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Improving construction management practice with the Last Planner System: a case study

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Abstract

Purpose – The purpose of this paper is to evaluate the effectiveness of implementing the Last Planner System (LPS) to improve construction planning practice and enhance site management in the Saudi construction industry.

Design/methodology/approach – LPS was implemented in two large state-owned construction projects through an action research process. The data collection methods included interviews, observations and a survey questionnaire.

Findings – The findings identify benefits including improved construction planning, enhanced site management and better communication and coordination between the parties involved. The paper describes the critical success factors for LPS implementation. The paper also describes barriers to the realisation the full potential of LPS, including the involvement of many subcontractors and people's commitment and attitude to time.

Research limitations/implications – The work reported in this paper is limited to two case studies.

Practical implications – The study has thus contributed to improving management practice and may aid the establishment of a basis for the development of further research in the area of lean construction. The research outcomes can inform practitioners of the opportunity to implement alternative management methods in construction, and give a good account of the opportunities and challenges. Beside the direct benefits to managerial practice, the study also contributed to practice by offering practical recommendation that can assist in the achievement of the full potential of lean and LPS in Saudi Arabia.

Originality/value – This is the first comprehensive academic study in the Saudi construction sector concerning the application of lean construction principles and techniques. The study has thus contributed to practice and developed a basis for the development of further research in the area of lean construction. It may help construction organisations to establish a new strategy and policies to improve their managerial practice. The outcomes of the case studies can be used as a reference for organisations seeking to improve their managerial practice.

Keywords Action research, Construction planning, Last Planner System implementation

Paper type Case study

1. Introduction

While it is accepted that construction management suffers from many practical problems (Wing *et al.*, 1998; Love *et al.*, 2002), research in this field tends typically to be descriptive and explanatory, which makes it inappropriate to solve the most persistent managerial problems (Koskela, 2008). One of the most commonly recurring problems in construction is delay.

AlSehaimi *et al.* (2013) examined most of the available literature about construction delay in developing countries including a number of delay studies in the Saudi

Engineering, Construction and Architectural Management
Vol. 21 No. 1, 2014
pp. 51-64

0969-9988
DOI 10.1108/ECAM-03-2012-0032

construction industry. Their study found that factors related to poor project management are common to most of the delay studies, although they vary in their importance from one study to another. It was also found that the delay causes cluster around two issues: management and project environment. Management-related factors include ineffective planning and control, poor site management, poor communication between the parties involved and unreliable availability of materials. The authors contended that such factors are controllable and efforts should be directed towards minimising their impact. In contrast, project environment factors (labour shortage, problems in material supply and financial difficulties), all of which are related to the immaturity of the economy, financial institutions and labour market in a developing country, are external factors that have to be taken as given in any project (AlSehaimi *et al.*, 2013). This paper argues that the impact of such controllable causes of delay needs to be minimised to improve performance. That is to say, controlling such causes of delay can be achieved via improving management practice.

One important improvement initiative, with direct practical impacts, has been the adoption of lean construction. Since the early 1990s, lean construction has evolved as a new way to manage construction more efficiently and effectively. Diverse lean techniques have been adopted in practice, aiming to enhance project management by eliminating waste, improving planning efficiency and reliability, improving productivity and maximising value (Ballard *et al.*, 2002).

The best known lean construction technique is the Last Planner System (LPS), which has been demonstrated as a very useful tool for the management of the construction process and the continuous monitoring of planning efficiency (Christoffersen *et al.*, 2001; Ballard and Howell, 2003). LPS has been tested in the field and refined over the last decade, with many reported benefits in diverse environments around the world, e.g. Fiallo and Revelo (2002) reports LPS implementation in Equator; Johansen and Porter (2003) in the UK; Thomassen *et al.* (2003) in Denmark; Koskenvesa and Koskela (2005) in Finland; Kim and Yang (2005) and Lim *et al.* (2006) in Korea; Alarcón *et al.* (2008) in Chile; and Junior *et al.* (1998) and Formoso and Moura (2009) in Brazil.

The literature, however, shows no evidence of LPS practical applications within Saudi Arabia. Therefore, this study is concerned with the application of existing principles (LPS) to a new context with a different working environment, where commitment and attitude to time make it likely to operate differently. The main aim of this research is to contribute to the improvement of management performance through practical endeavours. The LPS was tested to examine the utility of the technique in improving planning practice, thus enhancing management practice.

