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Estimating in Step with Advanced Work Packaging (AWP) for Enhanced Project Control

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Abstract — Advanced Work Packaging (AWP) is a structured mechanism that was co-developed by Construction Industry Institute® (CII) and Construction Owners Association of Alberta (COAA) as best practice for project planning and execution. However, predictability and closer cost control are contingent on producing a good quality funding estimate.

This paper proposes the concept of enhanced estimating work process implementation to provide estimate quantities, cost and man-hours as close as possible to actuals when the project is completed. In addition, providing estimated man-hour inputs by construction work packages (CWP) and by contract to project controls will enable far superior construction planning, scheduling and control in the field.

Estimate details will align with the AWP boundaries of engineering work packages (EWP) and construction work packages (CWP) so that budget information is available at the same level which will facilitate data integration into various project software. It is of paramount importance that estimated material/equipment quantities also be tracked and reported at the EWP/CWP level commencing in the front end vs. the common traditional tracking by commodity level for the overall project.

Predictability of cost and schedule are among the most important KPIs by which success of a project will be judged.

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1.0 Introduction

This paper deals with estimating work process that will provide necessary input information in a timely manner for projects implementing an advanced work packaging (AWP) work process. The objective is to generate material, labor quantity and man-hour inputs by engineering work package (EWP), construction work package (CWP) and by contract in the class 3 estimate. As these CWPs firm up and become part of the contract, the fidelity of labor quantity and man-hours by CWPs continue to be maintained by contract to set a more accurate control base, better planning, scheduling and control for better predictability.

"AWP is a disciplined approach to project planning and execution to increase project performance and predictability" – to quote from Construction Industry Institute (CII) definition of AWP. The model execution process RT-272 [1] has been co-developed by CII and COAA through extensive collaborative efforts spanning several years from owner, engineering and contractor organizations. AWP is a construction driven work process that advocates creation of EWPs, CWPs and procurement packages with identifiers to EWPs and CWPs during the front end engineering phase leading to well defined scope boundaries for precision planning and smooth execution. Subsequently during the construction phase, installation work packages (IWP) will be finalized and executed utilizing a process for ensuring all constraints are removed prior to commencing construction of the given IWPs (e.g.) engineering is complete, all material is available/staged, all resources are available, access is clear, etc. This latter stage has been an industry standard practice widely known as WorkFace Planning.

After extensive research carried out by CII under research topic RT-319 [2] to validate the performance success of the AWP execution model, AWP was promoted as a CII Best Practice in November 2015. AWP holds the potential of transforming major projects delivery process. CII has published the following results documenting gains achieved by projects implementing AWP work process in comparison to traditional projects performance:

- Up to 25% increase in field productivity
- Up to 10% decrease in total installed cost (TIC), with increased savings for owners and increased profitability for contractors
- Improved schedule performance, with many projects delivered on schedule
- Improved safety performance, with zero lost time accident records achieved on several projects
- Increased quality, with reduced construction rework
- Increased predictability, in terms of cost and schedule estimates

Many owner companies and EPCs (Engineering, Procurement and Construction contracting companies) are adapting AWP work process for their projects by creating company specific procedures for implementation. RT-319 findings indicate that KPIs (Key Performance Indicators) improve with increased maturity level of disciplined implementation of the AWP work process [2].

Sophisticated IT infrastructure and tools have been developed that support AWP. Effective integration of various project tools including 3D modelling, materials management software, construction visualization tools, inventory management, planning and cost control tools, etc. is key to successful implementation of AWP. Common threads that provide the back bone for such integration are EWPs, CWPs and IWPs. Project time lines for defining EWP, CWP and IWP are important considerations as every project functional discipline will need to produce drawings & documents aligned with the boundaries of demarcation. This is critical to ensure seamless communication between various software for streamlined and data centric project execution.

A Class 3 estimate for the project typically forms the basis for final investment decision and the approved project budget. However, level of detail of the engineering material take-off (MTO) available at the time of class 3 estimate development is generally not at the EWP/CWP level but at the WBS area level. That poses a major disconnect in the AWP work process. This results in performance monitoring that does not relate directly to approved budget but instead is measured against subsequent standalone man-hour estimates developed for each work package. This paper will discuss possible ways and means of bridging the gap.

In the proposed estimating work process implementation, estimate details shall be at EWP and CWP level with necessary coding incorporated at the prime account and various subprime levels. Such details in combination with designated identifiers for procurement RFQs and various planned contracts will provide the data structure for superior project controls and greater predictability.

2.0 AWP Process Overview

AWP process overview is outlined below:

- CWP boundaries, durations and sequencing are developed (articulate the Path of Construction)
- EWP boundaries, durations and sequencing are developed to support the Path of Construction. Each EWP (or group of EWPs) are linked to a corresponding CWP
- PWPs developed to provide quantities/deliveries to support EWP completion and all materials/equipment delivered prior to scheduled commencement of each CWP
- Workface planners break CWPs into Installation Work Packages (IWP)
- Construction foremen or other responsible personnel review completeness of IWPs
- Constraint Coordinators ensure all constraints removed prior to releasing IWPs for execution
- Construction Management makes decisions on IWPs release
- Foremen execute IWPs
- Project controls monitor IWPs
- Quality assurance audits IWPs

AWP requires commitment at the senior level of the project leadership team. It should be expected that each AWP implementation will be a staged process gaining experience and maturity level with each completed project. AWP entails development of company specific work practices and procedures and implementation plans developing from the guidelines provided by CII/COAA/other sources, incorporating lessons learned in due course.

AWP work process begins with the end in mind, of construction, completion and turnover. This means that front end planning takes into account the construction execution plan including the requirements of turnover for the commissioning & start-up group. Interactive planning commencing early in the front end planning engages all key stakeholders.

Importance of engineering work package (EWP)

EWPs are the most crucial links in the whole AWP work process. Besides the conventional deliverables of documents and drawings, each EWP is a bundled output defining Engineering scope in completeness inclusive of several drawings and documents for the work to be done. These may include modelled or non-modelled content and the EWP acts as a pivot point for the subsequent processes. Procurement packages including identification of EWPs against individual items within the procurement package provide the required visibility of materials delivery status. Contractor mobilizes and plans construction based on engineering forecast release of IFC EWPs. MTO downloads from 3D model carry the designation of respective EWP numbers. Consistent use of EWP nomenclature relates all electronic data to the common data centric platform for efficient data integration/inter transfer between various software used in project execution. COAA recommends that each project set up the rules of credit for progressing of EWP, CWP and IWP packages. Rules of credit have been used for construction packages but it may be a considerable barrier to get these rules established and accepted at the EWP level.

