THE PRINCIPLES AND APPLICATIONS OF LEAN CONSTRUCTION IN SINGAPORE

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ABSTRACT

Lean construction is a new way to design and build capital facilities. It advocates the simultaneous consideration of product and process development using simultaneous engineering. This philosophy has challenged the belief that there is always a trade off between cost, time and quality. This study examines the pre-requisites and barriers for the possible implementation of lean construction in the local industry. Interviews are done with the managing directors and construction managers from selected Singapore ISO 9000 certified construction firms. From the research findings, it is found that only certain features of lean construction have been implemented locally. The biggest barrier is the cultural resistance to change.

Key Words: Lean construction, Quality, Barriers, Singapore, Value, Waste.

INTRODUCTION

The chronic problems of construction are well known: low productivity, insufficient quality, poor co-ordination, high costs etc. (Eaton, 1994). A number of solutions have been proposed to address parts of these problems. However, these tend to be versions of procedures adopted by the manufacturing sector and modified to suit the conditions of the construction industry (Koskela, 1992a). For example, Quality Assurance (QA) has been advocated as a remedy for poor quality (BSI, 1987). Further suggestions included a computerised integration of design and procurement as a remedy for low productivity (Betts, et al., 1994) and electronic data interchange for poor co-ordination (Dym & Levitt, 1991).

The Construction 21 (C21) report (1999) reviewed the state of the construction industry and Singapore and criticised its performance. One of the reports recommendations to improve the efficiency of the construction industry is for the industry to adopt lean construction (LC) as one of the emerging global trends and recommends its implementation to ensure the competitiveness and relevance of the Singapore construction industry Presently, Lean Production (LP), which stresses on the important theories and principles related to production processes, is being developed and implemented in manufacturing (Shingo, 1992; Schonberger, 1990; Plossl, 1991) to rectify the present situation.

Koskela (1993) reviewed the concepts, principles and methods of LP and analysed their applicability in construction. He also found that 6 to 10% of the total project costs in Sweden

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and the USA to be waste. Melles (1994) found the instruments of LP to be in existence in construction; however, it enforces a real change in attitude to utilise them in order to be lean.

Koskela, (1992b) criticised conventional construction for being pre-occupied with managing only tasks and flows are neglected. This is seen the main reason that construction is characterised by a high share of non value-adding activities. One case study taken in USA in 1998 shows remarkable benefits of implementing LC (Garnett, et al., 1998):

- Office construction times reduces by 25% within 18 months
- Schematic design reduces from 11 weeks to 2 weeks
- Turnover increases of 15-20% (Pacific Contracting)
- Satisfied clients looking to place repeat orders
- Reduction of project costs

THE CONCEPTS OF LEAN CONSTRUCTION

Lean Production (LP) was developed by Toyota production system in the 1950s led by Engineer Ohno who was committed to eliminating waste (Howell, 1999). The term "lean" was coined by the research team working on international auto production to contrast it with craft and mass forms of production (Womack, et al., 1991).

The core concept behind LP is to enable the flow of value creating work steps while eliminating non-value steps i.e. waste by focusing on fast cycle times. When waste is removed from the production process, cycle times drop until physical limits are reached. Value-adding activities are however, first improved through internal continuous improvement and fine-tuning of existing machinery. Only after these improvement potentials are realised, major involvements in new technology are considered. The primary goal of LP in Japanese is Muda, that is, to avoid waste of time, money, equipment etc (Shingo, 1992). Lean construction (LC) accepts Ohno's production system design criteria as a standard of perfection (Howell, 1999). Waste is defined by the performance criteria for the production system. Failure to meet client's unique requirements is waste. The evidence of waste in Ohno's terms is overwhelming (Koskela 1992a). Waste in construction and manufacturing arises from the same activity-centred thinking. Howell (1999) argues that there is a need to maintain pressure on every activity to ensure continuous improvement through the reduction of cost and duration of each activity.

