QUALITY MANAGEMENT TOOLS FOR LEAN PRODUCTION - MOVING FROM ENFORCEMENT TO EMPOWERMENT

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ABSTRACT

The recent, worldwide, push for improved construction quality has led to the attempted implementation of ISO9000 in many countries. This has resulted in the application of a bureaucratic management model to both design and construction processes.

However, as the principals' and head contractors' motivation to use these bureaucratic management models was contractual risk shedding rather than the desire to control the process, in most instances, the resulting quality systems tend to be abstract and have scant relevance to the actual construction process on site.

In this paper the shortcomings of current quality management approaches are discussed, suggestions for a new conceptual framework are made and management tools developed from a process control perspective are presented. This new framework combines the logic of Last Planner™ for creating reliable processes through careful planning with a PLAN-DO-CHECK loop that brings quality assessment and improvement into the weekly planning and review cycle. It also embraces lean philosophies with regard to quality control and worker empowerment.

KEY WORKS

Quality management, production control, managerial tools

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INTRODUCTION

The paper presents some of the causes of defects on construction projects in Sydney and provides suggestions for their management. Research for the paper involved *identifying the cost* of defect rectification (on four sites), *analysing the causes* of defects (on 13 sites) and developing defect management tools. At the time of writing, these tools were being trialled on construction sites. They are designed to complement the Last Planner™ framework for planning and control by explicitly and continuously considering the management of quality issues at a detailed process level.

Construction planning is relatively unreliable; and experience has shown that on most sites less than 70% of tasks are completed in the week that they are planned. Lead manufacturers have adopted improved planning and control tools (lean production) and these have the potential to be applied to construction (Ballard and Howell 1997) through tools such as Last Planner™.

Construction has no theory of production control only a means of project control (Koskela 1992). As a result, current management practices produce plans that are gross abstractions of the actual process on site and these are inherently ineffective as production control mechanisms. Regularly, plans are finalised prior to project commencement, without any input from many of the final project actors, under the implicit assumption that construction is a stable and constant process. In fact, experience confirms that construction is highly dynamic, complex, uncertain and often near chaotic.

Control often translates to monitoring work output against these plans. However, these initial *plans* are essentially little more than informed *guesses*, causing many of the shortfalls in planning (Ballard and Howell 1997). Control in such a situation is retrospective (only able to identify problems that are in the past); subsequently. only permitting the commencement of remedial action after the event. Ballard and Howell (ibid) suggest that 'where manufacturing control is forward looking and acts directly on the production processes, construction control tracks results in order to identify which party is at fault.'

QUALITY IN CONSTRUCTION

Quality failures in construction have been estimated to cost the industry between 2% and 12% of construction turnover in rework alone (Burati et al. 1992; Ledbetter 1994, Love 2002). On the four projects where defects were costed, the direct cost of defects was found to range between 2% and 4% and the indirect costs in both the head contractor and sub contractor organisations amount to nearly as much again. In an industry where it is widely accepted that margins are low, the problem of poor quality is clearly significant. Quality management in construction is complex, multi-faceted and includes the consideration of both product and service quality (Forsythe 2000), the effect of process quality on productivity (Langford et al. 2000), the effect of the contractual relationship of the parties (Marosszeky et al. 2002) and the implications of cultural factors on the quality of the outcomes (Al-Khalifa et al. 2000).

Most of today's quality problems do not have a technical origin but are rather a result of the motivations and attitudes of both managers and operatives towards their work (Atkinson 1997; Bennett 2000). The attitudes of individuals towards work are developed through the influences of the organisational systems within which they function. Hierarchical management structures, top-down information systems and adversarial contracts are all integral parts of the operational framework of the industry and each has substantial negative consequences on the social and cultural fabric of the industry. Deming (1986) noted that ‘our prevailing systems of management have destroyed our people’; this may well be the reason why so many tradesmen and professionals leave the industry at relatively young ages due to burnout.

