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Evaluating Performance of TQM Management in Mechanical Construction in the UAE

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Abstract

Construction productivity has been a recurring problem throughout international construction. Stagnant productivity increases project costs and bid prices, jeopardizes completion dates, and adversely impacts safety and quality during project delivery. Reduced productivity can result from a variety of labour, management and sector/process factors. Management techniques can be argued to have the greatest potential for productivity increase and thus the focus of this study. Specifically, research was undertaken to explore the effectiveness of using Total Quality Management (TQM) in a middle-eastern context. TQM approaches have been proven to provide positive impact and to increase productivity in both controlled manufacturing and in construction activities. Nevertheless, the approach has been seldomly used in the (United Arab Emirates) UAE or the broader Middle East. Past efforts have demonstrated the effectiveness of TQM-based approaches on electrical subcontracts for commercial development and, using a similar approach, results are expanded to evaluate mechanical activities. On-going performance of teams completing like activities under a common schedule were evaluated and earned value data collected to compare the impact of active management to status-quo approaches, which are traditionally top-down and authoritarian in nature. Results are presented and compared to performance of electrical subcontracting activities to identify broader conclusions based on the research results. Future research efforts are outlined.

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Keywords: case studies; construction management; productivity; total quality management; TQM

1. Main text

Construction is a vital indicator of economic growth for countries around the world. This is particularly true for growing economies such as those in the rapidly expanding Gulf Cooperation Council (GCC) states, such as the United Arab Emirates (UAE). In these nations, ambition is on full display and construction activities continue to commence at a fervent pace building towards the Expo 2020 opening and beyond. The industry continues to be a significant economic driver as a multi-billion dollar sector contributing more than 20% of the national GDP. Together with tourism and finance, the UAE in general and Dubai in particular are on the map as one of the premier international tourist

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destinations. The city has, through its ambitious development, become a destination of prominence not only for tourism but for business and commerce.

The industry, historically, has "been buoyed by the oil economy, high liquidity, a stable political environment and the availability of cheap labor from surrounding Asian and African countries. … Construction project sites are typically a melting pot of dozens of nationalities, which brings about challenges in terms of language barriers and customs, cultural norms with respect to work initiative and views of authority, work ethics, and so on." [1] With strong drive directed, in general, by Arab culture ambition with a diverse central to east Asian workforce, authoritarian forms of leadership have become the norm with little consideration of input from labor. Leadership focuses on getting the job done expeditiously as opposed to collaboratively.

Studies performed throughout the literature and often based on western data have demonstrated that labor may account for upwards of 40% of the direct capital costs on projects overall and upwards of 50% on electrical and mechanical subcontracts [2]. These percentages have been demonstrated to apply both to Western projects and to international projects where the low cost of labor is countered by volume of skilled and unskilled laborers and reduced labor productivity per person [2]. This may challenge the prevailing or conventional wisdom that output in Middle East markets is not affected by labor due to the low wages. With such percentages, significant savings may result in terms of time and in terms of money by employing techniques to increase productivity in a Middle East context.

Inefficiencies which lead to reduced productivity result from labor, management and industrial/sector factors. Considering these three factors, there is limited benefit which can be realized by making the workers, 'work-harder'. Energy is limited and it does not do any good unless working harder is also coupled with working smarter. Management decisions are often directly tied to the ability of the work force to increase productive work time as opposed to expending effort on supporting tasks or non-productive tasks. While it is true that ergonomics and other factors can help workers develop increased performance, it is the focus of this study to address working smarter through management intervention and changes which have the potential for significant impact on job-site.

One proven approach to impact job-site performance is to alter the management style and there are many viable alternatives which have been shown to have benefit. One such approach is total quality management (TQM) which has been demonstrated to measurably improve performance in manufacturing globally and on construction projects nationally. Studies performed on construction projects have been shown to have some effect but despite the promise for positive impact, TQM adoption in the construction industry is sporadic when examining the international marketplace. In the Gulf-states, TQM is seldom used on construction projects, perhaps due to cultural perception or time/project delivery urgency. Given the potential of the approach, implementation on UAE construction sites is nevertheless attractive and it is theorized that, with the right leadership and deliberate implementation, significant impact could be made throughout the Middle East.