Lean theory, principles and techniques, taken together, provide the foundation for a new form of project management. From roots in production management, LC has produced significant improvements particularly on complex, uncertain, and quick projects. LC is a new way to design and build capital facilities. The objective of LC is to better meet client's demands and dramatically improves the Architectural/Engineering/Construction (AEC) process as well as product. LC advocates the simultaneous consideration of product and process development.

Managing construction under lean is different from typical contemporary practice (Howell, 1999) because it:

- Has a clear set of objectives for the delivery process
- Is aimed at maximising the performance for the customer at the project level

- Designs concurrently product and process
- Applies production control throughout the life of the project

PRINCIPLES OF LEAN CONSTRUCTION

Womack and Jones (1996) describe the business environment within which they see lean techniques being successful. Five key principles emerge:

Specify Value

Value is defined by the ultimate customer's needs through tools such as value management, quality function deployment and simulation. These will define attributes which are characteristics that deliver client's satisfaction (Garnett, et al., 1998) and are created by the MCs. Construction needs to adopt product focus that enables a long-term dialogue to be started concerning the nature of value and how the product delivers it. The client requires a building to suit his purpose and provides value for money. The vision that this product and customer focus suggests is not new. Aspects of it have been alluded to it in many previous reports (Atkin and Pothecary, 1994; Bennett, et al., 1988, 1989, 1996, 1998; Gray, 1996) but the ideas have not been developed by the industry. In construction, specifying value comes before design (Ballard and Howell, 1998).

Identify And Map The Value Stream

The value stream identifies all those steps required to make a product. Identifying value stream, the way value is realised, establishes when and how decisions are to be made. The key technique behind value stream is process mapping for a very specific reason: that of understanding how value is built into the building product from client's point of view. Value stream maps can be understood as processes flow charts that identify what action releases work to the next operation. Mapping brings choices to the surface and raises the possibility of maximising performance during construction. Normally, maps are prepared at the project level and then decomposed to better understand how the design of planning, logistics and operation systems work together to support customer value.

At a strategic level, it offers a perspective on defining what is to be done. By taking this top down approach, the idea of identifying value streams such as the structure and the building envelope and considering how these systems are to be designed, supplied and constructed, offers a different way of organising for construction.

At a more tactical level, the value stream map can identify where waste lies in a particular process and this process analysis shows how value stream can be achieved more effectively.

A set of all the specific actions required bringing a specific product through:

- ***Problem solving task*** running from concept through detailed design and engineering to production launch.
- ***Information management task*** running from order taking through detailed scheduling to delivery.
- ***Physical transformation task*** proceeding from raw materials to finished products in the hands of the customer.

Flows

Flows are characterised by time, cost and value. Resources (labour, material and construction equipment) and information flows are the basic units of analysis in LC. There are controllable and uncontrollable flows. Controllable flows such as materials or instructions from the warehouse or management respectively. Uncontrollable flows such as suppliers' provisions of resources and design information.

Strategically, flow is concerned with achieving a holistic route through the means by which a product is developed. It attacks the fragmentation that is inherent in the industry today by revealing it to be highly wasteful. Many have recognised this wastefulness (Latham, 1994) and the leading solution is seen to be partnering. Bennett (1998) points out that early stages of partnering are necessary pre-requisites for improving construction. However, partnering remains only a partial solution.

Lean works to eliminate places where value-adding work on material or information is interrupted. In construction, this may mean repackaging work so that parts of the project can proceed without completion of others and/or assure that resources are delivered in the order required and transported directly to the installation location (Howell and Ballard, 1998) to prevent double handling.

Construction problems are caused by negligence of flows. The construction process is seen as a set of activities, each is controlled and improved as such. Conventional managerial methods like Critical Path Method (CPM) deteriorate flows by violating principle of flow process, design and improvement. They concentrate on conversion activities. The resultant problem in construction tends to compound and self perpetuate.

Under lean thinking, improvement is possible by reducing uncertainties in workflow. Redesigning the planning system at the assignment level is the key to assuring reliable workflow and this step has to be implemented early.

