Abstract
The presentation is focused on the development of a total project cost management system for an owner using a case-study of a local DOT agency. The paper outlines a set of processes that were implemented to manage costs from the design stage transitioning to construction and closing out the project. The presentation further discusses several data points tracked from an engineer’s estimate (developed during design phase) that are used to derive a conceptual cost estimate for future projects with similar items. The item costs during the construction phase is validated using quantities summarized on a monthly basis in the form of a ‘Progress Estimate’. The progress estimate costs are utilized to develop the burn-rate used to forecast the project’s health, calculate earned value metrics and pro-actively manage contracts and change orders. Additionally dashboard style reports were developed to display earned value metrics using real-time project information. Our discussion involves challenges faced in areas of cost management concepts, communication, information sharing, and the consistent use of defined processes by sections within departments.

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Introduction:

AACE International defines total cost management (TCM) as follows:

“Total cost management is the effective application of professional and technical expertise to plan and control resources, costs, profitability and risks. Simply stated, it is a systematic approach to the managing cost throughout the life cycle of any enterprise, program, facility, project, product, or service. This is accomplished through the application of cost engineering and cost management principles, proven methodologies and the latest technology in support of the management process.”

There are several publications including Project Management Institute (PMI) that provides guidelines to support an owner/agency in developing a framework to support cost management through the lifecycle of capital improvement projects.

Owner/agency organizations supported by civic tax funds are faced with challenges that include the implementation of defined internal processes, assigning staff resources with required skills and communication protocols that must be seen to be transparent. Total Cost Management for an organization touches almost every aspect of its operations including managing projects/programs (project management), managing internal and external resources (resource management) and costs accounting (finance/fiscal management). In this case study the existing internal process for obtaining additional funding when a contract exceeds its budget is both time consuming and paper intensive. Having the ability to estimate project costs and establish more accurate budgets and Engineer’s estimates greatly enhances successful outcomes for the agency’s program. A cost management system that uses data for bid items from previous similar projects will provide that ability.

Prior to establishing a Cost Management, and eventually a Project Management Information System it is necessary to understand the culture of the organization. The culture defines the degree to which the PMIS will be combined with existing tools and placement of resources with needed skill sets. It is equally important that such initiatives are supported by the highest levels of an organization and backed up with robust training and skills enhancement plans. Dependent on the organization, a project is conceptualized in multiple ways and sometimes takes years to materialize. This article is a discussion and a record of experience in establishing a cost management system for an organization that is engaged in regional public works projects using traditional (design – bid – build) project delivery method.

*Figure 1 | Project Life Cycle for the Organization:*
Organization Challenges:
Owner agencies are mandated to maintain a transparent and auditable accounting of all project costs, including conceptual costs during the planning stage, an engineer’s estimate at the design stage and bid costs during the construction stage. The following is a list of challenges faced during each stage while implementing a cost management system.

Planning Stage
- Planning phase estimates are performed in isolated silos and are conceptual at the best. These estimate or goals are not clearly communicated to the next phase. Usually planning initiatives results in multiple projects generated for design and construction phase.
- Engineering designs are performed by design consultants; who are required to utilize uniform cost category (UCC) values to identify project items. However the lack of enforcement in using the UCC codes leads to inconsistency with bid items for construction phase.
- Inconsistency in using UCC creates during design phase leads to delays in identifying bid items (pay items) with issues during construction phase.

Design Stage
- The design project manager lacks resources to develop project estimates during the design phase and lack the ability to validate a project estimate prior to the advertisement for construction. This is a major budgeting issue for an agency in forecasting a construction budget which is dependent on an engineer’s estimate and has to be finalized prior to the advertisement.

Construction Stage
- The construction supervisor lacks the tools and resources to track and compare prices on ongoing construction costs. The contractor submits the progress payment on a monthly basis along with their schedule update. The internal process to approve a contractor’s progress payment takes more than 30 days and therefore on a mid to small size project at any given time the approved cost data is lagging almost 60 to 90 days from the current date.
- The legacy processes and tools caused delays in reporting real-time project status. This leads to the organization reacting to manage project issues rather than being pro-active to address real concerns.
- Weekly and monthly project status meetings do not provide any useful information and the lack of real-time project data prevents the organization from managing costs efficiently.