An opportunity existed to explore the impact of applying TQM principles on an actual project undertaken in the Emirate of Dubai for electrical subcontracting. The project utilized for this examination was symmetric around the centerline of development. To explore the concept, electrical subcontracting tasks were compared and contrasted using status-quo versus TQM approaches and results were published comparing mirror-image activities with TQM management versus status-quo authoritarian management [1]. This study extends the evaluation by using the same site to examine mechanical construction activities. As with the electrical study, one side of the project was constructed and managed using typical management procedures, which were generally top-down and authoritarian in nature. The other side of the project, contained all the same tasks but was constructed and managed incorporating TQM principles. The project will be described as will the alternative management approaches employed in the following sections. To measure the performance and to evaluate the differences between the respective teams or sides, earned value analysis data was collected and evaluated. The differences between the two approaches are shown to explore whether superiority of the TQM approach is justified by the results, either empirically or quantitatively.

2. Background Literature

The study undertaken seeks to prove the importance and benefit of employing TQM principles for mechanical subcontracting using a case study from the Emirate of Dubai and builds upon research previously published for electrical subcontracting. Employing TQM principles is intended to provide positive benefit in terms of productivity, which leads to positive impacts in cost control, time, quality and safety. The productivity 'crisis' has emerged due to stagnant or negative growth of the industry internationally, including in the GCC countries of the Middle East [2] and factors which affect the industry have been known, investigated and discussed for some time. [3,4,5,6]. These factors can generally be attributed to labor effects and labor effort or lack of effort, management practices and management

decision making, and instantiated inefficiencies within the industry, such as within codes and regulations. Studies have shown that limited benefit can be obtained by trying to coerce additional effort as workers are generally limited in terms of energy. Some benefits can be obtained through ergonomics but large benefits can be achieved by addressing management decisions which lead to non-productive effort or excessive supporting efforts. The management philosophy, such as the implementation of TQM, is one such factor that can be explored.

Total quality management (TQM) has been employed in manufacturing since the late 1970's / early 1980's. The approach focuses on customer satisfaction and involvement of all parties in improvement of the processes and subsequent products. With TQM, manufacturing processes have been revitalized while also changing the environment and culture surrounding work tasks. Combining these impacts gives the following guiding principles for TQM, as per the American Society of Quality: customer focus, total employee involvement, processed centered thinking, system integration, strategic and systematic approaches, continual process improvement, fact-based decision making, and communications. [7]

TQM has been shown to benefit a myriad of industries and construction is no exception. Despite the potential, there is little research supporting the benefits in mechanical, electrical and plumbing activities on construction sites. When applying the approach to a specific cultural context, such as the Middle East, research results and activities are even more scarce. This research activity and study seeks to add to the body of knowledge and to provide supporting information for more widespread application of TQM in the Gulf states. Research that does provide compelling evidence of effectiveness of the approach, while limited, is compelling. For instance, work done through sponsorship of the Construction Industry Institute (CII) found strong correlations between management practices and overall project performance with a 40% improvement of labor productivity in mechanical trades. [8] Higher gains were seen in pre-project planning tasks which further benefit the overall project delivery.

Surveys were implemented specifically in Dubai during the height of the construction boom in 2007 to identify factors which were deemed to be important for success of implementing TQM in construction. [9]. Barriers to implementation were also identified. While this work was qualitative and not statistically rigorous, it did show that top management commitment and customer satisfaction were critical to successful implementation of TQM. Other work performed in the region similarly showed best practices and critical success factors in Iran [5] and Egypt [10].