These issues are particularly important for construction quality management. The management of all project risks, including quality, and have traditionally been attempted through contractual mechanisms. In contrast the new management paradigm being adopted by other industries gives less emphasis to product technologies, it recognises the importance of *softer* management functions and process technologies (Bounds et al. 1994). A twin strategy of focussing on the planning and control of the production process, itself, combined with the engagement and empowerment of all the key actors in the planning, control and review of work is needed to enable significant improvements to be achieved.

Since the focus of this paper is on improved process control, a brief review of some of the relevant aspects of current practice is provided.

- *Product quality-disregarded:* This research found that existing quality control systems are comprehensive and thoroughly documented, however, site staff are very often reluctant to use them. Even when implemented, quality systems are abstract from events at the workface (Langford et al. 2000) and results derived from them could be described as mediocre at best. It has also been found that the more comprehensive the documentation associated with such systems, the less motivated site personnel become towards using them (Hughes et al. 1999). The perception among workers is that the quantity of paperwork and the exhaustive administration associated with such systems rarely translates into improved product quality. Clients have also become disillusioned with their application because they have not seen any evidence of these systems leading to improvements in quality (Marosszeky, 2001). Therefore the only conclusion that can be made is that such quality control mechanisms are designed to satisfy the administration requirements of the management system rather than the improvement of product quality for the client.
- *Motivation-largely ignored:* Quality is the result of a complex system incorporating technical, political, social and behavioural processes (Mallak et al. 1997). Industry is predisposed to the technical aspects of management and largely ignores human and social issues. Studies into quality deviation occurrence have reported that ‘the cause of defects and their mode of correction are continuously repeated, suggesting the defect problem is not so much a matter of not knowing what to do, but one of application - not doing what we know we should do’ (Atkinson 1997). In 1992 ten years after Toyota and GMH joined forces at NUMMI (to reinvigorate GM’s worst factory-Fremont), the same workers produced products of the highest quality efficiently - the essential change was not in the skills and knowledge of the workforce, but in the management approach and organisational culture (Cameron et al. 2000).
- *Process focus-largely neglected:* Planning and control in construction often translates into monitoring output against *master* programs and budgets

(Ballard 1994; Ballard and Howell 1996; and Koskela 1992). This holds true for quality management as well where quality is retrospectively controlled and measured against specifications. Quality planning at the broad project level comprises project quality plans and sub-contractor Inspection and Test Plans. Conceptually this is comparable to *master* programming in that it sets the framework for quality management but does not engage with the specifics of executing the work. Such planning forms a suitable basis upon which to build focussed, close-range, detailed quality control processes and systems; however, it does not engage with the day to day issues on site.

QUALITY AND LEAN THINKING

Lean thinking places considerable emphasis upon quality - the central tenet being the production of *defect-free* products in the shortest possible time with the least amount of resources (Shinohara 1988; Womack et al. 1990; Koskela 1992; Ballard and Howell 1997).

Koskela (1992) observed that systems with quality control problems commonly possess two characteristics:

- *Poor deviation detection.* The methods of control employed in construction often result in many defects remaining undetected by both the sub-contractor's and the head-contactor's quality control systems. In this research it was found that architects and client's project managers were administering defect schedules containing thousands of defects. These had either not been identified by those producing and managing construction or had been ignored by them.
- *Long cycle times from detection to correction.* As a result of poor detection the time taken to correct defects (from the time of occurrence to actual time of rectification) can be many weeks. Even when quality control systems are implemented as intended by sub-contractor and head-contractor management, these checks commonly occur well after task execution. Consequently, workers have often moved onto other tasks in other areas of the project, or in some situations, have even left the project completely. Either way, many weeks can pass between detection and correction.

To address the problems associated with existing practice, two fundamental questions need to be answered: where should quality be controlled? And, who should control it? It is noteworthy that inspection, in itself, is not a value adding activity and it does not correct the cause of a problem.

When total elimination is not possible, the financial implications, of any error, increase as the time between inspection and production lengthens. It therefore follows that those executing a task at the workface are best placed to control quality and correct defects. This concept is central to the Toyota Production System strategy with regard to quality control (Womack et al. 1990).

