Developing a Standardized Multidimensional WBS for Storage Tank Rebottoming Projects[1,2]

Abdullah Arief Su'aidy

ABSTRACT

Storage tank rebottoming projects are repetitive yet complex maintenance activities that require consistent scope definition, cost estimation, and project governance. However, current practices often lack standardized Work Breakdown Structures (WBS) and Bill of Quantity (BoQ) templates, leading to inconsistencies and limited cost comparability. This study aims to develop a standardized multidimensional WBS, integrate OmniClass classification into the WBS to standardize BoQ templates, and establish a WBS–OBS integration model to improve project governance. A Multi-Attribute Decision Making (MADM) approach using the Weighted Sum Model (WSM) was applied to evaluate four WBS alternatives. The results indicate that the OmniClass-based multidimensional WBS is the most effective, enabling standardized BoQ development using the US National Park Service (NPS) Class A template and improving accountability through WBS–OBS integration.

Keywords: *Work Breakdown Structure, Storage Tank Rebottoming, Multidimensional WBS, OmniClass, Project Scope Management, Maintenance Projects*

INTRODUCTION

1. Industry Context and Strategic Importance of Storage Tank Integrity

Fuel storage tanks constitute critical infrastructure within the downstream petroleum supply chain and play a key role in ensuring reliable fuel distribution and national energy security. Maintaining the structural integrity of these facilities is essential to prevent environmental incidents, operational disruptions, and financial losses caused by leakage or structural failure. API 653 states, "periodic inspection, repair, and maintenance

[1] How to cite this paper: Su'aidy, A.A. (2026). Developing a Standardized Integrated WBS for Storage Tank Rebottoming Projects (A Case Study); *PM World Journal*, Vol. XIV, Issue VII, July.
[2] This paper was originally prepared during a 6-month long Graduate-Level Competency Development/Capacity Building Program developed by PT Mitrata Citragraha and led by Dr. Paul D. Giammalvo to prepare candidates for AACE CCP or other Certifications. https://build-project-management-competency.com/our-faqs/

activities are fundamental elements of asset integrity management programs for aboveground storage tanks".[3]

In the downstream operations of the Indonesian national oil company, storage tank maintenance activities account for a significant share of operational projects. Maintenance records from the Central Java regional operations indicate that deterioration of tank bottom plates is among the most frequently encountered repair cases.

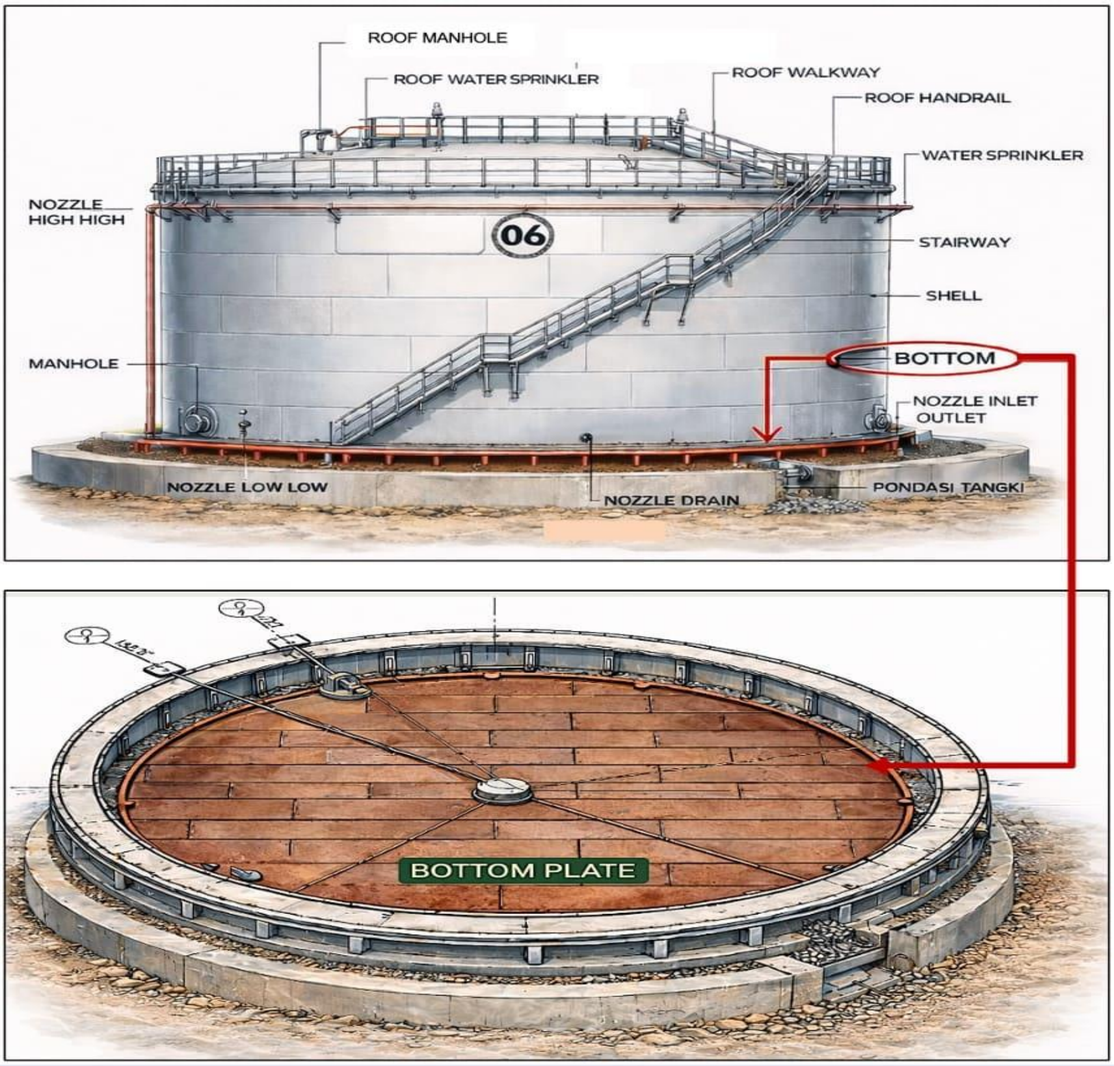

Figure 1 - Typical Structural Components of an Aboveground Storage Tank [4]

Figure 1 illustrates the principal structural components of a typical aboveground storage tank, including the roof structure, shell plates, bottom plate, nozzles, and safety

[3] American Petroleum Institute. (2014). API standard 653: Tank inspection, repair, alteration, and reconstruction. API Publishing.
[4] By Author.

equipment. In accordance with API 653, "Understanding these structural elements is important when evaluating maintenance activities such as tank rebottoming".[5]

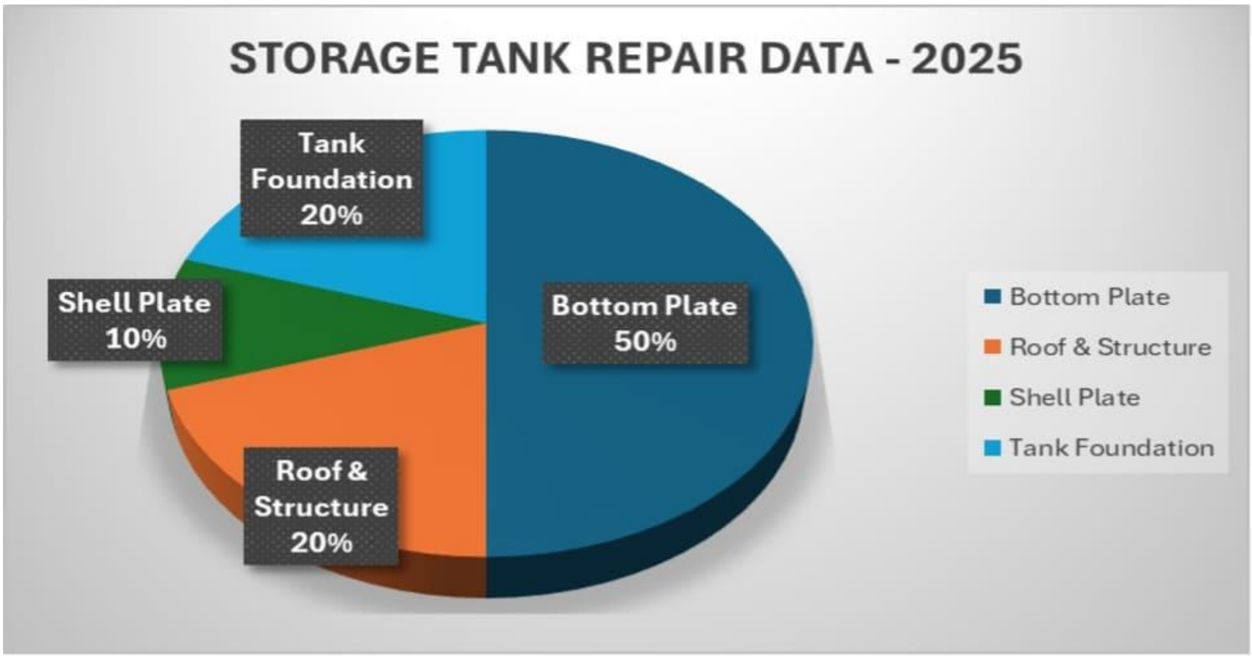

Figure 2 – Storage Tank Repair Data at RPD JBT 2025[6]

Based on repair data compiled by the Reliability Project and Development Department of Indonesia Oil and Gas Company, three of five documented tank maintenance projects required complete replacement of the bottom plate. These results indicate that tank rebottoming projects represent not only recurring maintenance activities but also technically complex engineering interventions that require structured planning and scope definition.

In addition to the asset's age, environmental factors play a substantial role in driving the corrosion mechanisms that impact the durability of tank bottom plates. According to Revie and Uhlig, "corrosion is defined as: the deterioration of a material because of a reaction with its environment".[7] High humidity, coastal atmospheric exposure, soil chemistry, and microbiologically influenced corrosion (MIC) accelerate the deterioration of steel structures and significantly reduce the service life of tank bottoms. These conditions

[5] American Petroleum Institute. (2014). *API standard 653: Tank inspection, repair, alteration, and reconstruction*. API Publishing.
[6] Indonesia Oil and Gas Company. (2025). *Storage tank repair data: Reliability Project and Development Department (RPD JBT)*. Internal report.
[7] Revie, R., & Uhlig, H. (2008). *Corrosion and Corrosion Control* (4th ed.). Wiley.

increase the likelihood that similar rebottoming projects will recur during future maintenance cycles.[8,9]

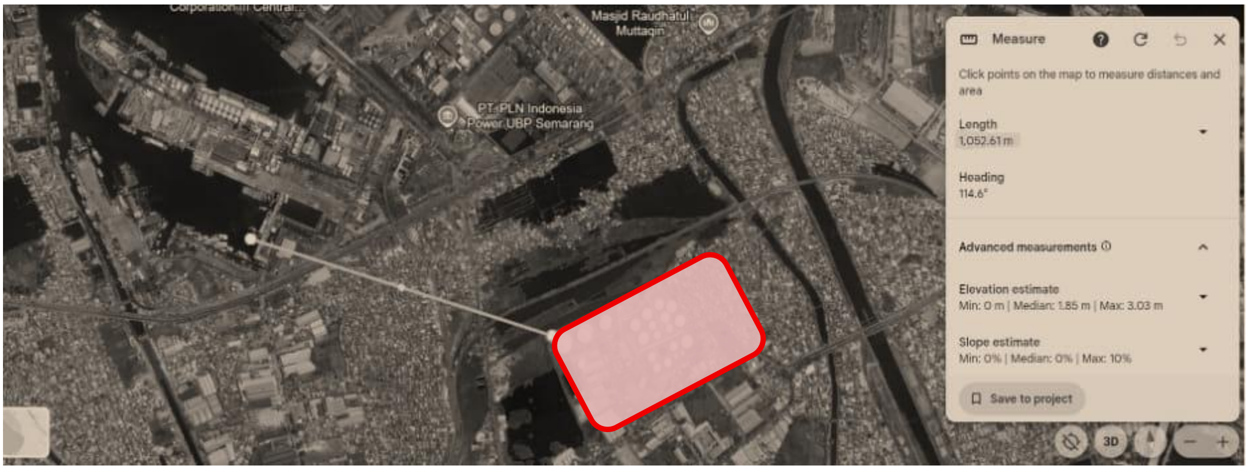

Figure 3 - Aerial view of the fuel terminal facility, illustrating its proximity to coastal environmental stressors.

Consequently, these environmental stressors require a more structured, standardised approach to maintenance project management.