3. The Opportunity for Comparison of Approaches

As previously mentioned, an opportunity to study the effectiveness of TQM processes presented itself during an electrical subcontract on a large, multi-use development in the Emirates of Dubai. A paper was written on this subject and previously published [1]. This same project, with the mirror-image activities, also permitted further exploration of the impact of management approaches on mechanical rough-in subcontract. The project is part of a large multi-use development with numerous commercial spaces for retail, parking, leisure and entertainment together with supporting infrastructure. In total, the overall project consisted of over a million square feet of development in a mirror-image arrangement as shown in Figure 1, which shows the symmetry but not the details of the project. The mechanical subcontract required rough-in of ducts with and without insulation, drainage pipes, CPVC cold water plumbing, and wet-pipe sprinkler systems. All mechanical elements were rough-ins and no fixtures were included in the subcontract. All required elements were identical for these elements on either side of the project with 74 identical units on mirrored on the centerline. The two sides of the project were divided into separate autonomous teams. Each team had its own skilled and unskilled labor, foremen and superintendents. The leadership on each side of the project reported directly to the project manager whom facilitated the study and collected data on the project as it was being performed. Crew sizes, equipment and support staff were, as much as possible, identical on both sides in terms of quantity and capabilities to minimize and eliminate bias as much as possible. Each team used the same inventory/storage facility, the same administrative staff/time-keepers and safety personnel. Independent quantity surveyors were engaged to confirm quantities installed and ensure the validity of the progress reports submitted.

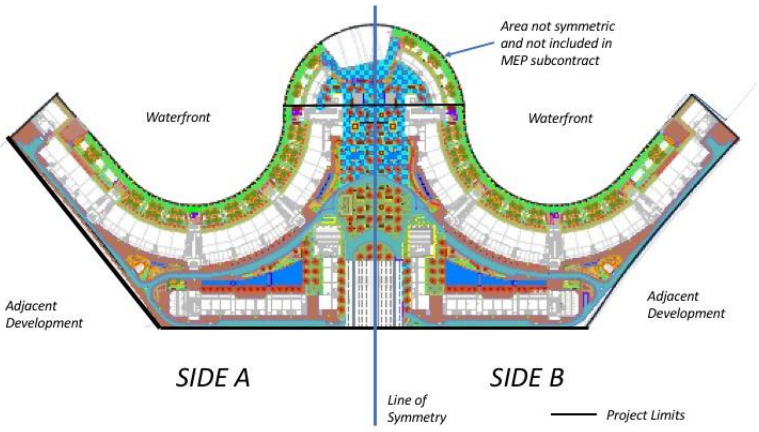

Figure 1: Project Plan Used for Research. [1]

Management using TQM principles were employed on Side A while traditional management approaches were employed on Side B. In the TQM approach, efforts were taken to develop a participatory management style, which laborers were unfamiliar with. This involved significant communication with all participants, skilled and unskilled, management and labor alike. A project quality steering committee was formed including project management representation, quality control engineers, quantity surveyors, project engineers, foremen and superintendents, charge-hands and labor representatives. The project quality steering committee met frequently with the goal of empowering the workforce and facilitating continuous process improvement. For the traditional side, a status-quo approach was taken and a typical authoritarian management style was used. With this style, there are orders that are conveyed from top to bottom with no opportunity for worker feedback. This is in stark contrast to TQM with involvement of all participants. For each side, progress was monitored over the entire period of performance. Quantities installed were recorded on a week-by-week basis as were actual labor hours which provided the basis for earned value management.

Each side had identical plans and schedules, identical activities, and the same availability for materials and any necessary equipment. As mentioned, the work force was identical in terms of composition and competency to minimize bias. The project manager was also careful to ensure that he was not giving undue personal attention to one side versus the other, which may have skewed the results. Although the management focus on the two respective sides greatly differed, the assigned project management support staff on the two sides had equal access and equal time with the project manager.

4. Data Collected

As mentioned, the project involved a set of mechanical rough-in for the facilities. There was no finish work and no installation of large mechanical systems, such as chillers or water treatment facilities. The work performed focused on installation of ductwork and ductwork insulation, the installation of cold water piping and drainage pipe, and fire suppression wet-pipes. The items and the estimated quantities and projected man hours are shown in Table 1. Each side has 259,402 cumulative man-hours budgeted for completion. HVAC installation and Fire suppression are both planned for nearly 100,000 manhours with 65,000 required for plumbing.