Timeline for defining EWP, CWP and IWP

It is of utmost importance to define physical EWP and CWP boundaries early in the front end planning phase such that project set-up including all documentation and 3D model have the same consistent basis to be carried through to project completion. Naming of the EWPs, CWPs and IWPs need to be established on a consistent basis early on and strictly adhered to across the project and different contractors. The significance of such disciplined work process is that the vast amount of data generated by the 3D model and several other integrated project software systems are electronically processed more efficiently. Changes to the EWP and CWP boundaries once defined should be only for incorporating any scope or layout changes and kept to a minimum. Installation work packages (IWPs) will be defined much later by the field staff well before commencement of construction of the IWPs.

Timeline of the AWP work process in the context of front end loading or phase 1 of project execution is shown in the following diagram:

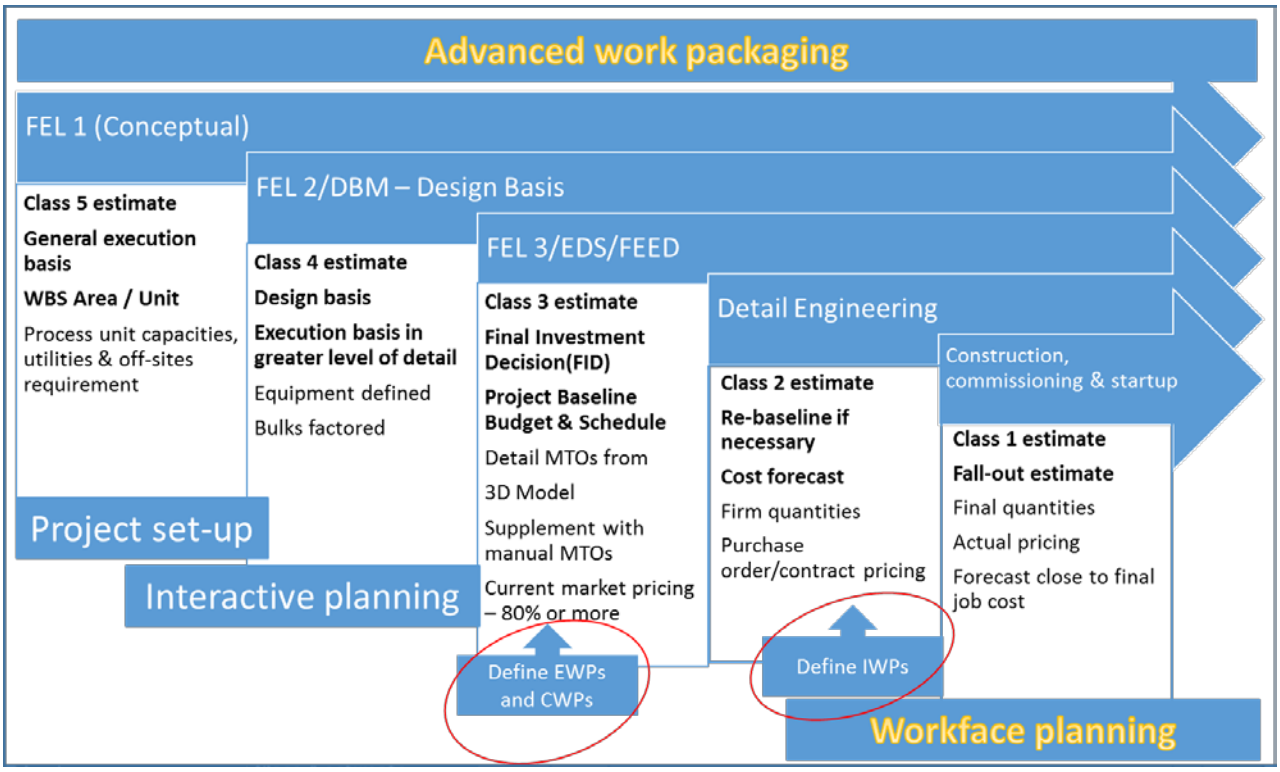


Figure 1: AWP Work Process – Interactive Planning and Timeline for defining EWPs/CWPs/IWPs

3.0 AWP implementation maturity and KPIs

The AWP work process is focused on organizing engineering, procurement and construction in such a manner that EWP/CWP structure lends itself seamlessly to verify absolute readiness of a given installation work package (IWP) well ahead of starting construction of the IWP. Documentation of each IWP will include the precise scope description, quantities, related drawings and specifications, construction equipment and labor resources assigned for the task. Labor resources required for each IWP is however assessed by the resource coordinator and is not derived from the approved budget estimate. At the current stage of evolution of AWP work process, this disconnect with approved budget estimate does remain and will likely be bridged with the advent of intelligent 2D/3D tools incorporating automated estimating modules within; it is necessary to point out that such integration does already exist, however the issue is completeness of MTOs in the 3D model / intelligent design systems which typically does not include manual MTOs and those that need to be factored. It is possible to create software modules within the 3D models which will use algorithms to generate the missing MTOs that are still to be modelled, as well as add supplemental manual MTOs and factored quantities; such developments to come in the future will eventually make labor man-hour estimates part of the 3D model downloads thereby increasing predictability significantly given proper assessment of productivity/location factors.

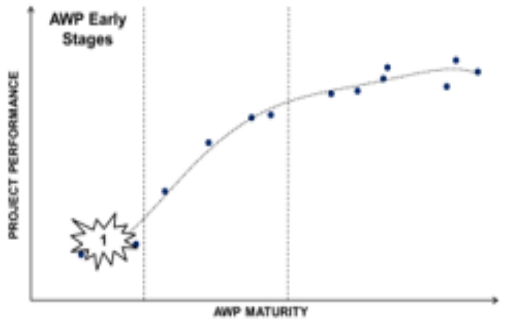
CII published their maturity model, three stages of which are characterized as below (ref CII IR 272 – Vol II) [3]:

- AWP Early Stages: AWP work process implemented for the first time such as on a pilot project by adapting recommended guidelines; top management commitment may still be tentative
- AWP Effectiveness: AWP work process accepted as standard work practice with contracts, project controls and payments etc., aligned with AWP. Major performance improvement gains become apparent
- AWP Business Transformation: Organizations which achieved this level of maturity in implementation of AWP will have procedures in place for all aspects of the AWP work process with EWP/CWP/PWP/IWP and material delivery dates integrated into schedule and budget for deriving full benefits of the AWP work process

CII further established six KPIs vis-à-vis AWP implementation maturity as shown in the figure below:

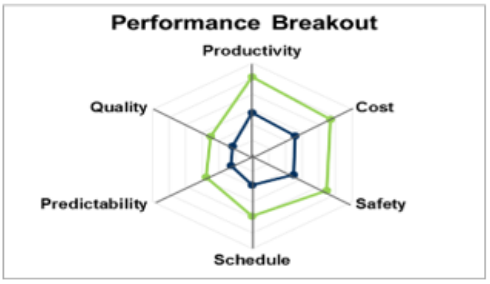
- Craft Productivity
- Cost
- Safety
- Schedule
- Predictability
- Quality

(1) AWP Early Stages



Performance Dimension	Maturity Stage		
	1 – AWP Early Stage	2 – AWP Effectiveness	3 – AWP Business Transformation
Productivity	Around 10% improvement	Around 25% improvement	Around 25% improvement
Cost	Project on budget	TIC 10% below estimates	TIC 10% below estimates
Safety	0 lost-time accident (TRIR below company average)	0 lost-time accident (TRIR improves with sporadic first-aids / near misses)	0 lost-time accident (TRIR improves with sporadic first-aids / near misses)
Schedule	Project experienced minor delays	Project slightly ahead of schedule during execution	Project slightly ahead of schedule during execution
Predictability	Significant deviation from baseline estimates	Minor changes to execution schedule	Execution schedule to plan
Quality	Rework in line with previous quality performance	Rework slightly below company's average	Rework substantially below company average + substantial reduction in RFIs

(2) AWP Effectiveness



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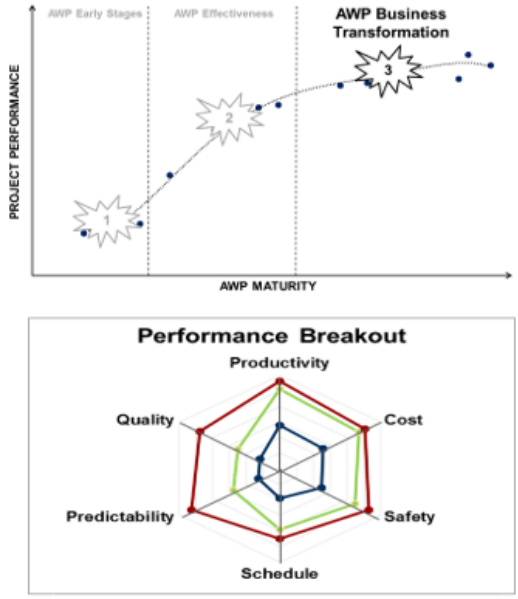
(3) AWP Business Transformation



Performance Dimension	Maturity Stage		
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Source: CII

Figure 2: Three stages of AWP Maturity Model showing KPIs

Predictability is a key performance parameter that requires not only efficient and well planned project execution but also a good quality control base estimate.

4.0 Estimating work process implementation for better predictability

Significant improvements have been demonstrated by successful implementations of AWP and derive from highly organized work processes which result in minimizing unproductive time. While that is at the core of efficient project implementation with improved productivity and minimized project cost, predictability has to do with estimating project quantities, cost, man-hours and other resources more precisely. Estimating work processes that will address these issues will be the absolute compliment to the AWP work process making it complete and thereby closing the gap on the key KPI of predictability. No matter how well the project is executed, its success will be judged by conformity to budget and time schedule.

TCM (Total Cost Management) Framework [4] and several Recommended Practices published by AACE® provide the framework necessary for producing a predictable estimate at various stages of the project, in the context of this paper a predictable class 3 estimate for funding approval. Prominent among them as applicable to process industries are:

- 18R-97, Cost Estimate Classification System – As Applied in Engineering, Procurement, and Construction for the Process Industries

- 21R-98, Project Code of Accounts – As Applied in Engineering, Procurement, and Construction for the Process Industries
- 28R-03, Developing Location Factors by Factoring – As Applied in Architecture, Engineering, Procurement, and Construction
- 31R-03, Reviewing, Validating, and Documenting the Estimate
- 34R-05, Basis of Estimate
- 36R-08, Development of Cost Estimate Plans – As Applied in Engineering, Procurement, and Construction for the Process Industries
- 73R-13, Establishing Labor Productivity Norms

TCM framework and recommended practices are comprehensive and no fundamental change is required in the estimating work processes; however, changes in implementation will be required for conformity with the overall project data integration. Narrative to follow in this paper will address the following aspects aimed at improving predictability:

1. Means of producing more complete MTOs closer to final quantities for class 3 estimate inputs
2. Making quantity reviews more effective and result oriented
3. Producing MTOs and estimate details by EWP/CWP to facilitate data integration with all other project software
4. Making greater use of several levels of coding as suggested in the RP-21R-98 [5] with the objective of providing much better control base data to project controls
5. Make use of the coding structure to provide objective review reports to various stakeholders enabling thorough reviews and buy-in
6. Make use of the coding structure to generate concise historical project completion reports and metrics for achieving higher levels of predictability in future projects

5.0 Coding structure

Optimal use of coding structure can drive most of the objectives listed above in achieving greater predictability.

Estimate planning and code of accounts

Estimate planning is the most crucial phase to secure alignment of stakeholders and project team members on the broader objectives of the estimate and what is expected as inputs to the estimate. It is not the intention of this narrative to make an exhaustive list of estimate planning criteria but the focus is on aspects relating to EWP/CWP in estimate planning. Inputs to estimating and completed estimate details need to include identifiers and codes in order to derive several different summarizations for superior planning and control. Most of such coding are indicated in the AACE Recommended Practice 21R-98 [5].

5.1 Different geographic groups or other categorization:

In addition to the WBS groups such as ISBL/OSBL, WBS area/unit, module/stick built scope, rack/off-rack/sleeper, module number, etc., identifiers for the work packages should be included in the MTOs:

1. Cost breakdown structure (CBS) – Labor, Sub-contract, Material, Module, Pipe spool fabrication, etc.
2. Construction work package (CWP) name as per documented procedure
3. Engineering work package (EWP) name as per documented procedure
4. Procurement request for quotation (RFQs) and contract numbers – based on procurement plan and contracting plan
5. Installation work package (IWP) name – later estimates when they become available
6. Isometric number – later estimates when they become available
7. Spool number – later estimates when they become available

5.2 Code of accounts:

Code of accounts typically include prime, sub-prime and detail codes; some code of accounts also incorporate cost type breakdown structure indicating material, labor, fabrication, sub-contract etc. Much more can be derived from the estimate by incorporating additional coding for labor activities and several other category groupings as in RP 21R-98 [5].

5.3 Labor activity codes:

Work type as referenced in 21R-98 [5] or labor activity codes can be very useful in summarizing specific labor operation quantities and man-hours for planning, monitoring and control purposes. It is possible to devise exhaustive list of coding for all labor activities in every prime account; however, to minimize effort early alignment on select labor activities identified for progress monitoring can be assigned with appropriate coding.