However, enabling those executing tasks to control quality involves a lot more than simply providing them with the necessary tools; it also requires a significant cultural shift. Lean production places considerable emphasis upon cultivating the social and cultural issues associated with organisations by 'creating benefits through socially rich, openly communicative, trusting, tight-knit, 'clan' like teams'(Ginato 1996). Finally, it requires the adoption of a learning culture within which workers and managers are committed to continuous innovation, solving production and quality problems, and creating new value for the ultimate clients (Spear et al. 1999).

LAST PLANNER™ AND ITS LIMITATIONS

Last Planner™ is proving itself as a management tool that overcomes many of the limitations of traditional methods of construction planning and control. Fundamentally, Last Planner™ aims to increase production process reliability by the elimination of all obstacles to work being completed at the planned time. This is achieved by bringing a focus to *making work ready*—identifying and planning pre-construction tasks that are necessary to ensure that there is no impediment to construction work being done as planned. This creation of certainty in plan execution is achieved by systematically looking six weeks ahead using what is named a *look ahead process*, creating a planning window that is far more detailed than that of the macro-level project *masterplan*. At the end of the six weeks detailed planning process, a *weekly work plan* sets out the specific requirements of work crews for the week ahead. The system aims to *shield* installation crews from uncertainties in workflow, increasing production reliability and thereby production rate (Ballard and Howell 1997).

According to Ballard (1994) the critical characteristics of a weekly work plan are that the:

- right sequence of work is selected;
- right amount of work is selected; and
- work selected is practical. Later formulations of quality characteristics of assignments by Ballard and Howell include definition and learning

The Last Planner™ management tool reviews outcomes on a weekly basis by comparing tasks actually completed against those planned in the *weekly work plan* and calculates a Percent Plan Complete (PPC) score as a simple metric of planning reliability. A low PPC is seen as a management failure resulting from scheduling work that is not ready to be done or from scheduling too much work, rather than the job being behind the planned schedule. Since impediments may exist at any organisational, process or function level, problem identification and analysis is a prerequisite to the modification of a problem source (ibid). The weekly review process identifies the main impediments to achieving production reliability. Once these are understood they can be removed, leading to improved plan reliability and, consequently, enhanced productivity (and higher PPC scores). Such systematic feedback and analysis are not normally undertaken in construction.

Conceptually, the Last Planner™ management framework is capable of incorporating all aspects of planning reliability in relation to issues such as safety, quality and environmental management. Its elements of careful advanced planning, performance measurement, feedback and review, achieved through a participative management process, are conceptually comprehensive and sound. However in practice, Last Planner™ has a production reliability focus. In order to achieve plan reliability the primary focus is on forward planning and the elimination of impediments to plan achievement. Review, performance measurement, problem solving and feedback are important to achieve defect cause elimination and continual quality improvement, but forward planning is the key issue.

While the management elements of a planning and control system (ie. planning resources, anticipating events, reviewing outputs and creating feedback) are similar for each area (ie production, quality and safety), the balance between them and the specific processes, also, need to be different. In the case of *safety*, a primary emphasis has to be on the identification of upcoming process risks that are different to those already encountered. This requires the ability to envision possible future situations. In the case of *quality*, the focus of site process control has to be on identifying defects one day and avoiding them the next. Because of these subtle differences, if all these aspects of process planning are rolled into one, the weekly planning and review process would become too complex and at the same time too diffuse. It would be extremely difficult to maintain sufficient focus in each area.

Quality: Low (1993) suggested that the construction industry is predisposed to the management of quantity to the detriment of quality. In contrast, an explicit tenet of Lean Production is the construction of defect free products as defective work is recognized as waste. While process transparency and reliability resulting from the use of Last Planner™ techniques help to identify some of the impediments to achieving defect free products, product quality is not explicitly considered.