The paper is organised as follows. First, a literature synthesis on LPS is presented, including a brief discussion of its prior applications around the world. Second, the action research method adopted is discussed and the research carried out is described. Following, the strategy of implementing LPS in two large state-owned projects is examined and key research findings are presented and compared to the corresponding outcomes of previous similar LPS studies. Finally, discussion is carried out and conclusions are offered.

2. Literature review: LPS™

The "Last Planner" is the person or group accountable for production unit control, that is, the completion of individual assignments at the operational level (Ballard, 1994). In essence, LPS enables the collaborative management of the network of relationships

and communications needed to guarantee effective programme coordination, production planning and project delivery. It was developed to make programmes more predictable, thereby improving the chances of delivering projects on time.

LPS was developed to increase the effectiveness of planning and control by making programmes more predictable, thereby improving the chances of delivering them on time (Ballard, 2000). The system works to enhance reliability in three ways: through look ahead planning and the "make-ready" process, in which construction managers make work ready by ensuring that materials, information and equipment are available; by filtering planned activities through the weekly work planning procedure to ensure that the preceding activities have been completed; and by seeking conscious and reliable commitment of labour resources by the leaders of the work teams involved (Ballard, 2000). According to Ballard and Howell (1994), the LPS focuses on quality characteristics of weekly work plans by helping in the selection of the right work sequence and the right amount of work and by ensuring that the selected work can be done.

The LPS has five main integrated elements (Ballard, 2000; Ballard and Howell, 2003): master planning, phase planning, lookahead planning, weekly work planning, percent plan complete (PPC) and analysis of reasons for incomplete assignments. When systematically implemented, they offer major benefits to construction planning (Ballard and Howell, 2003).

The LPS has been implemented in a large number of projects in several countries since 1992 (Ballard and Howell, 2003). Many reports and research papers have confirmed that the technique has achieved remarkable improvements, including better planning and control, improved work flow reliability, increased productivity, promotion of team building; improved quality and safety, enhanced predictability, thereby reducing the duration and cost of projects (e.g. Ballard *et al.*, 1996; Garnett *et al.*, 1998; Junior *et al.*, 1998; Ballard, 2000; Fiallo and Revelo, 2002; Thomassen *et al.*, 2003; Koskenvesa and Koskela, 2005; Kim and Yang, 2005). Via its applications in case studies in many countries, LPS has proven to be a powerful tool for the management and planning of construction. In the UK, Johansen and Porter (2003) studied the application of LPS in the UK and found that LPS added value by structuring the planning process. The study reported that the involvement of many subcontractors is considered part of the culture of the industry and found to be an identical barrier in the UK construction industry. In Chile, Alarcón *et al.* (2008) acknowledged that the benefits of LPS include improvements in management and control, enhancement of plan reliability, reduction of urgent procurement requests and reductions in project schedule. The authors attribute improvements in PPC to factors including top management support, involvement and understanding of the implementation process. Another study by Fiallo and Revelo (2002) in Equator, have concluded that LPS improved the reliability of work flow, thus reducing cost and duration. The study observed that the incremental improvement is the general tendency in PPC.

3. Research method

Recently, it has been argued that research approaches such as design science research (or constructive research) and action research offer alternative methods to improve the level of performance in practice (van Aken, 2005; Järvinen, 2007; Voordijk, 2009; AlSehaimi *et al.*, 2013). It is believed that organisations should benefit from advances in knowledge, rather than just being subjects of research. To make academic research

relevant, researchers should try out their theories with practitioners in real situations and real organisations (Avison *et al.*, 1999).

Action research allows the parties involved to review the existing process (problem domain), identify the problem, to introduce changes to improve the situation, to evaluate their effects and to reflect on the process and the outcome, as well as to generate new knowledge (Baskerville, 1999; Naoum, 2001). What differentiates action research from traditional research approaches is that the researcher plays an active role in the case under study, working collaboratively with other participants (Naoum, 2001; Herr and Anderson, 2005).

Action research was adopted in this study, to respond to the practical concerns of people and to provide solutions to existing practical problems (Järvinen, 2007) and to enable the data collection and reflection process to focus on aspects that cannot easily be captured by other, more descriptive research approaches (Eden and Huxham, 1996).