The quantity for each item was measured and recorded weekly as were the actual and earned man-hours, the difference of which could indicate cost over or under-runs. Differences in progress, however measured, gives an indication of differences in productivity between the two respective sides as does the ratio of actual and earned manhours.

Table 1. Activities, Quantities and Planned Labor Hours for Lighting and Power on Side A and Side B

Elements	Estimated Quantities	Planned Manhours
HVAC		
GI Duct	49,712	27,618
Black Steel Duct	32,433	18,018
Duct Insulation - Inside	1,148	25,000
Duct Insulation - Exhaust	5,861	23,444
Support Systems for Duct work	11,229	3,238
Total HVAC		*97,318*
PLUMBING		
Drainage Pipes - Above Grade (UPVC)	12,002	26,662
Cold water CPVC Pipes	7,883	6,532
Cold water CPVC Fittings	8,780	21,413
Hangers & Supports for drainage and water supply	6,400	10,140
Total Plumbing (Pipes, Hangers & Supports)		*64,747*
FIRE SUPPRESSION		
Fire suppression wet-pipe (25 to 80 mm)	2,675	24,398
Fire suppression wet-pipe (100 to 200 mm)	26,808	72,939
Total Fire Suppression	*29,483*	*97,337*
Total Man Hours - Project		259,402

5. Analysis and Results

For the HVAC and the plumbing systems, hangers and supports are required to be installed prior to the supporting ducts and piping. Both of these items were complete on both sides of the project before the schedule completion date at week 19. In terms of the HVAC supporting hardware, both sides were approximately on-target in terms of quantities. For the plumbing support equipment, Side A using TQM exceeded the quantities by 7% while Side be exceeded the expected quantities by 6%, which for all practical purposes is effectively equivalent. The progression of installation in terms of quantities is for HVAC and Plumbing supports are shown in Figure 2.

In terms of costs, the installation of supporting hardware exceeded the estimated costs for both the HVAC system and the Plumbing systems. One major reason for this is the disparity between assumed productivity valued in estimation and planning and the actual values experienced in the field. Considering the HVAC system, the quantities estimated and expected were fairly close to the actual values installed. Yet, in terms of man-hours, there was a 5% increase with the TQM approach and a 30% increase with the traditional approach. For the plumbing supports, quantities were increased due to field decisions on where to place the hardware. Increases were 7% for the TQM approach and 6% for the traditional approach. Actual man-hours were 23% and 34% higher than estimated for Side A and Side B respectively. This is alarming and jeopardizes the profitability of the activities due to unrealistic planning input values. This can be corrected through better data collection and the use of BIM models to ensure and control wastes.

While costs were seen to escalate on both sides of the project, time impacts are more clear and more convincing for supporting systems. Evaluating Figure 2 reveals that in both cases, the Support hardware, for all practical purposes, was effectively complete by week 8, less than 50% of the way into the project. With the traditional management approach, supporting systems were still being implemented during weeks 18 and 19 and possibly delayed other items.

