APPLICATION OF THE LEAN PRODUCTION CONCEPT TO IMPROVING THE CONSTRUCTION PLANNING PROCESS

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Abstract
The concept of lean production emphasises maximising the effectiveness of a production process while at the same time maximising the efficiency of the process. This concept provides a useful tool for developing an efficient and effective approach to managing the construction planning process. Four approaches to planning - satisficing planning, optimising planning, contingency planning and responsiveness planning - were identified from a review of general planning literature. Inputs to the construction planning process with significant value adding potential were identified using correlational analysis and were used as a taxonomy for assessing the appropriateness of the different planning approaches for efficient and effective construction planning. The assessment showed that construction firms need to shift from the current prevailing satisficing approach to construction planning and strive ultimately towards a contingency approach to construction planning in order to achieve efficiency and effectiveness in the construction planning process.

A continuous improvement plan for effective construction planning was developed as a guide for construction firms.

Keywords: lean construction, construction planning, continuous improvement

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INTRODUCTION

There has been a growing realisation in recent years that despite the development of advanced planning methods and techniques construction planning is not achieving its goal of improving the efficiency of the construction process (Cohenca et al 1989, Faniran et al 1994a). Researchers have therefore begun to focus more on the construction planning process rather than only on planning techniques in order to improve the effectiveness of construction planning efforts. These research studies have been directed mainly towards identifying means of improving the efficiency of the construction planning process so that client objectives can be better achieved through improved planning. This paper applies the principles of lean production to analyse the construction planning process and develop an efficient approach to construction planning which facilitates the achievement of construction planning objectives.

THE CONCEPT OF LEAN PRODUCTION

The conventional approach to managing production processes focuses on managing the conversion of an input to an output (Wild 1995). Lean production is an approach to managing a production process which emphasises attaining value efficiently (Koskela 1992). Lean production combines managing the conversion of the input to output with maximising the value of the output in the most efficient way possible. In general systems theory, effectiveness is the degree to which the actual outputs of a system correspond to its desired outputs, while efficiency is the ratio of actual outputs to actual inputs (Hofel and Schendel 1978). The concept of lean production can therefore be described as focusing on maximising the effectiveness of a production process while at the same time maximising the efficiency of the process.

APPLYING THE LEAN PRODUCTION CONCEPT TO THE CONSTRUCTION PLANNING PROCESS

Faniran et al (1994a) described the construction planning process shown in Figure 1. The process begins with the setting of the project objectives by the client(s) and the top management of the construction firm. The objectives are usually the achievement of the contract time, contract cost, and quality standards stipulated in the contract documents. Once the project objectives have been agreed upon, planning activities are organised and a planning team is put in place to develop the project plans. Relevant information pertaining to the project is then gathered and alternative strategies for achieving the project objectives are identified. A final decision on a specific strategy is taken after a systematic evaluation of the identified alternatives. Detailed operational plans based on the selected construction method(s) are then prepared to facilitate a smooth flow of work on site. Relevant information pertaining to the plans is then disseminated early enough to key participants in the implementation of the project. During project implementation, the effectiveness of the plans should be constantly monitored to ensure that project objectives are being achieved and to provide a basis for improving the planning process for future projects.

The concept of lean production provides a useful tool for developing a methodology for managing the construction planning process which emphasises efficiency in the planning process and focuses on the achievement of planning objectives. The construction planning process as described above can be empirically analysed and appropriate dimensions can be developed which adequately represent inputs into the construction planning process and outputs from the construction planning process.

