TCMA-3459

The Unit Price Process for Estimate Data Development and Benchmarking (Case Study)

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Abstract–Practical project cost estimate preparation depends upon having reliable, competitive reference data. The data is used both for inputs to the estimate (i.e., the resources and their costs) and to develop metrics (usually ratios or factors that reflect cost estimating relationships or CERs) for quantitative validation (a quality assurance process) of the estimate outputs. Historical data collection, analysis, and use in project and project system benchmarking have been shown to correlate with better project outcomes. To achieve a reliable and useful data process, one must apply reliable methodologies to facilitate proper data collection and management.

This paper addresses two topics. First, it addresses estimating database development, including a process for data collection using a standard breakdown structure at an appropriate level of detail for use in benchmarking metrics development. Specifically, it outlines the use of the International Construction Measurement Standard (ICMS). [1] although other structures can be used. The database aspect also addresses an effective methodology for data collection and maintenance, including data conditioning and normalization and capturing other project attributes, including key quantities. This process can and should be used for both cost estimates and actual project data. Second, the paper defines the use of a key metric called “unit price” for estimate development reference and estimate validation. Unit cost data, i.e., ratios of cost to key quantities, is perhaps the most common metric used in cost estimates of all classifications. There are many metrics that can be used, but unit prices are often of most interest to estimators and readily understood. Particularly for contracts based on unit pricing for which the client has no insight into hours or cost breakdowns within the units. A more robust set of metrics and rounded estimate validation process is covered in a draft AACE RP currently in review.

This year’s paper is one in a series of papers that will expand on benchmarking. The paper TCMA-3502, Benchmarking for Competitive Advantage, written by the same authors, provides a framework for introducing further topics. [1]

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Introduction and Background

Disclaimer

This paper was written and developed to provide a conceptual framework for organizations that want to develop and implement a benchmarking initiative. Therefore, the information contained in this paper is to be used for general educational purposes and not as a specific model for application in any specific application. All figures, charts, and other information are examples to illustrate concepts. Similarly, the paper's discussion of statistics and math are to illustrate concepts. Other references should be studied before any practical application, including for statistical and mathematical methods for analyzing benchmarking data[1].

What is Benchmarking and Why

AACE defines benchmarking as - *A measurement and analysis process that compares practices, processes, and relevant measures to those of a selected basis of comparison (i.e., the benchmark) to improve performance*. The comparison basis includes internal or external competitive or best practices, processes, or measures. Examples of measures include estimated costs, actual costs, schedule durations, resource quantities, etc. [2]

Global construction spending is projected to reach $11.2 trillion in 2019. [3]. Benchmarking, as a way of measuring project system performance and causes of poor performance, can play a big part in getting more out of these huge investments. Since benchmarking relies on project data and metrics, the importance of having an effective database, estimate coding structure, and database management process is essential.

This paper addresses two topics. First, it addresses estimating database development, including a process for data collection using a standard breakdown structure at an appropriate level of detail for use in metrics development. Specifically, it outlines the use of the International Construction Measurement Standard (ICMS). [1] although other structures can be used. The database aspect also addresses an effective methodology for data collection and maintenance, including data conditioning and normalization and capturing other project attributes, including key quantities. This process can and should be used for both cost estimates and actual project data.

Second, the paper defines the use of a key metric called "unit price" for estimate development reference and estimate validation. Unit cost data, i.e., ratios of cost to key quantities, is perhaps the most common metric used in cost estimates of all classifications. There are many metrics that can be used, but unit prices are often of most interest to estimators and readily understood. Particularly for contracts based on unit pricing for which the client has no insight into hours or cost breakdowns within the units. A more robust set of metrics and rounded estimate validation process is covered in a draft AACE RP currently in review.

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This paper refers to its focus on unit prices as the "unit price process (UPP)." This is a composite unit price, which includes material, labor, equipment, subcontract as separate cost elements, including labor hours and construction equipment hours. The cost elements can then be aggregated together to form one composite unit price. UPP uses metrics in general for which a resource (cost or hours) is the numerator and quantity is the denominator, including metrics such as "unit hours" (e.g., $ per LF, hours per LF, € per M, etc.). In all cases, the concept of key quantities is central to the UPP process. The key quantity will reflect a significant, clearly defined scope element [e.g., quantity of ductile iron pipe, 8" Dia (200mm)]. Costs can be for any item or element or combination thereof of the breakdown (e.g., direct cost or direct cost + indirect costs, etc.).

The paper focuses on an international standard coding structure, the International Construction Measurement Standard 2.0 (ICMS) [1]; however, similar structures could serve the purpose of UPP as well as long as they follow principles such as having a hierarchical discipline breakdown. Other industry coding structures will be discussed, such as Masterformat, Uniformat, and Omniclass. These have a longer history than ICMS, and are used in many estimating reference sources; however, the paper will discuss why they may be less than ideal for benchmarking.

The focus of this paper is to discuss benchmarking from an engineering and construction and capital project improvement perspective, rather than from a business or organizational improvement standpoint. The goal is to improve the projects with respect to goals or targets for unit prices (e.g., a bidding strategy), not to identify the causes of variations from expectations.

As a final note, this paper addresses day-to-day benchmarking of typical projects of similar scope, complexity, technologies, and usually similar locations. This does not include benchmarking projects of a unique or unusual nature; that is a topic for analytics using data to understand how the unique attributes drive metrics, not to make simple comparisons.

Benchmarking Functional Feedback

The goal of benchmarking is performance improvement. For projects, this means providing continuous quality feedback of (hopefully improving) historical project metrics, which can be designed for and used as benchmarks for the current estimate or project. Figure 1 shows a graphical representation of this data feedback loop and how uses vary throughout the life-cycle of the project:

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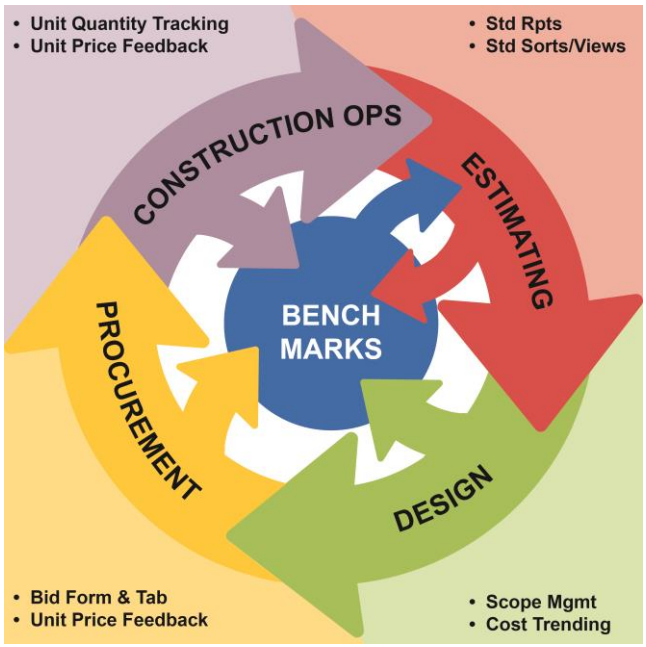

Figure 1–Benchmarking Feedback Loop Over the Project Life Cycle

The following explains how the feedback loops apply to the departmental or functional areas of a company shown in Figure 1:

1. Estimating –
    a. Inputs - Use the scope of work to develop the cost estimate using a standard estimating coding structure. [1]
    b. Outputs – Stanard reports, views, and sorts of the cost estimate.
2. Engineering and Design –
    a. Inputs – Cost estimate is used for scope management, cost trending, and value engineering.
    b. Outputs – Cost estimate is used for tracking of key quantities, cost trending, and value engineering analysis.
3. Procurement –
    a. Inputs – The cost estimate is used for bid form development and bid comparison.
    b. Outputs – Bit tab shows a comparison of bidders to the final cost estimate. If a unit price contract, bid comparisons of unit prices to the final cost estimate unit prices.
4. Construction Operations –
    a. Inputs – The schedule of values show the award contract costs. Key quantity tracking is performed at this phase. This would also include hours and quantities. Trend analysis is performed.
    b. Outputs – Final Schedule of Values. Final key quantities and hours. Final trend analysis report.

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As the estimate moves throughout the design phase or phase-gate process, the cost estimator assists the design team with scope tracking, cost trending, and value engineering. During procurement, the cost estimator assists the procurement team in developing the bid form and final bid quantities. Once the construction project received the project bids, the cost estimator then helps the construction team with the evaluation of the schedule of values and checking for excessive front-end loading by the contractor. The estimator does not have to be the sole expert in applying metrics; other specialists may use them as well (e.g., a value specialist, controls lead, etc.).

The Benchmarking Taxonomy

The benchmarking taxonomy is a classification hierarchy used to guide benchmarking planning by segmenting and prioritizing actions (e.g., define objectives) and data (e.g., metric types). This taxonomy is a form of strategic deployment that starts with the organization establishing mandates, and introducing applications and data that can be deployed in various elements of the organization as appropriate. [1] Figure 2 represents the taxonomy for planning and implementing project benchmarking using project data and commonly applied industry structures.