A number of distinct aspects of quality management can be identified:

- Design processes to ensure that production is as simple as possible and therefore the desired quality is relatively easy to achieve.
- Plan to avoid compromising quality through interference from trade contractors.
- Identify quality problems as close as possible to the time of the work being undertaken and limit waste arising from the repetition of defective work. This should involve analysis, innovation, problem-solving and learning.
- Motivate, based on performance measurement, by rewarding outstanding work and noting poor work.

The first two are essentially preplanning issues and fit within the scope of the Last Planner™ process. This paper focuses on the third and fourth, process control issues.

ACHIEVING QUALITY AT SOURCE

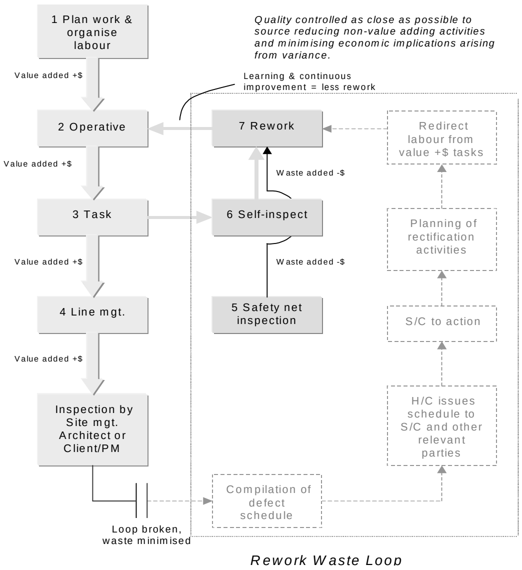


Figure 1: Process map: rework waste loop

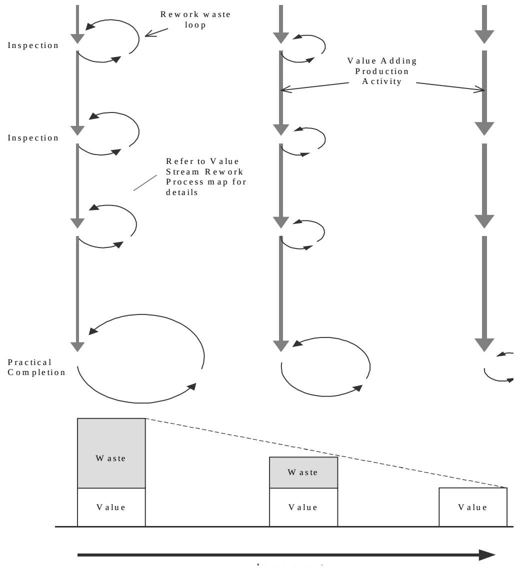


Figure 2: Waste minimised by control of defects close to source

Consistent with Koskela's observations in relation to deviation detection , the model of observed practice is described in figure 1. It features both poor deviation detection (detection usually undertaken by a process disparate third party) and long cycle times from detection to prevention (due to the many project actors in the information loop). Figure 1 illustrates the extent of the waste loop involved in rectification. The rework waste loop traditionally involves the architect, the head-contractor's and the sub-contractor's project management, the sub-contractor's field management and eventually the operative. Information has traditionally been passed through these loops to enable those at the top of the hierarchy to remain in *control*. This, however, often translates into nothing more than providing data for information purposes rather than control purposes.

Controlling quality at source by-passes both these problems, reducing the waste associated with defect detection and certification. Figure 2 illustrates the quality control process when empowered workers fulfil these functions at the production face. The size of the waste loop is significantly tightened and the amount of waste is reduced through the elimination of many of these redundant roles-redundant from a production perspective as opposed to an administrative/bureaucratic perspective.

Another issue is that construction control is commonly preoccupied with blame-allocation and contractual positioning as opposed to planning and control (Ballard and Howell 1997). Information flow through such organisational structures is slow, as is decision making. An example from research illustrates this point. The same defect occurred in each of approximately 150 apartments. Yet, the analysis of the site records showed that the problem had been observed and appropriately recorded by the project architects months prior to project completion. However, the mistake was repeated on numerous occasions throughout the balance of the project and was only properly addressed when retention monies were contested.