3.1 Research carried out

Two action research studies were conducted in Saudi Arabia to examine the impact of LPS on improving planning practices in government facilities projects. The contractors were selected because of their extended history in the business and recognised success in the market place. According to the Saudi contractors' classification, the firms were classified in the top rank of the organisations that typically bid for government projects and contracts. The two construction organisations were mostly active in building projects. However, they also worked on other types of construction including roads, water and drainage networks. Two ongoing projects were selected for the motivation of their staff with this research, the firm commitment of executive management and the cooperation of clients in providing access to data.

Data were collected through a number of tools:

(1) Two to three hour semi-structured interviews: conducted with two project managers, two site managers and one planning engineer working in each of the projects under study, in order to evaluate the existing planning practices. Questions included the planning techniques being used, the level of involvement of other parties in the planning process, frequency of meetings, the facilitation of medium term planning and means of communication adopted.

(2) Non-participant observation: lasted for two weeks, and aimed to help in the identification of existing planning practices, prior to LPS implementation.

(3) Facilitation of LPS implementation, through participant observation: the researcher attended weekly meetings over 18 weeks with the project teams, at both case studies. In these meetings, PPC figures were recorded and reasons for incomplete assignments were tracked and analysed.

(4) Unstructured interviews: including project managers, site engineers, client representatives and consultant engineers. The aim was to seek their views of LPS as a planning system, its advantages and the benefits gained during its implementation. Additionally, these allowed reporting difficulties so that potential solutions could be examined.

(5) Survey questionnaire: to assess stakeholders' perceptions of the LPS, aiming to: evaluate the implementation process and to examine the extent to which the LPS was perceived to improve planning practice; identify benefits and barriers

to LPS adoption; and identify the critical success factors (CSFs). In the first project, 32 questionnaires were distributed and 26 responses received. In the second, 40 questionnaires were distributed and 32 responses received.

Table I summarises the studied projects in terms of type, contract size and duration. There was only one subcontractor in the first project, for electrical work, while all other work was done by the contractor's personnel. In the second project, there were four subcontractors, doing structural, architectural, mechanical and electrical work. The last column of the table shows the contractors' classification. The first contractor was assessed as class 1 in building work (Ministry of Public Works, 2006), meaning that it was able to bid for projects over SR 200 millions (USD 53 millions), while the second was placed in class 2, allowing it to tender for building projects worth up to SR 200 millions. In both case studies, LPS was implemented half way through the project.

4. LPS implementation

4.1 Existing planning practices

In the first phase of the implementation (shown in Figure 1), interviews and non-participant observation were conducted to examine the current planning practice. Findings suggest that planning was mostly based on a master plan presented on a bar chart issued at the beginning of the construction phase. Construction commenced with a meeting of the main parties involved in the project execution, whose purposes was to establish acceptable ground rules and to ensure that contractors understood all the job requirements.

A systematic review of project planning was found to be rare or non-existent. Regarding project evaluation, most interviewees said that they did not tend to refer to past job records, as these were either non-existent or inadequate. The interviews also revealed an absence of detailed short-term planning and improvement meetings to discuss project progress. As for planning techniques, most of the interviewees stated that their firms used the critical path method.

After the interviews, the application of LPS was discussed in detail and examples from previous studies were considered. As part of these discussions, the weaknesses of the current planning practices were observed and thought was given to how the LPS could enhance practice. This also included training on LPS implementation.

4.2 LPS implementation

An implementation strategy was developed for each case study company, where the main components of LPS were gradually implemented in four phases, with an evaluation at the end of each phase. Whilst in most prior studies on the LPS, the implementation has started from upstream stages, from master and phase planning,

Project	Contract	Duration (months)	Percentage of time elapsed when the LPS was implemented	Subcontractors	Main contractor classification
1	USD 21 millions	17	50	Electrical Structural Architectural Mechanical	Class 1
2	USD 10 millions	17	50	Electrical	Class 2