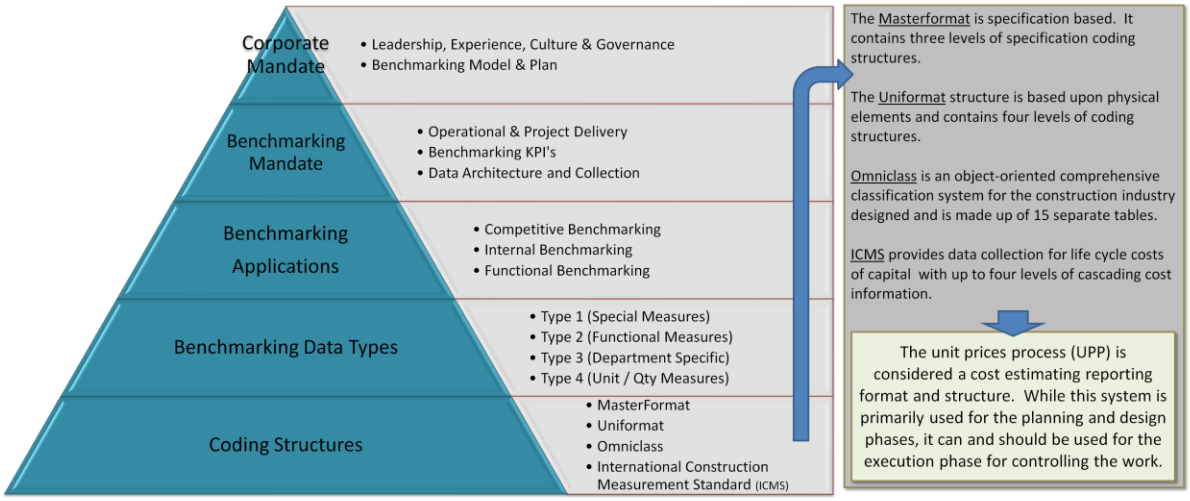

Figure 2–Benchmarking Taxonomy

As illustrated in the diagram above, the process moves from objectives through the organization into a benchmarking mandate, including data architecture, collection strategy, and defining specific key performance indicators (KPIs). The identification of KPIs provides an understanding of the type of benchmarking applications. Then allows the organization to determine what information is required. For example, if the organization decides only to complete an internal benchmarking assessment, then there may not be a need to condition the data for multiple coding formats. These decisions assist the organization in determining what and how information will be acquired and utilized. Further understanding of the elements of the taxonomy tree will be provided throughout this paper.

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Data Collection, Review and Validation Process

A prerequisite of benchmarking is having a database. Developing a database includes the collection of project information, the review and verification of data, the cleaning, conditioning and normalization of project data, defining data products and information (attributes, key performance indicators (KPI), metrics, etc.). This requires mapping to a standard data structure. Finally, it requires final quality review and publication of the data, i.e., the use of a defined publishing methodology into the benchmarking application tool (which may be part of the database system).

The verification process must be performed by an experienced person familiar with the project types; the required benchmarking data and metrics, and have the knowledge to spot missing or inconsistent data or coding structures. A benchmarking manager should perform the collection of representative data that will be used for estimate verification. The department manager or executive leadership should endorse the approval to publish the data. Finally, there may be a need for a dedicated benchmarking software administrator who is responsible for the setup and configuration of the project history database system.

Based on these requirements, a project history process map is provided below, shown in Figure 3. The process map is grouped into functional groups (swim-lanes) to illustrate exchange points within the process.

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Project History – Data Collection, Review and Publishing – Process Map

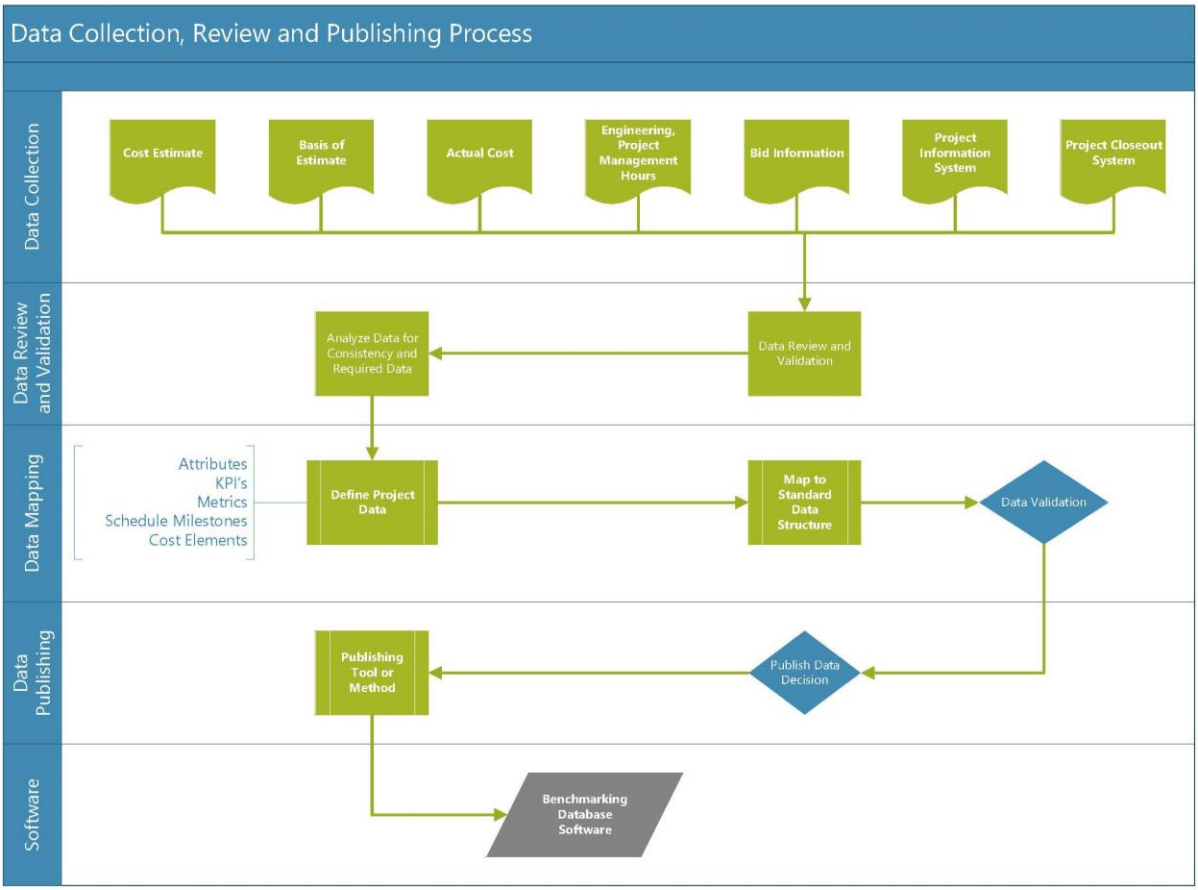

Figure 3–Data Collection, Review and Publishing for Benchmarking – Process Map

Key Benchmarking Terminology & Definitions

In addition to data collection of unit prices, labor and equipment hours, additional estimating data should be collected. The following are typical estimating data that should be collected for projects with terminology defined:

1. Project Attributes – Principal characteristics of a project or sub-project, which relates to aspects of the project. These attributes relate to: time, cost, the scope of work (boilerplate, i.e., 90,000 bbls/day), design, quality, quantity, procurement, location, and other features of the project.
2. Key Performance Indicators (KPI) – Typically, these are ratios of costs or quantities. Examples of these include cost ratios, quantity ratios, discipline ratios, indirect ratios, material ratios, labor ratios, labor/material ratios, engineering/construction ratios, and project management/construction ratios. For unit price process, we have limited ourselves to metrics of KPIs having quantity as the denominator. The other metrics are applied in estimate validation [5]
3. Key Quantities – Key quantities are the total quantities that can be tracked with cost relationships to the total construction or project cost. Examples include total CY or M3 of

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concrete, total LF or LM of buried pipe, total LF, or LM of exposed pipe, total pieces of process equipment.

4. Engineering Hours – Total engineering hours, including owner hours, contractor engineering hours, and design or consultant engineering hours related to a project.
5. Project Management Hours - Total project management hours, including owner hours, contractor project management hours, and design or consultant project management hours related to a project. This should include project controls, accounting, clerical, legal, and administrative costs. This should be sperate from field overhead cost or general conditions.
6. Home Office Expenses, Overheads, Profit, and Fees – The following elements make up the home office and overhead costs:
   a. Home Office Expenses: these are hours and costs associated with the following: corporate executives, business development, training, home office overheads (G&A), other costs, and profit.
   b. Administration Costs: these are hours and costs associated with the following: accounting, QC/QA, risk management, legal, human resources, travel expenses, labor relations, and license fees
7. General Conditions (also known as indirect costs)– The following elements make up general conditions:
   a. Typical Field Staff: Estimating, scheduling, document control, cost control, value engineering, constructability, safety managers, and other consulting staff.
   b. Typical Expenses: trailers/job offices, telephones, cell phones, radios, copiers/fax/office equipment, computers, office supplies, vehicles/fuel/ maintenance, document reproduction, postage & couriers, site signage, drug testing, temporary toilets, water/ice/cups, and dumpsters.
   c. Mobilization & Demobilization – these are considered generally consider part of the general conditions costs.
8. Direct Costs – in addition to the direct construction costs, they are typically regarded as direct costs of the project: project executive, project manager, superintendents, project engineers, startup and commissioning staff, process equipment services, spare parts. Other direct costs and expenses: builders risk insurance, subcontractor bonds, performance bonds, supplier bonds, warranty costs, royalty costs/fees, permitting costs, material layouts, field engineering & equipment, survey & layouts, temporary utilities, interim cleaning, final cleaning, fire protection, and site safety & security.
9. Labor Unit Hours – Total labor hours divided by quantity total. This would be for major items such as concrete elements: slab on grade, walls, elevated slab, etc. This would also include major items, such as buried pipe, exposed pipe, process equipment.
10. Construction Equipment Hours – Total construction equipment hours divided by quantity total. This would be for major items such as concrete elements: slab on grade, walls, elevated slab, etc. This would also include major items, such as buried pipe, exposed pipe, process equipment.
11. Unit Price Metrics – These can be high-level metrics such as $ per SF or $ per m2. These can be average costs, such as concrete $ per CY or $ per m3. For estimate validation, the

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may include ratios such as the average pound of rebar per CY of concrete or many other metrics designed to identify the cause of metric variation.