5.4 Contract number:

Recommended practice 21R-98 [5] suggests contract number, budget item or AFE number among others in the category group – “accounting and special”. Contract number in particular can be of extreme value if incorporated while creating estimate details. A construction work package (CWP) may include piling, concrete foundation, mechanical equipment, steel, piping, electrical and other accounts. Contracting plan may group different prime accounts to be installed by different contractors and may be installed at different time schedules. Hence, incorporating contract number in the estimate details will make it possible to derive labor operation quantity summary and budgeted man-hours by CWP for each contract. EPC schedule should provide planned start and finish dates for each CWP for each contract on which actual progress and man-hours can be plotted.

As the budgeted man-hours are derived from the approved estimate for each CWP within each contract, monitoring actuals against these would provide real insights on performance; real issues if any, will surface early giving more time for mitigation actions to be initiated. If the man-hours and quantities had been spread out in the schedule using an approximate s-curve distribution as is typically done, any performance issues or concerns will likely not become clear until much later.

Challenges estimators are likely to face are twofold; contracting plan may not be fully developed and contract numbers may not have been assigned in the class 3 estimate preparation time frame; secondly, MTOs are generally prepared at the WBS area level with most of the manual MTOs lumped at that level. These challenges can be overcome if sponsorship level commitment is secured for implementing AWP. On the former question of contracting plan, it will suffice to have a broad understanding of high level contracting plan using which placeholder contract numbers can be assigned and replaced with actual numbers when available. More difficult question is the latter to obtain complete MTOs down to the EWP/CWP level. Early alignment with engineering is needed to incorporate such requirement within their work process for creating manual MTOs and factored items at the EWP/CWP level. Authors of this paper have worked on mega projects with over 2000 CWPs where such work procedures were implements successfully, just to indicate that they are practical propositions.

6.0 Material take-offs – Predictable Quantities

Material take-offs should be carried out by EWP which will lay the foundation for rolling up material and labor quantities and man-hours at the required level for monitoring and control purposes. MTOs derived by downloading from the 3D model will naturally conform to the EWP and CWP boundaries as also the higher level WBS area/unit groups. However, when class 3 estimates are produced, the 3D models are typically at a 20% to 30% model review stage and hence cannot provide complete MTOs; much of the small bore piping and other items not modelled will need to be supplemented by manual take-offs. Conventional project execution typically aims at rolling up the estimates to WBS area levels and therefore manual MTO additions are done at that level. On projects implementing AWP work process, a greater effort to add manual MTOs at the EWP/CWP level would pay enormous dividends in superior planning and scheduling as also setting up a more accurate control base for monitoring progress.

Making quantity review process more objective and result oriented

Once the enhanced level of coding as described above has been incorporated, several quantity review reports can be generated in order to facilitate comparison of various metrics at different WBS levels and by different category grouping such as equipment module, pipe rack module, off-rack, sleeper, etc. Given the advent of several data visualization software, it is possible to create dashboards with interactive review reports that will enable drilldown to identify specific areas of deficiency; they can then be made up by supplementing with appropriate quantities instead of just throwing gross dollar allowances. Sample interactive reports for reviewing adequacy of small bore piping (Fig. 3) and one for review of large bore fittings (Fig. 4) are shown

below. Note: While the sample reports shown in this paper are for piping account, very similar approach for every other account will ensure production of more complete MTOs and better quality estimates.

SB Pipe Review by Area

Wbs1	LB_Pipe	SB_Pipe	SB Ratio
AREA1	322	221	41%
AREA2	9,458	10,780	53%
AREA3	18,429	8,965	33%
AREA4	11,121	5,045	31%
AREA5	2,300	383	14%
AREA6	8,094	165	2%
Grand Tot..	**49,725**	**25,559**	**34%**

SB Pipe review by Type of Piping

Std Type	LB_Pipe	SB_Pipe	SB Ratio
Equipment Module	13,895	10,245	42%
Offrack Stick Built	17,891	7,761	30%
Piperack Module	16,522	5,192	24%
Piperack Stick Built	1,218	129	10%
Sleeper Stick Built	198	2,233	92%
Grand Total	**49,725**	**25,559**	**34%**

SB Ratio Alert
- 40% and over
- Check - under 40%

Std Type
- (All)
- Equipment Module
- Offrack Stick Built
- Piperack Module
- Piperack Stick Built

Wbs1
- (All)
- AREA1
- AREA2
- AREA3
- AREA4

Wbs2
- (All)
- SUBAREA101
- SUBAREA102
- SUBAREA201
- SUBAREA202

Click here to try the interactive MTO review report on the web

Please note that quantities shown are for illustrative purposes and not from any real project.

Quantites in some areas are deliberately adjusted to highlight the objective nature of the review made possible by the visualization.

Figure 3: Making Quantity Reviews More Objective - Sample Interactive Report for Small Bore Piping Review

The example interactive report enables drilling down to identify deficiency of small bore piping in specific areas (WBS1), sub areas (WBS2) or CWPs and type of piping, equipment module, off-rack stick built, etc. by narrowing down the filters. The tables refresh to the selected filters and small bore ratios under 40% get flagged in orange to facilitate drilling down. The ratio alert threshold of 40% is only an example and can be set to appropriate value depending on anticipated ratios for the type of plant. Deficient areas identified can then be supplemented with quantum packets of small bore piping containing pipe, fittings, valves, insulation, heat tracing etc. within the module or stick built piping type.

Piping MTO Quantities summarized for review, mark-up deficiencies and supplementation

Quantity Summary by Item | Large Bore Fitting Frequency | Large Bore Valves Frequency | Small Bore Fittings Frequency | Small Bore Valves Frequency

LB Fitting Freq by Area

Wbs1	Pipe	Fittings	Fitting Frequency
AREA1	322	0	0
AREA2	9,458	4,375	46
AREA3	18,429	8,271	45
AREA4	11,121	1,006	9
AREA5	2,300	874	38
AREA6	8,094	725	9
Grand Tot..	**49,725**	**15,250**	**31**

LB Fitting Freq by Mod Stk

Std Type	Pipe	Fittings	Fitting Fre quency
Equipment Module	13,895	9,610	69
Offrack Stick Built	17,891	4,105	23
Piperack Module	16,522	1,325	8
Piperack Stick Built	1,218	167	14
Sleeper Stick Built	198	43	22
Grand Total	**49,725**	**15,250**	**31**

LB Fitting Freq by Dia Gr

Dia Gr	Pipe	Fittings	Fitting Frequency
3"-6"	33,505	10,212	30
8"-14"	10,798	3,668	34
16"-24"	3,550	917	26
26"-34"	244	140	57
36"-40"	380	83	22
42"-50"	947	136	14
>50"	301	94	31
Grand Tot..	**49,725**	**15,250**	**31**

LB Fitting Frequency ...
check<20per100m
over20per100m

Std Type
(All)
Equipment Module
Offrack Stick Built
Piperack Module
Piperack Stick Built
Sleeper Stick Built

Dia Gr
(All)
2"-2.5"
3"-6"
8"-14"
16"-24"
26"-34"
36"-40"
42"-50"
<2"

Notes for viewers: Click here to try the interactive MTO review report on the web

Please note that quantities shown are for illustrative purposes and not from any real project.