Owner’s Perspective:
The goal was to develop or update a cost management system and to bring current business processes up to speed in time for project delivery while being able to utilize current technologies to support cost management through the project life cycle. The intent is to develop an integrated system. The system includes modifying business processes and deploying tool sets to streamline development of project costs from an engineer’s estimate, then tracking project bid costs through the award process and tracking actual costs through the construction phase.
Objectives to develop a cost management system are includes the following:

- Utilization of UCC from the design phase to standardize cost items for tracking managing through construction phase.
- Develop and modify business processes to manage and track project costs and funding sources from planning to construction phase.
- Develop internal resources and training plans to support and educate users with cost management concepts and benefits to overall organization.
- Provide a set of tools for the design project managers to review the engineer’s estimate using a combination of data points collected from past engineers’ estimates, contractor’s bids as well as actual construction costs.
- Provide and develop a system to allow the construction inspector to record pay items through the use of a daily report and the construction supervisor to approve recorded pay items on a monthly basis to develop project estimate.
- Develop reports and dashboards to provide current project status with cost and schedule comparison along with the ability to forecast cost projections.
- A three phase approach was taken to develop cost management system for the client.

**Establishment of UCC:**
The uniform cost category (UCC) existed in the agency in different forms. The three digit item codes were established almost 20 years ago to group project items with construction divisions. The following table provides list of general items grouped by cost category.

**Table 1 | Cost Categories**

<table>
<thead>
<tr>
<th>Cost Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>General Requirements Items</td>
</tr>
<tr>
<td>200</td>
<td>Excavation and Concrete Items</td>
</tr>
<tr>
<td>300</td>
<td>Storm Drain and Utilities Items</td>
</tr>
<tr>
<td>400</td>
<td>Bridge Items</td>
</tr>
<tr>
<td>500</td>
<td>Asphalt Concrete Items</td>
</tr>
</tbody>
</table>
The agency defined higher levels of cost categories. Design consultants on their discretion further identified cost (pay/bid) items as related or needed for the work scope. There was no consistency by design consultants in organizing cost items. The method adopted was different between consultants and between projects designed by the same consultant. The lack of consistency made it almost an impossible to generate an agency wide cost control system using cost categories. We found that the end product was achieved by a mixing of cost codes. The consultants used code numbers from a past project or a number that was available from a numerical sequence. Items numbers used consistently on project by a consultant A would not match with similar scope items designed by consultant B.

The agency internal accounting (fiscal) was managed using a 26 character cost account code associated with each project. The 26 character cost account code was divided into the following categories.

<table>
<thead>
<tr>
<th>Account Code Categories</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Segment 1 (4 character)</td>
<td>Department ID</td>
</tr>
<tr>
<td>Segment 2 (6 character)</td>
<td>Project ID</td>
</tr>
<tr>
<td>Segment 3 (4 character)</td>
<td>Section ID</td>
</tr>
<tr>
<td>Segment 4 (6 character)</td>
<td>Funding Source ID</td>
</tr>
<tr>
<td>Segment 5 (6 character)</td>
<td>Type of Cost ID</td>
</tr>
</tbody>
</table>

**Implemented Solution:**

In order to implement a permanent solution and to achieve the desired goal, our first step was to identify characteristics and requirements for both UCC and account codes. The UCC code is also called bid codes, bid items, and cost items; these terms are used interchangeably in this discussion.

**UCC:** The UCC codes define items with a desired measure of units associated with each item. Such a system is not new and has been adopted by several local and state agencies throughout the nation. The purpose of publishing a UCC is to provide a uniform (consistent) value or a code that can be tracked across multiple projects as well as throughout a project life cycle.
The agency adopted a hybrid version of a UCC structure that keeps the old cost categories as pre-fix and suffix of 3 digits would allow identification of a specific items.

*Figure 3 | UCC Categories*

<table>
<thead>
<tr>
<th>Cost Category</th>
<th>Item Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3</td>
<td>4 5 6</td>
</tr>
</tbody>
</table>

For Example:

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>400 340</td>
<td>Steel HP 10 x 42 Bearing Pile</td>
<td>LF</td>
</tr>
<tr>
<td>200 010</td>
<td>Class 1 Excavation</td>
<td>CY</td>
</tr>
<tr>
<td>300 090</td>
<td>Flowable Backfill for Utility Cuts</td>
<td>CY</td>
</tr>
</tbody>
</table>

The UCC process resulted in a list of 3,600 standard items used by the agency in the past 20 years. This list consisted of line items, its description and units of measure. Design consultants were asked to utilize similar lists in preparation of an engineer’s estimate; which is a requirement of design submissions. The agency followed up with several training sessions for design consultants as well as in-house design project managers (agency staff) to educate and promote the use of UCC codes for future projects.