Benchmarking Data, Data Types, and Levels

Benchmarking Data

The role that an organization plays in the construction or capital project will determine the type of data that is collected. For example, the owner has actual contractual costs and associated corporate (internal) costs. The contractor has bid data which was won by the contractor. The engineer, architect or construction manager may have a combination of actual bid data, historical bid unit prices or historical estimates and estimated unit prices.

The following list defines the benchmarking data requirements typically found in the collection process:

1. Estimate – previous cost estimate, previous project unit prices, previous production rate, previous key quantities.
2. Historical – historical project costs, historical bid unit prices, or other historical references.
3. Actual – contractual or internal costs. Owners have actual contractual rates and internal costs. Contractors have contractual winning bid actual costs.

Benchmarking Data Types

Based on the benchmarking objective or mandate, the data types can be further expanded upon. The following is an example from the UK Government of some basic benchmarking data types [4]:

1. Type 1 Benchmarks (spatial measures) encompass the most common formats used by clients and industry to benchmark total construction costs, for example, $/SF or £/m2. They are related to throughput (quantity) in the sense, for example, of square feet or meters of accommodation delivered by a project.
2. Type 2 Benchmarks (functional measures) encompass a range of more department-specific benchmarks, which address business outcomes per £, for example, £/Place; Flood Damage Avoided £ / Investment £.
3. Type 3 Benchmarks address a range of more department-specific benchmarks but where business outcomes are related only indirectly to the benchmark, for example, ratio of indirect costs (or development cost) to total construction cost.
4. Type 4 Benchmarks are similar to Type 1 benchmarks but applied at an elemental throughput (quantity) level; for example, foundation costs $/CY or £/m3.

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Benchmarking Data Levels

Benchmarking data can be collected at various levels of the capital project or construction costs. There is a balance between the amount of benchmarking data collected and the level of effort to complete the data collection for a project (i.e., a saying in benchmarking is "the more you ask for, the less you will get"). The following are suggestions of typical data collection levels and suggested a number of fields of data one may expect:

1. Highest Level – Total Cost – Per Project Size or Capacity (3-4)
2. Secondary Costs, Hours and Metrics (5-10):
    a. Total Capital Costs
    b. Total Construction Cost
    c. Total Engineering Costs
    d. Total Project Costs
    e. Total General Conditions or Site Overheads
3. Division Level Costs, Hours (35-40)
    a. ICMS, MasterFormat or Uniformat
4. Average Costs, Hours and Metrics (15-20):
    a. Concrete Total
    b. Concrete Elements
    c. Buried Pipe
    d. Exposed Pipe
    e. Process Equipment
    f. Earthwork
    g. Pile Foundation
5. Unit Prices Costs, Hours – calculated from the cost estimate.
    a. Standard Unit Prices – Across all project types – 100-2700 – Note this is depending on the types of projects and how detailed the data collection needs are, and if the process is automated.

Note that "metrics" are not collected or captured or stored; they are ratios of cost or hours and quantities calculated by the estimating database or benchmarking system when they are needed. In that way, one does not have to maintain (i.e., normalize) both cost data and cost ratio metrics.

Coding Structure Systems

Industry Coding Structure Systems - Construction Specification Institute (CSI)

The cost estimate reporting systems are not only required to align cost estimates and reporting, but also the alignment with the project work breakdown structure (WBS), the company standard code of accounts, the project cost control structure and company financial system. These structures can be independent of each other but maybe referenced (cross-mapped) to the other structures. The estimate format structure must accommodate the ability to filter and sort

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information in ways that allow for organizing and viewing this data. The project closeout structure should align with the project cost control structure or financial reporting structure.

There are three common industry standards around design specifications in the US and Canada; all three are from the Construction Specification Institute (CSI):

1. MasterFormat – Specification-based system
2. Uniformat – Physical elements of building projects
3. Omniclass – Object-oriented tables for data exchange

MasterFormat

The MasterFormat is specification-based. It contains three levels of specification coding structures. The coding structure is widely used, including most estimating software packages.

The following table provides an example for concrete – slab on grade:

Concrete - Slab on Grade, 8" (200mm) Thick	
Masterformat Code	**Description**
31-22-16.00	Fine Grading
07-26-16.00	Below-Grade Vapor Retarders
32-11-16.00	Subbase Courses
03-15-13.00	Waterstops
03-11-13.65	Forms In Place, Slab On Grade
03-21-11.00	Plain Steel Reinforcement Bars
03-31-13.00	Heavyweight Structural Concrete
03-05-13.20	Concrete Admixtures And Surface Treatments
03-37-16.00	Pumped Concrete
03-35-00.00	Concrete Finishing
03-39-00.00	Concrete Curing

Figure 4–MasterFormat Example

Uniformat

The Uniformat structures are used for classifying building elements and related site work. These are physical elements or functions of the building regardless of the design, construction specification, construction methodology, or materials used. The Uniformat structure is based upon physical elements and contains four levels of coding structures. The following table is an example of the Uniformat structure:

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UNIFORMAT STRUCTURE					
LEVEL 1		LEVEL 2		LEVEL 3	
A	SUBSTRUCTURE				
		A10	FOUNDATIONS		
				A1010	Standard Foundations
				A1020	Special Foundations
		A20	SUBGRADE ENCLOSURES		
				A2010	Walls for Subgrade Enclosures
		A40	SLABS-ON-GRADE		
				A4010	Standard Slabs-on-Grade
				A4020	Structural Slabs-on-Grade
				A4030	Slab Trenches
				A4040	Pits and Bases
				A4090	Slab-On-Grade Supplementary Components
		A60	WATER AND GAS MITIGATION		
				A6010	Building Subdrainage
				A6020	Off-Gassing Mitigation
		A90	SUBSTRUCTURE RELATED ACTIVITIES		
				A9010	Substructure Excavation
				A9020	Construction Dewatering
				A9030	Excavation Support
				A9040	Soil Treatment
B	SHELL				
		B10	SUPERSTRUCTURE		
				B1010	Floor Construction
				B1020	Roof Construction
				B1080	Stairs
		B20	EXTERIOR VERTICAL ENCLOSURES		
				B2010	Exterior Walls
				B2020	Exterior Windows
				B2050	Exterior Doors and Grilles
				B2070	Exterior Louvers and Vents
				B2080	Exterior Wall Appurtenances
				B2090	Exterior Wall Specialties
		B30	EXTERIOR HORIZONTAL ENCLOSURES		
				B3010	Roofing
				B3020	Roof Appurtenances
				B3040	Traffic Bearing Horizontal Enclosures
				B3060	Horizontal Openings
				B3080	Overhead Exterior Enclosures

Table 1–Uniformat Example

Omniclass

Omniclass is an object-oriented comprehensive classification system for the construction industry designed for data exchange of building information models (BIM). Omniclass is made up of 15 separate tables, which outline the construction entities, form, function, spaces, elements, phases, work results, services, materials, products, disciplines, and organizational roles. While the MasterFormat structure is specification-based, the Uniformat is physically based, and the Omniclass is data-driven. The following table demonstrates the omniclass structure.

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OMNICLASS DATA STRUCTURE			
Table Number	**Table Name**	**Data Definition**	**Data Example**
11	Construction Entity by Function	Significant, definable unit of the built environment comprised of elements and interrelated spaces and characterized by function.	Department Store, Courthouse, Hotel
12	Construction Entity by Form	Significant, definable unit of the built environment comprised of elements and interrelated spaces and characterized by form.	High-Rise Building, Suspension Bridge
13	Spaces by Fuction	Are basic units of the built environment delineated by physical or abstract boundaries and characterized by function.	Kitchen, Mechanical Shaft, Office, Highway
14	Spaces by Form	Are basic units of the built environment delineated by physical or abstract boundaries and characterized by physical form.	Room, Alcove, Courtyard
21	Elements	A major component, assembly or function of the construction entity.	Structural Foors, Exterior Walls, Stairs, Roof, Stom Sewer Utility
22	Work Results	Are construction results achieve in the production stage or phase or by subsequent alteration, maintenance or demolition process and identified by one or more of the following: the particular skill or trade involved, the construction resources used; the part of the construction entity which results; the temporary work or other preparatory or completion of the work which is the result.	Cast-in-Place Concrete, Structural Steel Framing, Ceramic Tiliting, Interior Lighting
23	Products	Are components or asseblies of components for permanent incorporation into construction entities.	Door, Metal Window, Curtain Walls
31	Phases	Stages: Conception, Project Delivery Selection, Design, Construction Documents, Procurement, Execution, Utilization, and Closure. Phase: A portion of work that arises from sequencing work in accordance with a predetermined portion of a stage.	Conception Stage, Schedmatic Design Phase, Bidding Phase, Construction Phase, Occupancy Phase, Decommissioning Phase
32	Services	Are the activities, processes and procedures relating to the construction, design, maintenance, renovation, demolition, commissioning, decommissioning, and all other functions occurring in relation to the life cycle of a construction entity.	Designing, Bidding, Estimating, Constructing, Surveying, Maintaining, Inspecting.
33	Disciplines	Are the practice areas and specialties of the actors (participants) that carry out the processes and procedures that occur during the life cycle of a construction entity.	Architecture, Mechanical Engineering, General Contracting, Electrical Subcontracting, Legal, Finance
34	Organizational Roles	Are the functional positions occupied by the participants, both individuals and groups, that carry out the processes and procedures which occur during the life cycle of a construction entity.	Owner, Architect, Cost Estimator, Contractor, Facility Manager
35	Tools	Are the resources used to develop the design and construction of a project that do not become a permanent part of the facility, including computer systems, vehicles, scaffolding and all other items needed to execute the processes and procedures relating to the life cycle of a construction entity.	Computer Hardware, CAD Software, Temporary Fencing, Tower Crane, Formwork, Hammer
36	Information	Is data reference and utilized during the process of creating and sustaining the built environment.	CAD Files, Specifications, Construction Contracts, Regulations
41	Materials	Are substances used in construction or to manufacture products and other items used in construction. These substances may be raw materials or refined compounds, and are considered subjects of this table irrespective of form.	Rocks, Timber, Glass, Plastics, Rubbers
49	Properties	Are characteristics and property definitions of construction entities.	Color, Width, Length, Thickness, Depth, Area, Weight, Strength