Quantites in some areas are deliberately adjusted to highlight the objective nature of the review made possible by the visualization.

Figure 4: Making Quantity Reviews More Objective - Sample Interactive Review Report for Large Bore Fittings Review

Figure 4 is an example interactive report for reviewing large bore fitting frequencies by drilling down during the quantity review session to identify areas of deficiency in a similar manner as described for figure 3. Similar interactive reports for review of large bore valves, small bore fittings, small bore valves, etc. can be navigated using the tabs the top of the report. Such objective reviews will help make the MTOs closer to final design quantities with the addition of appropriate MTO allowances.

MTO Allowances

MTO allowances are an integral part of the total base line budget quantities and should not be treated as a mere dollar allowance. Conventional work processes applying single percentage allowance per account results in incorrect quantity base; (e.g.) If a 20% allowance is applied across the board for piping, it may result in overstating quantities for large diameter piping as well as exotic material, etc. which would likely have been quantified more completely in the model; by the same token, small bore pipe, valves and fittings quantities may end up short, as 20% allowance may not be adequate.

It would make sense to apply a stratified allowances matrix reflecting the base MTOs by category using the several codes that have been incorporated per following example.

Stratified MTO Allowances

Stratefied MTO Allowances | Rationale for MTO Allowance

COA	Description	2"-2.5"	8"-14"	16"-24"	36"-40"	42"-50"	>50"
300400	Demolition	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
301401	CS, Pipe	25.0%	10.0%	5.0%	3.0%	3.0%	3.0%
301411	CS, Fittings	30.0%	15.0%	10.0%	8.0%	8.0%	8.0%
301421	CS, Valves	15.0%	5.0%	3.0%	1.0%	1.0%	1.0%
301431	CS, SP Items	25.0%	10.0%	5.0%	3.0%	3.0%	3.0%
301441	CS, Inst Inlines	15.0%	5.0%	3.0%	1.0%	1.0%	1.0%
302401	SS, Pipe	12.5%	5.0%	2.5%	1.5%	1.5%	1.5%
302411	SS, Fittings	15.0%	7.5%	5.0%	4.0%	4.0%	4.0%
302421	SS, Valves	7.5%	2.5%	1.5%	0.5%	0.5%	0.5%
302431	SS, SP Items	12.5%	5.0%	2.5%	1.5%	1.5%	1.5%
302441	SS, Inst Inlines	7.5%	2.5%	1.5%	0.5%	0.5%	0.5%
303401	High Alloy, Pipe	16.7%	6.7%	3.3%	2.0%	2.0%	2.0%
303411	High Alloy, Fittings	20.0%	10.0%	6.7%	5.3%	5.3%	5.3%
303421	High Alloy, Valves	10.0%	3.3%	2.0%	0.7%	0.7%	0.7%
303431	High Alloy, SP Items	16.7%	6.7%	3.3%	2.0%	2.0%	2.0%
303441	High Alloy, Inst Inlines	10.0%	3.3%	2.0%	0.7%	0.7%	0.7%

Figure 5: Example of Stratified MTO allowances Matrix for Closer Prediction of Quantities – Piping Account

Documented Rationale for MTO Allowances

It is important to document the rationale for the MTO allowances in the basis of estimate to secure buy-in from various stakeholders and management; it could also act as a deterrent against arbitrary reduction of MTO allowances as one has to assume responsibility for doing so against well documented rationale. An example of such documentation is shown in Figure 6 below:

Documented Rationale for MTO Allowances

Stratefied MTO Allowances	Rationale for MTO Allowance

Notes for Viewers:
The table provides a qualitative rationale for growth allowance considering extent of completeness of MTOs

S.No	Item	Low	Medium	High	Assessment for current project	
	Normal Design Development					
1	Engineering maturity at MTO cutoff	>30%	20% to 30%	< 15%	Medium	
2	MSD, P&ID and Layout changes / routing changes etc	IFC	Hazop / IFD	IFR	Medium	
3	Hazop changes incorporated in the MTOs or not?	Yes	Partial	No	Medium	
4	Vendor data impacts	Yes	Partial	No	Low	
5	Model Review basis for MTOs	>	30% MR	<	Medium	
6	Piping MTO Methodology:					
6.1	Down to what dia is completed in the model?	>	4" & above	<	High	
6.2	Detail manual take off for remaining lines on P&ID		Complete	<	Medium	
6.3	Items generally not shown on P&IDs					
6.3.1	Utility Stations	Detail MTOs	Typical model	Not included	Medium	
6.3.2	Seal Plans	Detail MTOs	Typical model	Not included	Medium	
6.3.3	Vents & Drains	Detail MTOs	Typical model	Not included	Medium	
6.3.4	Process Drains	Detail MTOs	Typical model	Not included	Medium	
	Steam Traps	Detail MTOs	Typical model	Not included	Medium	
6.3.5	Sample Stations	Detail MTOs	Typical model	Not included	Medium	
6.4	Stress Analysis Impacts					
6.4.1	Expansion Loops - Extent of completion in the model	Complete	Partial	Not done	High	
6.4.2	Special supports / spring hangers quantified?	Complete	Partial	No	High	
6.5	Drain headers and collection detailed?	Complete	Partial	Not done	Medium	
6.6	Piping Undergrounds detailed?					
6.6.1	Fire water system	Complete	Partial	Not done	Medium	
6.6.2	Storm water drain	Complete	Partial	Not done	Medium	
6.6.3	Process Drains	Complete	Partial	Not done	Medium	
6.6.4	Hydrocarbon Drains	Complete	Partial	Not done	Medium	
6.6.5	Cooling Water Mains	>	Complete	<	Medium	
6.6.6	Other	Complete	Partial	Not done	Medium	
6.6.8	UG line coating requirements defined?	>	Complete	<	Medium	
6.7	Fire suppresant - deluge / dry foam system MTOed?	Complete	Partial	Not done	Medium	
7	Instrument Valves bypass requirements detailed?	>	Complete	<	Medium	
8	Valving around PSVs - detailed?	>	Complete	<	Medium	
9	Cascade (waterfall) type piping to multi bay aircoolers - ..	>	Complete	<	Medium	
10	Process vents to be piped to higher elevations (if applic..	Complete	Partial	Not done	Medium	

