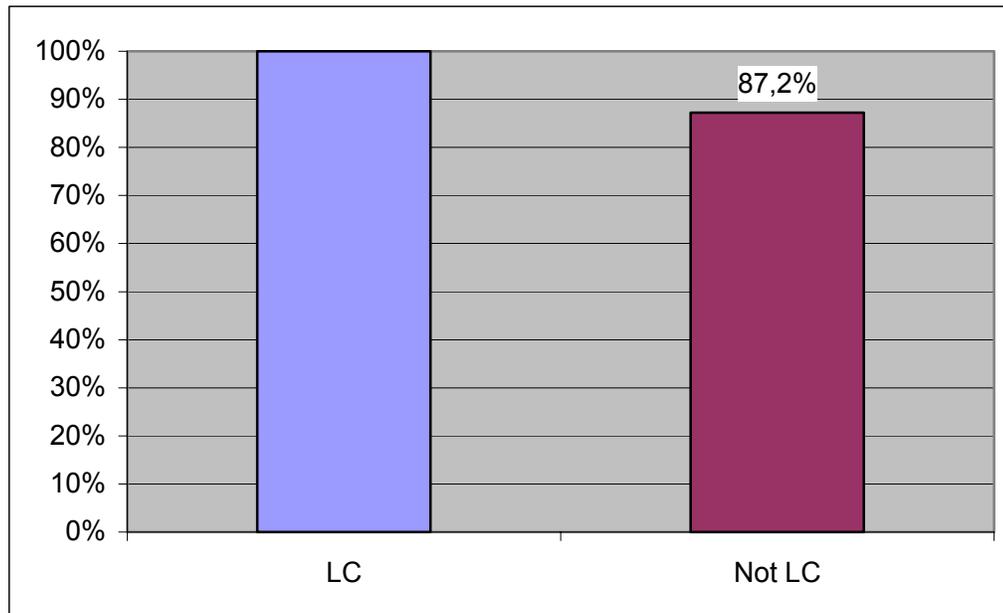


Figure 1: LC and profit, non-weighted average for completed projects above 700.000 euro

However, the very preliminary data do suggest that LC has a positive impact on profit as the average profit for the 3 LC projects is approximately 25% beyond the average profit for non LC projects. Both types of projects do not come up to expectations, but again LC projects perform better as the deviation between realised and budgeted profit is about 10% smaller for LC Projects.

Even though none of the 3 LC projects – unlike the 13 non LC projects - comes out with a negative net profit, the level of profit varies for these projects. Data from ongoing LC projects also suggest that even though LC may reduce uncertainties, they are not removed and in some cases LC projects will also perform significantly below the average. The way costs and time overruns escalate in some cases is still an issue that deserves attention.

PIECE RATES

A fundamental part of Lean Construction is to ensure an even workflow of activities (rather than trying to optimising the single activity on its own). Ideally, the focus on sound activities – i.e. activities are commenced only when the 7 aforementioned flow conditions are met – would imply a lower degree of disruption, which in turn is expected to generate higher piece rates.

But, as seen in table 3⁹, the piece rates for carpenters and concrete workers working on LC projects is only 1% beyond the piece rates for projects not using LC methods.

⁹ Table 3 only includes projects where MT Højgaard in-house carpenters or in-house concrete workers have been used. Only projects where some or all piece rates have been closed are included.

Table 3: Piece rates

		LC	Not LC
Carpenter	Projects	6	20
	No. of working hours	77.209	168.010
	Piece Rate (index)	100.0%	98.9%
Concrete	Projects	7	11
	No. of working hours	127.072	78.180
	Piece Rate (index)	100.0%	98.9%

The small difference does not necessarily imply that LC does not significantly improve piece rates. First of all, LC projects are more recent than the projects not using LC and as piece rates are usually set below the actual average as long as the project is ongoing, the LC piece rates may show up to be higher when projects are completed. The limited number of projects also inflicts uncertainty on the data. Finally, the efficiency of the building site is probably not the only variable that affects the level of piece rates.