The Work Breakdown Structure (WBS) is widely recognized as an effective method for organizing project scope. NASA states, that "WBS is a hierarchical decomposition of the total scope of work to be carried out by the project team."[10] This structure enables project teams to establish traceability between scope definition, cost estimation, scheduling, and project performance monitoring.

Given the importance of WBS for the success of the project, the next section discusses why storage tank rebottoming is considered a complex engineering intervention requiring such a meticulous planning framework.

2. Complexity of Storage Tank Rebottoming Projects

Storage tank rebottoming projects encompass many engineering and construction activities in addition to routine maintenance work. Typical duties include tank cleaning, internal inspection, removal of deteriorated bottom plates, inspection and repair of foundation, installation of new plates, welding operations, non-destructive testing,

[8] International Organization for Standardization. (2014). *ISO 55000: Asset management — Overview, principles and terminology*. ISO.
[9] Elsyca NV. (2022). *Corrosion protection for storage tanks*. https://www.elsyca.com/protect/storage-tanks
[10] National Aeronautics and Space Administration. (2007). *NASA work breakdown structure handbook*. NASA.

application of coating and recommissioning of the storage tank. The activities are subject to the strict engineering and safety standards applicable to petroleum storage facilities.[11]

Figure 4 - Storage Tank Rebottoming Work[12]

Rebottoming projects are multidisciplinary in nature requiring coordination between mechanical engineers, inspection specialists, welding technicians, coating experts and safety personnel. According to Revie and Uhlig, "Many tasks must also be conducted in confined spaces where flammable vapors may be present, introducing additional operational risks."[13]

[11] American Petroleum Institute. (2014). *API standard 653: Tank inspection, repair, alteration, and reconstruction*. API Publishing.
[12] By Author
[13] Revie, R., & Uhlig, H. (2008). *Corrosion and Corrosion Control* (4th ed.). Wiley.

Yet another challenge is posed by the hidden defects that are discovered during internal tank inspections. The defects could be foundation settlement, greater-than-expected corrosion damage or structural deterioration previously undetected. As analyzed by Mobin, "Such uncertainties frequently lead to scope changes during project execution."[14]

Current field practices show that although storage tank rebottoming projects are highly technically complex and repetitive, they are still defined by inconsistent and non-standardized Bills of Quantities (BoQ). This inconsistency directly prevents consistent cost comparisons, subverts benchmarking and makes it hard to control scope effectively. This leads to an inefficient process of estimation, a higher risk of variation orders and little opportunity to use knowledge from previous projects. These conditions point out some fundamental deficiencies in scope definition practices, which need a systematic and standard work breakdown structure (WBS) approach to ensure consistency, traceability and comparability in managing project scope and cost.

3. Standardized Work Breakdown Structure (WBS) for Rebottoming Project

As defined by Humphreys, "A multidimensional Work Breakdown Structure extends the traditional WBS by integrating several perspectives, including physical components, work processes, lifecycle phases, and cost categories. This approach enables project teams to analyze project scope from multiple viewpoints while improving integration between engineering planning and project control systems."[15]

[14] Mobin, M., Malik, A., Al-Fozan, S., & Al-Muaili, F. (2019). undefined. *Handbook of Case Histories in Failure Analysis*, 96-100. https://doi.org/10.31399/asm.fach.v03.c9001765
[15] Humphreys, K. (2011). *Project and cost engineers' handbook*. CRC Press.

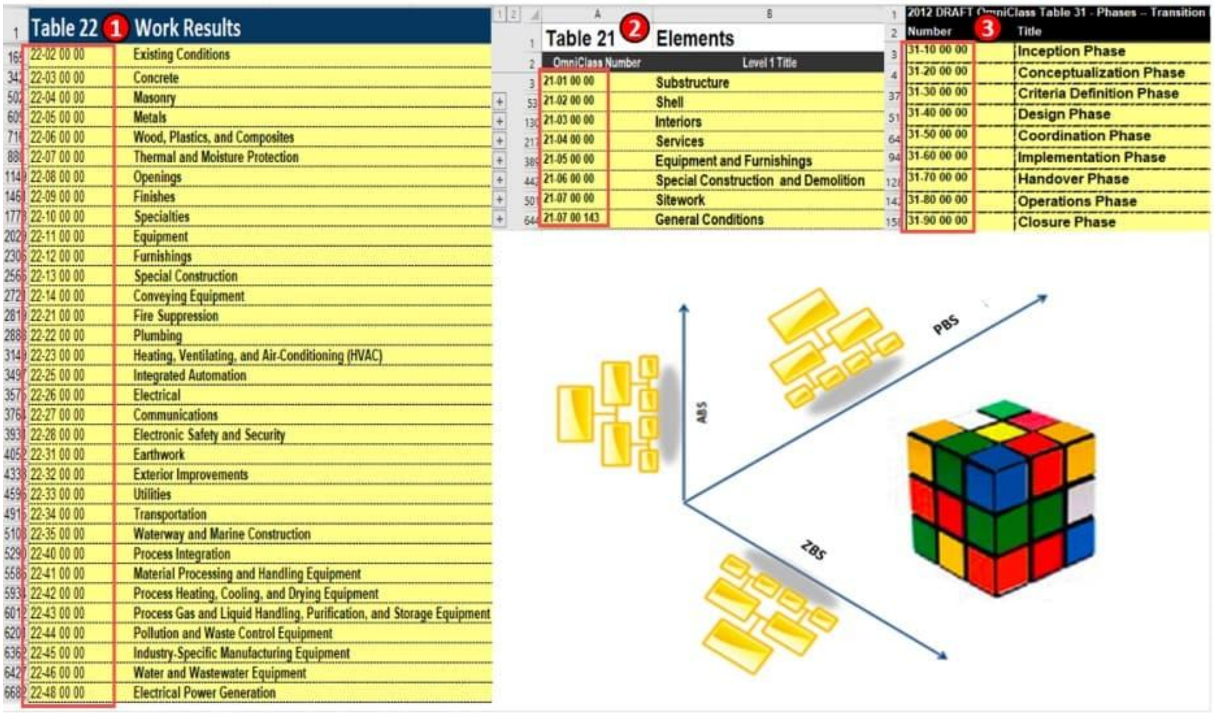

Figure 5 - Three Most Common Omniclass Tables used in Construction by both Owners and Contractors[16]

To support scope standardization and data consistency, classification systems such as the OmniClass Construction Classification System can be integrated into the WBS framework. OmniClass provides standardized coding structures for organizing construction information, work results, and project components.[17]

[16] *1.4.1.4 unit 4- Managing scope*. (2024). PTMC. https://build-project-management-competency.com/1-4-1-4-unit-4 Giammalvo, P. D. (2024). *Managing scope (Unit 4)*. PT Mitrata Citragraha. https://build-project-management-competency.com/1-4-1-4-unit-4/

[17] Construction Specifications Institute. (2019). *OmniClass construction classification system*. https://www.csiresources.org/standards/omniclass

4. Integration of WBS and Organizational Breakdown Structure

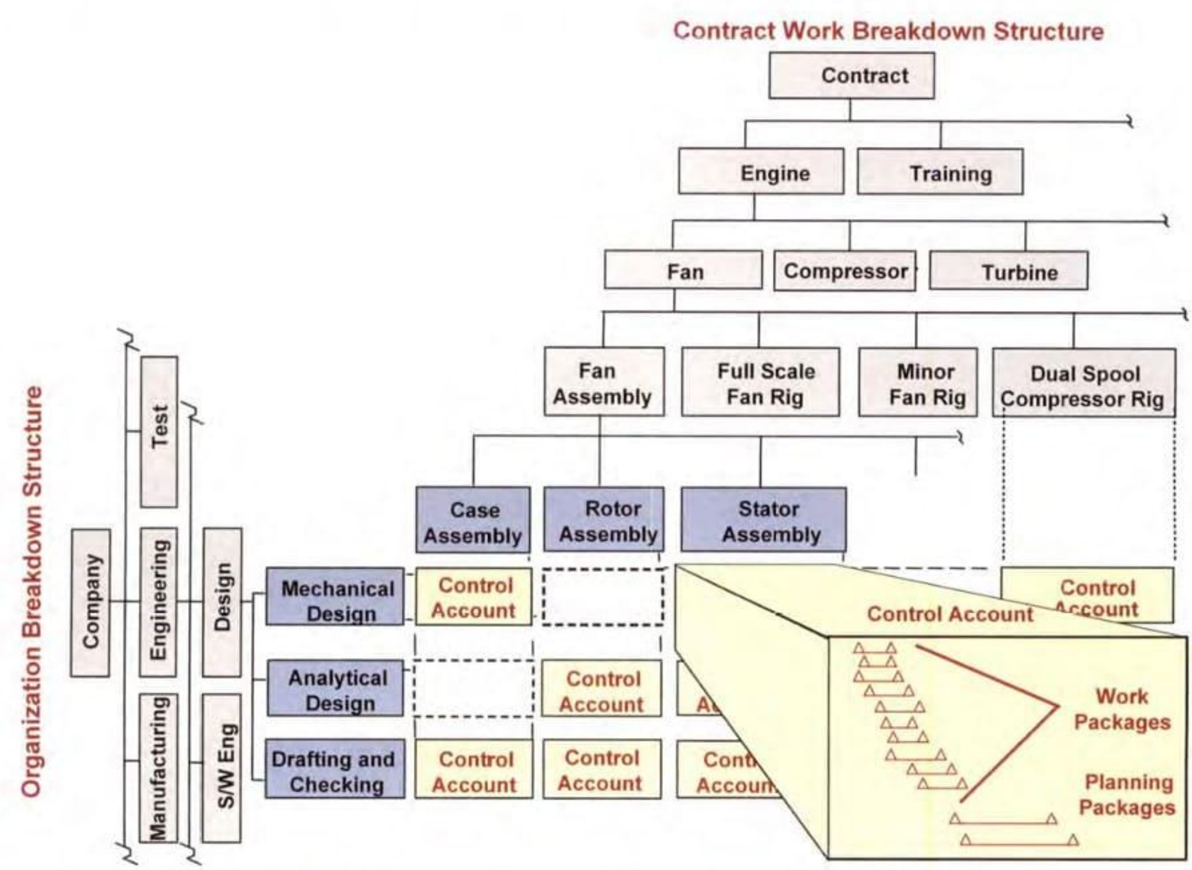

Figure 6 - Responsibility Assignment Matrix and Control Account Structure[18]

From the figure above, as noted by Humphrey, "establishing the control account at the proper level of detail is an important factor in the success or failure of any project management control System. Control accounts are created at the intersection of the WBS and OBS".[19]

[18] Humphreys, G. C. (2018). *Project management using earned value* (4th ed., Chapter 4: Relating Organizations, Responsibility, and Work Scope). Humphreys & Associates.
[19] Humphreys, G. C. (2018). *Project management using earned value* (4th ed.). Humphreys & Associates.

