Learned Techniques for Managing Engineers on Remote Major Projects

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***Abstract*--As world populations increase, the demand for non-renewable resources forces organizations to pursue mega projects in sparsely or non populated regions. Worldwide trends towards urbanization make it increasingly difficult to attract and hold skilled workers in these less attractive locations. As well, the skill sets required to design and build the large projects may not be required within the organization once the facilities are operating. The operating organizations turn to a variety of outsourcing techniques to provide the labor to design and construct their mega projects. The differing priorities of the organizations involved can create further problems on all sides. Over a fifteen year period, formal and informal interviews were held with a variety of players working on ten remote projects with budgets in the $1 to $20 billion range. Although the interviews included skilled craft doing the physical construction, this paper focuses on the design phase and in particular the challenges with the management of the engineering effort. Techniques that mitigated reappearing problems were found in some of the projects and are offered here. These learnings should assist others considering a venture into such an endeavor, particularly if they do not have the bench strength within their current organization.**

I. CLARIFYING DEFINITIONS

The use of terms within industry may vary between organizations, so the following definitions are provided to help clarify the details in this paper. When examples of companies are giving within these definitions, they are the largest representative in ranking from the Fortune 500 list of companies [1] without intending to imply that they were involved in this study.

Contingent Workers – these are people brought into the organization to supply work, contingent on the requirement for their services existing. They may be contracted employees, seconded workers from another branch, long term employees of a service provider, an independent contractor of the hiring organization or a service provider, or other any other arrangement that has the intent of a shorter term relationship.

EPC company – these organizations are suppliers of services involved in the engineering, procurement and construction of facilities, typically for owner operators. Their work is typically project specific, but they also provide ongoing technical support for operating and maintaining physical facilities. An example of this type of company is Fluor.

Knowledge Worker – in this paper, the term knowledge worker is used to indicate the people involved in projects that are not doing physical tasks. It would be clearer to use the term engineer, although many of the people performing the skilled work were not legally engineers, and held titles such as estimators, planners, designers, field coordinators, and managers. In many instances these people worked alongside the engineers and performed very similar work.

Owner / Operator company – this type of business generates profit through the use of physical equipment that requires significant engineering effort to design and high levels of funding to finance. An example is Exxon Mobil. Once built, number of people required to operate the plant is much lower than during construction, so they typically use a contingent workforce during initial setup and for expansions.

Skilled Craft – this term is used to signify the people who were trained in a trade such as welder, carpenter, or electrician and performed the physical construction work on the projects.

Turnkey project – this term is used to designate a project that is handed over to another organization to construct and commission for a fee. The owner paying for the work specifies what is required, lets a contractor design and build it and then accepts the facility once it is constructed. These types of arrangements are usually limited to low risk projects of a more routine nature as most managers at the owner organization would not trust the outcome without being involved in the process.

II. INTRODUCTION

This paper is the result of a study that started in 1998 as a formal benchmarking investigation within a large operating company. This organization was interested in maximizing the effectiveness of their capital program including an annual capex (capital expenditure) project budget of around $100 million and infrequent major programs that typically ranged from $500 million to $1.5 billion in size. As noted by Peter Drucker [2], it is unlikely for organizations to be expected to last as long as a researcher's career and in this case, a major corporate restructuring in 2005 following a merger caused a loss of interest in the study by the host company and also the termination of the researchers. The data collected by that point formed a framework to build upon as the scope was expanded to include projects up to $20 billion in size. As noted by other researchers (e.g. [3]), it is often difficult to gain access to data within industry, due to a number of factors including management's reluctance to expose any potential problems in their operation and protecting proprietary information. The findings presented here represent information that could have been part of the proprietary knowledge of that organization if it still existed, and would typically not be available for public distribution. As this study was performed over many years, it overcame many of the initial barriers to information that can be removed by the building of trust over time [4] and thus it contains rich findings that should be helpful to guide practicing managers in similar settings.