Initially there were several challenges faced as the change was a daunting task for the agency. However quick adoption by design consultants eased the transition to the use of UCC. During initial roll-out there were several items that needed to be modified and added to the list to accommodate items missed during the prior internal review. Design consultants used ‘other’ as a type of cost category quite frequently. As a result, several iterations were required to revise and fine tune the engineer’s estimate classified by UCC. As mentioned earlier the Engineer’s estimate is now a requirement for Project Scope and Estimate (PS&E) deliverable. It required consistent efforts from the agency project managers to curtail the old practice and drive the use of the correct UCC to support cost management throughout the project life cycle.

The benefits of utilizing a UCC includes a readily available standard code for items of work, which can be used to track costs through project development life cycle. It allows an agency to record estimated costs of a project at various design stages, record costs of bids, calculate the spending rate through actual costs as well associated change order costs. Recording these various data points allows an agency to develop certain project specific trends to improve the accuracy of the Engineer’s estimate and budget planning for project delivery. The integrated system stores costs at all data points in a centralized system which is then used in various reports to support the owner agency decision making.

**Account Codes:** It was envisioned that six characters of the UCC code will become part of a 26 character account code. However, due to requirements of the accounting system and processes of the accounting department; it was determined to tag cost items in an integrated system. This allowed flexibility of assigning one or multiple account codes. There was no change proposed to the accounting system or account codes during the implementation. Several reports to support the accounting
department and processes to award contracts and payment estimates were modified so that account codes are included in the integrated system.

**Technology:**
As the UCC and account codes were finalized; the agency invested in a web-based system using an off-the-shelf product. The integrated system is defined as the Project Management Information System (PMIS). The products selected included Oracle-Primavera Contract Management - Release 14.1 (PCM) and Oracle-Primavera P6 - R 8.4 (P6). The proposed systems were integrated using custom development to support certain functionality required by the agency. It reported data collected by these applications using Oracle – BI-Publisher – a default reporting tool. The following infographic displays the integration of the various applications to support cost management.

*Figure 4 | PMIS Components*

The PMIS consisted of off-the-shelf product, however each application was customized and configured specifically to meet the agency’s requirements. One aspect of such configuration change involved renaming some of the native fields in PCM including a module such as Bids and Award for agency’s utilization. The Bids and Award module allowed the agency to record engineer’s estimate linked with accounting codes and UCC code values to establish basis for the contract and subsequently consumption in IDR and progress payment. After the advertisement, the module is used to record contractor’s bid to be compared against each and with engineer’s estimate. The module also allowed to generate or create a contract document between the agency and the selected contractor with contract line items. These contract line items carried the association with UCC code established at the time of preparation of
engineer’s estimate. Such built-in functionality allowed the agency to promote the use of UCC code across departments thorough the life of a project.

Cost Management:
To develop a complete cost management system for an agency, several modules of these applications were used and a few custom solutions were embedded to support the agency practices. The use of these application in development of cost management solution is the focus and not on implementation of PMIS.

Figure 5 | PMIS and Project Phases

In addition to the phasing of the project life cycle, the cost break-down structure for the agency includes three distinct silos.

Operational Costs:
At the time of this implementation, the agency’s finance system would record agency’s direct or indirect costs related to the design or construction projects under the operational budget for the agency. There are several factors that needs consideration prior to including operational costs associated with the project within the project costs accounting. The focus of the agency is to be able to manage project costs and eventually include operational costs distribution with project costs.

Design Costs:
The design costs are estimated by the design project manager at the start of the project. However, due to the nature of the work these estimates are actually an estimate at the best and are often modified due to specific design aspects of the project. The account codes are generated at the time of award of design of a project. The codes are used to track the award costs, associated addendum (change order) and invoices (actuals) costs for the design portion of the project. The design disbursement of payments
includes funding for advertisement and the award phase of the project. This forms the basis of cost tracking for the project.

*Figure 6 | Project Costs*

The design costs continue to accrue through the life of the project. During the award phase design costs are associated with preparation of contract item addendums, response to bidders, organizing pre-bid meetings and participation of construction bid evaluation report. The relative accuracy of an engineer’s estimate is needed to establish the budget for the construction phase.

The challenges faced to track project specific design costs are listed below.