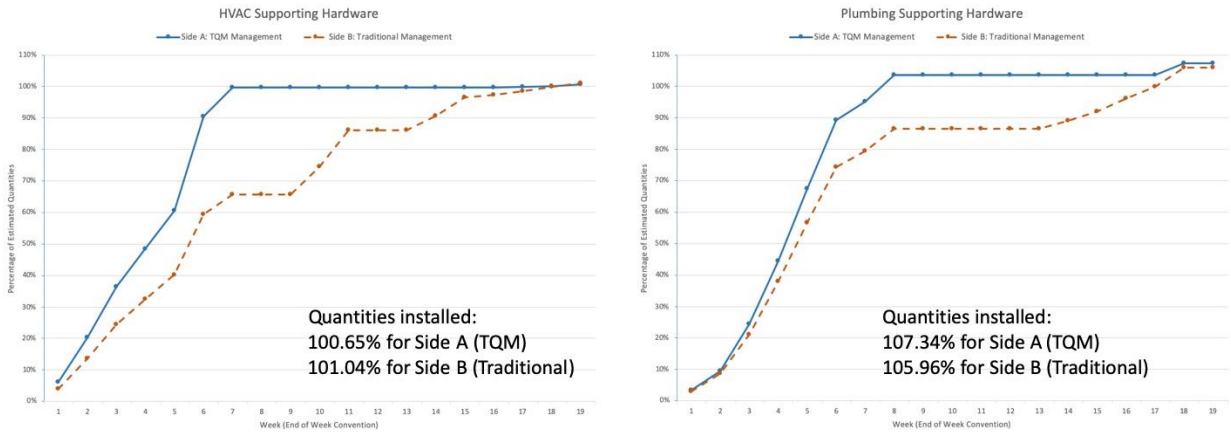

Figure 2: Progress of Supporting Hardware Installation for HVAC and Plumbing

Considering HVAC and Plumbing activities as a whole, the crews working on Side A with the TQM approach were able to complete the rough-ins by the 19-week deadline. For Side B, work was not completed within the required timeframe and delays were experienced. These delays can only be attributed to the management style and provide convincing empirical evidence of the impact of a TQM approach in the Middle East. Considering quantities, 89% of the estimated quantity of HVAC components were installed by the 19 week planned completion. These activities were not complete at week 19. For plumbing activities, actual installed values at completion on Side A were 109.1% corresponding to a 10% increase in plumbing materials. At week 19, Side B was not complete but was at 102% of estimated quantities. It is expected that the quantities installed would meet or exceed the quantities installed by the TQM focused crews.

The progress of the HVAC and Plumbing activities collectively can be sown in Figure 3. It may be seen that the productivities of the activities are comparable during the first two weeks of work for both sides of the project. However, the productivity steadily decreases over time on under traditional management approaches when compared to the equivalent activities being performed on Side A. Costs for both the ductwork and for the plumbing exceeded the estimates by 13% to 25% for HVAC, depending on the specific detail and 20% to 35% on plumbing. Overall costs were approximately 3% higher using the TQM approach for HVAC rough-ins. The opposite was true on plumbing where cost for the TQM approach was approximately 4% lower than traditional management costs. In both cases the cost escalation was an area of concern and can be attributed to higher than expected wastes and inefficient use of materials together with material price increases that were not properly accounted for.

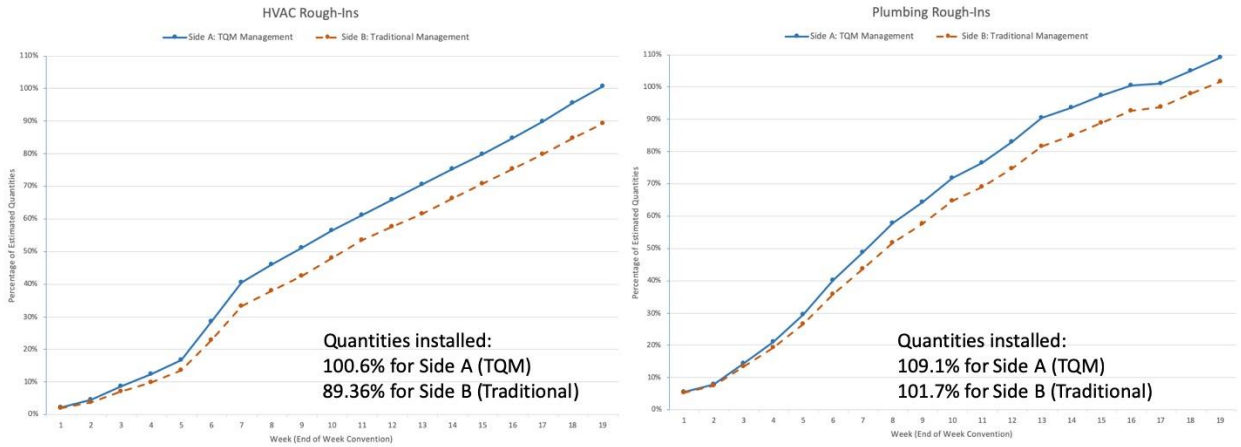

Figure 3: Progress of HVAC and Plumbing Activities Throughout Project

It is difficult to make a conclusion of the superiority of one approach versus another with respect to costs. However, it is clear when examining Figure 3 that the TQM approach has a clear impact on the time for project completion. This is compelling information that could encourage more widespread use of TQM in the Middle East.