It will be noted here that the initial review of this paper upon first submission suggested that the information contained here is not novel or particularly significant. From these comments, the idea that follows is that the best practice for managing large projects is well understood. This leads to the question of why the observed decisions being made during the research for this paper most typically were not in-line with these best practices? The underlying driver for presenting this paper has been a hope to mitigate the ongoing struggle experienced by engineering managers executing these types of projects and to rise above suboptimal performance. The outcomes of many of the projects were not acceptable to the organizations involved and legal disputes sometimes evolved around the management of the work. Even in cases with successful outcomes, the absence of learning at an organizational level was apparent when the next major endeavor they undertook failed due, at least in part, to a lack of understanding by the new management team. There has been a suggestion that the higher personnel turnover experienced in the past decade has created an attempt to replace tacit knowledge with defined processes [5]. The results observed during this study suggest that even if the methods leading to optimum performance are understood by academics at a theoretical level, they are not being followed by those with the ability to implement them in practice. This suggests a need to explicitly state the concepts learned, even if it is a repeated message for some. As one experienced project manager was recorded as saying during this study, "You think you have said something enough, but you need to remind your team at every meeting of what you might think are basic concepts."

III. PROJECTS OF INTEREST

This study focused on the challenges of large projects that represent considerable construction efforts in normally sparsely populated areas. The owner organizations lack the bench strength to execute the projects with their own permanent staff of knowledge workers, due to a combination of factors including the infrequent need for certain specialized services and difficulty in obtaining the consent of long term personnel to relocate to these less desirable locales. Skilled craft, on the other hand, are typically not a problem to source as many welders, pipefitters, boilermakers, and other trades have made a career of flying in to remote sites for short term assignments [6]. The nature of the work for such trades using journeymen allows for a largely seamless exchange of equivalent workers that provide an end result of sufficient quality to meet expectations. This process of interchangeable workers is not well suited for knowledge workers, however [7], and therefore the engineers, designers and other specialists are the particular focus of this paper.

The more senior managers at an owner organization pursuing this type of work are therefore saddled with the task of deciding how to build a team of these knowledge workers to complete the project at adequate levels of quality, cost and schedule. Options include outsourcing the project entirely to another organization in a turnkey model [8], building a team in-house using a combination of permanent and contingent workers [9], or any degree of control between these two extremes. Figure 1 is presented to provide a schematic representation of the general types of strategies used to execute the projects. As noted above, the geographical locations for the construction work challenges the organization where turnover rates of personnel placed at these sites can typically be expected to be 50% per year or higher [10]. Some of the costs for this high turnover are more easily measured, such as training time, recruitment, moving costs and severance payments. Other impacts are more indirect and difficult to assess such as lower efficiency, learning curves, low morale, and a lack of engagement when the worker expects to be somewhere else within 6 months [11]. Attempts to quantify the total costs of high employee turnover have found that the information gathered from workers in these settings is highly unreliable due to the subject's own reluctance to be involved in an initiative with which they do not have a sense of ownership [12]. But these studies do agree that although difficult to quantify, the costs in such circumstances are much greater than in more stable work environments, especially when the quality and performance of the physical output of the workers is considered.

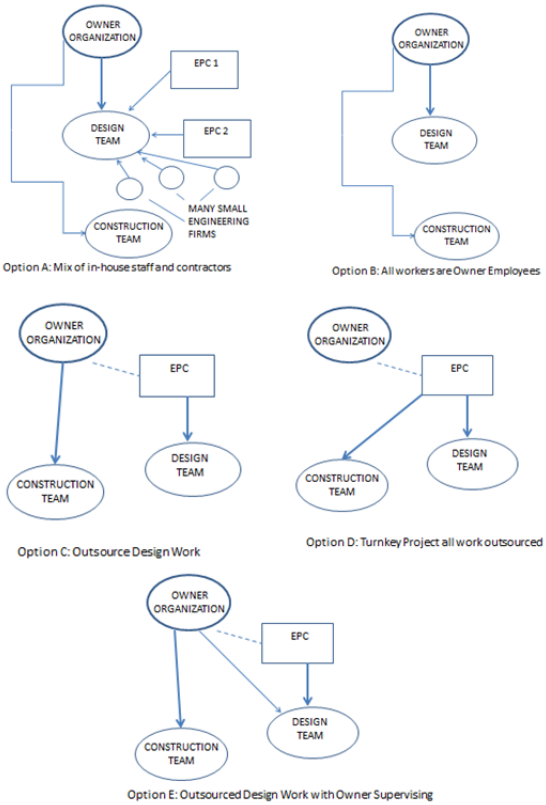

Figure 1: General organizational and contracting structures for executing the projects covered in this paper. The order from A to E represents the general degree of satisfaction of the results as reported by the owner representatives studied with A being the method reported to produce the best results.