Pull

At a strategic level, pull identifies the real need to deliver the product to the customer as soon as he needs it. The traditional construction process pushes the client into an often-protracted development process where risk and uncertainties are prevalent. The principle of pull suggests a decision where the ability to define quickly what the client needs from a building in relation to his business and subsequently customising and deliver them more predictably when the client requires them.

Three types of inventories need to be minimised:

- Material and design.
- Labour and its tools.
- Intermediate work product that has not been exploited.

Perfection

This is a key strategic level because what it defines is the need for this way of working and organising construction products to become a way of life with an inherent culture. To achieve perfection means constantly considering what is being done; how it is being done and harnessing the expertise and knowledge of all those involved in the processes to improve and

change it. With continuous improvement (Japanese: Kaizen) done and with waste eliminated along the flow process, perfection is the ultimate sweet reward that companies can achieve. In essence, LC is a project delivery system founded on the reliability and speedy delivery of value. Tools and techniques such as kaizen, simultaneous engineering and strategic alliances with the suppliers are in essence the result of applying these five main principles to what is already being done at a tactical level. The essential elements of LC can be examined separately but the benefits can only be achieved by the holistic approach of all the elements.

ISO CERTIFICATION – BUILDING BLOCK OF LC

The challenge that Kaizen is originated and employed solely for use in the Japanese culture (Green, 1999) is taken up when the Western version of Kaizen is developed. This modified version is part of Total Quality Management (TQM) based on certification according to International Organisation for Standardisation (ISO) 9000. TQM includes Quality Assurance (QA) and Quality Management (QM), which coincide with ISO roles.

Relevant ISO 9000 clauses for Lean Construction

The research has examined the relevance and compatibility of ISO 9000 core and supportive processes (figure 1) to lean construction.