Assessment for current project
High
Low
Medium

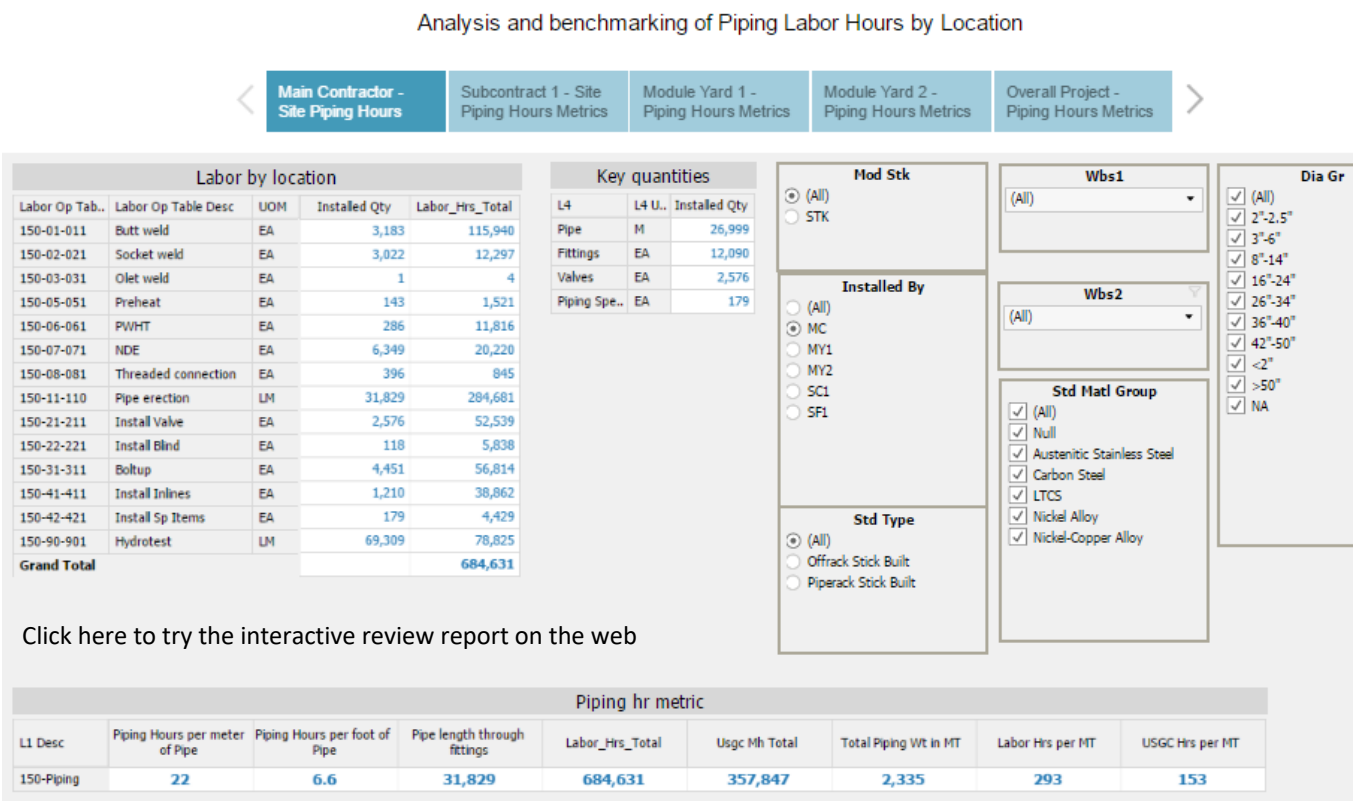
Figure 6: Example of Documented Rationale for MTO Allowances – Piping Account

The column "Assessment for current project" should be completed by responsible engineering and project personnel for each account depending on how each item has been quantified in the MTOs.

Implementing the work process as described above will pave the way for much closer quantity control base which will be the first step necessary for achieving predictability.

7.0 Interactive review reports for thorough review and benchmarking

Class 3 estimate reviews are often compressed due to delayed inputs and firm commitment of estimate completion date. In addition, other factors such as limitation of estimating tools/methods, lack of trust between owner & contractor, contracting philosophy, etc. may not be amenable for openness in sharing of estimate reports/data to facilitate thorough reviews. Predictability will depend much on how well the estimate basis have been set up with high level of stakeholder engagement as well as thorough review and benchmarking of the estimate. Putting aside the constraints of contracting philosophy and such issues, it is possible to produce very objective analysis reports by creating some standard dashboards as shown in the Figure 7 below:



Labor Op Tab..	Labor Op Table Desc	UOM	Installed Qty	Labor_Hrs_Total
150-01-011	Butt weld	EA	3,183	115,940
150-02-021	Socket weld	EA	3,022	12,297
150-03-031	Olet weld	EA	1	4
150-05-051	Preheat	EA	143	1,521
150-06-061	PWHT	EA	286	11,816
150-07-071	NDE	EA	6,349	20,220
150-08-081	Threaded connection	EA	396	845
150-11-110	Pipe erection	LM	31,829	284,681
150-21-211	Install Valve	EA	2,576	52,539
150-22-221	Install Blind	EA	118	5,838
150-31-311	Boltup	EA	4,451	56,814
150-41-411	Install Inlines	EA	1,210	38,862
150-42-421	Install Sp Items	EA	179	4,429
150-90-901	Hydrotest	LM	69,309	78,825
Grand Total				**684,631**

L4	L4 U..	Installed Qty
Pipe	M	26,999
Fittings	EA	12,090
Valves	EA	2,576
Piping Spe..	EA	179

L1 Desc	Piping Hours per meter of Pipe	Piping Hours per foot of Pipe	Pipe length through fittings	Labor_Hrs_Total	Usgc Mh Total	Total Piping Wt in MT	Labor Hrs per MT	USGC Hrs per MT
150-Piping	22	6.6	31,829	684,631	357,847	2,335	293	153

Note: Numbers shown in the example report are arbitrary and intended for illustration purposes only

Figure 7: Example of Interactive Report for Review of Site Labor Hours for Piping Account

The interactive report shown above refreshes to the selection of filters enabling drilling down the analysis report for site labor to check against benchmark metrics for the selection. It will enable efficient and objective scrutiny and identification of errors/oversight which can then be addressed, thereby improving quality, securing greater confidence and buy-in. Data visualization tools enable creating any such desired analysis reports and dashboards automatically by linking to underlying estimate details of different project estimates; that will

provide a means of comparing metrics from project to project and for benchmarking with industry in a very efficient manner.