Table I.
Description of the projects studied

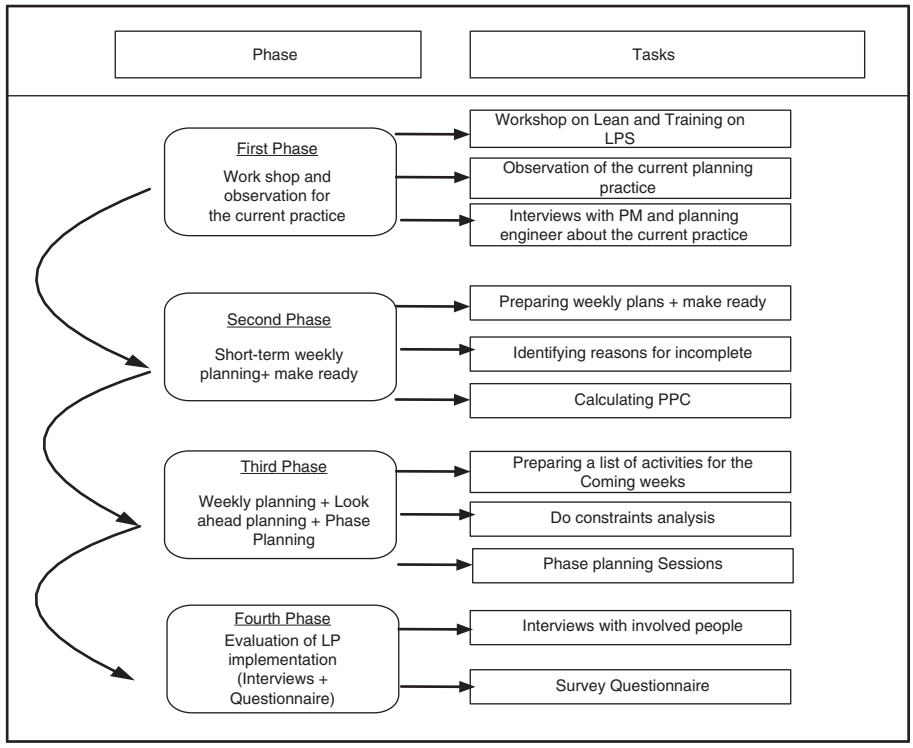

Figure 1.
LPS implementation strategy in the studied projects

here the implementation started from weekly planning, and progressed then towards upstream stages. However, few studies implemented LPS from short-term planning upwards including Koskenvesa and Koskela (2005) and Bortolazza and Formoso (2006).

The strategy was agreed upon after intensive discussion between project teams and the researcher. In both project, strategy of LPS implementation started with the short-term planning. Figure 1 shows the LPS implementation strategy adopted in both cases, followed by a description of the phases. In the first phase, a workshop on lean and training on the use of LPS were provided to highlight the benefits of LPS. After this, there was a two-week observation period to monitor the current practices, to interview the participants and to make notes.

In the second phase, it was agreed that PPC and reasons for incomplete assignments would be recorded weekly for five weeks. The focus was on short-term planning and make ready, while little attention was directed to lookahead planning. Two weekly meetings were held with the involvement of all project parties (contractor's team, client representatives, consultant engineers). Starting with short-term planning aimed to gradually introduce the other elements of LPS (look ahead planning, phase planning and stabilise production planning at the ground level. Invoking specific requirements such as definition, soundness, sequence, size and learning (Ballard and Howell, 1994) was introduced to achieve quality assignments. Furthermore, reasons for incomplete tasks were identified, analysed and acted upon, together with the PPC calculation in the weekly meetings. Constraints were documented according to

indications given by the project team and constraints analysis was performed jointly by all project members. Data, i.e. PPC and reasons for incomplete assignments, were collected during the summer, which is a very hot season in Saudi Arabia; in the year of the study, the temperature reached 52°C. Furthermore, data collection coincided with the month of Ramadan, when Muslims fast during daylight hours. Taken together, these factors significantly affected labour productivity and, hence assignment completion.

The third phase was the longest, lasting for eleven weeks in each project, during which two further components of the LPS were introduced: lookahead planning and phase planning. Phase planning allowed activities to be pulled through by reverse team planning and for resources to be optimised in the long term. In the first project, there were two lookahead windows, one covering four weeks and the other six weeks, whereas in the second case, only the four-week lookahead window was feasible. A possible explanation is that the involvement of many subcontractors made it difficult to produce six-week lookahead plans. Lookahead planning was extracted from the master plan zone by zone, then coordinated in the Last Planner (weekly) sheets. All planning levels were linked. During the all-day phase planning sessions, sticky notes were used to show the names, durations, prerequisites and locations of individual tasks on the project map. Each session was dedicated to a certain type of activity (i.e. finishing, mechanical), aiming to provide goals in each phase and then work backwards from the target completion date to achieve the proposed milestones. In practice, phase planning generates a detailed plan covering the respective project phase, thus allowing better visualisation of the flow of work, which assists all parties to negotiate deadlines for the planned work.