The type of projects being studied were all heavy industrial construction projects. The owner companies were in industries related to mining, electrical energy generation, and petroleum. Many of the projects related to oil sands extraction and refining. In some cases, temporary 'cities' or work camps of around 10,000 people would be constructed to house the workers involved to construct a facility that would employ around 1000 people once operating. In some cases, these projects were located 160 kms (100 miles) from any permanent community with a store and 800 kms (500 miles) from any community of more than 100,000 people. The total cost of all the projects studied for this paper is in excess of $60 billion dollars.

The projects fell into two general categories. The first were greenfield projects, defined as those that can be built without having to consider any existing facilities in the area. The other type consisted of expansions or major renovations to existing facilities. The latter were much more challenging logistically as the requirement for the physical presence of the engineers involved was greater. In the operating plants, the operations and maintenance personnel often had built up tacit knowledge of the plant that required interaction with the people designing changes or additions. As well, modifications to the existing facility were often not adequately documented, requiring frequent field verification of the actual physical conditions. For the greenfield jobs, the bulk of the engineering could be completed at major urban centers complemented by the occasional trip to the site.

IV. METHODOLOGY

The data was collected through a variety of discussions and interviews with key personnel within the various organizations. When asking about the effectiveness of a particular method, a follow-up question was asked to provide data that supports the view being given. Expert opinion alone has value, but one can often find examples where two comparably qualified experts in their field may have opinions that are contradictory. For an example outside this study [13], changes around a particular valve in an operating facility led to questions about its purpose. The maintenance manager with 20 years of service was adamant that the valve was to be closed during normal operations. The facility operator with 15 years service recommended that it only be closed during start-up and must be open all other times. A full investigation, including locating the retired engineer that originally designed the plant, yielded the result that the answer was complex and depended upon a variety of situational factors. The design of the additions to the plant was changed to eliminate the valve entirely. The impact of experiential bias was somewhat controlled for in this study by utilizing a round of Delphi-based [14] reviews of the findings of this study, utilizing the original participants when practical and engaging other managers when additional feedback was felt to be warranted. In some cases, managers representing an EPC company would not agree to findings that indicated maximizing the involvement of an EPC was not the optimum solution, but the findings are presented here if all representatives from owner organizations agreed they were valid.

V. THE PLAYERS

There were eight owner-operator organizations that executed projects covered in this study. The term 'owner' organization is used here to identify a company that has their primary business resulting from the operation of a valuable asset requiring significant effort and funding to set up. From 1998 to 2005, the focus was on one particular organization. This company originally had the vision of improving their ability to execute large construction projects and be an industry leader in effective management. Feedback from some of their customers stated that they were seen to be inefficient in executing large projects and this led to higher costs for their product. It was noticed that many of their peers they had contacted for information were also starting on similar initiatives, but these also all met a similar fate of being shelved following major organizational restructurings. Representatives from all eight owner companies reported that their experiences with the building of project execution teams had similar patterns in recent years as presented in this paper. It is important to note that these eight companies saw their own effectiveness in managing projects to be in a decline over time, which would certainly not be the case if best practices were widely known and understood by the managers at these firms.

Seven large Engineering Procurement and Construction (EPC) companies with more than 5000 employees world-wide provided varying degrees of service on the projects studied ranging from managing the project in a turnkey fashion (as noted above) to simply providing support within the owner's office. EPC companies were reluctant to provide contingent workers to owner organizations. There was a high rate of those workers relocated within the owner office to sign on as a permanent employee of the host organization. Also, the management of both the owner organizations and the EPC companies noted that the workers that were relocated to the owner's office very often adopted a perspective of increased loyalty to the host (owner) company. It was noted that this attitude may have stemmed from the desire to be recognized by the owner as being a good team player and hoping this would lead to an offer to come on board. At the same time, when an EPC was able to successfully integrate one of their employees into a longer term position within the owner organization and this worker recognized their role as agent for the EPC, the strategic advantage to the EPC was significant for developing business opportunities. It was also noted that the owner organization was seen to be the preferred employer for junior engineers and most of the movement from the EPC to owner organizations were from the less experienced ranks. On the other hand, it was rare for the owner firms to sign on mature

engineers, but it was common for senior engineers to move from the owner firms to the EPC companies. This agrees with the trend observed more than forty years ago [15] and again in more recent studies [16].