Closer prediction of final quantities in the MTOs generated for the funding estimate combined with objective reviews leading to corrective actions as described above will lead to a superior quality budget estimate. AWP work process implementation has a very significant bearing on construction, particularly on projects of greater complexity. As mentioned earlier, gains of adapting the AWP work process appropriately has been well established and more and more companies are embracing it. Estimating will need to work in step with construction and project leadership in assessing productivity/location factors to use as basis in the estimate; by factoring in the prior performance and productivities and what is anticipated for the current project.
There are several more valuable inputs that estimating can provide to make project execution and controls more efficient in achieving greater predictability, which will be discussed in the following sections.

8.0 Significant benefits of adapting estimating work process aligned with AWP

While AWP can still be adapted for project execution without the more rigorous estimating work process, there are very significant gains to be realized by doing so as follows:

1. Labor operations quantities such as number of welds, length of spools to be installed, length of cable to be installed etc. can be summarized by contract and by CWP
2. Budgeted man-hours can be summarized by contract, by CWP and by prime account
3. Once the planned start and finish dates for each CWP within each contract is defined in the EPC schedule, corresponding budgeted man-hours from the estimate details are reflected in the EPC schedule; that makes arbitrary distribution of total man-hours using approximate s-curve distribution unnecessary
4. Resource loading the schedule with budgeted man-hours from the estimate integrates the schedule and aligns with the class 3 estimate, resulting in better planning
5. Performance monitoring of field labor, be it self-perform or contract, becomes more transparent; actual progress can be plotted against budgeted quantities and man-hours by contract and/or by CWP flagging any performance issues instantly; that provides greater opportunity to take mitigation action
6. The entire work process thus can lead to better planning and predictability

Estimating work process enhancements

Estimating needs to play a key role in aligning various stakeholders and project team members to the estimating work process that synchronizes with AWP. Following are some of the factors that have a significant impact on predictability:

- Significant quantity growths entail overruns in field labor hour budgets
- Starting off with a project plan based on short budget often results in need for corrective actions at a later stage which tend to be disorganized and disruptive

- Budget estimate details are generally at the WBS area level; hence the EPC schedule resource loading is normally based on typical spread of hours over the duration; it may not relate to actual work scope over the time span and therefore any significant trends of overruns or underruns may not become apparent until much later
- Overruns, delays and disruptions result in spiraling effect as they impact all subsequent activities
- Overruns necessarily require additional funding approval by the board and may involve potential delays in preparing necessary documentation and securing approvals

Most of the issues listed above will be addressed adequately if a good quality estimate is prepared and well implemented management of change process and trending process.

Management of Change

An estimate basis that documents the project scope well and produces MTOs at the EWP/CWP level should naturally provide a more robust basis for management of change. Predictability needs to tie-in to the actual scope by current budget or re-baselining when necessary. It is important however, to differentiate scope change from normal design development which is provided for in MTO allowances.

9.0 Valuable inputs for construction planning and scheduling

Given complete MTOs at the EWP/CWP level and the enhanced coding incorporated in the estimate details, some extremely valuable inputs can be provided to project controls during the front end engineering design phase for construction planning and scheduling. With appropriate automation of the estimating work process, estimating can provide labor operation quantities and estimated man-hours by EWP/CWP, by contract and by prime account to project controls in parallel with estimate production, for construction planning. That will enable integration of EPC schedule with the class 3 estimate which means the field man-power projections will reflect estimate details.

Planned start and finish dates assigned for each CWP can then be used to create labor operations quantities and budgeted man-hours charts on a time scale for control purposes as shown in Figure 8 below:

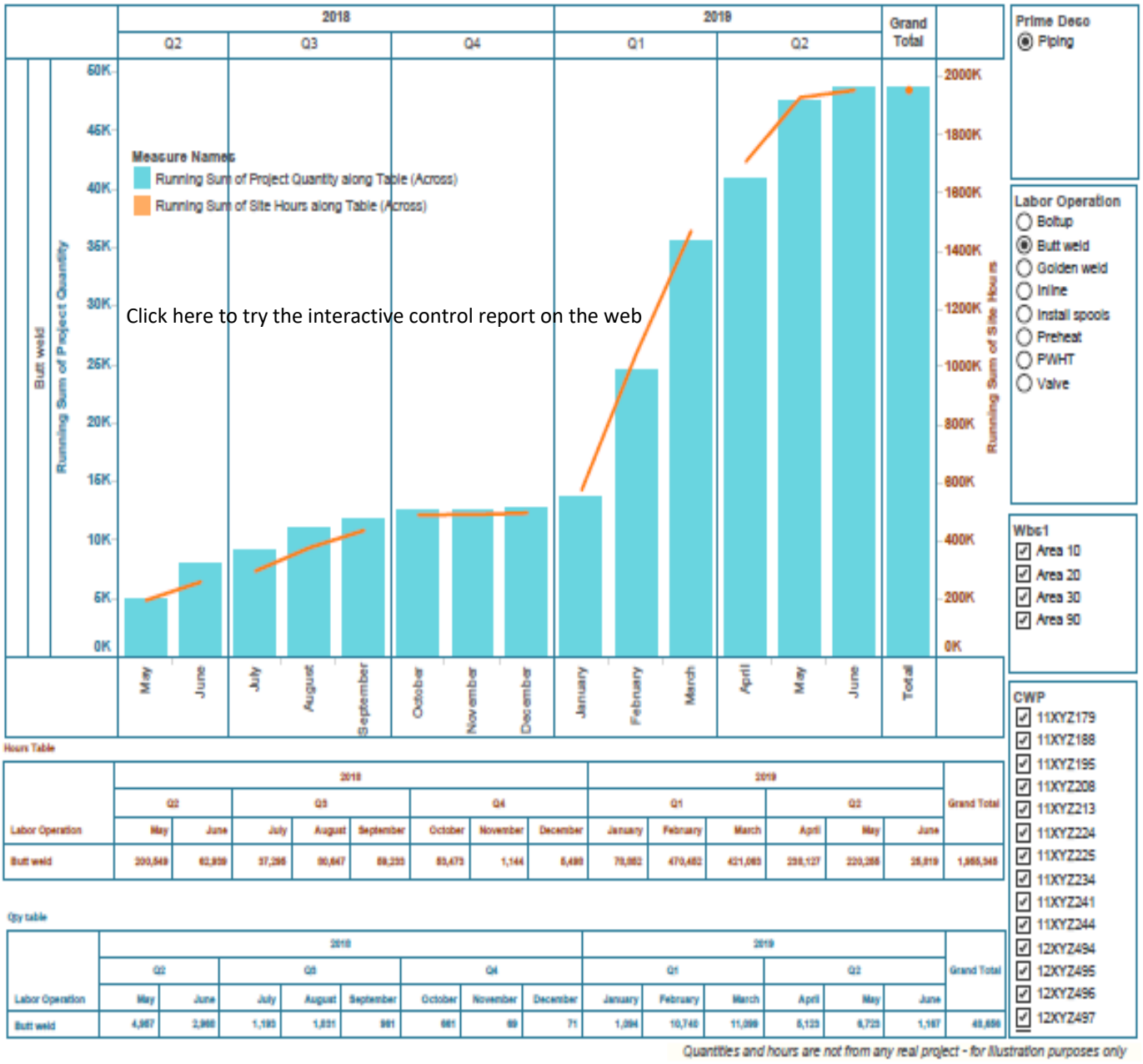


Figure 8: Example of Performance Tracking Reports that can be derived from the Enhanced Estimating Work Process