In the fourth phase, a survey questionnaire was administered to evaluate the LPS implementation. The key objective was to allow participants to self-report the benefits achieved, CSFs and barriers to LPS implementation in the project. The questionnaire contained ten questions, but only the questions related to the achieved benefits, CSFs and barriers for LPS implementation are covered here. Questions were formulated using a five-point Likert scale that requested participants to indicate their degree of agreement or disagreement with a series of statements. The respondents were given sufficient time to read the questionnaire, think about it and ask any questions they wished. Most participants answered in group sessions in the presence of the first author, who explained the questions, provided any clarification necessary and asked the participants to choose the answers they believed to be the most appropriate. The key findings obtained through the questionnaire are discussed in more detail below.

5. Research findings

5.1 Weekly PPC

PPC is a measure of the proportion of promises made that are delivered on time. It is calculated as the number of activities that are completed as planned divided by the total number of planned activities, presented as a percentage. At the time when the LPS implementation started, most of the work carried out consisted of structural activities. However, architectural activities started after week five and later after week 11, mechanical and electrical activities started. Generally, there was a gradual increase in weekly PPC over the implementation period, as shown in Figure 2, which indicates improvement in the planning practices. In the first project, PPC increased from 69 per cent in the first week to 86 per cent in the last week, peaking at 100 per cent in the first week after the introduction of lookahead planning and then stabilising at 86 per cent for

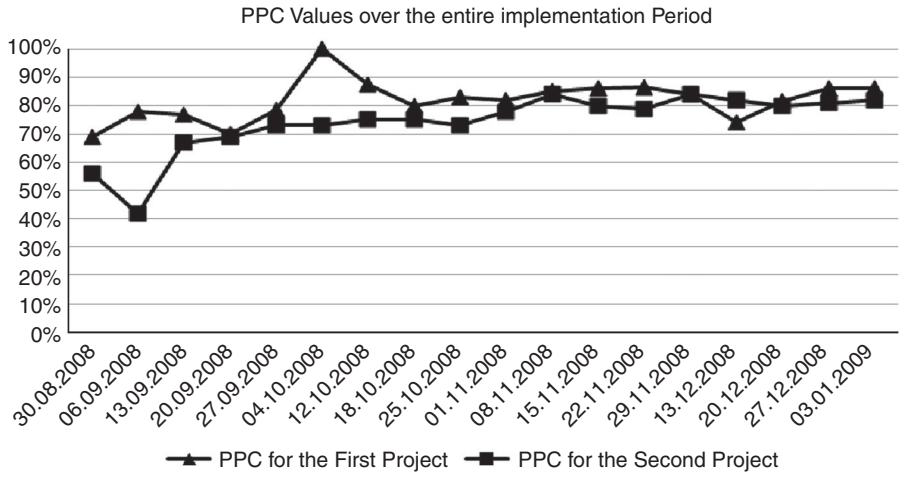

Figure 2.
Weekly PPC values over the entire implementation period for the two projects

the last two weeks of the project. In the second project, PPC rose from 56 per cent in the first week to 82 per cent in the last week, reaching a peak of 84 per cent and stabilising above 80 per cent for the last five weeks. In this project, PPC stabilised for many possible reasons; for example, a long time was spent in the preparation of the lookahead plans particularly during third phase, while learning from failure and mistakes experienced in the previous phase helped to improve this one. Additionally, the project team enhanced its professional practice and underwent continuous assessment to achieve this advanced result. Collectively, the gradual improvement in PPC over the period of the LPS implementation indicates that planning reliability improved over this period.