The owner organizations also drew from hundreds of small engineering firms that ranged in size from sole proprietors working out of their basements to an office of 50 engineers that typically provided services of a specialized nature such as geotechnical studies or harmonics in high voltage distribution lines. The researchers spent considerable time within the offices of the owner and EPC organizations, but only covered a sampling of these smaller organizations. In many cases, engineers would start their careers working for a number of years as an employee at one of these owner organizations and develop a specialized skill that was not in constant demand at their employer. The engineers would quit and the former employer would not be able to fill the vacancy in knowledge from within and they would be required to hire the former employees on contract. The new higher hourly rates of pay were often sufficient to cover for the lulls in work, and this was sometimes supplemented by any work obtained from similar organizations. This strategy was highly risky for the departing engineers as the decision to prohibit using their services was sometimes mandated by the owner management. If the specialist was lucky, a competitor would still take them in. Some of the owner offices studied had thirty of these specialist service providers working within their organization on contract at any given time.

VI. SHIFTS IN CORPORATE CULTURE

In the early 1990's, there was still an expectation by many employees that they would be building their career with one particular company until retirement. One indicator that this is no longer a viable expectation was the move by all 8 of the owner organizations to eliminate their defined benefit pension plans for all new employees. This due in part to the unlikely scenario that any new employee would be with them long enough for the plan to be effective, similar to what has been experienced by private companies in general [17]. This shift in employment expectation has the impact of reducing the long term vision within these owner organizations. For one example, the importance of this study was seen at its start to provide a strategy advantage for the company that sponsored it. As employee turnover increases, it is difficult to develop and contain best practices that are not soon adopted by all the peers since the learnings will travel with former employees to their new workplaces. Starting around 2003, it was found that less of the owner organizations were attempting to execute their large projects in-house, and in 2013, none of them were operating in that fashion. The reasons provided for this shift centered around the lack of confidence that the time required to build and train a team in-house would result in a net return on the investment required. One factor behind this was the lack of confidence within management that the team members would stay with the organization after the conclusion of the first project completed. It was also reported that it is easier from a personal effort perspective for the manager to outsource work to a third party. If that person does not have a long term goal to stay within the organization, the simpler route from a personal perspective may be chosen regardless of potentials for long term benefits to the company of another more difficult path.

As noted, all 8 owner organizations had embarked at one point on a path of building in-house project execution teams. Given the reluctance of EPC firms to supply people in the office of the operating company, as noted above, it was natural for the contingent workforce to be built in part from some of the hundreds of small suppliers of specialized services. In the case of 5 of the owner organizations, there was a move prompted externally to the projects group to streamline the logistics of having tens of service providers submitting invoices monthly. For these 5 companies, a decision was made by the CEO or a senior vice-president to replace all these small service providers with a single source service provider, which in every case was one of the large EPC companies. Also in every case, the people providing the work after the change included many of the same people that were working previously as one of the small vendors who now submitted their invoice to the EPC at a markup instead of directly to the owner organization. For one organization, this change increased their cost of engineering by $300,000 per year, with minimal change in the actual people working within the department.

In none of the cases was a financial justification for the move to single source engineering provided to the projects team. Also in none of the cases was the move seen by the senior management to be an improvement post implementation. In one case, the owner company proposing to consolidate their engineering providers did a study of those of their peers that had undergone such a change earlier and they concluded that none of these peers were satisfied with the move they made. That company still proceeded with switching to a sole source service provider and also reported after the move that it was not a positive experience. There appears to be an opportunity to improve the knowledge and implementation of best practices when a company would identify a low probability of seeing benefits of a change and still continue on their proposed path.

VII. DIFFERING PRIORITIES

Managers from the owner organizations agreed that their expectation for what constituted a successful major project was the long term profitability of the investment. When the execution is controlled in-house, the design team has the freedom to take risks in design or construction that may require modifications at some future point should the decisions to save money up front not prove out once the facility is operating. As well, the team members on the project are typically working flat out or putting in overtime.

They are motivated to innovate and develop methods that reduce the total work hours spent on the project.