- Design consultants more often combine invoices for multiple design tasks awarded under a single design contracts. To mitigate this issue a unique task identifier was generated at the time of design task award. The consultants were required to submit separate invoices for each task including hours associated with the task. This resulted in accurate accounting of actual design costs associated with the project.
- Design consultants would not submit an invoice if the amount for the invoice is negligible or the amount is included in an invoice for another project. This issue is understandably a concern for both design consultant and the agency; however in order to support accurate project reporting it was mandatory that design consultants submit design invoices on a monthly basis when the invoice amount is greater than $500. In the event an invoice amount is less than $500; consultants were allowed to carry forward the amount in a future invoice for the project.

The future phase of PMIS implementation would include design consultants uploading/emailing the monthly invoice to be captured and stored in the PMIS.

The design costs also includes costs associated with the advertisement of the project, community outreach activities and construction contract award activities. This phase includes all associated costs up to when the construction contract is awarded. The costs incurred by the agency related to
advertisement and award falls under operational costs while costs incurred by the design consultants are included in the design phase. This separation was not desirable due to minimal amount associated with the ad and award process.

The PMIS would provide an interactive tool to a design project manager to generate a report based on UCC code information to verify the accuracy of the engineer’s estimate. This report ties the UCC code value with costs from different phases, different bids, schedule of values and change order costs to derive an estimated cost for any of the selected UCC codes. The deliverable from a design consultant includes engineer’s estimate as part of PS&E package, which is recorded in PMIS along with account codes and UCC values in the Bids and Award module. The record from the engineer’s estimate forms the base for recording bids, schedule of values and change orders for the project and managing costs for construction project.

**Estimate Validation Tool:**
The custom developed report through a window allows users to enter one or multiple UCC codes for an engineer’s estimate validation. The unit costs are derived based on the average unit costs of historical records depending on the quantities entered in the input form. The report identifies all items (including contract items, change order items, and forced account items) that has quantities within a 20% range of quantities entered. This method provides additional check for accuracy in validating the engineer’s estimate and eliminates any fluctuation due to outliers. The following flow chart indicates the reporting process utilized to develop a validation tool for the engineer’s estimate.

*Figure 7 | Projects Flow for Validation Tool*
The analysis utilizes a method which accounts for estimated quantities thus improving accuracy of the estimated costs. Once the unit costs are derived, the estimated costs are simply calculated using multiplication with the quantity entered in the validation tool. The following is an image of a sample report of validation tool.

Figure 8 Validation Report

The general formula to derive unit price is based on standard weighted average of available units and unit costs.

Equation 1 Weighted Mean Average

\[ \text{Weighted Mean Average } (X) = \frac{\sum_{i=1}^{n} W_i X_i}{\sum_{i=1}^{n} W_i} \]

Bid Costs and Evaluation:
The Engineer’s estimate along with account codes and UCC values are recorded in the Bids and Award module in the PMIS. Bids from the contractors are verified for its compliance with the contract requirements and then recorded in to the PMIS alongside of engineer’s estimate for each contract line items. The PMIS allows cost comparison between bids within the project. However additional reporting functionality allows the project manager to compare bid items using a UCC code alongside costs from other projects from same contractor or average of costs to date. Such a comparison allows the agency to develop a trend and identify uneven pricing for unit price items.

The following is a report with attributes that were generated to support informed decision making process for contract award.

Figure 9 | Bid Costs Comparison Report
Reports similar to shown earlier supported DOT’s project manager’s to compare cost items across all projects and across all companies using past bids and actual project costs. Such reporting allowed DOT to develop long-term trending for cost analysis not available previously and to identify uneven and unbalanced bids. An unbalanced bid is one containing lump sum or front end loaded bid items which do not reflect reasonable actual costs plus a reasonable proportionate share of the bidder’s anticipated profit, overhead costs, and other indirect costs, which the contractor anticipates for the performance of the items.

There is no prohibition per se against a contractor submitting an unbalanced bid unless the agency has adopted a specific contract requirement precluding heavy percentages of cost on items performed early in the project. Such unbalanced bids may appear to be the lowest ultimate costs to the agency, however it may not be accepted due to uncertainties and reasonable doubt in performance of work and intention of the contractor.

The availability of on-demand reports to provide trend analysis allowed the agency to either reject the unbalanced bid or develop supporting documents for negotiation. Such trending allowed the agency to be better informed in negotiation of change orders, force accounts and review of engineer’s estimate. The data warehouse of cost information tagged with a unique value in terms of UCC codes provides a tool that the agency would leverage for costs related project decisions.

The following is an example of trending report developed for regularly used construction items.