5.2 Reasons for incomplete assignments

Figure 3 shows the reasons for incomplete assignments identified in the two projects. The numbers in the figure is the accumulative number of occurrence for each cause

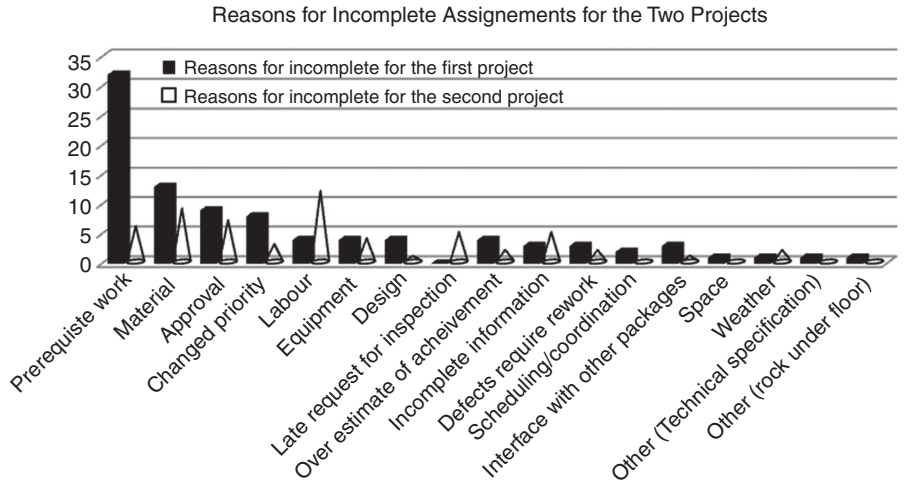

Figure 3.
Reasons for incomplete assignments over the whole period in the two projects

during the whole implementation period. Prerequisite work was the main reason for incomplete assignments in the first project. This is perhaps due to the nature of the stage that the project had reached, where most activities were dependent on structural assignments being completed. In the second project, labour supply was the main reason for incomplete assignments. It was clear that the project was always struggling to keep pace with the weekly and lookahead plans, because the available workforce was insufficient to meet the needs. The underlying cause was in the persistently high demand for skilled labour at a time when the country was passing through an unprecedented construction boom.

The second main reason for incomplete assignments in both projects was the restricted availability of materials, which occurred due to several factors. First, the approval procedure required by the client was time-consuming and caused delays in orders thus material delivery to the site. Second, suppliers did not always deliver the materials on time. Sometimes the wrong materials were delivered, mostly because the supplier was confused by the use of different block types and sizes.

In both projects, the third reason was related to approvals. The client's approval system was subject to bureaucracy and the overuse of paper-based communication, causing significant delays in decision making and in agreeing the purchase of materials. There was also an issue with requests being submitted too late for decisions to be made in time for the scheduled start of particular activities.

The fourth most common reason for incomplete assignments in the first project was a change of priorities, which mostly affected architectural activities, as they were not always sequence dependent. However, in some cases there was a need to change priority because of factors including the redistribution of labour between zones, confusion in sharing resources and the availability of professionals such as builders and carpenters. In the second project, the fourth reason for assignments incomplete was prerequisite work, which again applied mostly to structural and architectural activities.

The fifth reason for incomplete assignments in the first project was labour. However, in the case of the second project, the fifth reason was late or incomplete information. The sixth factor in the first project was equipment problems, which occurred with the same frequency in the second project.

5.3 Questionnaire outcomes (participants perceptions)

5.3.1 The effectiveness of the LPS implementation. There were four questions focused on the effectiveness of the LPS in improving construction management practice and improving site management, and the advantages of the LPS over traditional planning. In both case study companies, after eighteen weeks in implementation, most respondents agreed that the LPS is effective in improving planning. A strong majority (about 90 per cent) of the 26 respondents in the first project agreed that LPS was effective in terms of improving planning practice. In the second project, most of the 32 participants (about 86 per cent) also agreed. In respect to site management, a large majority agreed that LPS was effective, while most agreed that it was useful in minimising waste. When enquired about the advantages of LPS over traditional planning techniques; respondents revealed that benefits include: knowing the requirements of the project and prerequisites of tasks, helping to facilitate planning and control, and ability to better predict the completion date of the project.

5.3.2 Perceived benefits, CSFs and barriers. Three questions in the survey enquired about the CSFs for the implementation of LPS; the potential barriers for full use of the

system and the possibility of using LPS in the future projects. In terms of the benefits gained, results show that the process of implementing LPS was successful and beneficial for the both projects. The most important benefits, the key CSFs and the main barriers revealed by interviews and questionnaires are summarised in Table II. There are strong similarities between the two cases as to the benefits and CSFs, with slight differences only in the degree of agreement between respondents in the questionnaire.