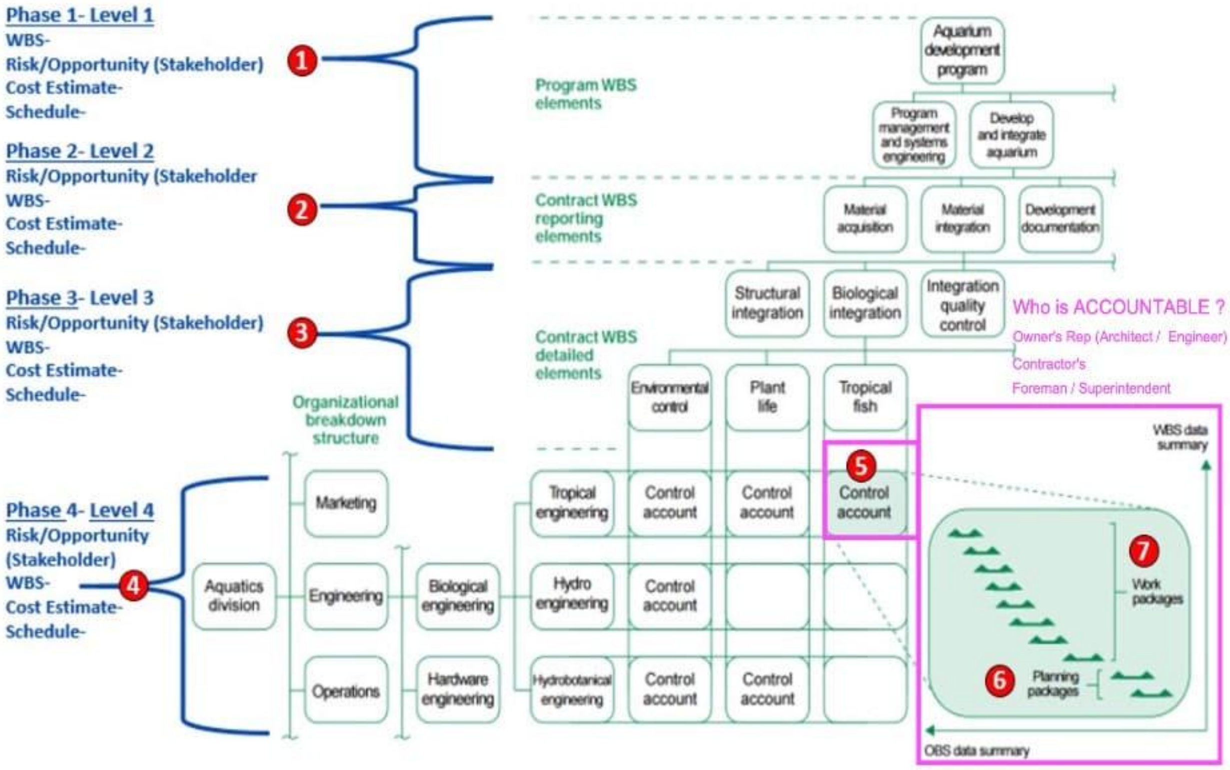

Figure 7 - Matrix Relationship between the WBS and OBS showing: Control Accounts, Work Packages, and Planning Packages[20]

The Work Breakdown Structure is not only useful for organizing the project scope but also provides a basis for defining project governance when combined with an Organizational Breakdown Structure (OBS). Fleming and Koppelman emphasize that "This integration enables the development of a Responsibility Assignment Matrix (RAM) that clearly identifies accountability for each work package within the project structure."[21]

This concept aligns with the principle of "centralized control and decentralized execution."[22] This principle emphasizes maintaining centralized strategic oversight while allowing operational units to execute tasks within clearly defined responsibilities.

[20] Giammalvo, P. D., & PTMC. (2021, October 14). *1.4.1.4 Unit 4- Managing scope*. https://build-project-management-competency.com/1-4-1-4-unit-4/ .
[21] Fleming, Q. W., & Koppelman, J. M. (2016). *Earned value project management* (4th ed.). Project Management Institute.
[22] Shamir, E. (2014). Peeling the onion: Why centralized control / decentralized execution works. *Air & Space Power Journal.*

5. Research Questions

While Work Breakdown Structures are common in project management practice, there has been little research on the development of standardized multidimensional WBS frameworks for storage tank rebottoming projects. NASA states, "Existing WBS guidelines primarily address large capital construction projects and may not fully consider the characteristics of recurring industrial maintenance activities."[23]

				Turbine Generator Equipment							
				Condensing System							
Organization Breakdown Structure			Work Breakdown Structure	Condenser Connections	Condenser					Vacuum System	Tube Cleaning System
					Waterboxes	Transitions necks	Tubes	Hotwells	Tube Sheets		
General Contractor	General Superintendent	Boiler Supt.	Supt. Boiler		X	X	X	X	X		
			Supt. Coal fdg		X	X	X	X	X		
			Supt. Ash hdlg		X	X	X	X	X		
			Supt. Fire prot.		X	X	X	X	X		
		Cooling System Supt.	Supt. Piping		X	X	X	X	X		
			Supt. Condenser		X	X	X	X	X		
			Supervisor Cooling Towers		X	X	X	X	X		

Figure 8 - Control Account Example : Integrated WBS and OBS[24]

Figure 8 "illustrates how a control account may be established in the WBS and OBS structure at very low level."[25] This approach ensures that even minor activities in the storage tank rebottoming project are systematically tracked.

A standardized implementation of multidimensional WBS directly addresses the common inefficiencies of the bidding process. The WBS provides a detailed and consistent breakdown of activities, which is the basis for an accurate Bill of Quantities (BoQ). This reduces ambiguity of scope and the risk of future Variation Orders (VO). The use of OmniClass codes helps to ensure that contractors are using a standard nomenclature when submitting bids, allowing for an apples-to-apples comparison of costs and

[23] National Aeronautics and Space Administration. (2007). *NASA work breakdown structure handbook*. NASA.
[24] Humphreys, G. C. (2018). *Project management using earned value* (4th ed., Chapter 4: Relating Organizations, Responsibility, and Work Scope). Humphreys & Associates.
[25] Humphreys, G. C. (2018). *Project management using earned value* (4th ed.). Humphreys & Associates.

improving the accuracy of bid evaluations. In the end, this efficient process turns the tender document from an unstructured list of tasks into a robust project control system that aligns the contractor's technical performance with the owner's cost and schedule objectives.

This research, therefore, seeks to answer the following questions:

• How can a standardized multidimensional WBS be developed for storage tank rebottoming projects?

• How can OmniClass classification codes be integrated into the WBS framework to standardize Bill of Quantity templates?

• What is the appropriate WBS-OBS integration model to improve project governance for tank rebottoming projects?

METHODOLOGY

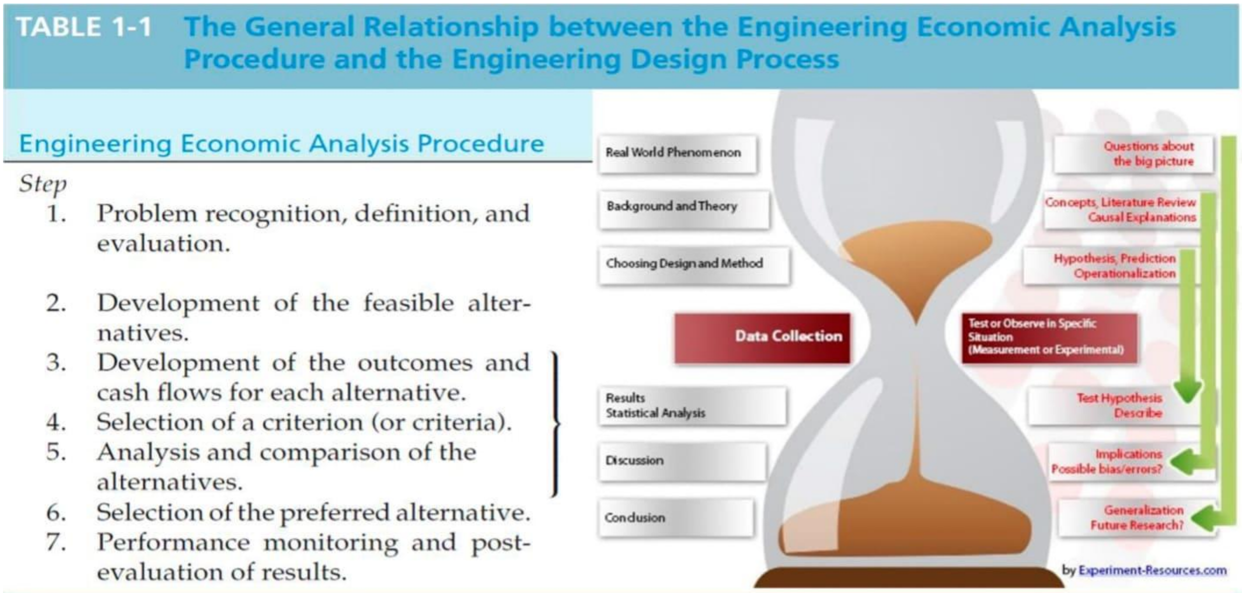

TABLE 1-1 The General Relationship between the Engineering Economic Analysis Procedure and the Engineering Design Process

Engineering Economic Analysis Procedure

Step
1. Problem recognition, definition, and evaluation.
2. Development of the feasible alternatives.
3. Development of the outcomes and cash flows for each alternative.
4. Selection of a criterion (or criteria).
5. Analysis and comparison of the alternatives.
6. Selection of the preferred alternative.
7. Performance monitoring and post-evaluation of results.

Figure 9 - Engineering Economic Analysis Procedure[26] & Step of the Scientific Process[27]

[26] Sullivan, W. G., Wicks, E. M., & Koelling, C. P. (2020). Chapter 2 Cost Concepts and Design Economics. In Engineering Economy Global Edition (17th ed.). Pearson UK.
[27] Shuttleworth, M. (2008, February 2). What is research? https://explorable.com/what-is-research

Step 1 - Problem Definition

The problem addressed in this research is the lack of a standardized, integrated framework for defining project scope in storage tank rebottoming projects.

In current practice, Work Breakdown Structures (WBS) are typically developed on a project-by-project basis, leading to inconsistent structures across similar projects. This lack of standardization leads to non-uniform Bill of Quantity (BoQ) formats, making it difficult to ensure consistency, comparability, and traceability of cost information.

Bill of Quantity/BoQ
Project Title
Revision ... Date ....

No	Work Detail	Volume	Units	Unit Price		Total Price	
				Material	Services	Material	Services
I.	PREPARATION WORK						
1	Mobilitation and Demobilitation	xxx	xx	0	$	0	$
2	Permit & Engineering	xxx	ls	0	$	0	$
3	....	xxx	ls	0	$	0	$
	Total I					0	$
II	CIVIL WORK						
1	Conrete	xxx	xx	$	$	$	$
2	....	xxx	xx	$	$	$	$
	Total II					$	$
III	MECHANICAL						
1	Piping	xxx	xx	$	$	$	$
2	....	xxx	xx	$	$	$	$
	Total II					$	$
IV	CLOSING						
1	Commissioning & Testing	xxx	xx	0	$	0	$
2	....	xxx	xx	0	$	0	$
	Total IV					$	$
		SUM OF MATERIAL + SERVICES (I+II+III+IV)				$	$
		CONTRACTOR PROFIT AND RISK (8% OR 10% OR 15%)					$
		TOTAL					$

Figure 10 - Bill of Quantity (BoQ) Template Currently Applied within the Indonesian Oil Company[28]

This condition has a significant impact. An inconsistent definition of scope reduces the reliability of cost estimation, limits the benchmarking between projects and increases the risk of scope changes during execution. This in turn affects the project performance in terms of cost overrun, schedule delays and less control over project outcomes.

[28] Ardiansyah. (2017). Indonesian State-Owned Oil and Gas Company Cost Estimating against GAO and NPS Best Practice: A benchmarking study. [Review of Indonesian State-Owned Oil and Gas Company Cost Estimating against GAO and NPS Best Practice: A benchmarking study. PM World Journal, VI(XI), 24–44. https://pmworldlibrary.net/wp-content/uploads/2017/11/pmwj64-Nov2017-Ardiansyah-indonesian-cost-estimating-against-gao-and-nps-best-practices.pdf.

This issue is especially critical in storage tank rebottoming projects, which are recurring maintenance activities of the asset lifecycle. As illustrated in Figure 11, early-stage decisions have the strongest influence on project outcomes, while the cost of changes increases significantly as the project progresses[29]. Therefore, deficiencies in scope definition at the early stage create long-term impacts that are difficult to mitigate.