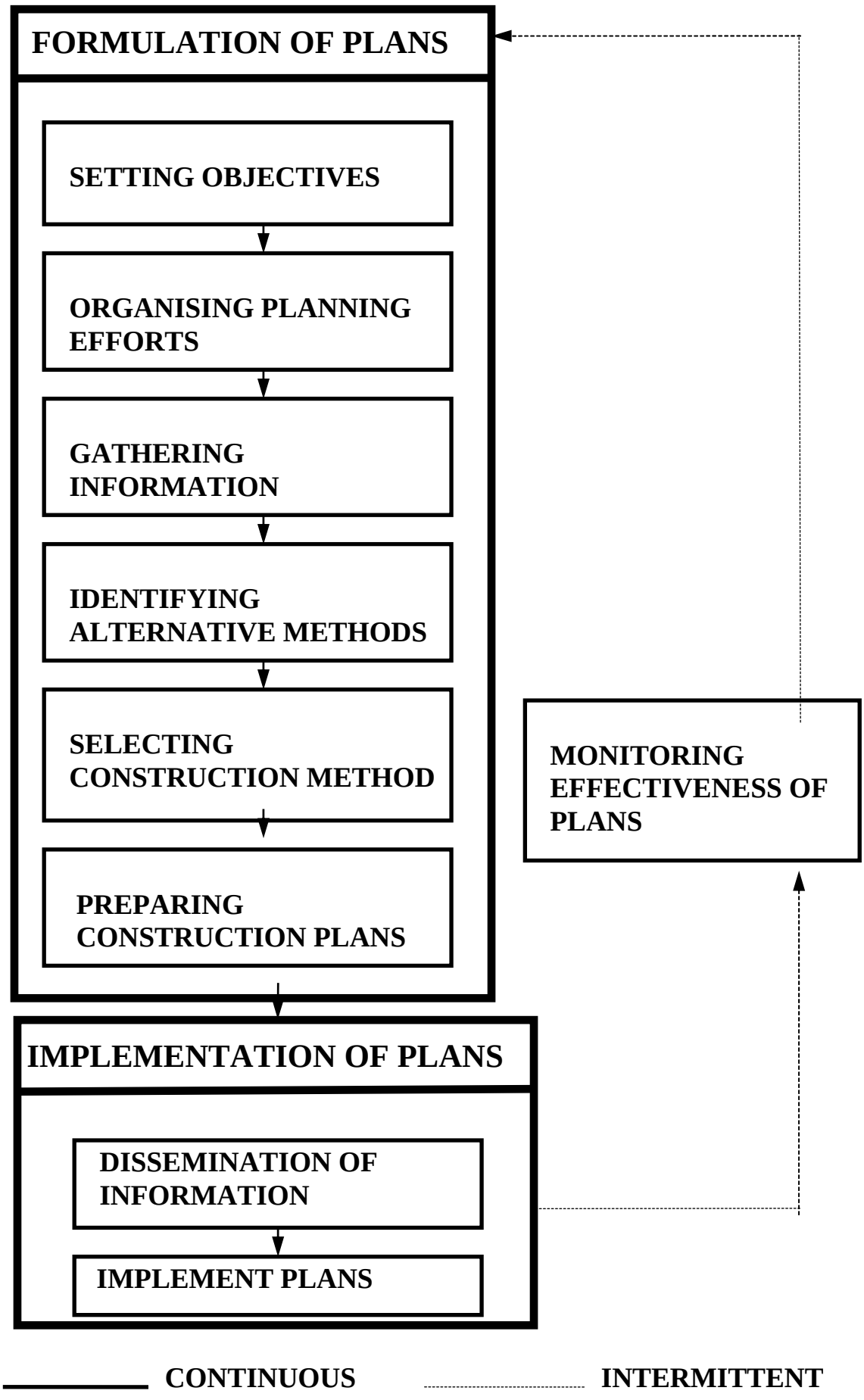

Figure 1 The construction planning process.