The suggested benefits given in the questionnaire questions, CSFs and barriers were gleaned from experience in LPS implementation, from the literature on LPS and lean construction, and from observation and notes taken during the involvement of the researcher in the implementation process over a period of time. In all, 16 benefits were listed and respondents were asked to indicate their degree of agreement with them. The most important reported benefits shown in Table II include enabling accurate prediction of resources, enabling site supervisors to plan their workload better, reducing uncertainty and preparing team members to collaborate. The most commonly identified CSFs were top management support, commitment to promises, involvement of all stakeholders and communication and coordination between parties.

The questionnaire survey also revealed that most of the barriers identified were common to both projects, with disparities only in their degree of importance. These included: lengthy approval process by the client due to bureaucracy and use of routine paperwork, cultural issues, commitment and attitude to time. The last two factors are probably what differentiate Arab societies from others, since in this culture, people are often not punctual: delays of some hours or even days are usual and tolerated. It is normal to start meetings an hour late and most people are used to this. Such attitudes to time can have an impact on the implementation of techniques that are time-dependent and where a commitment to punctuality is crucial.

Table II.
Benefits, CSFs and barriers to implementation of the LPS

Project	Benefits	Critical success factors	Barriers
1	1. Enabling site supervisors to plan their workload 2. Improving learning process 3. Improving planning and control practice 4. Enabling accurate prediction of resources 5. Reducing uncertainity 6. Preparing team members to collaborate	1. Top management support 2. Commitment to promises 3. Involvement of all stakeholders 4. Communication between parties to achieve teamwork 5. Close relationship with suppliers 6. Motivating people to make change	1. Lengthy approval procedure by client 2. Cultural issues 3. Commitment and attitude to time 4. Short-term vision
2	1. Enabling accurate prediction of resources 2. Improving planning and control 3. Enabling site supervisors to plan their workload 4. Improving site management 5. Improving learning process 6. Reducing uncertainty	1. Commitment to promises 2. Communication and coordination between parties 3. Involvement of all stakeholders 4. Top management support 5. Close relations with suppliers 6. Managing resistance to change	1. Involvement of many subcontractors 2. Lengthy approval procedure by client 3. Commitment and attitude to time 4. Cultural issues 5. Short-term vision

When asked about implementing the LPS in future projects, the respondents (58 participants) stated: 88 per cent said that they would implement LPS in the future, while 12 per cent said that they would recommend its use. These positive responses perhaps reflect the degree of satisfaction of the parties with the system.

5.4 The present study compared to previous implementations of the LPS

It is opportune to compare the PPC achieved in this project to prior studies in LPS implementation. The study by Koskenvesa and Koskela (2005), in Finland, revealed that the PPC rose from 47 to over 80 per cent (average of four case studies). In this study, as shown in Figure 2, the PPC stabilized over 80 per cent in the last seven weeks. Some other quantitative statistics on implementing LPS are given by Koskela and Ballard (2006): in 1996, a mechanical contractor applied Last Planner to an industrial project and learned after six weeks of data collection that his PPC was averaging 60 per cent and that 70 per cent of plan failures were the result of late, incomplete or defective materials or deliveries. After action on the root causes of these failures, PPC increased to 80 per cent and the contractor completed the project with a 31 per cent gross margin. In another case study set in Korea (Kim and Yang, 2005), PPC rose from 62 to 85 per cent in the eighth week of LPS implementation after a series of meetings and after the analysis of reasons for incomplete assignments. Collectively, the tendency for an incremental improvement in PPCs indicates improvement in construction planning practice.

Another point for consideration is the causes of assignments incomplete. The dominant reason for non-completion in the first project was prerequisite work. This is in agreement with earlier studies (e.g. Ballard, 2000; Koskenvesa and Koskela, 2005). In the second project, labour was the main cause for incomplete assignments, as was also the case in a recent study by Formoso and Moura (2009). Their study revealed that the majority of the problems were of mainly internal origin (including the categories of labour, materials, equipment, design and planning), while few were of external origin (client interference, weather problems and suppliers).

Concerning the CSFs, the main CSFs identified by the questionnaire respondents were top management support, commitment to promises, involvement of all stakeholders and communication and coordination between parties to achieve teamwork. This is in agreement with the trends in lean and LPS, since much emphasis has been placed on these factors (Salem *et al.*, 2005; Alarcón *et al.*, 2008).