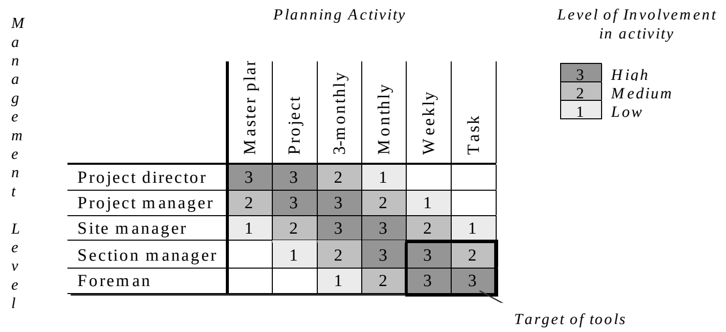


Figure 3:Process focus of quality management

Figure 3 illustrates the level at which the proposed management tools are intended to be used. By controlling *quality at source* the number of actors involved in the process is reduced to a minimum. Control is focussed at the level of production, whereas typical quality management systems are controlled by senior managers who are remote from the workface. Quicker and more responsive decision-making results as organisations become less bureaucratic and more dynamic and quality improvements are realised as a consequence. Also, importantly, this is the level at which innovation and learning has to take place to solve problems and create new solutions.

MANAGEMENT TOOLS FOR QUALITY AT SOURCE (QAS)

QAS is a management tool, presently, being trialled on construction projects in the metropolitan area of Sydney. The tools embrace the quality management concepts presented in this paper and apply them to contemporary construction work situations. The aim is to demonstrate that the quality management principles developed by lead manufacturers over the past three decades, can be adapted within the construction sector. A robust, validated and credible set of lean management tools will be presented to industry upon the completion of the pilot studies.

Bennett (2000) suggested that management tools are normally used to codify well-established processes into procedures, hence, determining actions for workers in certain situations where standardised processes can be defined by procedures or rules. The application of rules and procedures in attempting to control and improve quality has been previously questioned (Shammas-Toma 1994). Therefore, the technique presented in this paper does not conform to Bennett's definition of a management tool, though it has elements of control and record keeping that are essential for the assurance that quality standards have been met at all levels.

As Hanover CEO, William O'Brien, stated (Peter Senge 1990), successful organisations of the future need to 'address the fundamental challenge of learning how to help people make good decisions without coercing them into making a particular decision'. To achieve this, team motivation, innovation and problem-solving skills need to be improved: workers need to be encouraged to use their existing knowledge and skills, fully, as well as develop new skills.

The tools proposed in this paper aim to *help* people to do their job, rather than to *tell* them how to do it. They are designed to provide the following functions in project organisations:

- to define quality goals, clearly, through structured checklists;
- to empower workers to sign off on correctly completed work—checked by audit, levels of which are commensurate with the level of confidence established within the team;
- to measure quality thereby providing a foundation for benchmarking and continuous improvement;
- to design a feedback mechanism that will provide motivation for improvement and learning; and
- to establish analysis and feed-forward mechanism which will promote innovation and problem-solving and thereby overcome quality challenges at the workface.

Figure 4 illustrates the quality management system being proposed. It has three primary elements:

- task-based checklists
- completion matrix
- quality league table.

By themselves none of the above components are unique; in fact, the first two are present in many construction company quality systems. However, the detailed way in which they are integrated to achieve a number of complementary outcomes is unique. Also, each step has within it a number of important ingredients.