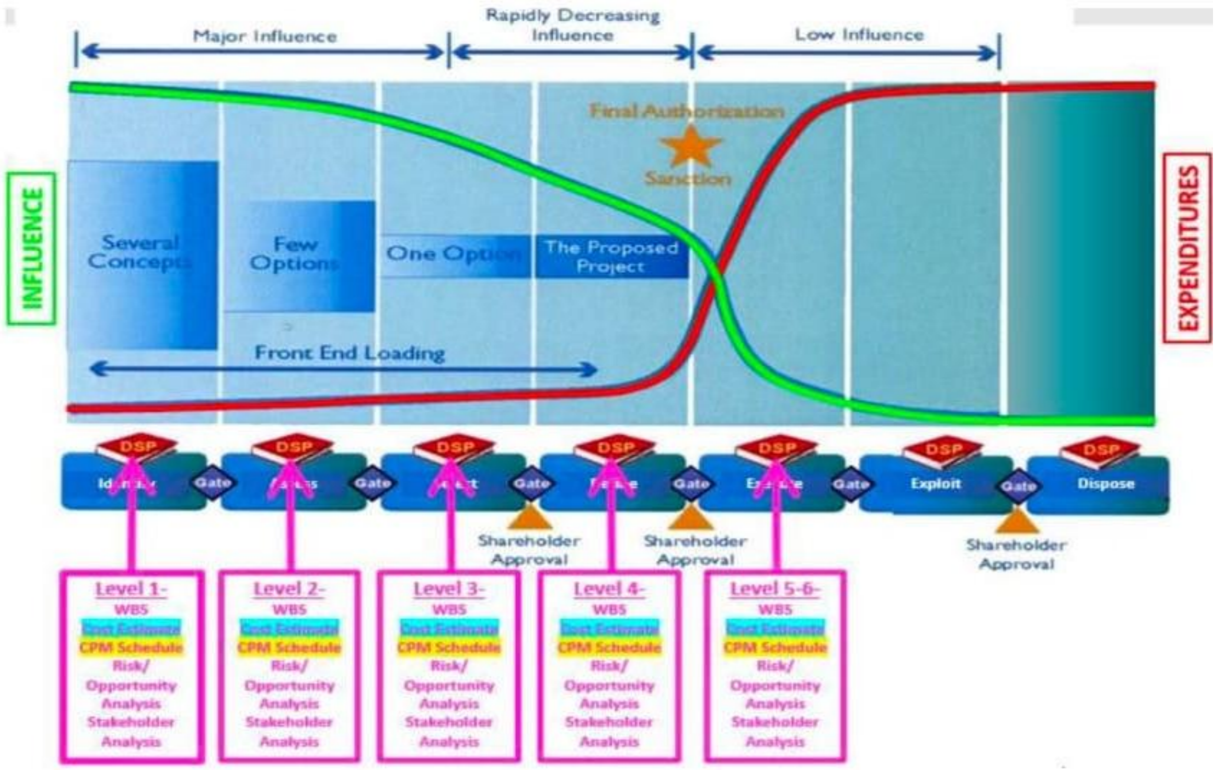

Figure 11 - Decision Support Package (DSP) and Project Influence Curve[30]

To address these limitations, a structured approach is required to develop a framework that ensures consistency, standardization, and integration in defining project scope. Specifically, this research aims to develop:

1. A standardized multidimensional WBS structure,
2. A WBS framework integrated with BoQ standardization,
3. A WBS–OBS integration model to improve project governance.

[29] Giammalvo, P. D. (2021). The Bigger Picture: Project Life Cycles from a Broader, Real-World Perspective. PM World Journal, 10(6).
[30] Ibid.

Step 2 - Identification of Feasible WBS Alternatives

To address the problem identified in Step 1, several feasible alternatives are considered for structuring the Work Breakdown Structure (WBS) in storage tank rebottoming projects.

As noted by Rashid (2016), "the WBS serves as a framework for defining project work elements and organizing cost and management information."[31] This highlights the importance of selecting an appropriate structure to ensure effective project execution and control.

Four alternatives are identified:

- **Alternative 1 – Conventional Single-Dimensional WBS**

  A single-dimensional hierarchical structure based on activities or cost elements.

  As described by Humphreys, "a WBS decomposes project scope into manageable components".[32] However, when developed on a project-specific basis, it lacks standardization and integration.

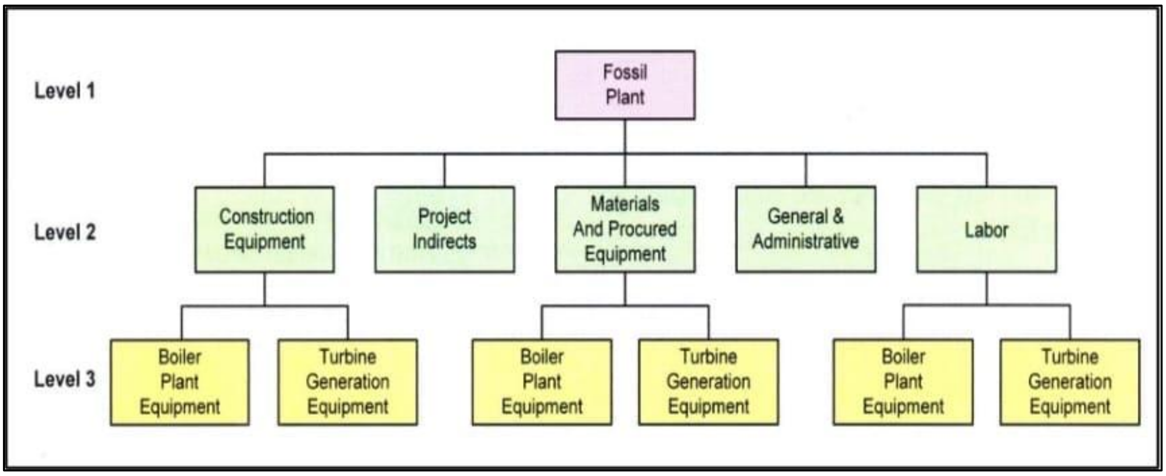

Figure 12 - Example of a Cost-Oriented Single-Dimensional WBS Illustrating Fragmentation of Scope Elements[33]

[31] Rashid, M. E. (2016). The Influence of Non-Standard Work Breakdown Structure on Change Orders and Cost Estimation for Sudan Oil and Gas Projects. *PM World Journal, 5*(12).
[32] Humphreys, K. K. (Ed.). (2005). *Project and cost engineers' handbook* (4th ed.). CRC Press.
[33] Ibid.

- **Alternative 2 – Multidimensional WBS with Standardized ISO 19008:2016**

  The second alternative is a standardized cost coding system to structure the WBS, ISO 19008:2016. The framework is based on three complementary aspects: Physical Breakdown Structure (PBS), Standard Activity Breakdown (SAB) and Code of Resources (COR) to give a consistent method for classifying physical scope, activity components and resource-related cost information[34]. This alternative provides a better cost coding control and a higher degree of standardization than the conventional single dimensional WBS. However, it is still mainly used for oil and gas facilities and may not be as flexible as for more extensive multidimensional classification needs.

- **Alternative 3 – Multidimensional WBS with Standardized Omniclass Construction Classification System (OCCS)**

  A multidimensional classification system consisting of 15 independent tables.[35]

  As noted by Giammalvo, "There is no rigid hierarchy between the tables, allowing flexible classification across multiple dimensions."[36] This enables consistent and flexible representation of project scope.

[34] International Organization for Standardization. (2016). *Standard cost coding system for oil and gas production and processing facilities (ISO Standard No. 19008)* (1st ed.).
[35] Omniclass. (2020). *About Omniclass™*. Construction Specifications Institute. https://www.csiresources.org/standards/omniclass/standards-omniclass-about
[36] Giammalvo, P. D., & PTMC. (2021, October 14). *1.4.1.4 Unit 4- Managing scope*. https://build-project-management-competency.com/1-4-1-4-unit-4/ .

OmniClass™ Table		Description
Table 11	Construction Entities by Function	Construction Entities by Function are significant, definable units of the built environment comprised of elements and interrelated spaces and characterized by function.
Table 12	Construction Entities by Form	Construction Entities by Form are significant, definable units of the built environment comprised of elements and interrelated spaces and characterized by form.
Table 13	Spaces by Function	Spaces by Function are basic units of the built environment delineated by physical or abstract boundaries and characterized by function.
Table 14	Spaces by Form	Spaces by Form are basic units of the built environment delineated by physical or abstract boundaries and characterized by physical form.
Table 21	Elements	An Element is a major component, assembly, or "construction entity part which, in itself or in combination with other parts, fulfills a predominating function of the construction entity"
Table 22	Work Results	Work Results are construction results achieved in the production stage or phase or by subsequent alteration, maintenance, or demolition processes 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 work which is the result.
Table 23	Products	Products are components or assemblies of components for permanent incorporation into construction entities.
Table 31	Phases	For purposes of usage in OmniClass™ classifications, a Stage is a higher-level of categorization and a Phase is a subordinate level of titling within a Stage. - Stage: A categorization of the principal segments of a project. Stages usually are: 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.
Table 32	Services	Services are the activities, processes and procedures relating to the design, construction, maintenance, renovation, demolition, commissioning, decommissioning, and all other functions occurring in relation to the life cycle of a construction entity.
Table 33	Disciplines	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.
Table 34	Organizational Roles	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.
Table 35	Tools	Tools are the resources used to develop the design and construction of a project that do not become a permanent part of the facility
Table 36	Information	Information is data referenced and utilized during the process of creating and sustaining the built environment.
Table 41	Materials	Materials are substances used in construction or to manufacture products and other items used in construction.
Table 49	Properties	Properties are measurable or definable characteristics of construction entities.

Table 1 - The 15 interrelated OmniClass tables with their explanation [37]

- **Alternative 4 – Integrated WBS–OBS Framework**

  Integration of WBS with Organizational Breakdown Structure (OBS) to form a Responsibility Assignment Matrix (RAM), improving governance and accountability.[38]

[37] Omniclass. (2020). *About Omniclass™*. Construction Specifications Institute. https://www.csiresources.org/standards/omniclass/standards-omniclass-about.
[38] Humphreys, G. C. (2018). *Project management using earned value* (4th ed.). Humphreys & Associates.

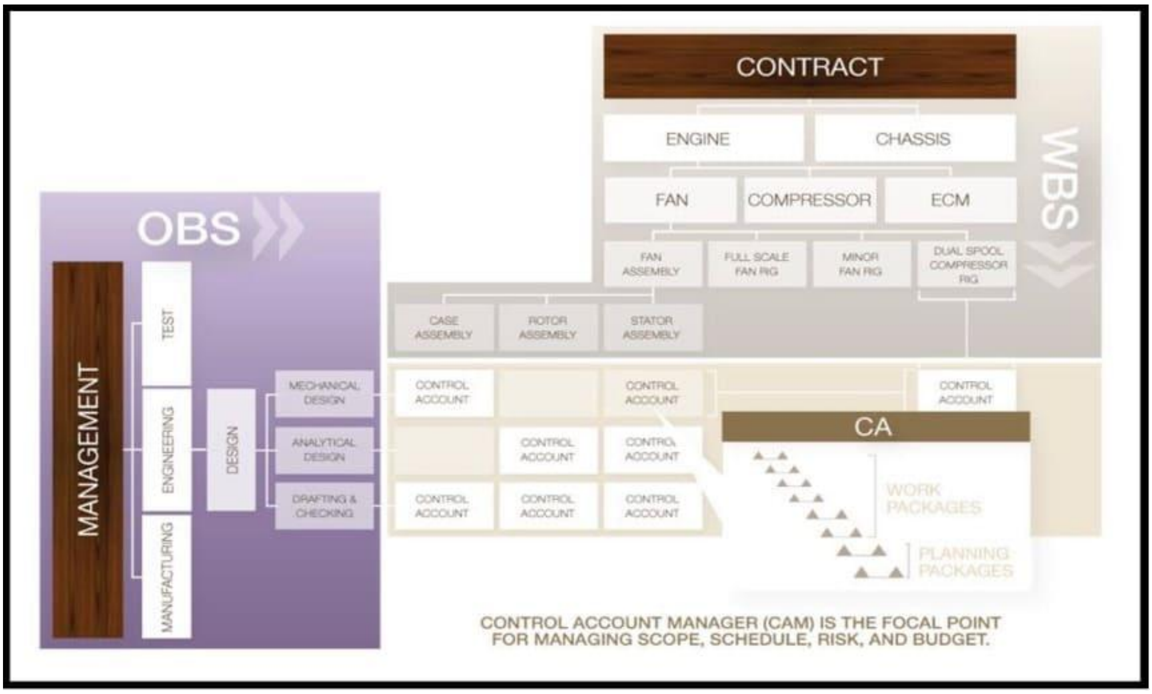

Figure 13 - Example of WBS–OBS Integration through Responsibility Assignment Matrix (RAM)[39]

Step 3 - Initial Evaluation of WBS Alternatives Using MADM

A preliminary evaluation is conducted using a Multi-Attribute Decision Making (MADM) approach. As defined by Ilbahar et al., "MADM is a procedure for evaluating and selecting the best alternative based on multiple attributes"[40].