*Figure 10 | Trending of Item Pricing*

![Avg Item Pricing Chart](chart.png)

**Construction Costs:**
The construction costs are derived from the winning bid for the construction of the detailed design in the bid drawings. The agency has an internal process to advertise, collect bids, bid review and notice of award for each construction project. The PMIS plays a vital role in the agency’s effort to manage and control costs providing real-time costs information linked with schedule activities. The challenge for the agency is to have the ability to reconcile installed costs with budgeted costs in real-time, usually
installed costs are not available. The agency relies on approved progress estimates along with approved schedule updates to track and monitor progress; thus the agency relies heavily on the contractor to provide information for estimate and schedule updates.

**Installed Costs:**
Collecting and reporting installed costs on real-time basis is the real challenge for the agency. The solution using PMIS relied heavily on inspector’s daily report (IDR) data to develop real-time costs information. Pay items of the awarded contract are made available in the IDR module for field inspectors; that allowed inspectors to record daily installed quantities on a daily basis.

The quantities recorded by inspectors are summarized in the report and combined with the unit price from the budgeted contract to provide real-time installed costs. UCC code values of each line item was configured to be a primary key linking budgeted cost items with installed items. The IDR module would allow a record using quantities that are in budgeted contracts and approved change orders. The total available quantities for installation is current using this method.

**CPM Schedule:**
The agency specification required the contractor to submit cost loaded schedule and monthly status updates to support progress estimates. However, due to the complexity involved in reporting directly from the contractor developed P6 schedule, the agency maintains an in-house milestone construction schedule cost loaded using UCC code. These schedules are utilized to manage the agency program and projects in Primavera P6. The following attributes are used to maintain current information in the program schedule.

- Resources in P6 are coded using the UCC value to enable use across projects. The $1/hr unit costs is configured for each resource (represented by UCC code) allowed the agency to use either resource units or costs for reporting and comparison purpose.
- Data sharing between PCM and P6 is used to transfer the costs data between applications. This allowed reconciliation of budgeted costs and actual costs between the two applications. This functionality subsequently allows us to generate earned value metrics for all levels of project participants including field engineers, resident engineers and the agency management.
- CPM schedules were imported in a separate P6 database for review and analysis of monthly updates submitted by the contractor. An approved monthly schedule is a requirement to process the progress payment.
- The baseline of approved program schedule is created using contractor’s approved cost loaded ICPM to develop and manage cash-flow for the agency.
Actual Costs:
Since the CPM schedules are developed by contractor, it is difficult to incorporate actual costs from contractor’s schedule in to the PMIS managed by the agency.

Figure 11 | Costs Reconciliation

However, this issue was resolved leveraging PCM using the following process steps.

- Contract pay items (budgeted contracts and approved change orders) are available in IDR module in which field inspector records daily installed quantities. These installed quantities and pay items are linked using UCC codes across the PMIS.
- The actual recorded daily pay quantities are signed and accepted by the contractor at minimum on weekly basis using internal work-flow.
- The accepted quantities are then used to process and approve a monthly progress estimate that is in-line with accepted monthly schedule update.

The reports using the installed quantities and costs are usually the latest and therefore provides near real-time update on the project progress. Such reporting allowed the agency to report on installed quantities within 7 days of installation as IDR’s are required to be approved by the contractor. The data sharing between PCM and program schedule in P6 resolves the issue of the inability to connect the contractor developed P6 schedule with the agency maintained program schedule.
The following is a sample of report that collected schedule data from P6 to display time percent complete and installed costs from PCM to display installed costs.