When the design and construction is handed off to a third party to execute, the priorities of the team shift. The design team knows that the finished project is now expected to work flawlessly from the start. As one manager at an EPC said, "the project triple constraints are all equally important, but scope is more equally important than the others." All the managers from the owner companies stated that they considered the facilities to be over designed and more costly than required when farmed out to an EPC. The managers from the EPC companies stated that the owners complain about cost and schedule, but the consequences of not meeting specifications are not worth the risk of trying unproven cost saving or time saving experiments. As well, the contract structures between the owner and EPC are very typically based on an hourly rate for the EPC workers. The income for the EPC is highly dependent upon the total number of hours that can get billed on a project and there is little incentive for the firm to focus on reducing the hours required on a given job.

When a simple project is done in-house, an owner company manager may decide to rely upon drawings used from a similar job and have an engineer make hand mark-ups to show the changes for this particular job. When this same job is executed by an EPC, the contractual requirements enforced by this same owner company may stipulate that all designs must follow a formal controlled process, adherence to specified drawing formats and compulsory inter-disciplinary reviews. One owner organization compared the costs for the engineering phases of similar small projects executed in-house versus farming them out and noted that the latter were often three times higher. In all cases, when the work was done in-house, the owner manager knew the team members and had control over who was charging to the job. When the work is removed to a third party organization, all owner managers voiced concern that they did not know who was billing to their job or what roles all the people they were paying for were doing. Many times, the owner organization is resource constrained and their managers accept this cost as a reality of their business. At one company, the annual cost of engineering work for a similar portfolio of projects rose from $2.3 million to $6.1 million once it was moved to a sole source provider. In addition, the project sponsors reported that they were not satisfied with the quality of the design despite the much higher cost and associated increase in hours spent on design.

In one instance, the researchers discussed the health of the business relationship between an owner and their sole source EPC service provider. The owner had eliminated all in-house work and removed all their engineers and support from their internal project execution group. They had signed a multi-year agreement with an EPC that was geographically located 30 kms from their plant. In formal meetings, representatives from both groups agreed that it would take some time to develop the trust and processes to be effective at a level that was satisfactory to both parties. In private, the owner manager stated that all indications were that the EPC was "gouging" them by charging many more hours to complete tasks than should be required. They stated that since the funding was limited, it would be better for the EPC to streamline their processes and provide more deliverables for the same total dollar amount they would be getting. On the other side, this suspicion was supported by private conversations with the EPC management who stated that they lacked confidence that the owner organization would maintain the relationship for any length of time and it was better to maximize the billings while the contract was still in place. The contractual relationship was terminated within two years of being set up.

VIII. CASE 1: ASSURING SCOPE IS MET

One owner company began the execution of a major expansion with a budget of $3.5 billion. There was concern that the final product may not be able to meet design capacity. They had experienced some problems in the past with certain elements being under designed and they had to engage in debottlenecking projects to bring their plant to expected capacity. The contract to an EPC to provide the design and construction management included a $4 million bonus if the plant operated at the design capacity upon start-up. During the design phase, the engineers were focused on meeting the target and collecting the $4 million bonus. When design decisions were made on two choices, it was most common to pick the larger piece of equipment to assure that part was not a bottleneck in the final operation. The project had a final cost of $5 billion and much of the $1.5 billion overrun was attributed to over design of many components. The EPC collected their $4 million bonus.

IX. CASE 2: ASSURING BUDGET IS MET

Another owner company planned to install a $125 million addition to their facility to increase their production. They engaged an EPC to complete the design and managed the construction themselves. In order to contain the potential for cost overruns, the owner offered a $1 million bonus to the EPC if the costs of the engineering and procurement of equipment met their budget limits. Those targets were met and the bonus was paid. A few years after the addition was in operation, the owner's operations team noticed that the new facilities were requiring a disproportionately high percentage of the annual maintenance budget. A review of the problems yielded findings that the new facility was constructed from materials of marginal robustness for their intended application and the choice was made to remove corrosion inhibitor systems from the final design.

For both Cases 1 and 2, it should be stressed that the problems encountered were likely not the result of a lack of competency or a desire to game the system. In both cases, the nature of the contract stressed which aspects were of

highest importance to the client. The service provider assured that these priorities were met. When operating within a single organization, it is possible to manage without defining all details in advance and changes to the plan can be easily made midstream. When the directions are provided in the form of a formal contract, the management team outline the goals likely lacks the skill to provide a complete directive for the desired outcome and certainly cannot anticipate changes in the environment that would require deviations from the original plan to assure optimal performance. In some of the cases studied, the managers overseeing the execution of projects voiced concern that they suspected their organization was not operating optimally. In some cases they stated their processes were being mandated by people higher in the organization, which again raises the question of why such a situation would exist and persist? If the best practices are widely known and well communicated within the engineering management community as was suggested by others, situations such as these described would not be the most common encountered.