A qualitative scoring scale is used:

Score	Interpretation
1	Very Low
2	Low
3	Moderate
4	High
5	Very High

Table 2 - Qualitative Scoring Scale for MADM Evaluation[41]

[39] Six, T. (2023, January 30). *The earned value management (EVM) building blocks*. Ten Six. https://tensix.com/the-earned-value-management-evm-building-blocks /
[40] Ilbahar, E., Cebi, S., & Kahraman, C. (2019). A state-of-the-art review on multi-attribute renewable energy decision making. *Energy Strategy Reviews*, 25, 18-33. https://doi.org/10.1016/j.esr.2019.04.014
[41] By Author

The preliminary scoring is based on expert judgment supported by established decision-making principles in engineering economics and multi-criteria analysis, "where qualitative assessments are commonly used to evaluate alternatives under multiple attributes."[42] "In the context of cost engineering, such evaluations are further supported by practical experience and domain knowledge, particularly when quantitative data is limited."[43]

Criteria	Evaluation Indicators	A1 Conventional	A2 Multidimensional ISO 19008	A3 Multidimensional OmniClass	A4 WBS–OBS
C1 Standardization	Code uniformity, repeatability, template consistency	1	4	5	3
C2 Multidimensional	Physical, phase, process/resource, lifecycle, deliverable hierarchy	1	3	5	3
C3 Data Integration	Traceability, interoperability, cross-project reuse	1	3	5	3
C4 Cost & BoQ Alignment	Quantity mapping, bid consistency, estimate reliability, measurable work packages	2	4	5	3
C5 OBS Compatibility	Responsibility mapping, control account structure	1	3	4	5
C6 Vertical Integration	Hierarchical cost roll-up capability	1	4	5	3
C7 Data Architecture Compatibility	Suitability for RDB (tabular) and OODB (object-based) systems	1	3	5	3

Table 3 - Preliminary MADM Screening Matrix for WBS Alternatives Based on Evaluation Indicators[44]

Preliminary screening suggests that the alternatives differ most in their potential to support standardization, multidimensional scope representation and integration with organizational structures. Conventional WBS is limited by its single-dimensional nature, ISO 19008 offers stronger standardization but remains domain-specific, OmniClass provides the most flexible multidimensional classification structure, and WBS–OBS integration is most effective when built on a standardized WBS foundation.

Step 4 - Selection of Evaluation Criteria

Following the preliminary assessment conducted in Step 3, the next step involves the formal selection of evaluation criteria to support a structured and objective comparison of the identified WBS alternatives.

Based on the results in Tabel 3, five evaluation criteria are defined as follows:

[42] Triantaphyllou, E. (2000). *Multi-criteria decision making methods: A comparative study*. Springer.
[43] Humphreys, K. K. (Ed.). (2005). *Project and cost engineers' handbook* (4th ed.). CRC Press.
[44] By Author

Criteria	Description
C1 – Standardization	Ensures consistency and repeatability of WBS structures
C2 – Multidimensional Capability	Ability to represent multiple dimensions of scope
C3 – Data Integration	Consistency and interoperability of project data
C4 – Cost & BoQ Support	Support for cost estimation and BoQ development
C5 – OBS Compatibility	Aligns WBS elements with organizational structures
C6 – Vertical Integration	Ability to support hierarchical roll-up of cost and productivity data
C7 – Data Architecture Compatibility	Compatibility with both Relational Databases (RDB) and Object-Oriented Databases (OODB)

Table 4 - Evaluation Criteria for MADM Analysis of WBS Alternatives[45]

The criteria selected together define the basic functional and structural needs for a successful WBS framework for storage tank rebottoming projects.

By formalizing these criteria, the evaluation moves from a qualitative observation (Step 3) to a structured and measurable framework, allowing for objective comparisons of alternatives in the subsequent analysis.

These criteria will serve as the basis for weighting and quantitative evaluation in the next step using an MADM approach.

FINDING

Step 5 - MADM Analysis Using Weighted Sum Model

The Weighted Sum Model (WSM) is used to quantitatively evaluate the WBS alternatives based on the criteria defined in Step 4.

"WSM is widely used in engineering decision-making due to its simplicity and effectiveness in handling multi-attribute problems."[46,47,48]

[45] By Author
[46] Sullivan, W. G., Wicks, E. M., & Koelling, C. P. (2020). Engineering Economy (17th ed.). Pearson.
[47] Triantaphyllou, E. (2000). *Multi-criteria decision making: A comparative study*. Springer.
[48] Tzeng, G. H., & Huang, J. J. (2011). *Multiple attribute decision making: Methods and applications*. CRC Press

$$S_i = \sum_{j=1}^{n} w_j x_{ij}$$

Where:

- S_i = total score of alternative i
- w_j = weight of criterion j
- x_{ij} = performance score of alternative i on criterion j

The weights are assigned according to the relative importance of each criterion in supporting effective WBS implementation.

Criteria	Weight
C1 – Standardization	0,143
C2 – Multidimensional Capability	0,143
C3 – Data Integration	0,143
C4 – Cost & BoQ Support	0,143
C5 – OBS Compatibility	0,143
C6 – Vertical Integration	0,143
C7 – Data Architecture Compatibility	0,143
Total	**1,00**

Table 5 - Criteria Weights for MADM Evaluation of WBS Alternatives[49]

Since seven evaluation criteria are used in this study, equal weighting is applied to each criterion. Therefore, each criterion is assigned a weight of 1/7 = 0.142857, which is rounded to 0.143 for practical calculation purposes.

[49] By Author

Alternative	C1	C2	C3	C4	C5	C6	C7
A1 – Conventional	1	1	1	2	1	1	1
A2 – ISO 19008	4	3	3	4	3	4	3
A3 – OmniClass	5	5	5	5	4	5	5
A4 – WBS–OBS	3	3	3	3	5	3	3

Table 6 - Quantitative Scoring Matrix of WBS Alternatives for Multi-Attribute Decision Analysis[50]

Rank	Alternative	Score
1	**A3 – OmniClass**	**4,86**
2	A2 – ISO 19008	3,43
3	A4 – WBS–OBS	3,29
4	A1 – Conventional	1,14

Table 7 - Ranking Results of WBS Alternatives Using the WSM[51]

The results of the analysis show that the OmniClass-based WBS (A3) is the highest-ranked alternative and performs better on most of the criteria. The WBS–OBS integration approach (A4) shows better relevance due to its close alignment with the organizational structures, but its effectiveness is dependent on the robustness of the underlying WBS framework. Therefore, the results confirm that a multidimensional OmniClass-based WBS, integrated with OBS, provides the most comprehensive approach for storage tank rebottoming projects.

Step 6 - Standardizing WBS using CSI Omniclass Coding Structure

In accordance with Table 7, a multidimensional WBS for the storage tank rebottoming project was developed by integrating several CSI OmniClass Tables, specifically Tables

[50] By Author
[51] Ibid

11[52], Table 31[53], Table 21[54], Table 22[55], Table 32[56], Table 23[57]. The coding results are shown in Appendix 1[58].

By utilizing the coding structure for the storage tank rebottoming project from the National Oil & Gas Company, shown in Appendix 1, a Work Breakdown Structure (WBS) was developed based on the CSI OmniClass Tables :

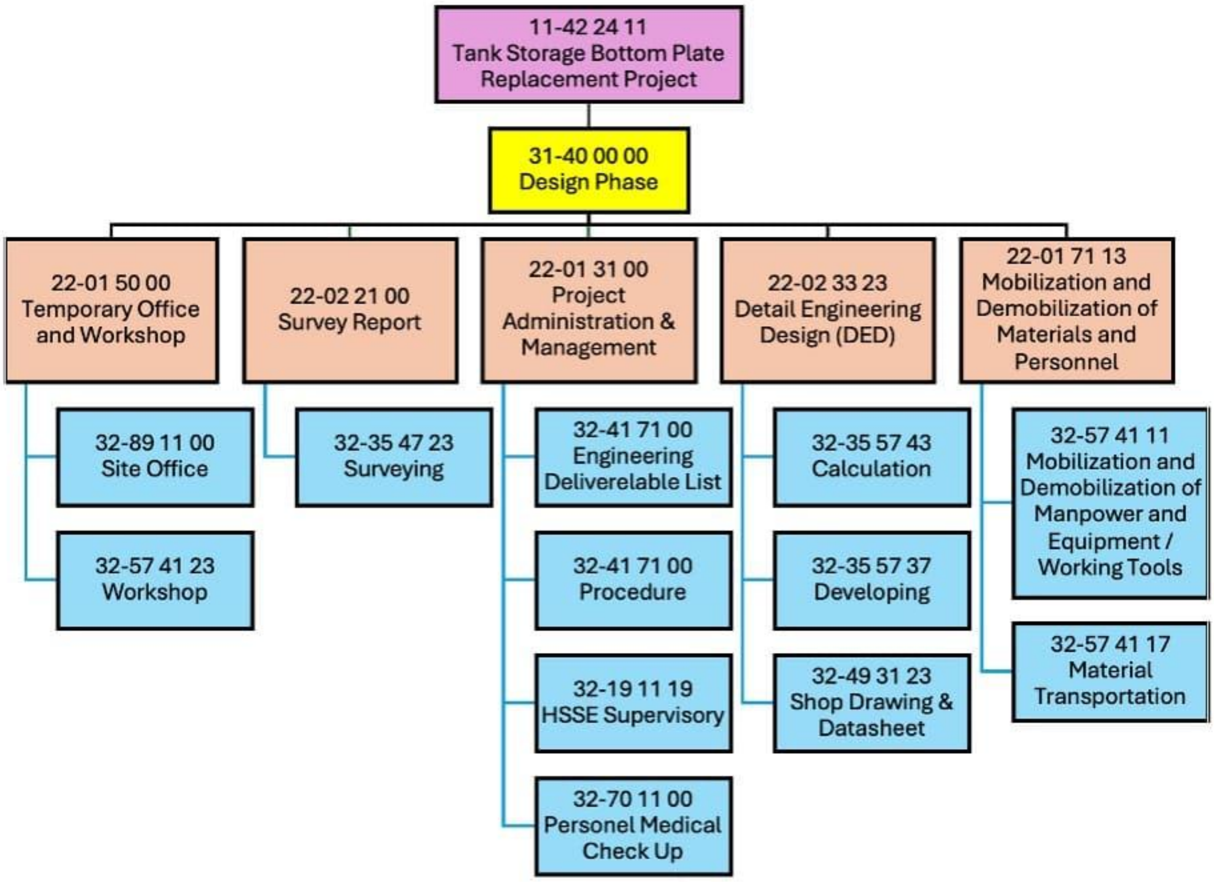

Figure 14.A - Multidimensional WBS for Storage Tank Rebottoming Project

---

[52] OmniClass. (2020). Construction Entities by Function - Table 11. https://www.csiresources.org/standards/omniclass
[53] OmniClass. (2020). Phases - Table 31. https://www.csiresources.org/standards/omniclass
[54] OmniClass. (2020). Elements (includes Designed Elements) - Table 21. https://www.csiresources.org/standards/omniclass
[55] OmniClass. (2020). Work Results - Table 22. https://www.csiresources.org/standards/omniclass
[56] OmniClass. (2020). Services - Table 32. https://www.csiresources.org/standards/omniclass
[57] OmniClass. (2020). Products - Table 23. https://www.csiresources.org/standards/omniclass
[58] This paper includes APPENDICES that will demonstrate how to IMPLEMENT what this paper recommends. For anyone who needs or wants the APPENDICES, email me < abdullah.aace.2026@gmail.com > and the author will email you with the full paper with the APPENDICES.