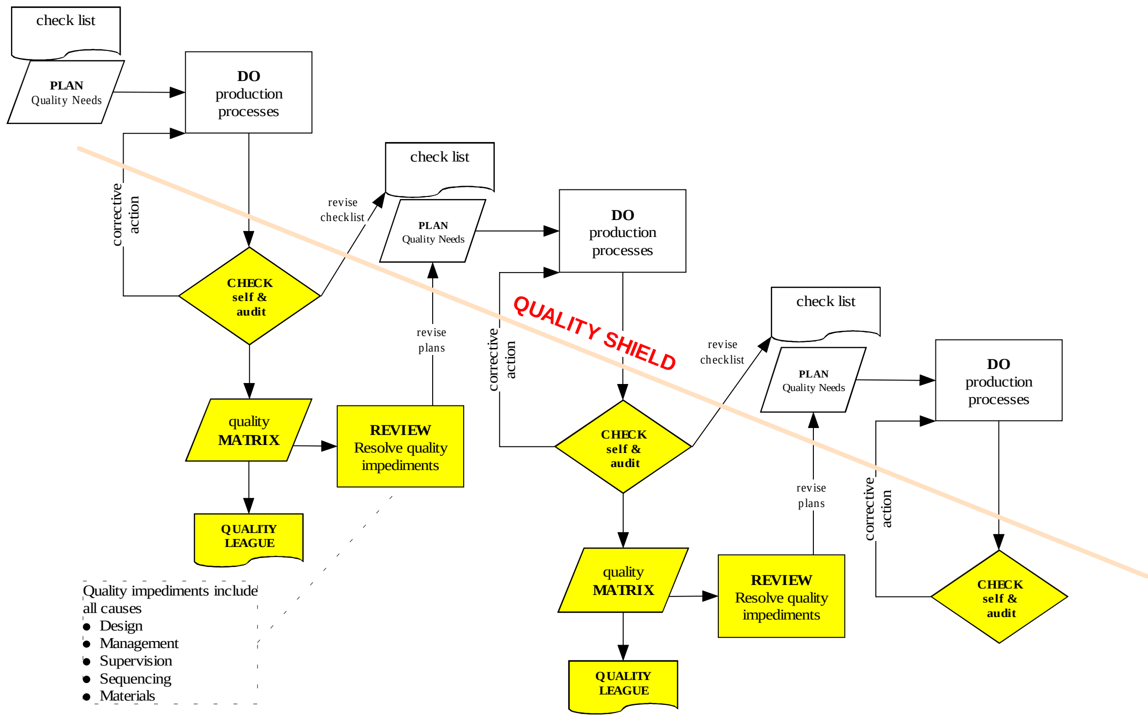


Figure 4: QAS quality management process with feedback and feed-forward

QAS is a short-term task-planning tool, intended for use by construction supervisors

Task Based Checklists - Task complete check sheets (TCC)

These combine a number of elements:

- *Contents:* Only critical quality issues are included, it is well known in industry that long checklists lose their meaning and are inevitably filled in on Friday night, possible over a beer. There should be between 5 and 10 items on a checklist. The items should be developed in cooperation with all parties, from designers through to the workers doing the task. Ultimately they should reflect the most critical issues from two perspectives-the user and physical performance.

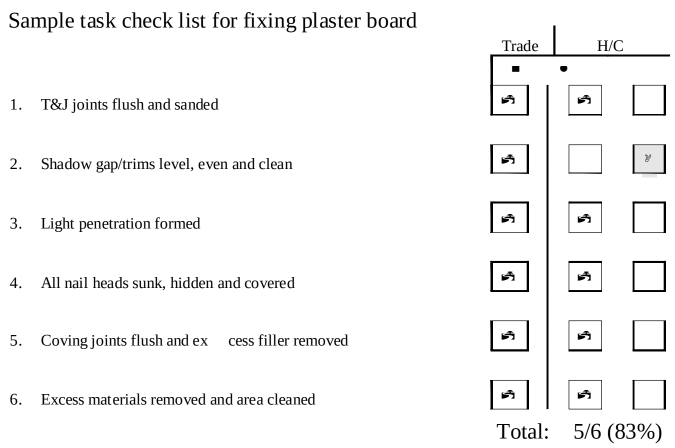


Figure 5: Sample Task Check list

Feedback*: The checklist is filled in by the person doing the work and reviewed by the immediate head-contractor supervisor. This gives an immediate audit and a score is agreed to by the parties. It should be used to set up the environment for problem identification, performance review, problem-solving and learning.*