X. LEARNINGS AND RECOMMENDATIONS

The owner managers interviewed were unanimous in their opinion that the most satisfactory results were obtained when the projects were executed in-house. There was no concern over the make-up of the individuals on the team, whether they were permanent employees of the owner organization, consultants from the small service providers or representatives of EPC firms sent to help meet resource levels. All managers reported that when the work was done under the owner's roof, there was no concern over team member priority or alignment. This arrangement was never stable once established in any of the companies studied for reasons not understood by the managers responsible for project execution. As noted several times above, decisions were made external to the group that prevented any long term establishment of an in-house execution team. None of the eight owner organizations had used in-house teams since 2011, and all would require considerable restructuring of their current departments to attempt to build the bench strength to return to what had been normal practice fifteen years ago.

Some of the owner organizations had structured their execution team in a matrix fashion when they outsourced their work to an EPC. In these trials, between three and six owner representatives became discipline leads located within the EPC organization in an attempt to control the design and construction of the facilities. In each of the cases looked at, the owner managers reported that this relationship had poor outcomes. The reasons proposed were along the line that the owner turned to the EPC to execute the project because the owner lacked the skills and resources to do the work themselves. The EPC is an organization that has developed processes to effectively execute projects in the manner stipulated under contractual agreements. To then send in the owner managers with little experience in this type of work to oversee the processes added very little and caused a wide variety of complications and confusion. It was unanimously supported by the owner and EPC managers that this technique is not desired. If the work is being done at the headquarters of a third party, it is best to let them proceed with the execution in the fashion they have developed for their organization. Even with this being stated here, it is again surprising that the owner organizations would return to this mode every few projects and relearn the lessons they should know. This paper may help direct some readers to avoid having to learn this through direct experience.

As noted above, greenfield projects were successfully executed with the engineering and other knowledge workers mostly operating out of EPC offices hundreds of kilometers from the location of the finished facility. In some of the cases, the unfamiliarity of the team with the local conditions and regulations led to considerable overdesign and higher cost than the owner expected from experience. When modifications were being done to existing facilities, attempts to have the bulk of the knowledge work done remotely were largely not successful and teams were moved to site mid-project in the cases where this was tried. Once a manager sees hourly rates averaging $160 or more for these remote teams, however, there is considerable pressure to move the people back to regions where costs are more competitive.

In some instances, the work was split between two or more large EPC firms being in charge of separate portions of the final facility. The owner managers reported that in these instances problems in areas of unclear responsibility were difficult to delegate to anyone accepting accountability for handling. Each of the parties tended to deflect the blame claiming it to be the others' responsibility. It was recommended that unless clear boundaries were definable, the work should be clearly given to one party to execute. In one case, the work was split so that two EPC firms were given responsibility for constructing one half of a plant. A few years into the operation, the owner organization decided to sole source their engineering support. The senior executives that drove this change were given assurances that the transition would be smooth and critical knowledge would be transferred seamlessly to the EPC that was chosen to continue providing services. It was found, however, that in reality the EPC that was being removed did not show enthusiasm for the new arrangement and minimal support was provided post announcement of the change. Much of the knowledge they took with them had to be relearned from the documents and through design calculations by the replacement EPC at considerable expense to the owner.

Several of the owner organizations reported executing projects that were close to $1 billion in cost, but were composed of many small independent components of similar scope. In one case, the owner's manager considered contracting several EPC's and splitting the design work amongst them to gain on schedule by maximising the number of people utilized. This was reconsidered with the rationale

that much of the design from the first component could be copied "cookie cutter" style to the subsequent components at a considerable savings in effort and cost at the expense of some extended duration. When the cost of the design work was tracked, it was found that the last component designed cost almost the same amount to design as the first, with no evidence of a savings by replicating the similar elements. Most of the managers at the owner organizations voiced this concern over the expectation of savings for similar projects and that this never seemed to be realized. The amount of effort required by the EPC appeared to be only dependent upon a proportion of the dollar value of the installed plant and it was very common to have back and forth discussions on why the job required as much effort as it did. An increase in the reliance upon following set procedures has been observed in another study [18] and the managers of the owner organizations were critical of the appearance that this was happening on their projects. That is, it appeared that all designs had to follow the same checks and reviews, even when they just completed a design of a very similar nature. The management of the EPC firms defended their practice stating that cutting corners could result in an error that they would be responsible for fixing. This reflects back to the observation that workers within the owner organization have the luxury of taking risks and correcting mistakes (and learning from both successes and failures) but when the work is defined by a contractual relationship, this luxury is lost.