Performance tracking and trending

Performance tracking reports like the example shown above which reflect actual budget quantities and man-hours by CWP and by contract will bring to light any significant performance issues in the field very early as they occur. It will give an opportunity to the project leadership team to take mitigation actions before the issues get aggravated. This is one of the greatest gains of enhanced implementation of estimating work process as described in this paper.

Consistency in estimating work process

While such performance tracking reports will link trending to actual budget, there will be another set of man-hour data produced at the installation work package (IWP) level by the AWP resource allocation coordinator. Total quantities and estimated man-hours from the set of IWPs comprising of a CWP should align with the current budget numbers for the CWP; it is necessary therefore to adapt consistent estimating standards and productivity/location factors for the budget estimate as well as the IWP level estimates produced by the AWP team prior to construction, recognizing that there will be more of crew based estimates of man-hours in the latter case. Any disconnects between the current budget estimates and the IWP level estimates summed up to a higher level will need to be addressed by way of trending. It will not change the current budget but will provide useful inputs for better alignment of future estimates.

10.0 Other significant factors impacting predictability

While the narration so far deals with a more rigorous implementation of the estimating work process for closer prediction of quantities and construction labor man-hours, it is obvious that there are several other components of the estimate which will make up the published total approved budget bottom line. It is not the intention of this paper to discuss those cost components for producing a better overall budget. However, such other components are listed below for the sake of completeness and to remind ourselves that the unforgiving measure of predictability will be at the overall budget.

Other significant factors and components of the estimate comprising the overall budget:

1. Equipment and material pricing – target to obtain current market pricing for a minimum of 80% of budget value
2. Sub-contract pricing – Obtain current market pricing and benchmark against check estimate to validate and fix any errors and omissions
3. Sub-contract pricing –responsibility matrix for various components of indirect field cost (IFC) including supervision and construction management
4. Align on responsibility matrix for logistics and delivery basis
5. Indirect Field Costs
6. Miscellaneous field contracts and support third party engineering contracts
7. Camp and catering
8. Home office engineering costs
9. Spares
10. Vendor supervision
11. Mechanical completion and handover – interface
12. Commissioning support
13. Owners cost
14. Contingency
15. Forward escalation
16. Allowance for major event risk held at company corporate level

11.0 **Future work in development of tools for AWP for better predictability**

As discussed under the section "AWP implementation maturity and KPIs", labor resources required for each IWP is assessed by the resource coordinator and is disconnected from the approved budget estimate. This will likely be bridged with the refinement of automated estimating modules within 3D tools. As pointed out, the issue is completeness of MTOs in the 3D model which typically does not include manual MTOs and those that need to be factored. There are different ways by which the 3D models can be designed to provide complete MTO downloads at different stages of model development [6]. Greatest advantage of such development would be MTOs downloads will be relatively more complete and can be derived very efficiently in minimum amount of time. In addition, automated estimating algorithms built-in to the 3D tool will be in direct alignment with the class 3 estimate assuming such a level of maturity can be achieved in the future development of 3D tools. This will have a significant impact of increasing predictability assuming proper assessment of productivity/location factors.

12.0 Emerging technology and its impact on estimating

The modern database systems have evolved where handling of vast amounts of data or computational power/speed do not pose any significant limitations. The new generation of integrated 2D/3D systems provide ways and means of adding intelligence during the design stages that can be rule driven, logic based or volumetrically attributed to each and every element/component in the design.

Starting with the WBS, the EWP/CWP hierarchy all the way to the IWP level can be easily attributed in contemporary design systems now. Therefore, if the coding structure, numbering conventions and attribution requirements are set early on the project, populating such intelligence in the model can be easily done as the design is progressing. Model review sessions can now include additional analysis of reviewing engineering design to a quantity base; contracted scopes by contract numbers, EWP/CWP can now be reviewed visually in 3D.

An estimator need not rely on only the flat tables and data structures; if models carry the intelligence then the estimate i.e. the modelled quantity can be viewed in 3D as well. As suggested in earlier sections, stratified allowances for individual areas can be captured with more precision than that accomplished traditionally.

New systems that integrate 3D design, materials, scheduling and work packaging can now provide greater levels of insight early in to the project. The opportunity exists where by adding the control estimate at the EWP/CWP levels in such integrated platforms can provide precise baseline to measure and give visibility to the project health on a continual basis of the "Plan versus Actuals".

13.0 Conclusion

Predictability of cost and schedule are among the most important KPIs that project success will be measured on. AWP provides a structured work process to increase project performance and many owner and EPC companies have adapted it as their standard work process. Predictability however, continues to be somewhat an elusive goal. Estimating work process implementation suggested in this paper will enhance predictability by addressing the following:

1. Facilitate production of more complete MTOs by detail estimate planning
2. Interactive quantity review reports to identify areas of deficiency to supplement with quantities
3. Stratified MTO allowances and documented rationale to support the extent of allowances applied
4. Production of MTOs by EWP and CWP in addition to project WBS areas
5. Applying much enhanced coding including for labor operation activity, contract ID, procurement responsibility, etc.
6. Interactive review reports by account to foster thorough review and buy-in by various stakeholders
7. Provide estimated man-hours by CWP and by Contract and prime account to project controls to enable integration with EPC schedule
8. Facilitate construction planning and scheduling at the CWP level
9. Detail scoping of indirect field cost and other costs including owner's costs
10. Proper assessment of contingency and forward escalation

AWP will provide a structured framework for data centric execution facilitating integration of various software systems used on the project. Estimating work process in step with the AWP framework will enhance predictability substantially.

14.0 References

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2) Research Topic 319, Making the Case for AWP as a Standard (Best Practice) by the Construction Industry Institute (CII)

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4) AACE - Total Cost Management Framework Section III. Project Control Process Chapter 7 - Project Control Planning, 7.3 Cost Estimating and Budgeting

5) AACE Recommended Practice 21R-98, Project Code of Accounts – As Applied in Engineering, Procurement, and Construction for the Process Industries

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