SUBCONTRACTORS PROFIT

The data presented above has shown the effect of LC on the payment of the single worker (i.e., the piece rates) and on a firm level of the main design-and-build contractor managing the overall process. Data on external subcontractors' profits are usually harder to get, and consequently we have to limit the analysis to profit of internal subcontractors. More precisely, the net profit on completed and ongoing projects performed by our carpentry division has been analysed.

As seen in figure 2, based on a data set that includes 9 LC and 27 non LC projects, it seems that LC projects perform better as their profit on average is approximately 10% beyond the level of projects without LC.

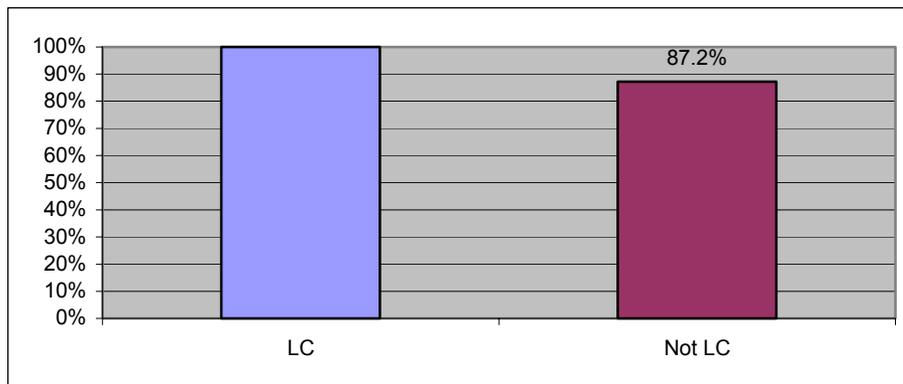


Figure 2: Net profit on ongoing and completed projects beyond 150.000 euro for carpentry division

ABSENCE DUE TO ILLNESS

Absence due to illness is another indicator that might inform us about what impact LC has on the people working on the site. Investigations by the Danish Institute for the working environment (“AMI”) have shown, that almost 50% of absence due to illness is related to psychological aspects of the working environment. Hence, a lower rate of absence due to illness would imply that the building site is a safer and / or a nicer place to work.

The absenteeism due to illness for craftsmen working in our internal carpenter and concrete division is displayed in figure 3.

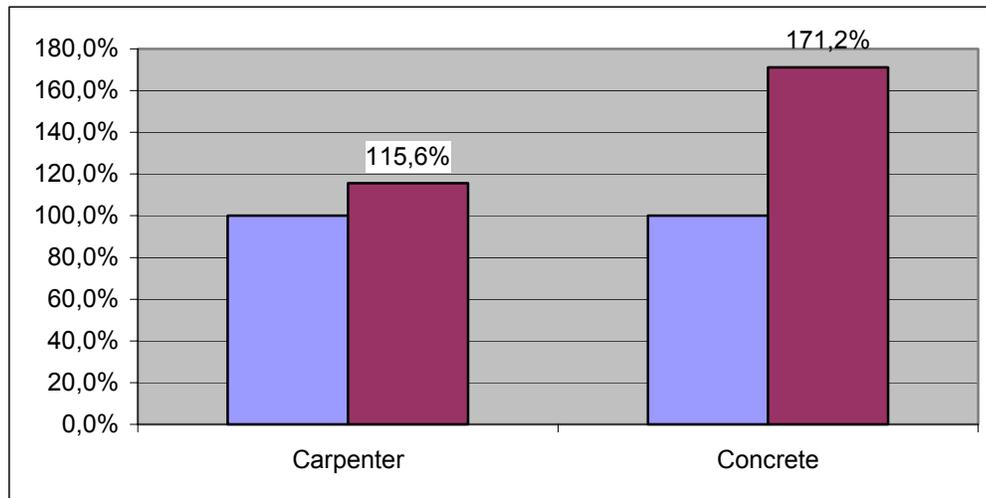


Figure 3: Level of absence for internal carpenters and concrete workmen

The data is based on the same dataset used for calculating the piece rates (see table 3.3).

Where the impact on piece rates, at least on the face of it, appeared to be minimal, the LC effect on absence due to illness is much greater. If we assume that the data is not a result of statistical variability, these findings suggest that LC is used for “working better” (i.e., improving the working environment) rather than “working faster”.