*Figure 12* | Project Status Report

<table>
<thead>
<tr>
<th>Project Name:</th>
<th>Reconstruction of Footways</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contract No(s):</td>
<td>ABC 1234</td>
</tr>
<tr>
<td>Contractor: Field Office:</td>
<td>Local Construction Company Inc Address Line 1, City, State, ZIP [1234567890]</td>
</tr>
<tr>
<td>NTP:</td>
<td>06/29/15</td>
</tr>
<tr>
<td>Org. Duration:</td>
<td>366</td>
</tr>
<tr>
<td>Time Extension:</td>
<td>30</td>
</tr>
<tr>
<td>Revised Duration:</td>
<td>396</td>
</tr>
<tr>
<td>Duration to Date:</td>
<td>257</td>
</tr>
<tr>
<td>Duration % Complete:</td>
<td>64.90%</td>
</tr>
<tr>
<td>Remaining Duration:</td>
<td>139</td>
</tr>
<tr>
<td>OCD:</td>
<td>06/29/16</td>
</tr>
<tr>
<td>Org. Contract Amount:</td>
<td>$ 1,182,515.30</td>
</tr>
<tr>
<td>Approved EW Amount:</td>
<td>$ 30,470.00</td>
</tr>
<tr>
<td>Revised Contract Amount:</td>
<td>$ 1,212,985.30</td>
</tr>
<tr>
<td>Estimate To Date:</td>
<td>$736,146.27</td>
</tr>
<tr>
<td>Installed To Date:</td>
<td>$756,146.27</td>
</tr>
<tr>
<td>Cost % Complete:</td>
<td>60.69%</td>
</tr>
<tr>
<td>Remaining Balance:</td>
<td>$ 476,839.03</td>
</tr>
<tr>
<td>RCD:</td>
<td>07/29/16</td>
</tr>
</tbody>
</table>

Additional reports provides a tool for field inspectors and resident engineers that would provide on-demand comparison of project items to display contracted quantities and installed quantities to-date.
Earned Value Metrics:

An Earned value management system is project management and control system that integrates work scope, schedule and resources to enable objective comparison of the earned value to the actual cost and the planned schedule of the project.

In a single integrated system EVM is able to forecast performance issues early to effect timely decision making. At the agency the purpose of developing earned value metrics was to support the reporting of standard key performance indicators (KPIs) for the program. The metrics would forecast project performance and be used as a tool that allows the agency to monitor and accumulate Earned Value on a weekly or monthly basis. EV is used as a KPI in this case not an indicator to the project status.

The metrics include a combination of schedule and cost indicators. Schedule indicators include schedule delays, time used in comparison with original duration and duration with change orders. Schedule Variance calculated as the difference between planned and earned value (PV-EV) was used in conjunction with the project’s CPM schedule to measure on time completion. This is because the Critical Path ultimately determines the project’s duration, and big dollar activities that are not critical have the propensity to hide the impact of poor performing small budget critical activities.

Cost indicators included cost variances, percent of costs completed in comparison with original costs and costs with change orders. Composite indexes included baseline execution index and various ratios of cost and time to derive performance indexes.
Dashboards:
Standard P6 EPPM dashboards were also used to communicate project status information to the agency’s management. Dashboards in P6 EPPM were customized to meet the agency’s needs by using the specific thresholds for performance indexes. The use of dashboards eliminated the need of printing ad-hoc reports, and provided the management a unified source of real-time information on project status.

Figure 14 | Schedule Performance Dashboard in P6 EPPM

![Schedule Performance Dashboard](image1)

Figure 15 | Earned Value Performance Dashboard in P6 EPPM

![Earned Value Performance Dashboard](image2)
Conclusion:
The development of any cost management system needs to be customized to meet the client’s requirement. In our case study, the cost management system was designed and developed using a combination of applications and customized reports to support the agency. Some of the lessons learned from development of a cost management system that provides a holistic approach for an agency using the traditional project delivery model to execute construction projects follows:

- The proposed system requires a disciplined approach in data entry, data validation especially during the design and construction phases to maintain checks and balances of the system.
- Several challenges including a lack of documentation on institutional knowledge and the clarity of responsibility by project stake holders can provide non-technical problems.
- The communication system needs to be focused on project delivery. Historically it was dependent on using email clients, and disconnected from any project referencing.
- The proposed system must be scalable so it can be further developed based on required complexity and analytical requirements for the client.
- Due to lack of skilled internal resources and contractual arrangements, the agency faced a challenging task to maintain the system. A single consultant was not engaged and resulted in a lack of consistency in development.
- The owner agencies are uncertain about required roles to manage a cost management system and struggle to utilize the skill sets of inter-departmental resources.
- Project participants lack the ability to see the big picture and establish long term goals for the continuous development of a cost management system.

The following is a list of benefits achieved by the agency during the process.

- The process allowed to standardized cost items under UCC across the department in each phase of the project.
- Improved the quality of engineer’s estimate to support to increase accuracy in the budget for the construction projects.
- The implementation of PMIS allowed to record actual costs during construction phase to develop earned value metrics.

The process with focus on total cost management is important because for publically funded agency additional funding for the change order takes long time; however having an accurate budget due to improved engineer’s estimate reduces the need for the change order.
References:


iii Earned Value Project Management – Quentin W. Fleming and Joel M. Koppelman – 2006