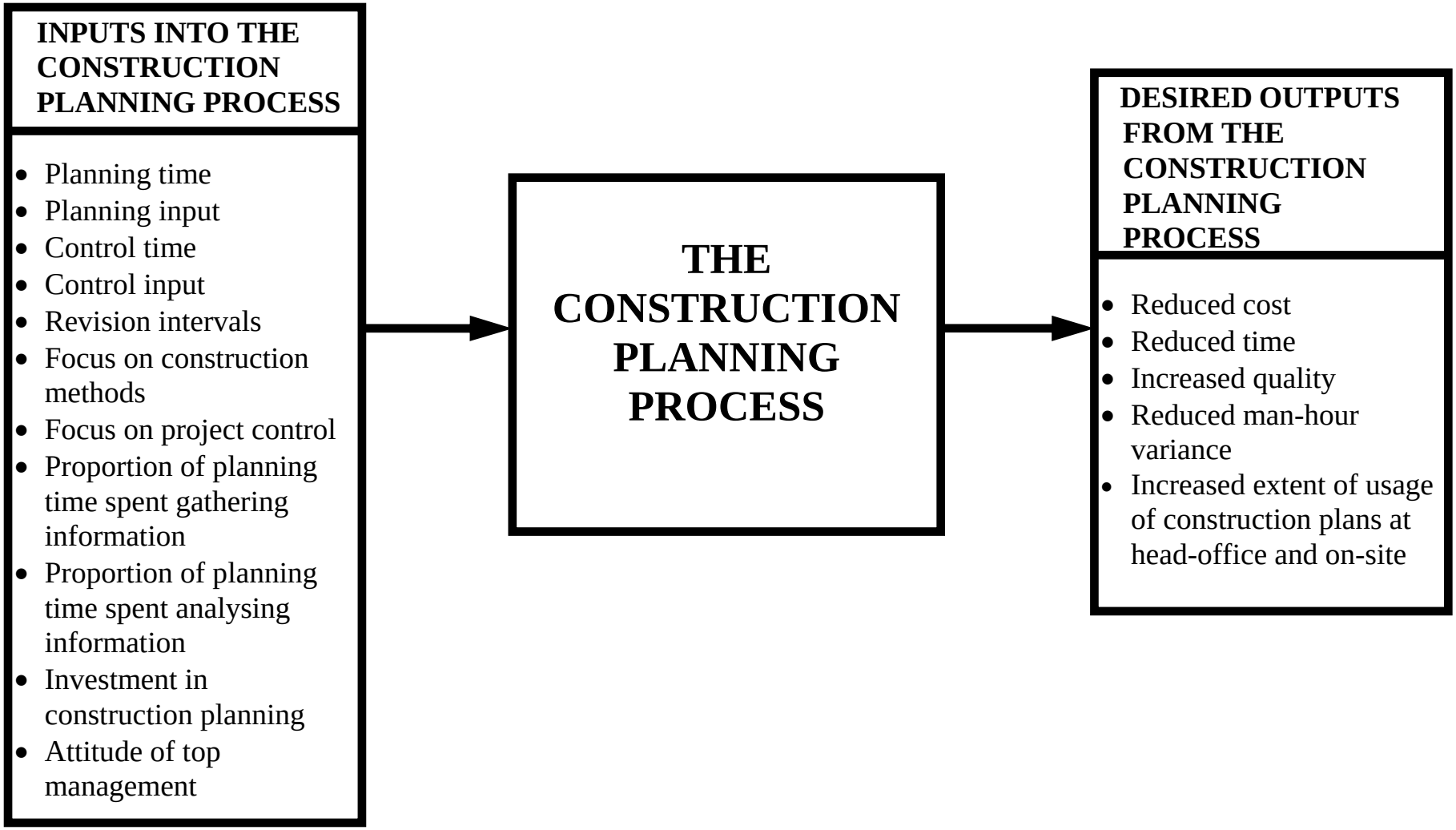

Figure 2 Input-Output model of the construction planning process.

Figure 2 shows an input-output model of the construction planning process consisting of inputs into the construction planning process, the construction planning process, and outputs of construction planning. The input and output variables were identified from a review of relevant literature. The literature review is discussed in detail in Faniran et al (1994b). The description of the variables is given in the Appendix to this paper. The concept of lean production can be applied to the model in figure 2 by determining inputs into the construction planning process which have significant value adding potentials and therefore contribute significantly to the achievement of desired outputs from the construction planning process. Inputs found to have significant value adding potential can then provide a framework for developing an approach for efficiently managing the construction planning process and achieving desired outputs.

RESEARCH METHODOLOGY

Data for the study was collected using a questionnaire sent to 50 randomly selected construction firms. The questionnaire contained questions relating to inputs into the construction planning process as well as outputs from the process. Respondents were asked to select a building project completed in the last 5 years and complete the questionnaire with respect to the selected project. Twenty-six of the firms responded giving a 52% response rate. Relationships between the inputs and outputs were explored using Pearson product-moment correlations and relationships with a 0.05 level of significance were identified as being significant.

RESULTS

Correlation coefficients significant at the 0.05 level and above are presented in Table 1. The results indicate that the following inputs into the construction planning process have significant value adding potential and therefore contribute significantly to the achievement of desired outputs from the construction planning process.

- Time invested in planning prior to commencement of work on site;
- The extent to which emphasis is placed on the determination of construction methods during construction planning;
- The frequency with which construction plans are reviewed after the commencement of work on site;
- The proportion of planning time spent analysing information; and
- Investment of resources in construction planning activities by top management of construction firms.

Furthermore, the results indicate that overemphasis on project control after the commencement of site operations reduces construction planning effectiveness. These value adding inputs into the construction planning process provide a framework for developing an approach to managing the construction planning process.