Table 2–OmniClass Structure

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Issues with CSI Coding Structures

The problems with the procurement-focus industry coding structures such as MasterFormat for UPP are viewing these costs by all of the activities which make up a completely installed unit price since the coding structure crosses multiple divisions of work. There are typically multiple activities that make up a single unit price. Some of these activities span different divisions of work, across multiple master format items. The solution for overcoming this coding problem is to create a unique coding structure for tracking the unit prices, and data dictionaries for what is included in each code. This is similar to recommended practice 73R-13 Establishing Labor Productivity Norms [6] in which the user must make decisions about what is included in their specific unit price codes. Are fittings included with buried pipe or exposed pipe, but the valves are separated unit price codes? For buried pipe, include trench dewatering and trench box support costs, but costs for wellpoint dewatering and trench sheeting are shoring separate unit price codes than for the standard buried pipe codes? On the other hand, the Uniformat was designed to combine costs for various building elements, which can be used for gross unit prices such as cost/M2 for a concrete slab, but its use is constrained to building projects.

AACE International Coding Structures for Process Plants and Mining

AACE provides two Recommended Practices that define coding structures for process plants (RP 21R-98) [7] and mining (RP 103R-19) [8]. The CSI codes above are primarily used for building and civil projects. Process plant and mining industry owners and contractors evolved code structures over many decades that, while not formal standards, are reasonably uniform at higher levels (e.g., all codes have a piping account). Many owner firms in these industries are actively involved in benchmarking and sharing of metrics such as unit prices between companies (e.g., working with IPA, Inc.). The coding is sufficiently consistent for industry data to be generated for unit prices at a discipline level (e.g., $/M3 of concrete). DACE, the Dutch Association of Cost Engineers, publishes both a Labour Norms and Price Booklet for the process industry that shares the typical piping-centric process structure. [9] Until ICMS develops detail codes for these industries, these codes are likely to remain the prevailing norm, and can be used effectively.

International Construction Measurement Standard (ICMS)

The ICMS structure provides global consistency and a recognized framework for classifying, defining, measuring, recording, analyzing, presenting, and comparing entire life cycle costs of capital projects. ICMS is a high-level cost classification system (unlike MasterFormat), with up to four levels of hierarchical cost information. Currently, the ICMS provides standard sets of attributes for 14 project types shown in Table 3, with more planned in the future. The ICMS system can easily be configured for specific industry project types if already defined in the standard. The following shows the four levels of the ICMS:

1. Level 1 – Project or Sub-Project (re: the 14 types in Table 3)
2. Level 2 – Cost Categories (Life-Cycle)
3. Level 3 – Cost Groups (elemental breakdown)
4. Level 4 – Sub-Cost Group (more detailed breakdown of Groups) (Optional)

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01.	Buildings	08.	Pipelines
02.	Roads, runways and motorways	09.	Wells and boreholes
03.	Railways	10.	Power-generating plants
04.	Bridges	11.	Chemical plants
05.	Tunnels	12.	Refineries
06.	Waste water treatment works	13.	Dams and reservoirs
07.	Water treatment works	14.	Mines and quarries

Table 3–ICMS Sub-Project Types

There is one common coding structure of building type projects and another structure for civil related projects for Cost Categories Level 2 and Cost Groups Level 3.

Figure 6 outlines the relationship from the project or sub-project level to the cost group level (note: acquisition is capital investment as applies to this paper):

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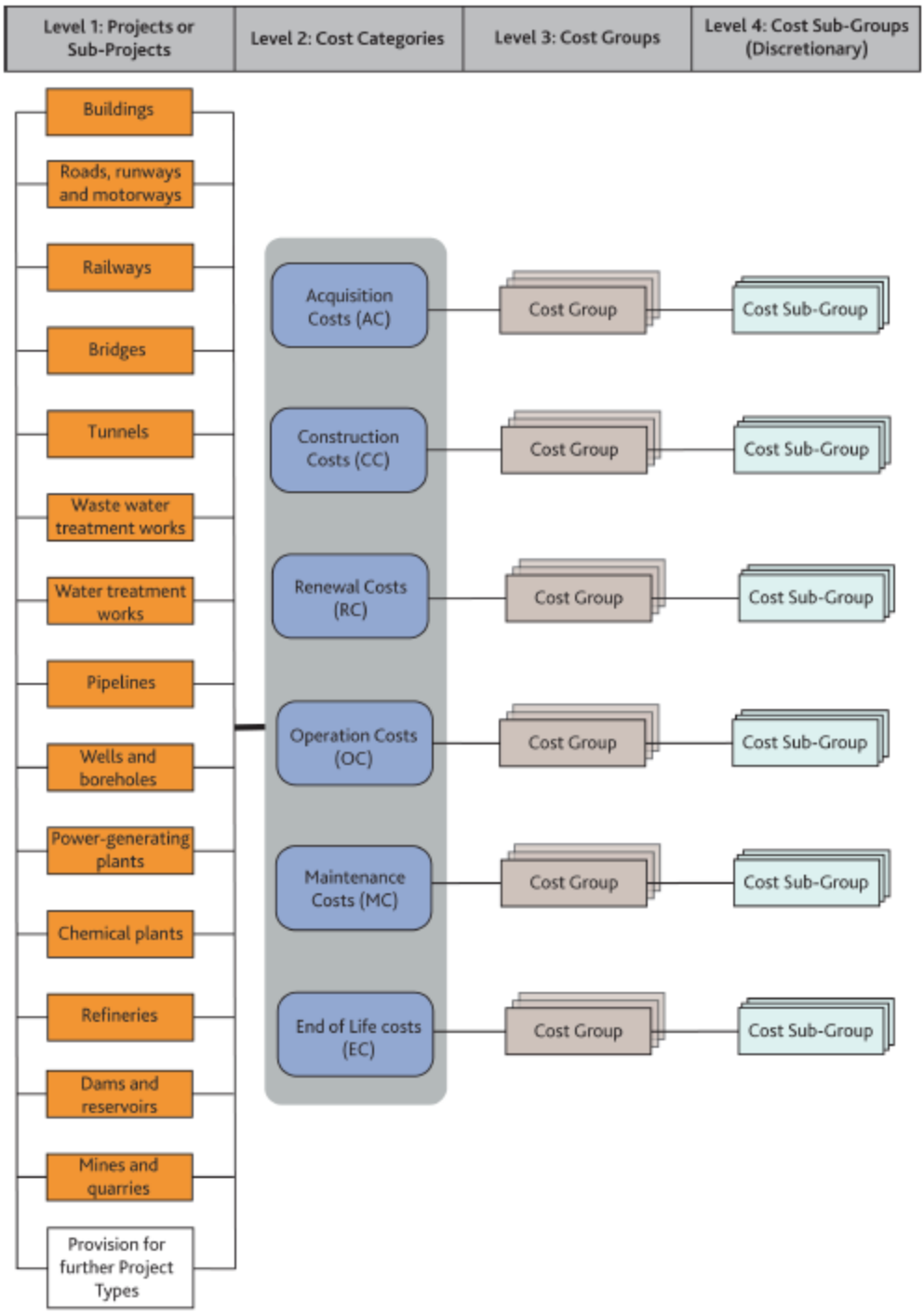

Figure 6–ICMS Levels

ICMS Code Structure

Benchmarking requires a code of account to be used that is reliably consistent for the purpose at hand. For example, in the process industry, companies have been benchmarking at the asset ($/barrel per day) and discipline level (e.g., $ per tonne of steel) for decades. However, the ICMS is closest to providing an ideal standard. However, it does not yet cover all industries in detail,

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such as the chemical process. The ICMS structure can be used for cost comparisons at a level, while keeping the company's native project coding structure in place. Company cost data can be mapped in two ways:

1. Native Estimating Coding Structure
2. ICMS Coding Structure – Level 3 or Level 4

It should be noted that ICMS Level 4 is an optional coding structure. Level 4 could be combined with the organization's native project coding structure. Cross coding the native project coding structure to the ICMS Level 4 provides meaningful data for comparison and analysis. Cross mapping to other coding structures may be useful, but consideration to the level of effort is required. Adjustments for time (escalation), project location, units of measure (metric to imperial), project complexity, and scope need to be determined to allow for a proper comparison.

When using the ICMS system, one area which is not clear in the standard is the allocation of supportive costs, in which a primary project type is dis-aggerated into sub-projects. For example, a hospital project (primary) may include a chilled water building (sub-project), steam building (sub-project), and emergency power building (sub-project) along with associated items such as access roadway, site lighting, parking lot and stormwater pond. Organizations must determine how the allocation of these supportive costs are applied to the sub-projects.