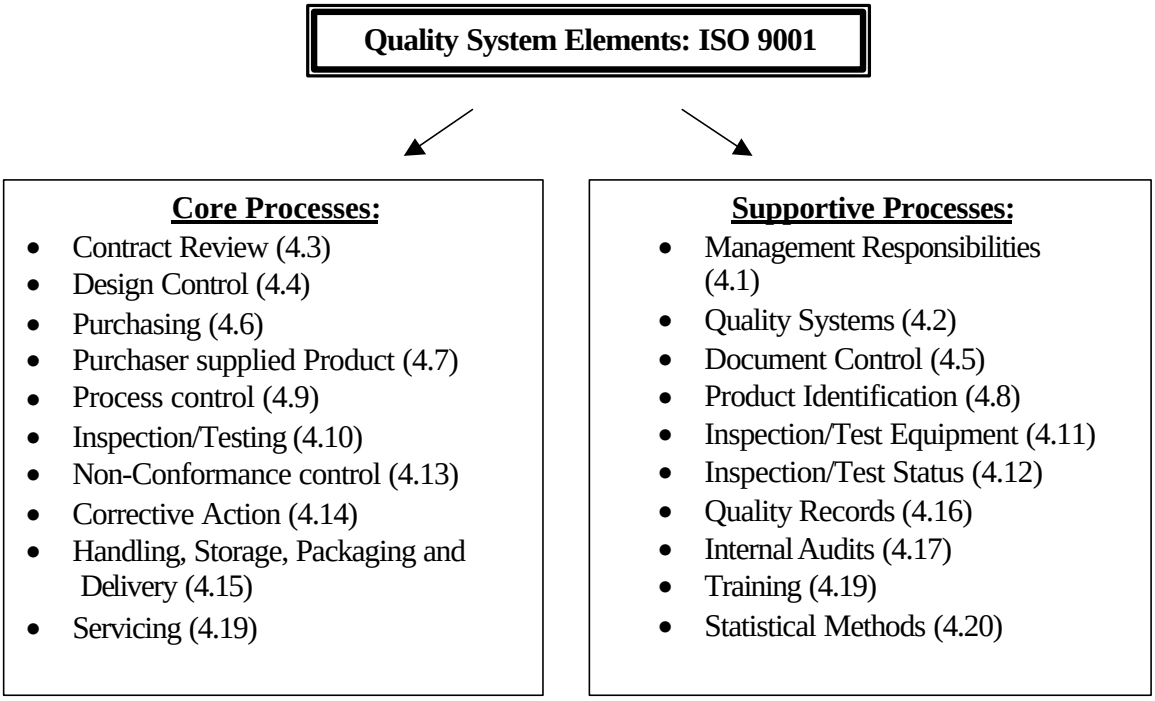

Figure 1 ISO9000 clauses and its comparative LC principle

CORE PROCESSES

1. Design Control

Companies need to have design verification and validation procedures with adequate controls to assure an acceptable design (Peach, 1997) and ensure the client's requirements are confirmed thus reducing the incidents of rework. The principle of value specification through the instrument of customer orientation coincides with this clause. This is particularly crucial for contractors undertaking D&B projects where they are expected to design most parts of the building. Internal reviews are to be carried out at different stages of the design process since the estimated cost of executing a change due to design error is five times more at the site than at the drawing board (Lam, et al., 1994).

2. Purchasing

Under this clause, the performance of the SCs and the suppliers are assessed, recorded and reviewed on an annual basis (Lam, et al., 1994; Yeoh & Lee, 1996) thus selection can be based on these assessments. LC's principle of making the value flow (section 2.5.3) through strategic alliance with the suppliers (section 3.2.5) corresponds with this clause. In addition, it also overlaps with the principle of pull (section 2.5.4) since erratic and slow delivery can be minimised on the suppliers' part as it is founded on strong relationship.

3. Process Control

Controlling construction processes involves the identification, planning, monitoring and controlling of operations. A process chart has to be drawn, indicating the whole construction process from reception of invitation to tender, to the construction and maintenance stages (Lam, et al., 1994; Yeoh & Lee, 1996). This is similar to LC's principle of mapping the value stream, identifying the steps where value can be realised, and eradicating waste in the process. Good communication and process structures ensure that any foreseeable problems are openly discussed and the updated information disseminated downstream smoothly.

4. Inspection/Testing

The material controller is to inspect the quality of the delivered material by reviewing the Delivery Order and the Purchase Order. Any non-conforming material is to be reported to the Project Manager (PM). This requires the employee to work as a team within the principle of making the value flow since any defective material transfers down the construction process has become part of the building structure and it entails more cost to rectify the error.

5. Corrective Action

Peach (1997) contends that this clause ensures an organised method for continuous improvement while Lam, et al., (1994) feels that this helps the firm in monitoring their failure costs in any project following the control of non-conformances. Kaizen principle is involved since the ultimate goal is in satisfying the client's needs. Flow principle is included as there is a need to remove obstacles that can hinder the smooth transition of the materials physical transformation.

6. Servicing

During the Defects Liability Period (DLP), the MCs are still responsible for any defects in the building works that arise during this time. When defects are related to the MC's works, the PM appoints the site engineer to rectify them. The same applies to the nominated SCs. Such follow up action tallies with the mentality of customer orientation.

SUPPORTIVE PROCESSES

1. Management Responsibility

This requirement involves developing leadership policies and project plans directed towards quality in construction. It is vital to delegate responsibilities and authority to perform required functions contributing to quality within the organisation (Battikha & Russell, 1998). Communication throughout the organisation is enhanced with the implementation of this requirement (Peach, 1997). It is noted that close management involvement signals a commitment to quality and quality management systems must be initiated 'top-down' for it to be effective.

This clause is actually the very starting point in which LC can be initialised since only top management is empowered to implement new systems with the aim of being better in identifying the changing needs of the clients.

2. Quality Systems

A quality manual has to be written in order to ensure that the client's requirements are met (Peach, 1997; Yeoh & Lee, 1996). Together with this manual are the work instructions, project quality plan and inspection records. With quality system in place, there is consistency in the way in which construction is done. This would provide a basis upon which improvement can be documented so that such valuable lessons learnt could be applied for the next project.