It is at first hand a bit surprising that the LC improvement in absenteeism is greater for the concrete workers than for the carpenters. The concrete workers are in the beginning of the line of production and are consequently less affected by an uneven workflow than the carpenters are. In this perspective it would seem more logical if the carpenters benefit the most from an improvement in workflow obtained by LC.

SAFETY

The previous section discussed how LC affected the psychological as well as the more physical working environment. Statistics on accidents make it is possible to take a more focused view and only look at the latter. Data on accident rates for internal carpenters, concrete workers, and bricklayers (and one category for “all”) are displayed in table 4.

Accident rate is here defined according to US-standards, i.e., the number of accidents causing one or more days of absence per 200,000 working hours.¹⁰ Only craftsmen are included in the statistics, i.e., neither the number of working hours nor the accidents of project management etc. are counted.

Table 4: Accidents and accident rates

		LC	Not LC
<i>All</i>	No of working hours	305604	580371
	No. of accidents	12	41
	Accident rate [%]	7,85	14,13
	p^{11}		6,95%
<i>Concrete</i>	No of working hours	131188	296237
	No. of accidents	7	21
	Accident rate [%]	10,68	14,18
	p		51,40%
<i>Carpenter</i>	No of working hours	126281	177386
	No. of accidents	5	14
	Accident rate [%]	7,92	15,78
	p		17,70%
<i>Bricklayer</i>	No of working hours	48135	106748
	No. of accidents	0	6
	Accident rate [%]	0	11,24
	p		10,00%

For the total set of observations it is almost 95% certain (100% - 6,9%) that the rate of accidents is lower for LC projects than for projects not using LC. If we look at each of the trades, the results are less significant due to smaller data samples but again it seems that LC substantially improves the working environment.

On one hand it may seem surprising that LC affects the level of accidents since LC in the outset does not deal directly with safety. But on the other hand, LC is based on an approach to the building process that potentially can affect safety:

- *Sound activities*. It is not hard to imagine how the presence of each of the seven conditions for sound production can affect safety; if *information* is present in due time, the craftsmen can plan their work properly; *previous activities* completed as planned prevents crowding of people in a limited space; *sufficient manning* reduces the possibility of working long hours; the *right equipment* and a *proper building site* also reduce the risk of accidents etc. In general, sound activities perhaps make it easier to stay in the space of non-chaos (Ramussen 1997).

¹⁰ The Danish way of defining accident rate is per 1,000,000 working hours. Hence, the figures presented here have to be multiplied by 5 in order to make them comparable with Danish standards.

¹¹ The p-value informs us about the likelihood that the two sets of observations in fact are identical due to statistical uncertainty even though they may look different. The p-values are calculated for a poisson distribution (a distribution used for random events) (Hair et al 1998).

- *Delegation of decisions.* A fundamental part of LC is a bottom up approach to planning. The foremen and the other people working on site play a vital part in the weekly planning process. Hence, the people who are the first to observe problems and who are the ones to do something about them, have the possibility of affecting the building process. In the terminology of Rasmussen (1997), the effect of delegation is perhaps that it is easier to operate at, or very close to, the edge of chaos as feed-back chains are much shorter and the system more manoeuvrable.

In conclusion, it seems that these preliminary data and reflections on safety represent an approach that is fundamentally different from approaches that focus directly (and narrowly) on safety. What is suggested here is that safety issues – and perhaps other issues like QA – are not matters in their own right but are the result of the way we understand, and consequently manage, the process of building.

PROJECT MANAGEMENT COSTS

The previous sections have pointed out a number of benefits from using LC. A reasonable objection would be that the improvements simply are a result of an increased managerial effort (and subsequent higher administrative costs). In order to investigate this claim, the costs used for salaries to project management on LC (14 observations) and not LC projects (18 observations) have been analysed (figure 4).