Estimate Coding Structure Recommendations

In the author's experience, a four-level coding structure provides an effective coding structure for data collection of estimating data. In the process world, the four levels may be summarized as area or process, unit, system, discipline. In ICMS, this is a project, cost category, cost group, and cost sub-group. As stated earlier, the structure to be used should be the same coding structure, regardless of the types of projects. This allows for comparison across different project types. Each company may have other required coding structures for WBS [7], CBS, finance, and other requirements. Once a coding structure is extended beyond four levels, it becomes challenging to mandate and apply by all parties (and may create resistance) and adds little value from a performance improvement perspective. With this said, one of the author's organizations successfully implemented a unit price process that has four levels. It is recommended that companies define and mandate their coding structure and enforce the use of this coding structure across the enterprise level, at least for significant capital projects.

Unit Price Process – Coding Structure

For this paper, the unit price process (UPP) is considered a cost estimating reporting format and structure. While this system is primarily used for the planning and design phases (e.g., estimate benchmarking, bid development, etc.), it can be used for other purposes.

At the author's organization, information is processed to five levels, as shown in Table 4 using the CSI MasterFormat (MF), while four code levels are used for historical project cost tracking.

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The 4th level, which is called work activity, informs project personnel of the scope of work, complexity, location, and quantities. The work activity also assists in explaining all of the estimate line items under this code, which is not used for historical data collection. Table 4 shows the company's UPP code structure, purpose, and the use in benchmarking:

Level	Level Code Name	Structure	Suggested Length	Benchmarking Types	Use In Benchmarking	Example
1	Project Type or Facility Name	Company Standard Project Types, Names or Facility Names	3-5 Digits	Project Metric	Comparison of Similar Project Types or Facilities	$ per SF or $ MGD
2	Work Package	CSI Masterformat - Level 1	2 Digits	Ratios (Cost to Cost)	Percentage of Total Costs (Division) and Ratios	Percentage or Overall $ per CY
3	Trade Package	Associated to CSI MF Level 2, but Customized for Company Use	5 Digits	Average Unit Price	Provides Rollup Averages for Various Critical Elements or Cost	Average $ per CY: Slabs, Walls, Elevated Slab or Exposed Pipe $ per LF: Steel Pipe, Ductile Iron Pipe, PVC Pipe.
4	Work Activity	Structured off of Work Pack, Trade Package with 4 Significant Digits	10 Digits		User Defined Field, which describes the group of estimating line items, provides scope, details, elevations or key assumptions and quantities.	31.15.0005 Overall Site Erosion Protection - 25 AC - 24 Months
5	Unit Price Code	Associated to CSI MF Level 3, but Customized for Company Use	10 Digits	Unit Price - Cost per Quanitity	Provides project unit prices and hours at common level with common norms	8" Dia (200mm) Slab on Grade $ per CY or Buried 8" Dia (200mm) Ductile Iron Pipe

Table 4–Unit Price Process – Code Levels

A work activity code can have multiple unit price codes assigned, which explains the complexities of a critical element or scope of work. These unit price codes can also be included in different divisions of work, such as Concrete (03), Earthwork (31), Utilities (33). With this said, the work activity is used for reporting only and not used for cost benchmarking since it spans multiple CSI Master format codes. An example of a work activity and associated unit prices is as follows:

- By-pass pumping for the 36" Influent Pipe at the Headworks – Elev 205'
  - 01.51.01.00 - By-Pass Piping, 24" to 36" Pipes
  - 03.37.01.00 - Pipe Encasement, 36" Dia
  - 31.50.01.00 - Earthworks, Sheeting, and Shoring
  - 33.31.05.36 – Buried Pipe, Ductile Iron, 36" Dia

The data collected at each of the four levels associated with the UPP change metrics depending on which level is viewed. The facility-level shows overall capacity-driven metrics. The work packages show CSI division level metrics and provide a percentage of the total cost, which is helpful for the review and validation of a cost estimate. The trade package level shows average unit prices for concrete elements or types of pipes. The unit price level shows the lowest level of data collection, which includes quantities, unit hours direct unit prices and totals with indirect. All unit prices include unit hours, labor, construction equipment, subcontractor costs, and other costs at each of the four levels of data collection. See appendix B, for example, reports.

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Data Collection Structure

An organization should define the specific project types and which levels of data collection work for themselves. This includes attributes and summary level data, intermediate level data, and detail level data collection. Each organization should determine the amount of data collection that supports their business and project objectives without introducing unnecessary work or complexity. It cannot be overstated that data collection must be collected in the same manner for each project type. Standardization of data is critical to ensure a consistent estimate validation and project comparison. Organizations must strike a happy medium between data collection and along with the level of effort and cost to collect the data.

Project Attributes

The following describes the understanding and requirements for determining and identifying project attributes. Attributes are information that allows project data to be sorted into a comparison dataset for benchmarking use (in benchmarking, these are sometimes called "compsets"). In other words, to support apples-to-apples comparisons. These may include organizational information such as the business unit, or the type of contract approach used, the location, or any of a myriad of identifying characteristics such as the level of technical complexity. These attributes are not corrected for by conditioning and normalization; attributes are used to optimize the compset, so corrections, which add uncertainty in themselves, are not needed.

The ICMS defines standard attribute information for each of its 14 project sub-types. These suggested attributes provide a good starting point for an organization to establish further and expand their respective attributes. Again, there should be common attributes used across all project types as well as project-specific attributes by project type. The authors recommend the following number of data fields for project attributes as being reasonable:

1. Common Project Attributes - 15 to 30.
2. Project Type Attributes - 10 to 25.
3. Key Quantities – 10 to 15.
4. Key Ratios – 15 to 25.

Data Conditioning and Normalization

With all benchmarking assessments, conditioning, and normalization of comparison, set data is needed to assure apples-to-apples comparison. Conditioning is an adjustment made to the data so that it matches the "condition" of the project or item at hand. Attributes (e.g., location) may indicate that something that calls for adjustment. It also adjusts for the "condition" of the data, e.g., adjust for statistical outliers. Normalization is a form of conditioning, but specifically for adjusting the data to a common basis in time (i.e., adjust for escalation) and currency (adjust for exchange rates). These will not be covered in detail; they are database development and management topics for other how-to papers.

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Conditioning

Adjusting data for project conditions should be done before normalization of the data is required. The analyst must determine the credibility, maturity, and usefulness of the information available. This includes determining which data should be removed from the data set. Any data that is skewing the median of the benchmark metric should be removed from the data set unless its variation is within reasonable expectations. [8]

Other conditioning adjustments to data may need to be made for known differences in project attributes, project characteristics, or specific project conditions or cost accounting anomalies. The need for adjustments may be flagged by the descriptive information often included in the project closeout notes but can also be specific attributes for the project data. Project conditions can also be excessive quantities, which can result in outlying data but can be reasonably corrected for within a collection of project data. The following are examples of project characteristics or conditions that can be adjusted for:

1. Poor Soil Conditions – due to the poor soil conditions, the project required 5,000 CY of over-excavation under the majority of the foundations.
2. Imported Fill and Pre-loading – the project required 10’ of additional fill material for flood control and protection and required preloading of 20,000 CY of fill material for 12 months.
3. Pile Foundations – based upon the soil conditions and foundation types, the project required 6,500 EA pile foundations.

Other examples of conditioning adjustments are correcting for cost anomalies, such as the occurrence of a major risk event, the cost for an unusual duty, an environmental penalty, etc.

Normalization

AACE International defines normalization as – “In database management, a process used to modify data so that it conforms to a standard or norm (e.g., conform to a common basis in time, currency, location, etc.).” [2] Typically, the adjustments are applied using factors, which include time, currency, and location.

These adjustments are typically calculated independently of each factor. These factors can be applied independently to the base costs or aggregated together and then applied as on aggregated adjustment factor. The following are the normalization adjustment types:

1. Time Adjustment – Escalation from the base cost date to the current analysis date. [10]
2. Location Factor – This is a geographical adjustment, which can be regional, state, city, providence, or other location determination. [11]
3. Currency – This adjustment is for converting one base currency to another currency. This can be a single or multiple currency for specific elements of the project. [10]

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Comparison Set Reporting

After data has been conditioned and normalized, and one has developed a comparison dataset, the benchmark metric of interest must be selected. It can be a single value (e.g., mean or median) or optimally shown as a statistical range. Typically the range is displayed a box chart that shows the mean or median, with a target range in a box (e.g., 50 percent confidence interval) and a bar with endpoints that represent an outside bound (e.g., 80 or 90 percent confidence interval). This is something like a bulls-eye with better comparability if one is "within the box."

Case Study

The author's company has developed a process for data collection for use in estimate validation and benchmarking of projects, which is the focus of this paper. The author's company tried to implement a historical project benchmarking software for over five years ago. The author found that they had no consistent and standard estimating coding structure other than the MasterFormat. We had to develop a coding structure that is specific to our project types, and we could use across all of our project types. The outcome of this development is the Unit Price Process (UPP). Then estimators had to be trained on the new coding structure. Enforcement of this coding structure was a challenge for the estimating staff. The author's company has implemented a project historical tracking software called *Cortex Project History* by the Eos Group. The software will is used to track historical construction cost estimates and professional services labor hours from the US, UK, and Australia. The initial pilot included the following project types: high school building, pharmaceutical packaging plant, pulp, and paper mill, and roadway. The data is loaded into the software using the International Construction Measurement Standard (ICMS) [1] and the native coding structure for the project type. The software is configured for ICMS attributes are and company attributes. The ICMS attributes provided a template for pharmaceutical packaging plant, pulp, and paper mill project types since they are not part of the current standard. Project-specific key quantities, metrics, and ratios have been created for each project type. The authors had to change to the basis of estimate [16] requirements to add additional design information to match the project attributes to be used for benchmarking.