Table 1 Significant correlations (at $p<0.05$) between Inputs into and Outputs from the construction planning process.

INPUTS INTO THE CONSTRUCTION PLANNING PROCESS	OUTPUTS FROM THE CONSTRUCTION PLANNING PROCESS								
	Achievement of Client Objectives						Other Measures		
			Quality					Usage of Plans	
	Cost Variance	Time Variance	Workmanship	Suitability for User	Aesthetic Contribution to Environment	Satisfaction of Client	Man-hour Variance	At Head-Office	On-Site
Planning Time	-0.37								
Control Input							0.34	0.28	
Revision Intervals	-0.25								
Focus on Construction Methods	-0.25			0.39				0.39	
Focus on Project Control			0.25	0.30				0.32	
Proportion of Planning Time spent Gathering Information		-0.36	0.40	0.39	0.36				
Proportion of Planning Time Spent Analysing Information		-0.24	0.33	0.40			-0.33		
Investment in Construction Planning					0.38				

DISCUSSION

Four approaches to planning can be identified from the general planning literature (Ackoff 1970). These are : satisficing, optimising, contingency and responsiveness planning. Satisficing planning is planning in which the planner seeks to do "well enough" but not necessarily "as well as possible". Once objectives and goals are set, the satisficing planner seeks only one feasible way of achieving them (not necessarily the best way). Satisficers seldom systematically formulate and evaluate alternatives because any feasible means is acceptable to them. In optimising planning an effort is made not just to do "well enough" but "as well as possible". The optimising planner uses mathematical models to determine the best available means of achieving stated objectives. The optimising planner tries to: (i) minimise resources required to attain specified levels of performance; (ii) maximise performance attainable with available resources; (iii) obtain the best balance of resources and performance. Contingency and responsiveness planning are both forms of adapting planning where emphasis is placed on developing a capability to respond to different situations. This can be achieved either through contingency planning where different plans are prepared for all anticipated eventualities; or responsiveness planning where the plan is designed to quickly detect deviations from the expected and respond to them effectively. The attributes of the different planning approaches are summarised in Table 2.

The value adding inputs to the construction planning process derived from the results of this study can be used as a taxonomy for assessing the appropriateness of the different planning approaches for achieving desired construction planning outputs. Tables 3 and 4 show the assessment of the different planning approaches. The tables show that satisficing planning is the least appropriate planning approach for achieving efficiency and effectiveness in the construction planning process.

On the other hand, contingency planning was found to be the most appropriate planning approach for achieving efficiency and effectiveness in the construction planning process.

Current approaches to construction planning can be described as falling into the category of satisficing planning (Faniran 1995). In satisficing planning, while the emphasis on project control after the commencement of work on site is minimal, the time invested in planning prior to commencement of work on site is insignificant and the focus of planning is on forecasting project performance at specified milestones with no attempt being made to explore and compare probable alternative construction methods in order to arrive at the best method of project implementation. Furthermore, investment of resources in construction planning activities is insignificant. The satisficing approach to planning is therefore the least suitable for effective construction planning. The assessment in tables 3 and 4 indicates that in order to improve the efficiency and effectiveness of the construction planning process, there is a need for approaches to construction planning to gradually evolve from satisficing planning through optimising and responsiveness planning and ultimately to contingency planning. In the contingency approach to construction planning, substantial quality time is invested in planning prior to commencement of work on site and the focus of planning is on evaluating all possible alternative construction methods for all probable project environment conditions in order to produce detailed operational plans for the different anticipated project environments. Furthermore, investment of resources in construction planning activities by top management is substantial.

Table 2 General planning approaches and their attributes.

Planning Approach	Attributes
Satisficing Planning	• Emphasis is on producing project schedule and cost plan. • Only one acceptable way of project execution is considered. • Requires minimum time, money and technical skills. • information gathering is limited. Only information available from internal records is used. • During implementation, instead of taking appropriate measures to correct performance variances, prepared plans are adjusted to actual performance.
Optimising Planning	• Emphasis is on resource planning - minimising resources required to obtain specified level of performance or maximise performance with available resources. • Extensive data analysis is undertaken in which several alternative means of project execution are evaluated to produce a plan which promises the best results. • Only one probable project environment is considered. • Emphasis is placed on developing a control system capable of detecting and correcting anticipated errors.
Contingency Planning	• Focuses on the preparation of several detailed alternative plans for all anticipated project environments. • Involves extensive information gathering and analysis in which hypothetical future environments are reviewed and alternative plans are evaluated. • Requires considerable time and cost investment. • Requires an in-depth technical knowledge of the process being planned. • Response time to changes in project environment conditions is minimised by the availability of several contingency plans.
Responsiveness Planning	• Emphasis is placed on developing a project control system which can quickly detect variances from the original plan and respond effectively. • Only one general project plan is prepared. The plan does not include details of individual operations. Rather, the plan is designed to be flexible so that response time to changes in project environment conditions are minimised.