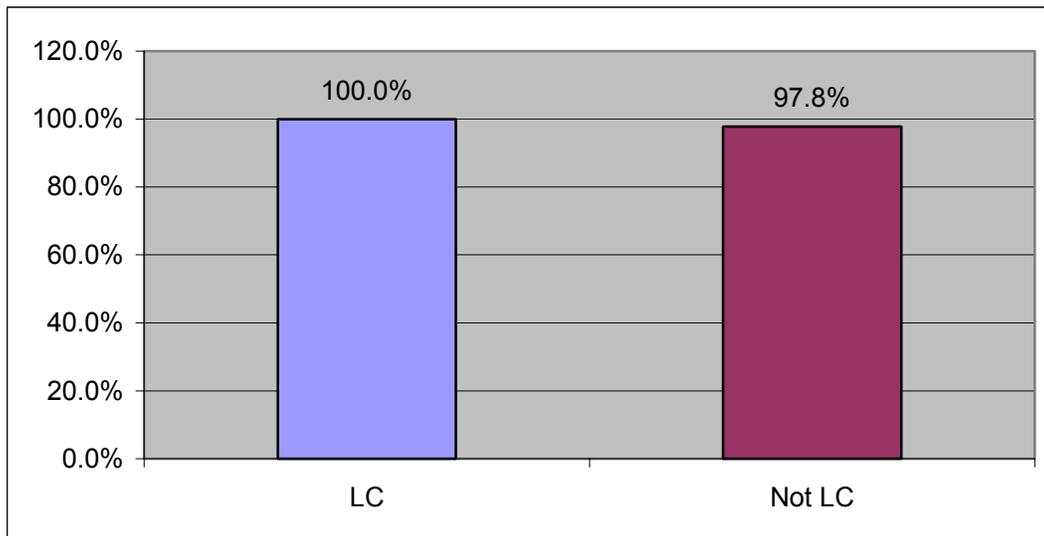


Figure 4: Project management costs (non-weighted average)

As seen, costs to project management are only slightly higher for LC projects. As a percentage of the total expenditure on a Main or a Design-and-Build Contract, the difference is only 0.1%.

The identical level of project management costs is very surprising as, at the present stage, we have added new functions but not yet reconfigured the present organisation (some of the traditional managerial roles on the building site may turn out to be obsolete). This suggests

that the increased cost associated with the work done by the process manager is saved on the “fire fighting” that typically occurs towards the end of traditional projects.

In addition, the application of LC principles is new on most projects. It is plausible that when these roles become more ingrained in our organisation, further reductions in costs can be made. Hence, it may turn out that project management by LC principles in the long run is cheaper than “traditional” project management.

CONCLUSION AND FURTHER PERSPECTIVES

This paper has offered an insight in how LC has been implemented in the Building Division in MT Højgaard. Furthermore, preliminary data on the results achieved have been presented.

Acknowledging the limitations of the present data, it seems justifiable to suggest that all parties can benefit from using LC. The profit of main / design and build contractors as well as subcontractors is increased, and the workforce on the building site experiences an improvement in the working environment.

The success of applying LC in the Building Division makes it obvious to consider how LC can be implemented to other parts of the building process and to other divisions within MT Højgaard.

At present, we work with using lean principles in the design phase. The first real life examples with *Lean Design* are promising. Initial theoretical reflections also suggest that the basic understanding and concepts of lean indeed are relevant to use in the detailed design phase as well (Koskela, Ballard and Tanhuanpää 1997, Freire and Alarcón 2000, Ballard and Zabelle 2000, Thomassen et al 2003).

The application of Lean Design will also make it possible to plan and structure the ordering of supplies and deliveries in a much more systematic way. Hence, Lean Design may pave the way for *Lean Supply* (Lamming 1996).

One of the general problems we have experienced is that it is difficult to implement the entire LC concept on all projects. Some parts of LC are easy to adopt whereas others contradict existing ways of perceiving the building process and consequently are hard to implement. The main barrier to success appears to be *attitude*, perhaps in particular the attitude of people not working on building sites.

Thus, it seems that ongoing teaching and support at all levels of the organisation is essential. Management “back at the main office” has to understand, support, and reward project managers in their use of lean concepts. Subcontractors also have to be involved as they play a vital role in the bottom up planning process. Thus, subcontractors are not easily replaced with new ones. This points towards the usefulness of combining LC with Supply Chain Management (creating long-term relations with preferred subcontractors).

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