Conclusion

The development of and getting agreement on a standard coding system for a company is perhaps the most challenging part of the development of a good benchmarking system. Organizations must adopt a standard coding structure for use in historical project data management, which includes projects or estimates and closeout information. The standard coding structures must be enforced by organizational leadership, who should introduce the appropriate culture, behavior, and governance to ensure future corporate and project success. Furthermore, common project attributes, KPI's, metrics, key quantities, schedule milestones, and cost elements must be defined for each project type. The International Construction Measurement Standard (ICMS) [1], can provide a good start for the development of project

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attributes for almost all organizations. However, other viable structures may be better for a particular industry.

As discussed earlier, most cost estimating software in the US, are based around the MasterFormat or the UniFormat coding structure for estimate development and reporting. These standard coding structures do not align with the way a cost estimator wants to review unit price information since these structures are specification based or physical location-based. These standard coding structures span across multiple divisions of work. Therefore, the authors presented a unit price process coding structure. The standardization of these unit price codes must be rigidly adhered to by all cost estimators in a company, which can be a challenge. This challenge may extend to the development of the project attributes, KPI's, key metrics and ratios that are used across a global enterprise. Finally, the determination of the appropriate levels of data collection and the location of information can introduce other obstacles as well. This paper has identified challenges organizations will face in the development of a benchmarking and data collection system as well as provided the necessary recommendations to support the introduction and use of a sophisticated benchmarking system within an organization. Determining this appropriate balance between data collection, closeout data, and benchmarking metrics is a significant challenge for most organizations.

Finally, this paper has shown a unit price data collection process used for benchmarking of cost estimates, which has shown the data collection process used for benchmarking along with benchmarking terminology. In closing, the authors have presented the following benchmarking concepts to support:

1. Benchmarking feedback loop.
2. Data collection process.
3. Benchmarking terminology.
4. Benchmarking data types and levels
5. Estimate coding structures.
6. Issues with coding structures.
7. ICMS coding structure.
8. Project characteristics and attributes.
9. Benchmarking levels and types.
10. Data conditioning.
11. Data normalization.
12. Case study

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APPENDIX A – SAMPLE KEY QUANTITIES

The following are sample key quantities:

Key Quantities	Unit of Measure	
Description (Total Quantities)	**Imperial**	**Metric**
Total Site Area	AC	ha
Total Building Area	SF	m2
Excavation	CY	m3
Backfill	CY	m3
Imported Backfill	CY	m3
Stone	CY	m3
Pile Foundations Length	LF	m
Pile Foundations Count	EA	nr
Steel	Ton	t
Rebar	LBS	kg
Special Coatings	SF	m2
Concrete	CY	m3
Buried Pipe	Ton	t
Exposed Pipe	Ton	t
Process Equipment	EA	nr
Electrical Conduit and Raceway	LF	m
Electrical Wire and Cable	LF	m
Electrical Motor Control Centers	EA	nr
Instruments	EA	nr
I/O Count	EA	nr

APPENDIX B – UNIT PRICE PROCESS – EXAMPLE REPORTS

Facility Report

The report shows metrics and unit prices at the facility level:

Facility	Description	Takeoff Quantity	UOM	Labor Hours	Equip Hours	Labor Unit Hours	Equipment Unit Hours	Direct Total Cost/Unit		Direct Total	Grand Total Price		Grand Total with Markups	% Total
001	GENERAL CONDITIONS	24.00	MO	84,102.820		3504.284	0.000	2,356,064.47	/MO	56,545,547	3,175,655.11	/MO	76,215,723	12.315%
006	SITEWORK	31.00	AC	98,860.891	65,209.538	3189.061	2103.533	576,896.88	/AC	17,883,803	846,688.55	/AC	26,247,345	4.241%
007	YARD PIPING	47,060.00	LF	28,150.742	25,213.792	0.598	0.536	578.03	/LF	27,201,882	837.77	/LF	39,425,225	6.371%
008	SITEWIDE ELECTRICAL, SUBSTATION, SWITCHYARD AND DUCTBANKS	56.00	MGD	62,542.000	18,451.963	1116.821	329.499	734,450.51	/MGD	41,129,229	1,130,367.63	/MGD	63,300,587	10.228%
009	SITEWIDE INSTRUMENTATION AND CONTROL	56.00	MGD			0.000	0.000	214,285.71	/MGD	12,000,000	320,825.93	/MGD	17,966,252	2.903%
010	SITEWORK DEMOLITION	31.00	AC	6,000.000	6,000.000	193.548	193.548	31,492.58	/AC	976,270	47,758.09	/AC	1,480,501	0.239%
012	STRUCTURES DEMOLITION	20.00	CD	2,728.767	1,564.384	136.438	78.219	15,832.78	/CD	316,656	23,791.49	/CD	475,830	0.077%
103	INFLUENT PUMP STATION	56.00	MGD	63,542.906	12,315.545	1134.695	219.920	1,042,747.67	/MGD	58,393,870	1,495,251.90	/MGD	83,734,106	13.530%
110	HEADWORKS	56.00	MGD	33,490.137	3,206.666	598.038	57.262	193,129.18	/MGD	10,815,234	285,639.59	/MGD	15,995,817	2.585%
130	PRIMARY CLARIFIERS - CIRCULAR	56.00	MGD	101,274.890	8,169.235	1808.480	145.879	405,754.14	/MGD	22,722,232	597,375.41	/MGD	33,453,023	5.406%
220	BIOREACTOR BASINS	56.00	MGD	192,858.405	11,753.234	3443.900	209.879	709,326.83	/MGD	39,722,303	1,042,879.61	/MGD	58,401,258	9.437%
230	SECONDARY CLARIFIERS - CIRCULAR	56.00	MGD	149,184.682	9,842.593	2664.012	175.761	633,968.46	/MGD	35,502,234	933,975.14	/MGD	52,302,608	8.451%
262	BLOWER BUILDING	15,636.00	SF	15,336.110	1,246.128	0.981	0.080	367.71	/SF	5,749,504	551.20	/SF	8,618,519	1.393%
370	UV DISINFECTION FACILITY	56.00	MGD	26,036.811	2,004.039	464.943	35.786	160,995.05	/MGD	9,015,723	238,457.69	/MGD	13,353,631	2.158%
430	STORAGE AND WORKSHOPS SYSTEM	11,000.00	SF	11,987.347	11,000.000	1.090	1.000	187.52	/SF	2,062,713	282.41	/SF	3,106,474	0.502%
440	CHP BUILDING	56.00	MGD	6,685.038	519.290	119.376	9.273	140,422.03	/MGD	7,863,633	209,504.82	/MGD	11,732,270	1.896%
470	ADMINISTRATION BUILDING SYSTEM	54,000.00	SF	191,697.733	30,345.666	3.550	0.562	486.34	/SF	26,262,414	725.61	/SF	39,182,726	6.331%
475	OPERATIONS BUILDING COMPLEX	32,000.00	SF	71,188.741	697.741	2.225	0.022	279.24	/SF	8,935,616	423.00	/SF	13,536,055	2.187%
494	EMERGENCY POWER GENERATOR	8.00	KW	9,119.047	415.000	1139.881	51.875	2,388,964.98	/KW	19,111,720	3,560,449.94	/KW	28,483,600	4.603%
630	DIGESTER BUILDING	5,000.00	SF	2,185.570	25.040	0.437	0.005	123.24	/SF	616,182	183.87	/SF	919,355	0.149%
700	DEWATERING BUILDING	24,170.00	SF	65,104.887	7,513.465	2.694	0.311	699.30	/SF	16,902,080	1,031.72	/SF	24,936,674	4.029%

Note – There are unit prices not shown for labor, material, construction equipment, subcontractor, and other costs as part of this data set.

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Work Package

This example report shows metrics, average unit prices, and percentage of total, which is helpful in the review and validation of a cost estimate:

Work Pkg	Description	Takeoff Quantity	UOM	Labor Hours	Equip Hours	Labor Unit Hours	Equipment Unit Hours	Direct Total	Direct Total Cost/Unit		Grand Total Price		Grand Total with Markups	% Total
01.0	General Requirements	24.00	MO	84,102.820		3504.284	0.000	56,545,547	856,750.72	/MO	1,154,783.68	/MO	76,215,723	12.315%
02.0	Existing Conditions	31.00	AC	8,728.767	7,564.384	281.573	244.012	1,292,926	41,707.28	/AC	63,107.44	/AC	1,956,331	0.316%
03.0	Concrete Work	120,673.38	CY	454,710.882	23,378.706	3.768	0.194	87,975,802	729.04	/CY	1,062.84	/CY	128,256,163	20.724%
03.5	Precast Concrete	196,565.00	SF	39,738.215	4,999.280	0.202	0.025	7,937,713	40.38	/SF	59.25	/SF	11,646,327	1.882%
04.0	Masonry	89,236.80	SF	22,055.255	855.117	0.247	0.010	2,341,718	26.24	/SF	39.26	/SF	3,503,661	0.566%
05.0	Metals	51,874.00	SF	23,469.239	5,276.719	0.452	0.102	4,987,937	96.16	/SF	140.70	/SF	7,298,514	1.179%
07.0	Thermal and Moisture Protection	54,940.00	SF	3,468.947	1,205.726	0.063	0.022	372,204	6.78	/SF	10.16	/SF	558,182	0.090%
08.0	Openings	140.00	EA	981.259	236.000	7.009	1.686	370,238	2,644.56	/EA	4,046.91	/EA	566,567	0.092%
09.0	Finishes	183,860.50	SF	39,211.893	4,605.946	0.213	0.025	6,959,733	37.85	/SF	57.02	/SF	10,484,147	1.694%
11.0	Commercial Equipment	145,406.00	SF	300.000		0.002	0.000	96,643	0.67	/SF	1.02	/SF	147,606	0.024%
12.0	Furnishings	145,406.00	SF	300.000		0.002	0.000	94,721	0.65	/SF	1.00	/SF	144,786	0.023%
13.1	Buildings Complete	11,000.00	SF	7,260.000	11,000.000	0.660	1.000	1,238,889	112.63	/SF	170.28	/SF	1,873,095	0.303%
21.0	Fire Suppression	275,956.50	SF	5,820.000		0.021	0.000	3,247,939	11.77	/SF	17.31	/SF	4,776,612	0.772%
22.0	Plumbing	275,956.50	SF	7,765.000		0.028	0.000	2,636,103	9.55	/SF	14.10	/SF	3,890,655	0.629%
23.0	HVAC	275,956.50	SF	40,900.000		0.148	0.000	9,856,543	35.72	/SF	52.99	/SF	14,624,149	2.363%
26.0	Electrical Work	1,350,360.00	SF	126,541.214	19,252.529	0.094	0.014	51,040,653	37.80	/SF	58.32	/SF	78,747,346	12.724%
28.0	Electronic Safety and Security	86,000.00	SF	8,600.000		0.100	0.000	939,326	10.92	/SF	16.84	/SF	1,448,462	0.234%
31.0	Earthwork	31.00	AC	155,292.104	92,277.942	5009.423	2976.708	36,777,134	1,186,359.16	/AC	1,723,001.30	/AC	53,413,040	8.631%
32.0	Exterior Improvements	31.00	AC	27,360.768	12,459.143	882.605	401.908	5,793,040	186,872.25	/AC	274,787.30	/AC	8,518,406	1.376%
33.0	Utilities	57,005.00	LF	35,915.188	30,691.803	0.630	0.538	53,343,741	935.77	/LF	1,348.53	/LF	76,872,801	12.422%
33.9	Tank Construction	75,000.00	GAL	750.000		0.010	0.000	335,216	4.47	/GAL	6.25	/GAL	469,054	0.076%
40.0	Process Pipe	37,949.00	LF	39,035.173	1,065.023	1.029	0.028	13,984,757	368.52	/LF	544.22	/LF	20,652,480	3.337%
40.9	Instrumentation & Controls	1,350,360.00	SF	21,068.870		0.016	0.000	15,707,071	11.63	/SF	17.54	/SF	23,684,648	3.827%
41.0	Material Processing and Handling Equipment	10.00	EA	2,659.200	98.000	265.920	9.800	1,391,013	139,101.31	/EA	206,529.09	/EA	2,065,291	0.334%
43.0	Process Gas and Liquid Handling Equipment	155.00	EA	12,063.662		77.830	0.000	9,183,448	59,248.05	/EA	88,113.65	/EA	13,657,616	2.207%
44.0	Pollution and Waste Control Equipment	20.00	EA	3,773.000	96.000	188.650	4.800	2,767,214	138,360.70	/EA	205,844.94	/EA	4,116,899	0.665%
46.0	Water and Wastewater Equipment	176.00	EA	44,430.067		252.444	0.000	19,273,279	109,507.27	/EA	162,369.95	/EA	28,577,111	4.618%
48.0	Electrical Power Generation	6.00	EA	5,776.000	431.000	962.667	71.833	23,238,298	3,873,049.58	/EA	5,783,651.13	/EA	34,701,907	5.607%

Note – There are unit prices not shown for labor, material, construction equipment, subcontractor, and other costs as part of this data set.

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Trade Package

This report shows metrics and averages for elements such as concrete, buried pipe, exposed pipe and process equipment:

Work Pkg	Trade Pkg	Description	Takeoff Quantity	UOM	Labor Hours	Equip Hours	Labor Unit Hours	Equipment Unit Hours	Direct Total Cost/Unit	Direct Total	Grand Total Price	Grand Total with Markups	% Total
03.0		*Concrete Work*											
	03.10	Cast-In-Place Concrete Work	6,929.63	CY	10,584.572		1.527	-	1,902.79 /CY	13,185,626	2,708.02 /CY	18,765,599	2.904%
	03.12	Cast-In-Place Concrete, Pad Footings	940.00	CY	1,920.741	164.154	2.043	0.175	460.05 /CY	432,447	677.39 /CY	636,746	0.099%
	03.18	Cast-In-Place Concrete, Slabs on Grade	65,535.96	CY	132,823.580	11,502.082	2.027	0.176	461.47 /CY	30,242,986	678.97 /CY	44,497,050	6.886%
	03.20	Cast-In-Place Concrete, Straight Walls	33,549.37	CY	205,817.717	7,189.438	6.135	0.214	938.90 /CY	31,499,576	1,372.69 /CY	46,053,015	7.127%
	03.22	Cast-In-Place Concrete, Tilt Up Walls	302.66	CY	1,506.370	125.294	4.977	0.414	393.32 /CY	119,042	564.05 /CY	170,716	0.026%
	03.23	Cast-In-Place Concrete, Columns	123.00	CY	1,488.806	38.707	12.104	0.315	1,567.05 /CY	192,747	2,281.65 /CY	280,643	0.043%
	03.24	Cast-In-Place Concrete, Elevated Slabs	11,740.42	CY	87,936.291	3,088.255	7.490	0.263	858.31 /CY	10,076,968	1,245.40 /CY	14,621,538	2.263%
	03.25	Precast Concrete	3,771.00	SF	249.552	61.333	0.066	0.016	43.32 /SF	163,348	64.44 /SF	242,998	0.038%
	03.27	Cast-In-Place Concrete, Equipment Pads	461.12	CY	1,673.147		3.628	-	760.60 /CY	350,727	1,110.81 /CY	512,214	0.079%
	03.29	Cast-In-Place Concrete, Stairs	26.00	RISR	104.000	104.000	4.000	4.000	463.38 /RISR	12,048	672.77 /RISR	17,492	0.003%
	03.35	Concrete - Fill	107.00	CY	1,674.777	566.201	15.652	5.292	4,204.73 /CY	449,906	6,213.88 /CY	664,885	0.103%
	03.54	Precast Architectual Concrete	25,200.00	SF	3,265.559	177.827	0.130	0.007	15.22 /SF	383,484	22.14 /SF	558,015	0.086%
	03.90	Concrete Reinforcement	6.67	TON	365.380	147.072	54.780	22.050	7,024.48 /TON	46,846	10,208.79 /TON	68,082	0.011%
		03.0 Concrete Work	*120,673.38*	*CY*	*454,710.882*	*23,378.706*	3.768	0.194	*729.04 /CY*	*87,975,802*	*1,063.10 /CY*	*128,288,253*	*19.853%*
33.0		*Utilities*											
	33.02	Buried Process Pipe, Ductile Iron	27,480.00	LF	11,555.671	13,887.486	0.421	0.505	286.29 /LF	7,867,121	425.35 /LF	11,688,570	1.809%
	33.03	Buried Process Pipe, Carbon Steel	3,105.00	LF	7,045.835	5,604.295	2.269	1.805	3,122.90 /LF	9,696,617	4,577.40 /LF	14,212,827	2.200%
	33.05	Buried Process Pipe, PVC/CPVC	14,000.00	LF	6,008.201	2,655.071	0.429	0.190	115.57 /LF	1,618,012	170.09 /LF	2,381,300	0.369%
	33.07	Buried Process Pipe, HDPE	4,500.00	LF	728.162	1,492.947	0.162	0.332	29.24 /LF	131,580	42.66 /LF	191,978	0.030%
	33.11	Buried Process Pipe, Concrete Cylinder	2,100.00	LF	4,116.616	3,167.946	1.960	1.509	882.04 /LF	1,852,277	1,305.18 /LF	2,740,881	0.424%
	33.31	Buried Structures, Precast Manholes	22.00	EA	1,131.663	786.056	51.439	35.730	6,617.62 /EA	145,588	9,651.05 /EA	212,323	0.033%
	33.33	Buried Structures, Precast Catch Basins	10.00	EA	581.465	235.932	58.147	23.593	5,216.26 /EA	52,163	7,514.35 /EA	75,144	0.012%
	33.54	Storm Utilities	3,000.00	LF	513.751	808.741	0.171	0.270	54.13 /LF	162,400	76.58 /LF	229,744	0.036%
		33.0 Utilities	*57,005.00*	*LF*	*35,915.188*	*30,691.803*	0.630	0.538	*935.77 /LF*	*53,343,741*	*1,348.87 /LF*	*76,892,259*	*11.900%*
40.0		*Process Pipe*											
	40.00	Exposed Process Pipe	800.00	LF	750.780		0.938	-	161.50 /LF	129,199	236.19 /LF	188,950	0.029%
	40.10	Process Pipe, Ductile Iron	1,900.00	LF	1,543.305		0.812	-	136.82 /LF	259,963	200.00 /LF	380,006	0.059%
	40.11	Process Pipe, Carbon Steel	24,706.00	LF	25,441.906	866.653	1.030	0.035	340.37 /LF	8,409,284	502.18 /LF	12,406,956	1.920%
	40.12	Process Pipe, Stainless Steel	2,793.00	LF	3,645.013	173.330	1.305	0.062	428.98 /LF	1,198,143	633.52 /LF	1,769,410	0.274%
	40.13	Process Pipe, PVC/CPVC	2,800.00	LF	1,494.246		0.534	-	102.35 /LF	286,590	149.22 /LF	417,825	0.065%
	40.14	Process Pipe, Copper	3,500.00	LF	1,924.025		0.550	-	90.88 /LF	318,073	131.86 /LF	461,514	0.071%
	40.20	Odor Control Duct, Stainless Steel	1,450.00	LF	1,561.418		1.077	-	324.13 /LF	469,981	477.27 /LF	692,041	0.107%
	40.30	Process Valves, Gate Valves	14.00	EA	206.000		14.714	-	25,171.27 /EA	352,398	37,549.89 /EA	525,698	0.081%
	40.33	Process Valves, Ball Valves	97.00	EA	239.340		2.467	-	1,438.19 /EA	139,504	2,136.34 /EA	207,225	0.032%
	40.34	Process Valves, Plug Valves	320.00	EA	1,352.900		4.228	-	5,425.32 /EA	1,736,103	8,087.44 /EA	2,587,981	0.401%
	40.35	Process Valves, Butterfly Valves	50.00	EA	249.500		4.990	-	5,967.39 /EA	298,369	8,893.59 /EA	444,679	0.069%
	40.37	Process Valves, Check Valves	93.00	EA	274.300		2.949	-	2,496.08 /EA	232,135	3,715.23 /EA	345,517	0.053%
	40.39	Process Valves, Relief Valves	1.00	EA	14.000		14.000	-	5,762.66 /EA	5,763	8,536.99 /EA	8,537	0.001%
	40.46	Process Valves, Diaphragm Valves	7.00	EA	6.440		0.920	-	530.06 /EA	3,710	787.32 /EA	5,511	0.001%
	40.49	Process Valves, Other Valves	20.00	EA	154.000		7.700	-	3,863.96 /EA	77,279	5,733.66 /EA	114,673	0.018%
	44.40	Process Equipment - Pumps	12.00	EA	43.200		3.600	-	4,761.20 /EA	57,134	7,098.06 /EA	85,177	0.013%
		40.0 Process Pipe	*37,949.00*	*LF*	*38,900.373*	*1,039.983*	1.025	0.027	*368.22 /LF*	*13,973,630*	*543.93 /LF*	*20,641,702*	*3.194%*