Table 3 Assessment of appropriateness of different planning approaches for efficient and effective construction planning.

Approach to Planning	**INPUTS INTO THE CONSTRUCTION PLANNING PROCESS**		
	Planning Time	Control Input	Revision Intervals
Contingency Planning	Substantial quality time invested in construction planning prior to commencement of work on site	Moderate resources invested in project control during construction work on site.	Several plans are prepared prior to project execution for different possible project environments. Therefore, during project implementation, the original plan is reviewed only once in a while.
Responsiveness Planning	Fair amount of time invested in construction planning prior to commencement of work on site.	Substantial amount of resources invested in project control during construction work on site.	Only one construction plan is prepared prior to project implementation. Therefore, in order to minimise response time to changes in project environments, original construction plan is regularly reviewed and critically reexamined to seek means of improvement through changes in construction methods.
Optimising Planning	Fair amount of time invested in construction planning prior to commencement of work on site.	Substantial amount of resources invested in project control during construction work on site.	Progress of work is reviewed regularly to detect deviations between planned and actual performance. However, corrective action is limited to re-allocation of resources and revising the original schedule.
Satisficing Planning	Time invested in construction planning prior to commencement of work on site is insignificant.	Investment in project control after commencement of work on site is minimal.	Original construction plans are seldom reviewed during project implementation. Detected performance variances are ‘corrected’ by adjusting original schedules to actual performance.

Table 4 Assessment of appropriateness of different planning approaches for efficient and effective construction planning (continued from Table 3).

Approach to Planning	**INPUTS INTO THE CONSTRUCTION PLANNING PROCESS**		
	Emphasis placed on Construction Methods	Information Analysis	Investment in Construction Planning
Contingency Planning	Alternative construction methods are evaluated for all probable project environments. Detailed operational plans that include work methods, resource allocations, cash flows, staffing etc. are drawn up for different anticipated project environments.	Information Analysis is extensive. Construction planner evaluates all possible alternative construction processes for all probable project environment conditions. Suboptimal plans are eliminated for each project situation to produce the best plans for all the situations under consideration.	Investment in construction planning activities by top management is substantial. Requires quality time and considerable technical skills.
Responsiveness Planning	Alternative construction methods are evaluated for what is considered to be the most probable project environment. One detailed operational plan is prepared including work methods, resource allocation, cash flow, staffing etc. for the project environment being considered.	Construction planner evaluates alternative construction processes for what is considered to be the most probable project to produce the best possible plan. Sophisticated planning models are employed that incorporate probability analyses relating to either the variable nature of activity durations or variations of the network logic itself.	Top management invests moderately in construction planning activities.
Optimising Planning	The focus is on time planning, resource allocation and cash flow analysis. 'How to' carry out the work, i.e. method statement, does not receive much attention. Emphasis is on minimising resources required to achieve project objectives or maximise project performance with available resources.	Information analysis focuses on the use of sophisticated mathematical models to obtain the best balance of resources and performance.	Top management invests moderately in construction planning activities.
Satisficing Planning	Emphasis here is on forecasting project performance at specified milestones on the basis of the most feasible and acceptable (not necessarily the best) method of project implementation. No attempt is made to systematically explore and compare alternative methods.	Information analysis is very simplistic. Construction planners use simple mathematical formulae to forecast project cost and time performance. No attempt is made to seek the best possible way of project execution and no allowance is made for the probability that unexpected occurences might arise.	Investment in construction planning activities by top management is insignificant. Only minimal time, money and technical skills are required.

Tables 3 and 4 represent a continuous improvement plan for guiding construction firms in developing appropriate strategies for improving efficiency in the construction planning process and maximising the achievement of construction planning objectives. The continuous improvement plan seeks to motivate construction planners to change from the current prevailing satisficing approach adopted in construction planning and strive ultimately towards a contingency approach to construction planning.