When the owner organizations shifted from doing work in-house to relying on third party support exclusively, all managers voiced how they had the expectation of better continuity of the team and better knowledge management as a result. Because the owner firms did not have a continuous supply of large projects, they would frequently have to reduce staff during the slow periods and then rebuild when the demand increased. Managers from all eight owner firms stated that they started with the expectation of being able to leverage the work when they used a third party since the EPC could put the team players on other clients' work during the slow periods. This made intuitive sense and was an advantage stated for making the change to outsourcing the work. All eight also reported, however, that once the relationship was established the EPCs requested they supply a steady stream of work or the team would be disbanded anyway. The promise of being able to ride the wave of uneven work levels was not realized.

Although a shift had occurred in the increased use of EPC firms to perform the engineering, in the period around 2005 – 2009, the owner organizations had largely maintained the management of the construction phase of the project internally. During that time, the owner managers had stated that they were not satisfied with turning the execution of large projects over in a turnkey fashion, as this appeared to them to cost considerably more and they felt the EPC's were more skilled at the engineering design work and lacked the expertise to effectively construct the projects. Since 2009, 6 of the eight owner organizations have moved to exclusively farming out their new facility construction as turnkey projects designed and constructed by their EPC partners. Managers of three of the owner organizations stated that they had made the decision to not build a competency in construction and to focus on the operation of their facilities once they are running. Again it is somewhat surprising that although these companies have more employees, they appear to be more resource constrained than in their past. During the Delphi round of reviews of this paper, two of the owner organizations that are currently constructing facilities in the $5 billion range stated that they are now not satisfied with the turnkey model and are considering the move back to controlling the construction phase internally. It is not clear, however, that they will be able to easily reverse the changes they have made to get to their current state.

A final observation to be offered is in the area of unintended consequences. When the owner organizations were performing work in-house, they would retain their best workers and lay-off those people they felt were not a good fit with their team. When they moved to third party support from an EPC, they all reported that many of the new team consisted of those people who they had let go. This was a natural consequence as the EPC would recruit people with experience in the owner company's line of business.

XI. CLOSING COMMENTS

This study looked at some of the intricacies in managing large construction projects in remote locations. None of the situations covered were in areas where the work would be executed in a location where there is a ready supply of knowledge workers. It is not clear whether the learnings provided here would apply in those situations or not.

A question that remains unanswered is whether there has been a shift in the way knowledge work is performed now compared to fifteen years ago. It is surprising when one considers that these owner companies generally have more employees now than they did when the study started, but now none feel they have the resources to handle large projects in-house and all such projects are now handed over to third parties to manage. This is even after considering that the managers of the owner organizations have a consensus that they achieved the most satisfactory results when they managed the projects internally. This should prompt some consideration on whether the present methods that seem to be the standard practice at these organizations are indeed the most effective and best use the resources available.

It appears that many of the players involved in this study recognized that the work was being executed sub-optimally. Many were able to describe improvements that could be made if they had the authority to make the changes. One of the factors that appears to contribute greatly to the inability to manage effectively is the high rate of employee turnover. The reversal of this trend is not something within the control of the managers executing these projects. It is clear that there is no longer an expectation within the ranks of employees that

they will be retiring with their current employer. This state is not expected to be reversed and organizations are compensating by increasing their reliance on explicit procedures to replace the drain on tacit knowledge. Even when the best practices are known, it may not be within the power of the manager to align their projects to achieve their desired outcome. It is interesting to note that many of the strategies used in the projects observed were implemented in the belief that the outcomes would be an improvement over previous work. The outcomes demonstrated that the intuitive answer was not always the best choice. It is hoped that some readers of this paper will be able to use it to help in their decision making processes and prevent them from having to learn through first-hand experience.

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