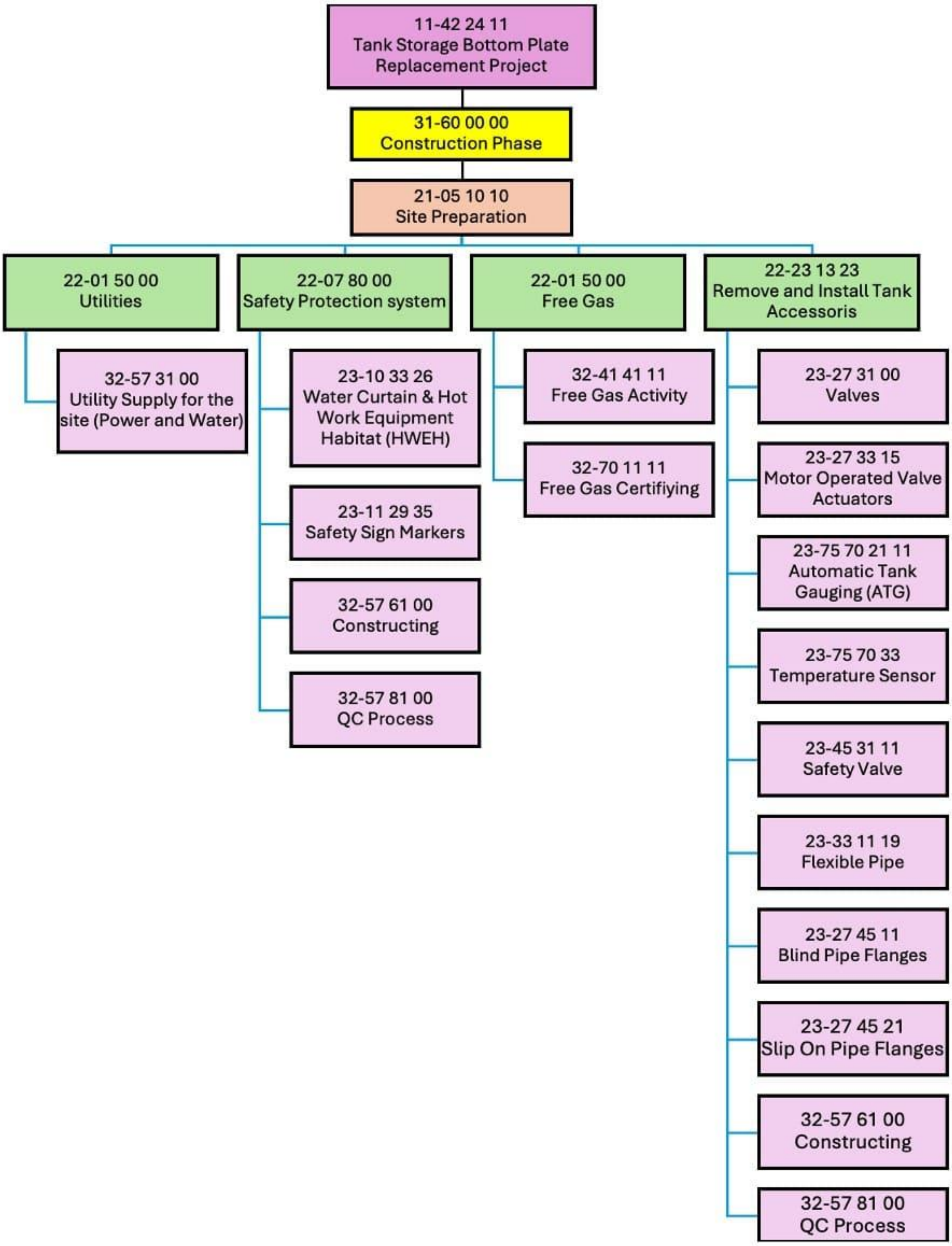

Figure 15.B - Multidimensional WBS for Storage Tank Rebottoming Project

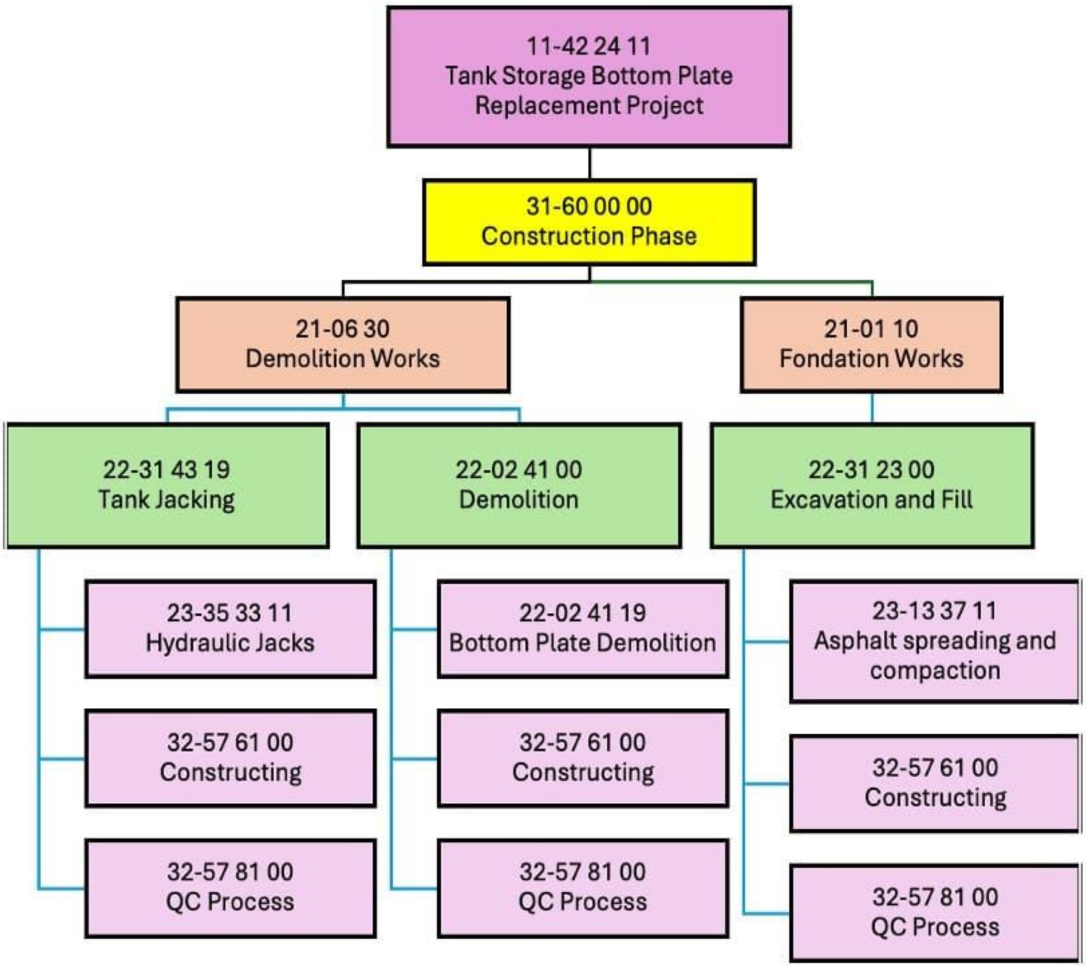

Figure 16.C - Multidimensional WBS for Storage Tank Rebottoming Project

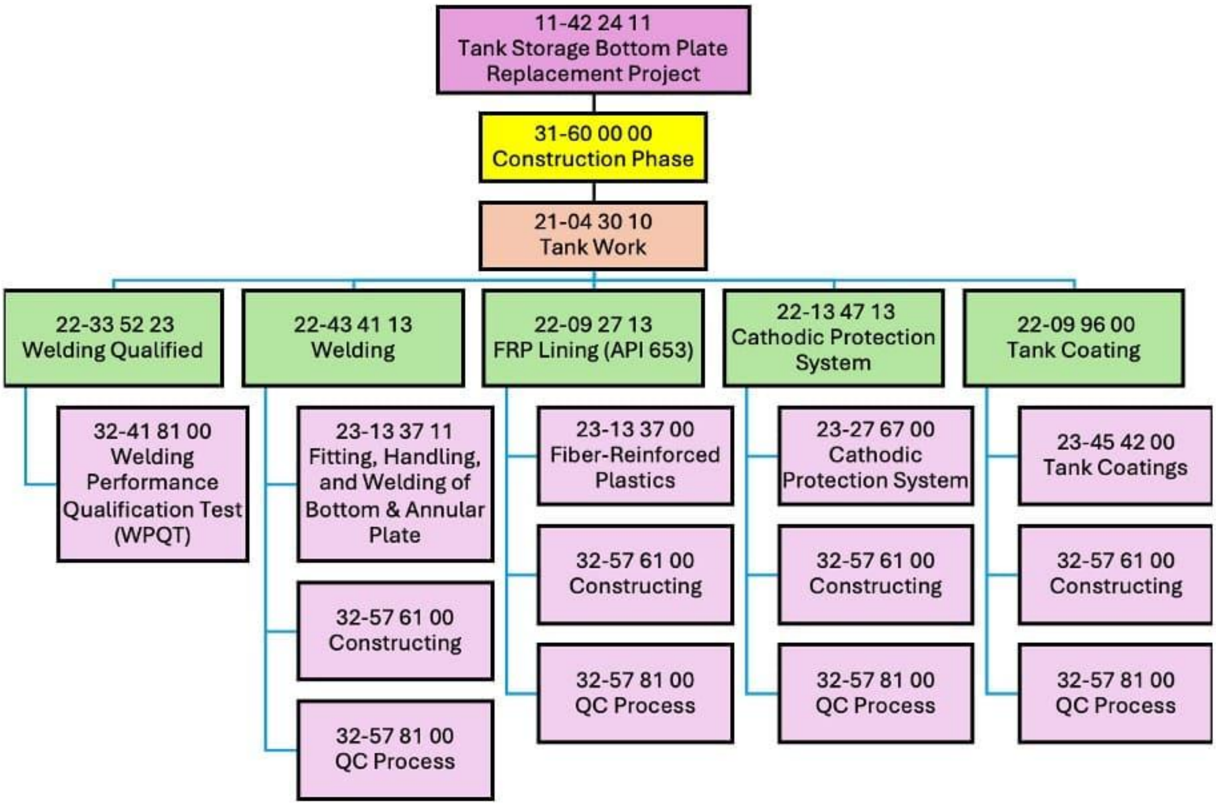

Figure 17.D - Multidimensional WBS for Storage Tank Rebottoming Project

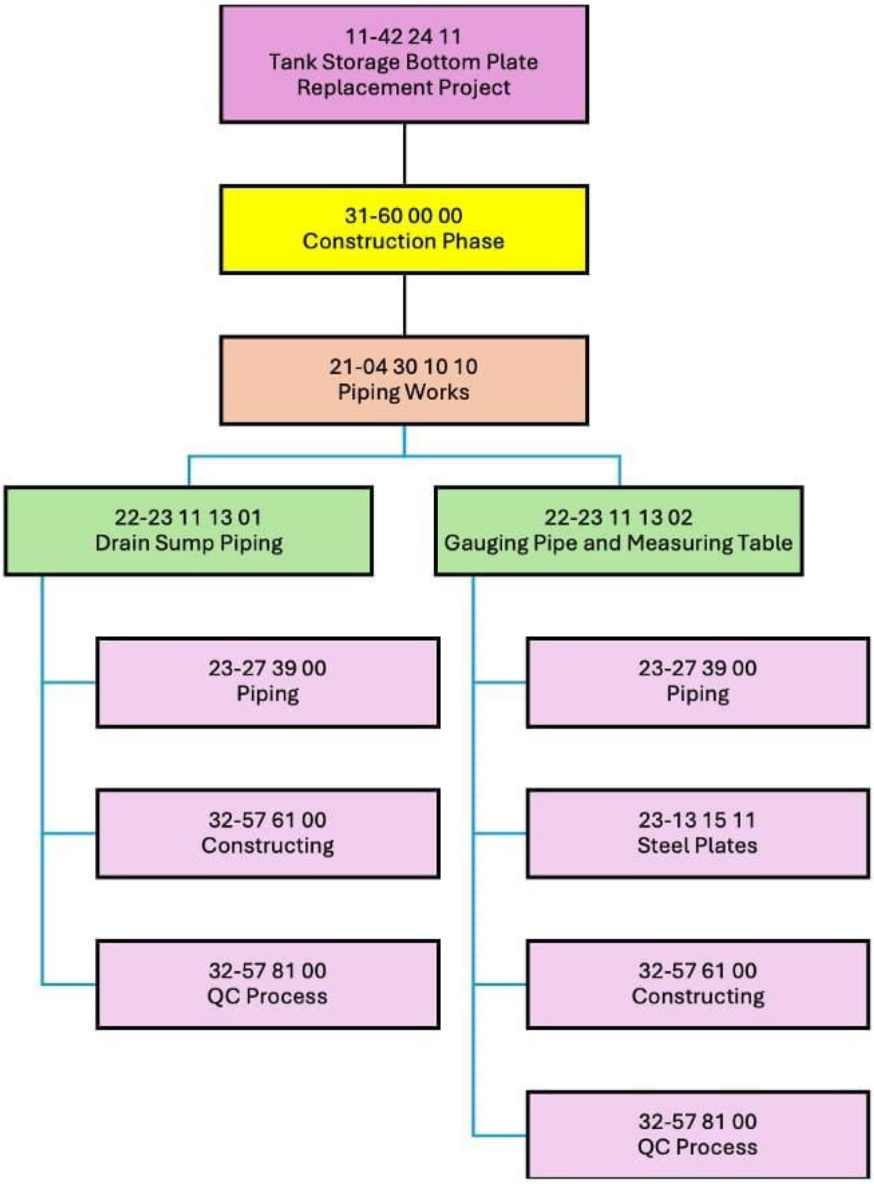

Figure 18 - Multidimensional WBS for Storage Tank Rebottoming Project

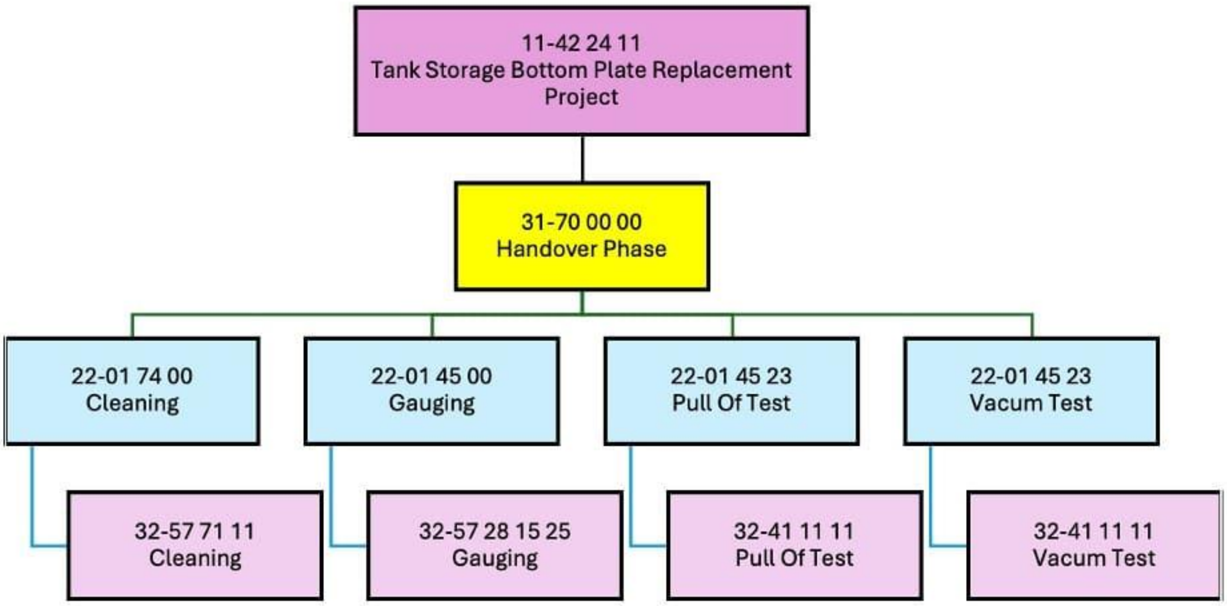

Figure 19 - Multidimensional WBS for Storage Tank Rebottoming Project

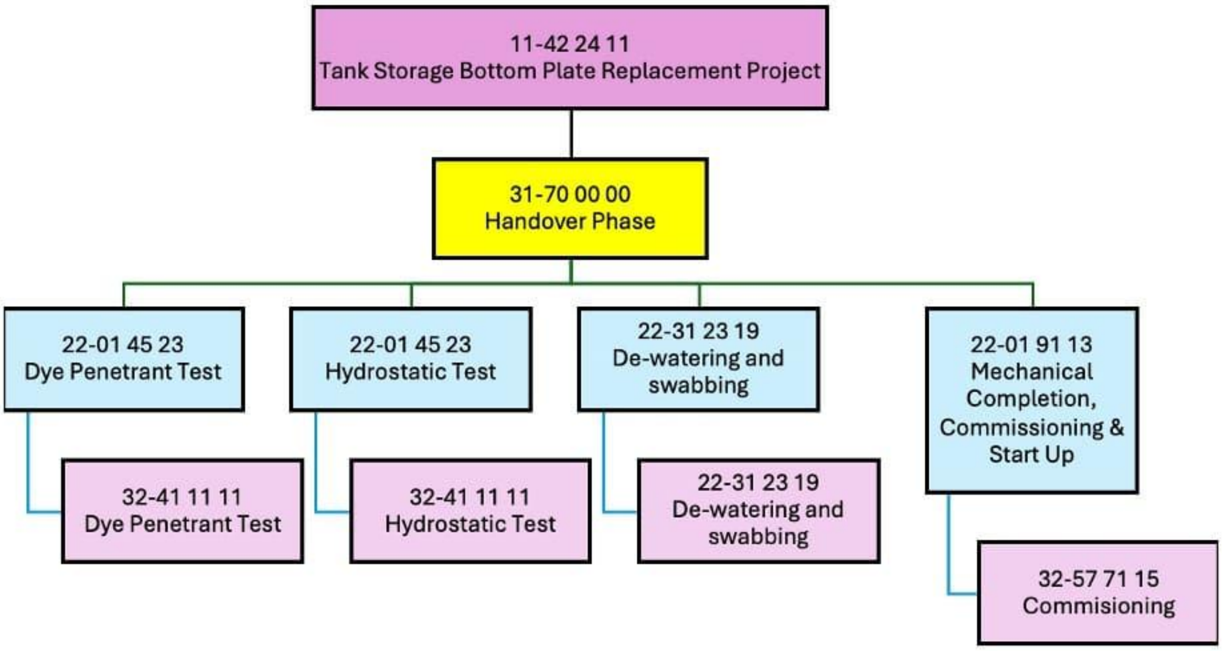

Figure 14.G - Multidimensional WBS for Storage Tank Rebottoming Project

After the development of the WBS framework, the next step is to implement it for the standardization of Bill of Quantity (BoQ) templates. The US National Park Service (NPS) Class A Bidding Template is the preferred option for the storage tank rebottoming project.

Considering various resources[59,60,61], the most suitable estimation class is the one that incorporates the Contractor's Point of View on the scope of work.

Bid Item No.	Bid Item Description	Total Material Cost	Total Labor Cost	Total Equipment Cost	Total Direct Construction Costs	Design Contingency 0.00%	General Conditions 0.00%	General Contractor Overhead 0.00%	General Contractor Profit 0.00%	Contracting Method Adjustment 0.00%	Inflation Escalation (APR 0.00%, Month 0)	Bid Item Total
Bid Item: 1	Asset / Project Element 1					TOTAL VALUE OF GOVERNMENT FURNISHED PROPERTY (if any):						$ -
	WBS L2 WBS Description	$ -	$ -	$ -	$ -							
	WBS L2 WBS Description	$ -	$ -	$ -	$ -							
	WBS L2 WBS Description	$ -	$ -	$ -	$ -							
	WBS L2 WBS Description	$ -	$ -	$ -	$ -							
	WBS L2 WBS Description	$ -	$ -	$ -	$ -							
Total - Bid Item 1	Asset / Project Element 1	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Bid Item: 2	Asset / Project Element 2					TOTAL VALUE OF GOVERNMENT FURNISHED PROPERTY (if any):						$ -
	WBS L2 WBS Description	$ -	$ -	$ -	$ -							
	WBS L2 WBS Description	$ -	$ -	$ -	$ -							
	WBS L2 WBS Description	$ -	$ -	$ -	$ -							
	WBS L2 WBS Description	$ -	$ -	$ -	$ -							
	WBS L2 WBS Description	$ -	$ -	$ -	$ -							
Total - Bid Item 2	Asset / Project Element 2	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Bid Item: 3	Asset / Project Element 3					TOTAL VALUE OF GOVERNMENT FURNISHED PROPERTY (if any):						$ -
	WBS L2 WBS Description	$ -	$ -	$ -	$ -							
	WBS L2 WBS Description	$ -	$ -	$ -	$ -							
	WBS L2 WBS Description	$ -	$ -	$ -	$ -							
	WBS L2 WBS Description	$ -	$ -	$ -	$ -							
	WBS L2 WBS Description	$ -	$ -	$ -	$ -							
Total - Bid Item 3	Asset / Project Element 3	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Bid Item: 4	Asset / Project Element 4					TOTAL VALUE OF GOVERNMENT FURNISHED PROPERTY (if any):						$ -