The contract required the installation of fire suppression wet-pipe and values were aggregated into small (800 mm and below) versus large (100 mm or above) diameter pipe. Overall, values between the two sides in terms of quantities tracked very closely between the two sides as may be seen in Figure 4. This is a curious result as one would expect that the TQM approach would show a similar trend to the observed data for HVAC and Plumbing. It is unknown why a clear difference between the two approaches was not observed and more information and additional research must be performed to identify the causes. It is possible that material availability limitations with large diameter wet-pipe, which was still not complete at week 19, constrained the installation of smaller diameter pipes. Costs of the fire suppression activities were significantly above estimates nearly doubling on both sides of the project. The costs on the TQM side were clearly superior and were 10% less than the equivalent costs on Side B with traditional management. It is uncertain as to why the difference occurred given the similar timeframe of materials installation. This would infer that there is less efficiency of the crews with traditional management styles but more information must be collected to validate that hypothesis. The fire suppression system was incomplete on both sides of the project at the conclusion of week 19.

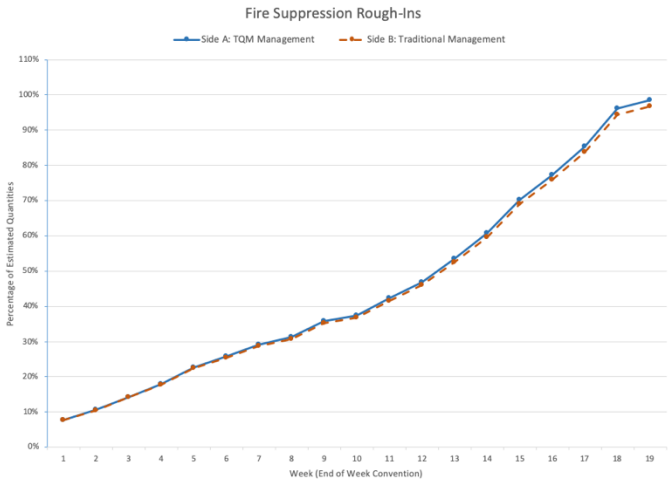

Figure 4: Progress of the Installation of Fire Suppression Wet-Pipe on Side A versus Side B.

The quantities installed as well as the manhours expended can give an estimate of the differences in productivities between the two sides. Looking at quantities, there is approximately a 14% increase in productivity that was observed for HVAC duct installation and associated insulation. For plumbing pipe installation and fixtures, an increase of 8% was observed by applying the TQM approach as calculated using quantities. The difference in fire suppression wet-pipe was nominal with a calculated increase of 1.5% observed by using TQM.

6. Summary and Conclusions

This research effort capitalized upon the unique opportunity presented by a mirror-image project in the Middle East. With the forward-thinking of the subcontractor and project manager, a research student was introduced for a small subcontract with mechanical rough-ins. This paralleled and built upon the successful results found through electrical subcontracting on the same project [1]. The project was structured where one-half of the project was delivered using a TQM approach while the mirror image was completed using status-quo authoritarian approaches. The data collected showed quantities installed together with manhours expended and earned value. The data was evaluated to make conclusions based on the results. It was shown for the HVAC installation, Plumbing installation and associated HVAC/Plumbing supporting elements, that there was a clear difference in the performance between the TQM and status quo approaches. Significant productivity gains were realized. Costs on both sides escalated; however, this was due to insufficient or overly optimistic estimates or unexpected material price escalation. With the mirror

image projects started at the same time, the TQM approach clearly finished within the time-frame in cases where work was delayed under the traditional management approach. The one exception is the installation of fire-suppression wet-pipe, which was delayed on both sides of the project.

7. Acknowledgements

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