3. Product Identification

Johnson (1993) notes that this clause refers to three types of identification systems that a facility may use. Firstly, there must be means of tracing input from the source to the output. Secondly, the contractor must be able to identify specific operations upon the output. Finally, the ultimate destination of the output must be identified. In the construction industry, this can be used to trace defective materials or equipment to its source. It also assists the MC in his evaluation of SCs and suppliers.

This clause overlaps with the principle of making the value flow since the relationship of the suppliers with the MCs is at stake. This can act as an impetus for all involved to be more committed in their work and to co-operate as a team.

4. Training

The skills and knowledge of workers are vital to a construction project that aims to have few defects and low re-working costs. Effective training programmes can result from feedback programmes that identify areas for improvement (Johnson, 1993). Either in-house teams or external trainers like the Construction Industry Training Institute (CITI) run by the Building Construction Authority (BCA) can conduct the training programmes. This is appropriate as the actions of participants affect the quality of the project. In addition, such courses encourage the pursuit of perfection by harnessing the expertise of others and as a result, staffs are more equipped to identify beyond the articulated needs of the clients

EVALUATION OF THE ISO 9000 SYSTEM

In measuring the effectiveness of the ISO 9000 systems, it must be linked with objective measures to ensure that the constructed product has met the required quality (Al-Nakeeb, et al., 1998; Low, et al., 1998; Hoyle, 1998). One such measure in Singapore is the Construction Quality Assessment Scheme (CONQUAS). Keivani, et al., (1999) on a study of

the UK construction firm, highlights that the effectiveness of ISO 9000 registration depends on correct implementation, formulation and interpretation of ISO procedures according to the specific requirements of the firms.

In conclusion TQM is an integral concept of all units integrator of instruments in LC, which results in a real change in attitude of employees. This can only be discovered 3 to 4 years after the commencement of the programme. TQM based on ISO 9000 is essential to create an environment in which other instruments of LC can be worked on. Commencement with other instruments only has very temporary nature. Though not all ISO clauses support the concept of LC, it aids in shaping the attitude of the employees and provides the groundwork for LC implementation.

THE RESEARCH

The study has carried out a series of interviews with local contracting firms. The main objective was to assess the local construction industry's receptiveness and readiness in implementing LC. A total of 21 firms were approached and only 6 firms agreed to take part in the exercise. Five firms are G8 registered firms meaning they can tender for projects in excess of S$50 million and only one firm is G7 which means they can bid for projects worth up to S$50 million. All the firms have attained their ISO certification and are associate members of Singapore Contractors' Association Limited (SCAL). Managing directors are targeted as they are most familiar with the operation of their quality management systems and they are in the position to implement new concepts such as LC.

RESULTS AND DISCUSSION

The following are the issues that have been identified as being barriers for implementing certain aspects of LC.

Heavy Reliance On Poorly Skilled Foreign Workers

The construction industry has all along been cast as being in a hazardous and hot working environment. Due to the poor image the local construction industry portrays, it is unable to attract high calibre personnel to enter the workforce. This leads to the heavy reliance on poorly skilled foreign workers to perform the bulk of the works. With the infiltration of the latter in the workforce, the image that is cast to the society is not very positive, thus most do not take pride in their work and the vicious cycle of it being a challenging task to employ quality staff starts all over again. Although these workers are unskilled and perform most of the works, the companies are unwilling and find it infeasible to train these ones more than the necessary legislation requirement. The reasons are:

1. Government legislation

The short time period of work permit extension may not allow the firms to reap the full returns on training the workers. The same contractor remarks, ' . . . permit is only maximum four years, how many can you train? '

2. Work background

The workers generally have agricultural background thus they do not have any experience in construction. Even if they have construction related skills, there is a vast difference in the home country's standards from those practised locally.

This issue seems to have influenced the extent to which LC principles and instruments have been implemented. One such aspect is supervision where contractors have to provide extensive support and directions to such workers. This is considered to be waste in LC since all the workers should be entrusted and empowered to achieve high quality works independently to ensure flow is not disrupted through multi-functional groups. All the respondents feel this is an indispensable feature to ensure quality work is produced unless there is a drastic change in the nature of the workforce.