	WBS L2 WBS Description	$ -	$ -	$ -	$ -							
	WBS L2 WBS Description	$ -	$ -	$ -	$ -							
	WBS L2 WBS Description	$ -	$ -	$ -	$ -							
	WBS L2 WBS Description	$ -	$ -	$ -	$ -							
	WBS L2 WBS Description	$ -	$ -	$ -	$ -							
Total - Bid Item 4	Asset / Project Element 4	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Bid Item: 5	Asset / Project Element 5					TOTAL VALUE OF GOVERNMENT FURNISHED PROPERTY (if any):						$ -
	WBS L2 WBS Description	$ -	$ -	$ -	$ -							
	WBS L2 WBS Description	$ -	$ -	$ -	$ -							
	WBS L2 WBS Description	$ -	$ -	$ -	$ -							
	WBS L2 WBS Description	$ -	$ -	$ -	$ -							
	WBS L2 WBS Description	$ -	$ -	$ -	$ -							
Total - Bid Item 5	Asset / Project Element 5	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Total Bid Items 1-6	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -

Figure 15 - National Park Services Bidding Template (Class A Construction Cost Estimate)[62]

Detailed BoQ for the Storage Tank Rebottoming Project based on the NPS template is provided in Appendix 2[63].

Consistent with the conclusions in Step 5, the (A4) WBS-OBS integration proves more relevant, offering better project governance through robust organizational alignment. The formulation of the OBS for the storage tank rebottoming project using OmniClass Table 34 is created in Figure 16.

[59] 1.4.1.4 unit 4- Managing Scope. (2021). PTMC. https://build-project-management-competency.com/1-4-1-4-unit-4/

[60] Pradibta, I. (2024, March). *Standardized multidimensional WBS–CBS for storage tanks*. PM World Journal. https://pmworldlibrary.net/wp-content/uploads/2024/03/pmwj139-Mar2024-Pradibta-Standardized-Multidimensional-WBS-CBS-for-Storage-Tanks.pdf

[61] Pragitatama, W. (2024, October–November). *Standardized bidding documents for jetty pier project*. PM World Journal. https://pmworldlibrary.net/wp-content/uploads/2024/11/pmwj146-OctNov2024-Pragitatama-standardized-bidding-documents-for-jetty-pier-project-2.pdf

[62] National Park Service. (2021, May 27). Class A Construction Cost Estimate Template. NPS.gov (U.S. National Park Service). https://www.nps.gov/dscw/upload/ClassAConstructionCostEstimate_Template_5-27-21.xlsx

[63] This paper includes APPENDICES that will demonstrate how to IMPLEMENT what this paper recommends. For anyone who needs or wants the APPENDICES, email me < abdullah.aace.2026@gmail.com > and the author will email you with the full paper with the APPENDICES.

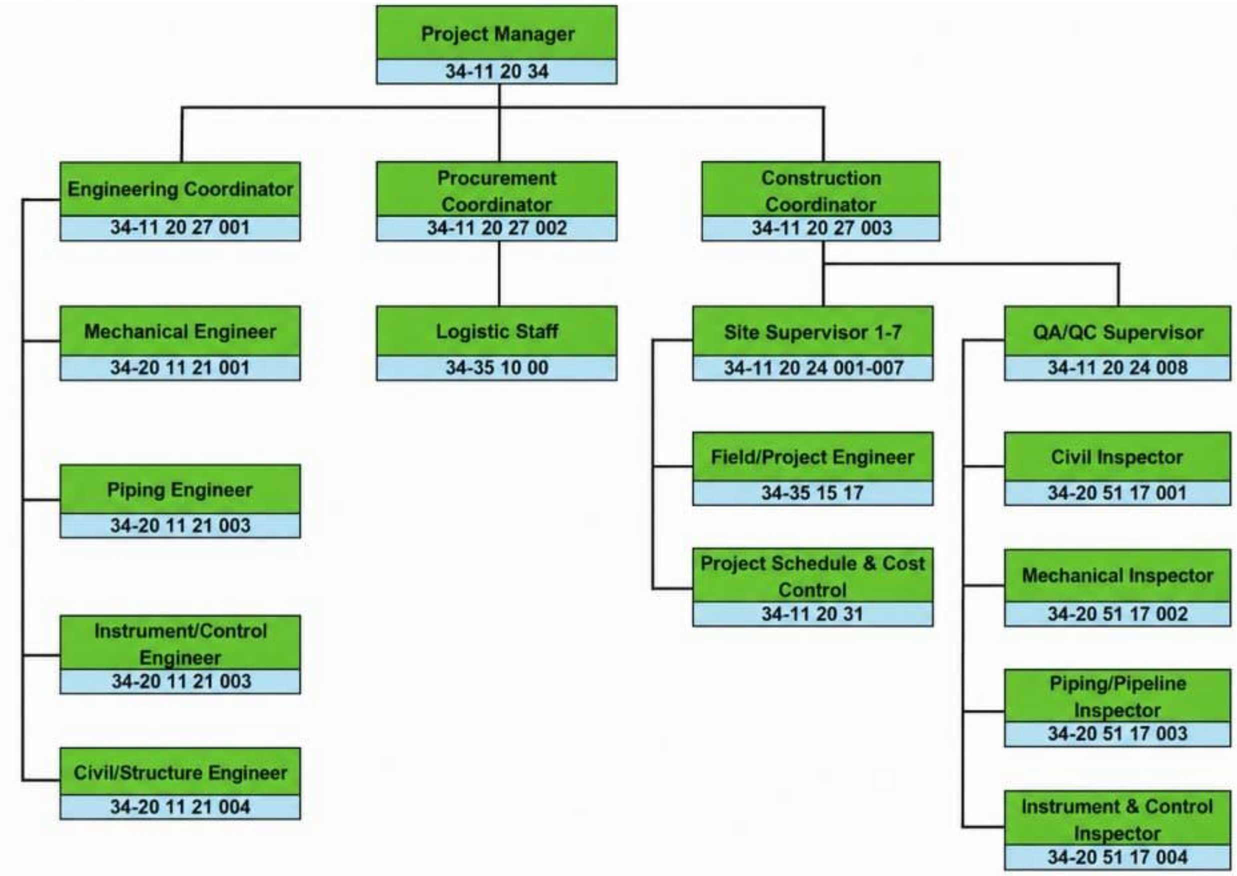

Figure 16 - Organizational Breakdown Structure (OBS) for Storage Tank Rebottoming Project

From the established OBS, a Responsibility Assignment Matrix (RAM) is formulated (See Appendix 3[64]).