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Unit Price

This report illustrates the lowest level of detailed cost tracking. There are approximately 2,700 separate unit price codes that are used across all project types. This show metrics, key quantities, and unit prices:

Work Pkg	Unit Price	Description	Takeoff Quantity		Labor Hours	Equip Hours	Labor Unit Hours	Equipment Unit Hours	Direct Total Cost/Unit		Direct Total	Grand Total Price		Grand Total with Markups
03.0		*Concrete Work*												
	03.00.99.06	Concrete, Mud Mat, 06" Thick	6,111.11	CY	6,893.333		1.128	-	196.83	/CY	1,202,870	288.10	/CY	1,760,601
	03.00.99.24	Concrete, Mud Mat, 24" Thick	818.52	CY	691.239		0.844	-	201.20	/CY	164,689	295.89	/CY	242,194
	03.10.05.12	Cast-In-Place Concrete, Slabs on Grade, 12" thick	2,608.63	CY	5,626.366	30.438	2.157	0.012	515.36	/CY	1,344,372	754.57	/CY	1,968,406
	03.10.05.24	Cast-In-Place Concrete, Slabs on Grade, 24" thick	42,256.33	CY	86,547.866	7,892.361	2.048	0.187	466.52	/CY	19,713,603	686.54	/CY	29,010,488
	03.10.05.36	Cast-In-Place Concrete, Slabs on Grade, 36" thick	18,079.00	CY	35,391.075	3,127.913	1.958	0.173	442.81	/CY	8,005,464	651.67	/CY	11,781,555
	03.10.05.60	Cast-In-Place Concrete, Slabs on Grade, 60" thick	2,592.00	CY	5,258.273	451.369	2.029	0.174	455.07	/CY	1,179,548	669.99	/CY	1,736,601
	03.10.06.08	Cast-In-Place Concrete, Straight Walls, 8" thick	5.00	CY	61.981	1.083	12.396	0.217	1,420.25	/CY	7,101	2,060.56	/CY	10,303
	03.10.06.12	Cast-In-Place Concrete, Straight Walls, 12" thick	2,707.87	CY	24,520.468	570.336	9.055	0.211	1,269.93	/CY	3,438,814	1,852.75	/CY	5,017,003
	03.10.06.15	Cast-In-Place Concrete, Straight Walls, 15" thick	664.00	CY	4,924.115	142.500	7.416	0.215	1,054.49	/CY	700,179	1,539.06	/CY	1,021,933
	03.10.06.16	Cast-In-Place Concrete, Straight Walls, 16" thick	391.00	CY	2,796.073	83.913	7.151	0.215	1,029.51	/CY	402,538	1,503.04	/CY	587,688
	03.10.06.18	Cast-In-Place Concrete, Straight Walls, 18" thick	11,839.75	CY	77,225.556	2,541.064	6.523	0.215	957.37	/CY	11,334,958	1,398.36	/CY	16,556,176
	03.10.06.24	Cast-In-Place Concrete, Straight Walls, 24" thick	3,999.00	CY	21,579.357	858.235	5.396	0.215	827.13	/CY	3,307,707	1,209.33	/CY	4,836,114
	03.10.06.30	Cast-In-Place Concrete, Straight Walls, 30" thick	1,825.25	CY	8,662.191	391.715	4.746	0.215	758.67	/CY	1,384,759	1,110.25	/CY	2,026,480
	03.10.06.36	Cast-In-Place Concrete, Straight Walls, 36" thick	138.00	CY	613.730	29.620	4.447	0.215	729.10	/CY	100,616	1,067.54	/CY	147,321
	03.10.07.12	Cast-In-Place Concrete, Circular Walls, 12" thick	620.00	CY	5,737.815	133.062	9.255	0.215	1,435.16	/CY	889,796	2,098.83	/CY	1,301,272
	03.10.07.24	Cast-In-Place Concrete, Circular Walls, 24" thick	10,078.00	CY	54,413.135	2,162.869	5.399	0.215	897.84	/CY	9,048,453	1,315.03	/CY	13,252,853
	03.10.08.12	Cast-In-Place Concrete, Tilt Up Walls, 12" thick	302.66	CY	1,506.370	125.294	4.977	0.414	393.32	/CY	119,042	564.05	/CY	170,716
	03.10.09.18	Cast-In-Place Concrete, Columns, 18"	123.00	CY	1,488.806	38.707	12.104	0.315	1,567.05	/CY	192,747	2,281.65	/CY	280,643
	03.10.10.12	Cast-In-Place Concrete, Elevated Decks, 12" thick	7,265.17	CY	60,503.430	2,026.395	8.328	0.279	914.38	/CY	6,643,107	1,325.02	/CY	9,626,503
		03.0 Concrete Work	*120,673.38*	*CY*	*454,710.882*	*23,378.706*	3.768	0.194	*729.04*	*/CY*	*87,975,802*	*1,063.10*	*/CY*	*128,288,253*
33.0		*Utilities*												
	33.00.01.02	Yard Pipe, Construction Equipment	7.75	MO	288.000	374.665	37.161	48.344	11,576.09	/MO	89,715	17,104.91	/MO	132,563
	33.00.04.04	Buried Pipe, Ductile Iron, 4"	7,500.00	LF	2,102.716	2,805.846	0.280	0.374	89.29	/LF	669,668	131.71	/LF	987,857
	33.00.04.06	Buried Pipe, Ductile Iron, 6"	5,020.00	LF	1,444.433	1,369.703	0.288	0.273	90.62	/LF	454,901	133.67	/LF	671,039
	33.00.04.10	Buried Pipe, Ductile Iron, 10"	1,780.00	LF	519.388	501.588	0.292	0.282	107.16	/LF	190,737	158.49	/LF	282,121
	33.00.04.12	Buried Pipe, Ductile Iron, 12"	5,055.00	LF	2,040.185	3,034.365	0.404	0.600	169.81	/LF	858,408	251.19	/LF	1,269,781
	33.00.04.16	Buried Pipe, Ductile Iron, 16"	800.00	LF	423.190	415.190	0.529	0.519	267.55	/LF	214,039	396.61	/LF	317,290
	33.00.04.24	Buried Pipe, Ductile Iron, 24"	4,500.00	LF	2,335.752	2,464.082	0.519	0.548	377.67	/LF	1,699,502	561.16	/LF	2,525,215
	33.00.04.48	Buried Pipe, Ductile Iron, 48"	3,725.00	LF	3,164.047	3,042.047	0.849	0.817	937.20	/LF	3,491,059	1,396.14	/LF	5,200,634
	33.00.05.72	Buried Pipe, Carbon Steel, 72"	55.00	LF	201.853	142.563	3.670	2.592	2,309.72	/LF	127,035	3,428.92	/LF	188,591
	33.00.07.01	Buried Pipe, PVC, 1/4" to 1"	1,200.00	LF	276.080		0.230	-	52.50	/LF	63,005	76.38	/LF	91,659
	33.00.07.08	Buried Pipe, PVC, 8"	3,000.00	LF	1,202.082	738.072	0.401	0.246	95.25	/LF	285,745	139.90	/LF	419,690
	33.00.07.10	Buried Pipe, PVC, 10"	8,000.00	LF	3,302.368	1,145.758	0.413	0.143	110.85	/LF	886,823	163.13	/LF	1,305,032
	33.00.07.12	Buried Pipe, PVC, 12"	3,000.00	LF	1,503.751	771.241	0.501	0.257	148.48	/LF	445,443	218.86	/LF	656,578
	33.00.09.04	Buried Pipe, HDPE, 4"	500.00	LF	161.086	312.551	0.322	0.625	61.77	/LF	30,885	90.02	/LF	45,009
	33.00.09.06	Buried Pipe, HDPE, 6"	4,000.00	LF	567.076	1,180.396	0.142	0.295	25.17	/LF	100,695	36.74	/LF	146,970
	33.00.10.12	Buried Pipe, RCP, 12"	3,000.00	LF	513.751	808.741	0.171	0.270	54.13	/LF	162,400	76.58	/LF	229,744
		33.0 Utilities	*57,005.00*	*LF*	*35,915.188*	*30,691.803*	0.630	0.538	*935.77*	*/LF*	*53,343,741*	*1,348.87*	*/LF*	*76,892,259*

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