3. Language and education barrier

Not having received much education, the workers are unable to even read the drawings, thus their supervisors and project managers play the crucial role of giving specific work instruction. The problem is aggravated, as the speaking of different tongues does not allow effective transfer of skills to the workers. One contractor explains, "we even have to use gesture and body language to communicate to them what they have to do! They can't even read a simple drawing."

All the companies also find that it is impossible to have multi-functional groups, an instrument for LC due to the following reasons:

- The great number of diversified works and specialised technicalities involved in construction.
- The tremendous amount of wet trades involve is simply too time consuming that there is little time left to train the workers so that they can form a flexible multi-functional task group that can accommodate to unforeseeable changes quickly.

Due to the foreign workers limited education level and lack of skills; they are also not well equipped in identifying the value and mapping the value stream.

Massive use of the four design characteristics of Buildable Design, standardisation, prefabrication, precast and repetitive building components, is suggested to suit the needs of the locals where the team can be multi-functional in the same area of the work i.e. aligning, propping, installation of precast items such as beams, columns, slabs etc. This is also one of the ways in which supervision can be reduced since in repetitive works, the workers' experience can be tapped.

The Extensive Use of Subcontractors

The fragmented and highly volatile nature of the construction industry is extremely sensitive to economic changes. To keep low overhead cost MCs subcontract the bulk of the work. Most however, still try to keep their core pool of quality staff at the headquarters during economic downturns. One contractor remarked, "all except the preliminary items are done in house… good planning can ensure control is achieved".

This unique feature of the industry contributes to increased specialisation on the part of the SCs since they are most informed of the latest technology and method of construction in their scope of trade. ISO required the MCs to call up at least three SCs during quotation for competitive comparison under the Purchasing section. Usually the SCs, who have gained

expertise with various projects for the same trade upon analysing the drawings, are able to propose to the MCs alternative or novel construction techniques, enabling the MCs to obtain more attractive pricing even with improved quality.

To ensure they can secure future jobs with the MCs, the SCs are willing to share this information with them. In this way, the MCs feel they are released of the responsibility to innovate since they can be kept abreast of the latest materials and technology without having to invest in any research and development (R&D). One contractor even relates and elaborates this point, saying,

> " Especially for Design and Build (D&B) projects, months prior to the commencement of the project, we even include the precasters and the specialist subcontractors to sit in the discussions...foreseeable problems are brought up and thrashed out even before the actual construction!.…in one of the projects we have handled, there is this special cantilever slab that has to have a higher working load since it has to carry more weight and this requires a mould that is just going to be used once! Moulds are expensive you know! So the precaster actually suggest that we modify the design a little such that the moulds that are used for the other floors that have even higher working load can be used for this additional slab...that was certainly cost saving for us… "

Lack Of Long Term Commitment To Change And Innovation

The industry does not have stringent requirements, thus even small, family-based construction companies are allowed to enter the industry. Such firms are seen to be shortsighted, emphasising primarily on profitability. Therefore, the culture of R&D for new methods of construction is lacking, as it demands a long-term investment.

This short termism seems to be evident in the research sample. One of the contractors explained "even with the grants from the government to innovate, this is still insufficient and we still need to fork out a large sum of money … if the present system still brings in the desired profits, why should we invest the money elsewhere?"

Thus all but one of the companies does not put aside monies to invest in this area of development. LC's principle of Kaizen and continuous improvement through R&D on top of making the value flow are not facilitated here.

All the companies allow their employees to attend training courses/seminars that are organised and is mandatory by the Building and Construction Authority (BCA) and Construction Industry Training Institute (CITI). Only one company however, takes the initiative to organise trips to the main foreign contractors that are based in Singapore, to learn more about the latter's specialised construction techniques.

In accordance with ISO clause 4.19, which specifies training, the firms do conduct on the job training on site and mainly focus on the foreign workers. The senior management staffs continue to upgrade themselves with the latest construction techniques through reading of international construction journals and overseas visits. They will then employ or disseminate the relevant useful information to the lower management.