Another point of comparison, the major potential barriers to LPS implementation can be summarised as the involvement of various subcontractors, lengthy approval procedures on the part of the client (government departments), commitment and attitude to time in the Arab world and cultural issues (i.e. ideas, beliefs in the traditional system and behaviours when implementing a new system). The last two of these are probably what differentiates Arab societies from others. The second and third factors have been identified in this study for the first time, adding to the literature on LPS implementation. Previous studies have found some similar barriers; for example, Johansen and Porter (2003) cite the involvement of many subcontractors and cultural issues were found to barriers in the UK construction industry.

6. Discussion

In this study, incremental implementation helped to gradually stabilise the elements of LPS, to minimise resistance to change and to provide an opportunity to evaluate each phase and gather lessons learned. Additionally, starting by the short-term planning

enabled bringing all the involved parties together. Moreover, it was noticed that participants' confidence in the tool was strengthened by this gradual implementation. Short-term planning facilitated the introduction of lookahead planning and other LPS elements. After the first phase, which was focused on weekly planning, the majority of the site team believed that the LPS added value by structuring planning. Additionally, it enhanced the communication and collaboration between parties involved and helping the participants to be more disciplined. Further, participants revealed that LPS is more elaborated and informative and providing more and easy control for the successful execution of the project.

The results show a broad similarity between the two projects in the identity of the factors causing assignments to be incomplete. There was a tendency for PPC to increase gradually over the period of LPS implementation in the two cases. It is apparent from Table II that many advantages were gained including improvement in planning and control practices and enhancement in site management. Other benefits incorporate enable site supervisors to plan their workload, facilitating accurate prediction of resources and reducing uncertainty. By calculating PPC, analysing the reasons for incomplete assignments and conducting a constraints analysis, while the preparation of lookahead plans, continuous assessment and learning from failures and mistakes all helped to improve performance. Additionally, the action research process, involving collaboration between researchers and the organisations studied, allowed the researcher to influence practice directly (researcher input). At the start of LPS implementation, the researcher worked as a facilitator of the process. However, three months after the start, the project teams were able to drive the process forward without the researcher input.

The results of the questionnaire survey demonstrate that the implementation of LPS was perceived as successful at both case projects. Collectively, responses to the four questions concerning the effectiveness of LPS in improving management practice indicate that LPS has positive impact on improving management practice. LPS enabled the achievement of process stability and resource reliability, as well as the reduction of uncertainty in relation to the execution of production activities. Such stability has also been achieved in case study projects presented in previous research efforts, and it has been stated as an essential initial step towards improvement. LPS has proved to be a very proactive approach in reorganising the planning process, assisting in collaborative planning and providing forward information for control. Further, it helped through the visualisation of prediction of resources. The most important CSFs recognised by participants and mostly agreed upon include top management support, commitment to promises and involvement of all stakeholders. Participants' views of the potential barriers to LPS implementation indicate the following factors; involvement of many subcontractors, lengthy approval process by client and commitment and attitude to time.

7. Conclusion

This study contributes to existing construction research in the form of action research and its integrative implementation, which partially overcame some of the delay problems in construction projects. Through collaboration between the researchers and the organisations studied, improvements were achieved in terms of quality of work practice, enhancement of managerial practice, knowledge expansion and learning.

At the case studies carried out, LPS proved to be a proactive approach to reorganising the planning process, assisting in collaborative planning and providing forward information for control. Additionally, LPS enabled site teams to be more organised, effective and productive, which resulted in significant improvement. LPS

can facilitate a new, more effective way of performing production planning. In the case studies, it improved teamwork and enhanced continuous improvement.

This is the first comprehensive academic study in the Saudi construction sector concerning the application of lean construction techniques. Besides utilising LPS in its future projects, the leadership of one of the firms studied has taken an active interest in introducing lean practices stating "Implementing LPS should be viewed as an initial step towards building more competitive lean enterprise". The study has thus contributed to improving management practice and may aid the establishment of a basis for the development of further research in the area of lean construction. The research outcomes can inform practitioners of the opportunity to implement alternative management methods in construction, and give a good account of the opportunities and challenges. Beside the direct benefits to managerial practice, the study also contributed to practice by offering practical recommendation that can assist in the achievement of the full potential of lean and LPS in Saudi Arabia. These include the need for full support, interaction and commitment from top management and reducing the reliance on subcontractors. In addition, reconsideration of the bureaucratic style of management is needed and the adoption of ICT for making communication faster and more efficient is required. The outcomes of the case studies can be used as a reference for organisations seeking to improve their managerial practice.

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