- *Innovation, learning and empowerment:* Immediate feedback on performance creates a basis for defect recognition and rectification by the tradesman doing the work. Also, it is the basis for problem-solving and innovation to avoid problems and create better solutions. These may include any area that impacts on quality: design, detailing, product selection, workmanship and management.
- *Job specific:* The checklist is job specific in that it reflects the particular quality issues on a job, it is changed on the job to include new quality problems as they are identified.
- *Motivation:* The score is used to compare the quality being achieved in different trade packages and by different tradesmen. This introduces an element of motivation and competition, and should be the basis of reward.

COMPLETION MATRIX

The task completion matrix similarly combines a number of management elements. These are:

- *Overview:* The Completion Matrix gives a project overview and can be used to identify problem areas. It is an important tool because it records that all areas have been signed off-an essential pre-requisite for assurance at all levels.
- *Planned hold points:* The matrix can be used to plan review or hold points as in the example; a mandatory check has to be conducted before drywall walls are closed off. To establish agreed quality levels, it may be desirable to create a quality review when certain early areas of work are complete.
- *Motivation:* The scores can be used as the basis of a quality league table and a recognition system that can motivate the workforce.
- *Innovation:* Problem areas become the focus of innovative efforts to develop improved solutions. Solutions are then fed forward to change processes and to avoid the problems reoccurring.

Task	*Level – room/unit*				**Ave. Scor**	**Commer**
	201	***202***	***203***	***204***		
Drywall stud/nogs	85	95	97	95	92%	OK
Drywall 1st pass	88	94	97	95	94 %	OK
Electric conduits	95	96	94	93	90 %	OK
Plumbing 1st fix	87	84	91	88	88	OK
Mandatory check						

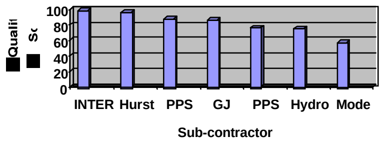
Figure 6: Task Completion Matrix

QUALITY LEAGUE

The quality league simply provides positive feedback. This is recognised as having a good effect on workforce motivation at all levels. Recent safety research at the ACCI (Trethewy et al. 1999) showed that positive feedback about the safety of the site environment, in itself, provided an effective stimulus for ongoing improvement.

July Project Site Newsletter

Quality league:
Outstanding quality workmanship by sub-contractor Inter, lead by site foreman Steve Jones, has meant that Steve and his team win the July quality league and $400 to add to their social fund.



Hurst came in a close second and look set to scoop the prize in the near future. Many other contractors have been performing well and with a number of new sub contractors coming onboard in the next few weeks competition looks set to be tough.

Figure 7: Quality League Reporting

CONCLUSION

This paper has presented an approach to quality management from a lean perspective. The structure of the management tools is a fundamental departure from traditional quality management thinking in the construction sector and a development of the Last Planner™ tool in that it is focussed on quality control from a process perspective.

The proposal combines several disparate aspects of quality management—workface responsibility with the need for overall system planning and control. Process control at the local level provides a basis for an empowered workforce to innovate and learn by solving problems and develop improved solutions. A recording system provides an overview and identification of weaknesses on a comparative basis. Combined with a quality league it also provides the basis for recognising excellence and encouraging quality improvement.

The implementation of this system requires a fundamental review of management styles (traditionally bureaucratic) and site culture (traditionally highly structured). Conceptually it replaces traditional contractually based control mechanisms with ones based on motivation and empowerment.

By proposing a system that has elements of local empowerment and control together with elements of formal record keeping, the paper recognises that in relation to quality management a balance needs to be maintained between local empowered systems that encourage innovation and control and the records required for the assurance of quality at all levels. Rather than having dual systems for these purposes, an attempt to integrate the two essential perspectives of quality management has been presented.

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