It is found that the nature of the companies shapes the organisational structure and this affects the dissemination of information. Family-based companies are usually not as transparent in comparison with the corporations. ISO aids in setting up the basic feedback

system under clause 4.9 of Process Control (section 4.2.3). A contractor said, "We have group discussion and weekly meeting with the foreman and supervisors…The Project Manager is the main co-ordinator. He will act as the judge and choose to adopt the better system and changes."

Price-Oriented Tendering System

The current open tendering system where the lowest tenderer wins the project does not promote the use of new construction techniques due to the costs they entail. One contractor expressed dissatisfaction, saying, "I was ready to make a loss of $500,000 on paper for my last project just to ensure continuity of works".

Clients play a crucial role for MCs to initialise new systems or concepts to the projects since most of the MCs are unwilling to bear the additional costs. If the contract clearly states that LC project delivery system is be practised, then MCs are obliged to experiment with it. One contractor said, "Based on past experience, our company believes in the efficiency of precast works to speed up the construction process although it costs more than traditional wet trades. And when we proposed to use that method, they agreed – on the condition that we bear the additional costs! How many do you expect to be like us? "

Long-Term Relationship With Suppliers Exists For Most Companies

The definition of suppliers here includes the SCs over and above the material providers. Four of the companies practise long-term supplier relationship, which is a vital instrument and principle in LC. They agree that with this alliance, better work quality can be achieved. The two firms that disagree states the setting in of complacency to be the main fear since they are assured of the jobs based on this relationship. Quality declines as time passes. One contractor adds, "There is no such thing as X provides the best price and service all the time … it is just a matter time when human tendency to slack on the job will surface ... especially so when they think they can always get the jobs from you ... you cannot depend on just one guy ... this makes business sense . . . "

Although this worry seems to be nipped in the ISO framework under clause 4.6 and suppliers are taken off the company's approved list of SCs when their services or quality fall behind the competitors, it has not proved to pacify and reassure the two firms. Append on the fact that the industry is so price-oriented, these two firms have not experienced what the four companies have, that the suppliers are usually willing to trade off higher pricing and match the competitors' quotations to secure the projects based on these alliances.

To reinforce the importance of communication and maintaining cordial relationships even with the suppliers, one firm even goes the extra mile of creating opportunities for the employee to meet up with the alliances. This firm's representative explains, " Our company holds an annual open house and the suppliers and subcontractors that are in the approved list even new ones that have just joined us in projects are invited.. . receive feedback from them as well as to update them with the latest corporate development . . . this is also a good opportunity for both parties to meet up and get to know one another better".

Efficient Use of ISO

All the firms benefit from the certification. The first contractor remarks that "ISO ensures client's satisfaction ... market practice to set up mock up samples and only upon client's approval then we proceed with the assembly ... corrective actions ensure that the client's satisfaction is fulfilled even during Defect Liability Period". One contractor points out, "ISO aids my company in monitoring the subcontractors' work progress . . . and check whether they maintain their standards since there is assessment done yearly." A contractor expounds on how his company's mindset changes because of the implementation of ISO, saying, "This system forces the old timers in my company to make changes who are sometimes quite a challenge as they tend to go about doing their work based on their experiences which are not properly documented . . . With ISO, quality work is achieved as tasks are done with consistency, in accordance with the quality manual."

CONCLUSION OF THE STUDY

All firms have performed parts of the instruments and employ some of the LC's principles into their activities but with variations. Some of the principles and instruments are applied more frequently than others. The ISO framework has indeed prove to be of an "unspoken" driving force to motivate the MCs to improve. This is clearly seen from the responses above. Though they might not have seen the benefits they can reap with the certification, they are gradually harvesting the fruitage now. The MCs generally are open to LC's principles and instruments being incorporated but express reservations to the whole implementation of LC into the local context due to the unique features of our industry. They do acknowledge however that with full implementation, it expedites the rate in the realisation of the vision of being a "World Class Builder in the Knowledge Age".

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