CONCLUSION

Lean production requires that inputs into the production process are efficiently converted to the maximum level of desired outputs. This concept can be applied to developing a methodology for managing the construction planning process by identifying inputs into the process which have significant value adding potential and using these inputs as a framework for an efficient and effective approach to construction planning. Correlational analysis showed that the construction planning process is likely to achieve the maximum level of desired outputs efficiently if: substantial quality time is invested in construction planning prior to commencement of work on site; attention is focused during construction planning on determining appropriate construction methods on the basis of a systematic analysis of available information; construction plans are regularly reviewed after the commencement of work on site; and substantial resources are invested in construction planning activities by top management of construction firms. These inputs with significant value adding potential were used as a framework for assessing the appropriateness of different planning approaches for the managing the construction planning process. The assessment showed that construction firms need to shift from the current prevailing satisficing approach to construction planning and strive ultimately towards a contingency approach to construction planning in order to achieve efficiency and effectiveness in the construction planning process.

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APPENDIX: DESCRIPTION OF VARIABLES

Attitude of top management towards construction planning: Extent to which top management supports construction planning activities. Measured on a three-point scale with response categories ranging from "sceptic (top management only pays lip service to planning)" to "favourable (top management supports and rewards planning)".

Control input: Ratio of control costs to total project cost. Measured as a percentage.

Control time: Time invested in project control during work on site. Measured in man-days per month on a seven-point scale with response categories ranging from 'less than 5 man-days per month' to 'more than 50 man-days per month'.

Cost variance: Extent to which actual construction cost varies from value originally stipulated in contract documents at time of award). Measured as the ratio of final project cost to original project cost.

Extent of usage of construction plans: Extent to which prepared plans are used in the process of decision-making at head office and on-site. Measured on a three-point scale with response categories from 'negligible' to 'major usage'.

Focus on construction methods: Extent to which emphasis was placed during construction planning on determining and evaluating alternative construction methods and selecting the most appropriate method. Measured on a three-point scale with response categories ranging from 'no emphasis placed on the determination and evaluation of alternative construction methods during construction planning' to 'high emphasis placed on systematically determining, evaluating and comparing alternative construction methods in order to select the most appropriate construction method'.

Focus on project control: Extent to which emphasis was placed during construction planning on developing a systematic means of monitoring project progress and taking corrective action. Measured on a three-point scale with response categories ranging from 'no consideration given during construction planning to providing a systematic means of measuring and reporting project progress and taking corrective action' to 'high emphasis placed during construction planning on developing a systematic means of measuring and reporting project progress and taking corrective action'.

Investment in construction planning: Proportion of a construction firm's annual expenditure invested in construction planning activities. Measured on a seven-point scale with response categories ranging from 'less than 0.5%' to 'above 10%'.

Man-hour variance: Extent to which actual total man-hours on-site varies from the planned total man-hours. Measured in percentage on a seven-point scale ranging from 'less than 3%' to 'more than 18%'.

Planning input: Ratio of planning costs to total project cost. Measured as a percentage.

Planning time: Time invested in construction planning by planning personnel before the commencement of work on site. Measured in man-months on a seven-point scale with response categories ranging from 'less than 1 man-month' to 'more than 10 man-months'.

Proportion of planning time spent analysing information: Proportion of total planning time spent in analysing information. Measured on a seven-point scale with response categories ranging from 'less than 1%' to 'greater than 25%'.

Proportion of planning time spent gathering information: Proportion of total planning time spent in gathering information. Measured on a seven-point scale with response categories ranging from 'less than 1%' to 'greater than 25%'.

Quality: Degree of utility of the constructed product; extent to which it can perform the function for which it was designed. this was operationalised in terms of workmanship, suitability for user, aesthetic contribution to environment (all measured on a five-point scale with response categories ranging from 'very poor' to 'very good'), and satisfaction of client with final building quality (measured on a three-point scale with response categories ranging from 'very dissatisfied' to 'very satisfied').

Revision intervals: Frequency of major revisions in construction plans during construction. Measured in months on a seven-point scale with response categories ranging from ‘every 6 months or more’ to ‘every 2 weeks or less’.

Time variance: Extent to which actual construction time varies from time originally stipulated in contract documents at time of award. Measured as the ratio of final project duration to original project duration.