Step 7 - Performance Monitoring

To ensure the effectiveness of the Project Breakdown Structure developed for the Storage Tank Rebottoming Project, the following steps must be implemented:

1. Pre-Implementation Evaluation:
   - Evaluate the alignment of the planned WBS with current practices to determine their compatibility.[65]

[64] This paper includes APPENDICES that will demonstrate how to IMPLEMENT what this paper recommends. For anyone who needs or wants the APPENDICES, email me < abdullah.aace.2026@gmail.com > and the author will email you with the full paper with the APPENDICES.
[65] Andrian, Y. P. (2024). Building an Econometrics Model for Pier Construction in an Indonesian Oil and Gas Company. PM World Journal, 13(4). https://pmworldlibrary.net/wp-content/uploads/2024/04/pmwj140-Apr2024-Andrian-building-an-econometrics-model-for-pier-construction.pdf

- Provide training for schedulers and cost analysts on using this Multidimensional WBS structure.

2. Implementation:
    - Implementing a standardized Bidding Template to ensure contractors' bidding aligns with project conditions.
    - Integrating WBS-OBS to enhance project governance and accountability.
3. Post Implementation

By standardizing Multidimensional WBS for rebottoming projects, we can have a standardized cost and productivity that is assigned to each work package of WBS in all storage tank rebottoming projects. The integration of WBS and OBS enhances project governance by aligning scope definition with organizational responsibility. This is supported by the GAO Best Practice, which states that "The OBS reflects the responsible organization of the project and describes the hierarchy that will provide resources to perform the work identified in the WBS"[66], thereby ensuring clear accountability and effective resource allocation throughout project execution.

CONCLUSION

Given that storage tank rebottoming projects in national oil and gas companies are inherently repetitive in nature, it is essential to establish standardized Work Breakdown Structures (WBS), Bidding Templates, and WBS–OBS integration using best-proven methods. Such standardization can support the organization in project scheduling, cost estimation, Request for Quotation (RFQ) processes, and project governance, while ensuring that these standards can be consistently replicated across rebottoming projects throughout Indonesia.

Following the development of the WBS using the OmniClass standard, a standardized Bidding Template can be constructed based on the defined WBS structure and its integration with the Organizational Breakdown Structure (OBS). Based on the author's study in developing a standardized WBS framework, the research questions can be addressed as follows:

1. A standardized multidimensional WBS for tank rebottoming projects can be developed by structuring project scope across multiple dimensions, including physical components, work processes, and lifecycle phases. This approach

[66] U.S. Government Accountability Office. (2015). *Cost estimating and assessment guide: Best practices for developing and managing capital program costs* (GAO-16-89G). U.S. Government Accountability Office.

provides completeness of scope definition, improves repeatability and enhances traceability across projects. [67,68]

2. OmniClass classification codes can be effectively incorporated into the WBS to develop a consistent coding structure that directly maps to Bill of Quantity (BoQ) items. The BoQ template developed in this study is standardized and based on the United States National Park Service (US-NPS) Class A Cost Estimate format to provide a reliable and structured cost breakdown. This integration increases consistency of cost, allows interoperability of data, and enables reliable "apple-to-apple" bid comparison between contractors (Construction Specifications Institute [CSI], 2020).[69,70]

3. The combination of WBS and OBS generates a systematic governance framework that connects scope definition with organizational accountability. This allows the establishment of control accounts and a Responsibility Assignment Matrix (RAM) for accountability and efficient allocation of resources during project execution.[71]

Overall, the results validate that the OmniClass-based multidimensional WBS with OBS and a standardized BoQ template provides a robust and scalable solution to improve the scope standardization, cost consistency, and project governance in storage tank rebottoming projects.

REFERENCES

1. American Petroleum Institute. (2014). *API standard 653: Tank inspection, repair, alteration, and reconstruction*. API Publishing.
2. Revie, R. W., & Uhlig, H. H. (2008). *Corrosion and corrosion control* (4th ed.). Wiley.
3. International Organization for Standardization. (2014). *ISO 55000: Asset management—Overview, principles and terminology*. ISO.
4. Elsyca NV. (2022). *Corrosion protection for storage tanks*. https://www.elsyca.com/protect/storage-tanks

[67] Humphreys, K. (2011). *Project and cost engineers' handbook*. CRC Press.
[68] National Aeronautics and Space Administration. (2007). *NASA work breakdown structure handbook*. NASA.
[69] National Park Service. (2017). *Cost estimating requirements handbook*. U.S. Department of the Interior.
[70] Construction Specifications Institute. (2020). *OmniClass construction classification system*. https://www.csiresources.org/standards/omniclass
[71] U.S. Government Accountability Office. (2015). *Cost estimating and assessment guide: Best practices for developing and managing capital program costs* (GAO-16-89G). GAO.

5. Merrow, E. W. (2011). *Industrial megaprojects: Concepts, strategies, and practices for success*. Wiley.
6. U.S. Government Accountability Office. (2020). *GAO cost estimating and assessment guide*. GAO.
7. AACE International. (2020). *Total cost management framework: An integrated approach to portfolio, program, and project management*. AACE.
8. Blank, L., & Tarquin, A. (2018). *Engineering economy* (17th ed.). McGraw-Hill.
9. National Aeronautics and Space Administration. (2007). *NASA work breakdown structure handbook*. NASA.
10. Al-Mansoori, T. (2019). *Storage tank bottom failure mechanisms*. *(Lengkapi jika jurnal/proceeding tersedia)*
11. Kerzner, H. (2022). *Project management: A systems approach to planning, scheduling, and controlling* (13th ed.). Wiley.
12. Humphreys, K. (2011). *Project and cost engineers' handbook*. CRC Press.
13. Construction Specifications Institute. (2019). *OmniClass construction classification system*. https://www.csiresources.org/standards/omniclass
14. Fleming, Q. W., & Koppelman, J. M. (2016). *Earned value project management* (4th ed.). Project Management Institute.
15. Shamir, E. (2014). Peeling the onion: Why centralized control / decentralized execution works. *Air & Space Power Journal*.
16. Giammalvo, P. D. (2024). *Managing scope (Unit 4)*. PT Mitrata Citragraha. https://build-project-management-competency.com/1-4-1-4-unit-4/
17. Humphreys, G. C. (2018). *Project management using earned value* (4th ed.). Humphreys & Associates.
18. Construction Specifications Institute. (2020). *OmniClass tables (Tables 11, 12, 21, 22, 23, 31, 32)*. https://www.csiresources.org/standards/omniclass
19. Omniclass. (2020). *About OmniClass™*. Construction Specifications Institute. https://www.csiresources.org/standards/omniclass/standards-omniclass-about
20. Omniclass. (2020). *OmniClass®.* Construction Specifications Institute. https://www.csiresources.org/standards/omniclass
21. Giammalvo, P. D., & PTMC. (2021, October 14). 1.4.1.4 unit 4- Managing scope. https://build-project-management-competency.com/1-4-1-4-unit-4/
22. Giammalvo, P. D., & PTMC. (2024, April 22). 1.4.1.1 unit 1- Governance and integration. https://build-project-management-competency.com/1-4-1-1-unit-1/

23. Ilbahar, E., Cebi, S., & Kahraman, C. (2019). A state-of-the-art review on multi-attribute renewable energy decision making. Energy Strategy Reviews, 25, 18-33. https://doi.org/10.1016/j.esr.2019.04.014

24. International Organization for Standardization. (2016). *Standard cost coding system for oil and gas production and processing facilities (ISO Standard No. 19008)* (1st ed.).

25. Rashid, M. E. (2016). The Influence of Non-Standard Work Breakdown Structure on Change Orders and Cost Estimation for Sudan Oil and Gas Projects. *PM World Journal, 5*(12). https://pmworldlibrary.net/wp-content/uploads/2016/12/pmwj53-Dec2016-ElRashid-non-standard-work-breakdown-structure-sudan-featured-paper.pdf

26. Sullivan, W. G., Wicks, E. M., & Koelling, C. P. (2020). Chapter 14 Decision Making Considering Multiattributes. In *Engineering Economy Global Edition* (17th ed.). Pearson UK.

27. Sullivan, W. G., Wicks, E. M., & Koelling, C. P. (2020). Chapter 2 Cost Concepts and Design Economics. In *Engineering Economy Global Edition* (17th ed.). Pearson UK.

28. (n.d.). PM World Library | A Global Resource for Continuous Learning in PPM. https://pmworldlibrary.net/wp-content/uploads/2024/12/pmwj146-OctNov2024-Mulyawan-multidimensional-wbs-for-oil-pipeline-project-2.1.pdf

29. Andrian, Y. P. (2024). Building an Econometrics Model for Pier Construction in an Indonesian Oil and Gas Company. *PM World Journal*, *13*(4). https://pmworldlibrary.net/wp-content/uploads/2024/04/pmwj140-Apr2024-Andrian-building-an-econometrics-model-for-pier-construction.pdf

30. Pradibta, I. (2024, March). *Standardized multidimensional WBS–CBS for storage tanks.* PM World Journal. https://pmworldlibrary.net/wp-content/uploads/2024/03/pmwj139-Mar2024-Pradibta-Standardized-Multidimensional-WBS-CBS-for-Storage-Tanks.pdf

31. Pragitatama, W. (2024, October–November). *Standardized bidding documents for jetty pier project.* PM World Journal. https://pmworldlibrary.net/wp-content/uploads/2024/11/pmwj146-OctNov2024-Pragitatama-standardized-bidding-documents-for-jetty-pier-project-2.pdf

32. Hidayat, M. (2024, April). *Standardized Multidimensional WBS for enhanced BIM.* PM World Journal. https://pmworldlibrary.net/wp-content/uploads/2024/04/pmwj140-Apr2024-Hidayat-standardized-Multidimensional-wbs-for-enhanced-bim.pdf

33. U.S. Government Accountability Office. (2015). *Cost estimating and assessment guide: Best practices for developing and managing capital program costs* (GAO-16-89G). U.S. Government Accountability Office.

34. National Park Services. (2023). *Construction Cost Estimating Requirements Handbook*. National Park Service (NPS) - Denver Service Center (DSC).

35. National Park Service. (2021, May 27). Class A Construction Cost Estimate Template. NPS.gov (U.S. National Park Service).

https://www.nps.gov/dscw/upload/ClassAConstructionCostEstimate_Template_5-27-21.xlsx

36. U.S. National Aeronautics And Space Administration. (2017). *NASA cost estimating handbook Ver 4.0*. Createspace Independent Publishing Platform.

37. *Difference between RDBMS and OODBMS*. (2025, July 11). GeeksforGeeks. https://www.geeksforgeeks.org/dbms/difference-between-rdbms-and-oodbms/

38. Obregon, A. (n.d.). *Database vs. relational database: A beginner's guide*. Medium. https://medium.com/@AlexanderObregon/database-vs-relational-database-a-beginners-guide-86cc4e8357ad

About the Author

Abdullah Arief Su'aidy

Yogyakarta, Indonesia

Abdullah Arief Su'aidy is an engineer with over six years of professional experience in the oil and gas sector. Currently, he works as a maintenance engineer at the national oil company of Indonesia. Several projects have been completed in various downstream oil and gas projects, including fuel terminal, LPG terminal, and related infrastructure, with a focus on maintenance and asset reliability. He holds a bachelor of Computer Science in Informatics from STMIK Indonesia Banjarmasin. He is attending a distance learning mentoring course, under the tutorage of Dr. Paul D. Giammalvo, CDT, CCE, MScPM, MRICS, GPM-m, Senior Technical Advisor at PT Mitratata Citragraha to attain Certified Cost Professional (CCP) certification from AACE International.

Abdullah lives in Yogyakarta, Indonesia, and can be contacted at: abdullah.aace.2026@gmail.com