# Standardized Multi-Dimensional WBS for Enhanced BIM and Data Analytics in LPG Facility Projects [1, 2]

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## ABSTRACT

The escalating consumption of LPG in Indonesia has prompted the country's National Oil & Gas Company to embark on constructing a new LPG Facility. This paper addresses the imperative to streamline the Front-End Loading (FEL) stage to prevent cost and schedule overruns due to scope creep. The primary objective is to formulate a comprehensive Work Breakdown Structure (WBS) and Cost Breakdown Structure (CBS) for the LPG Facility Construction project, aimed at facilitating accurate cost estimation and scheduling processes for diverse stakeholders. Using the unfolded tesseract theory to analyze stakeholder needs and elucidate the object-oriented WBS, a Multi-Attribute Decision Making (MADM) analysis was conducted. The study concludes that a multi-dimensional WBS, particularly employing OmniClass, is the optimal choice for addressing the complexities of the LPG Facility Project and meeting stakeholder needs within BIM software.

**Keywords:** Work Breakdown Structure (WBS), Cost Breakdown Structure (CBS), Multi-dimentional WBS, OBS, Scope Change, Asset Manager, Omniclass, ISO 19008:2016, Artificial Intelligence, Econometrics, Data Analysis, Building Information Modeling (BIM), MADM

## INTRODUCTION

The role of Liquefied Petroleum Gas (LPG) in the energy consumption of the Household Sector in Indonesia is significantly vital. Examining the final energy consumption in Indonesia, the total consumption of LPG in the country has consistently increased each year. Between 2012 and 2022, there was a notable 70.4% surge in national LPG consumption.

According to statistical data from the Ministry of Energy and Mineral Resources (ESDM), Figure 1 illustrates the upward trajectory of LPG consumption in Indonesia. This rise is partly attributed to governmental initiatives, particularly the conversion program from

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[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/

kerosene to LPG for household fuel. As of 2022, LPG holds a substantial 48.45% share of energy consumption in the household sector, as depicted in Figure 2.

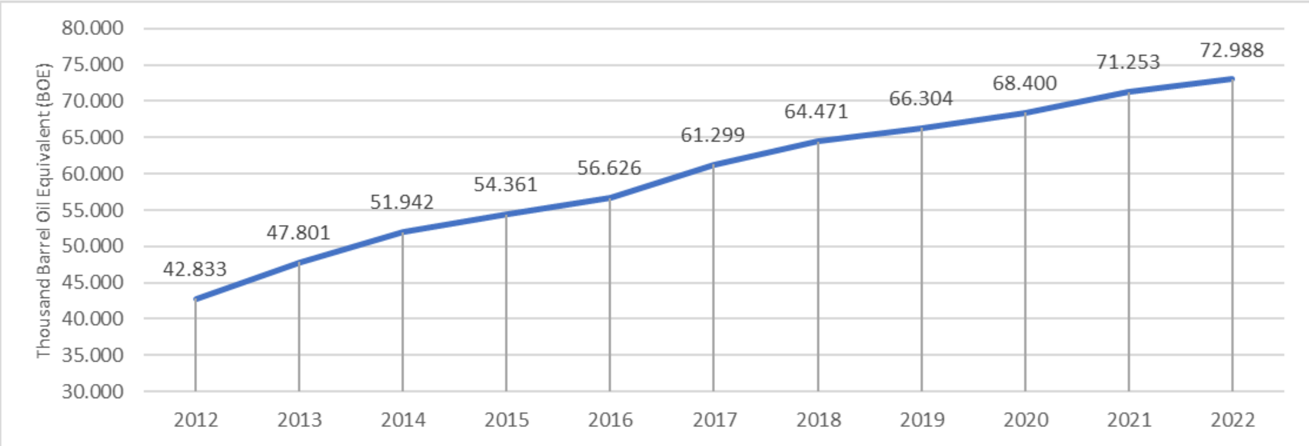


*Figure 1 – LPG Consumption in Indonesia*[3]

Indonesia's National Oil & Gas Company has undertaken various measures to bolster national energy resilience and support these governmental endeavors. Among these efforts is the establishment of several LPG Terminals. These initiatives align with the broader goal of enhancing energy security and facilitating the transition toward cleaner and more efficient household energy sources[4].

Establishing multiple LPG terminals by the National Oil & Gas Company is a step towards enhancing infrastructure and distribution networks. These terminals act as crucial hubs, ensuring a steady and reliable supply of LPG across regions. Such infrastructure investments facilitate accessibility and affordability, especially in remote areas, fostering a more inclusive energy landscape across the country.

[3] Ministry of Energy and Mineral Resources Republic of Indonesia (2022). Handbook of Energy & Economic Statistics of Indonesia

[4] Ministry of Energy and Mineral Resources Republic of Indonesia (2019). Dukung Konversi Mitan ke LPG, 4 Terminal LPG Dibangun di Indonesia Timur, retrieved from https://www.esdm.go.id/id/unit-news/directorate-general-of-oil-and-gas/dukung-konversi-mitan-ke-lpg-4-terminal-lpg-dibangun-di-indonesia-timur

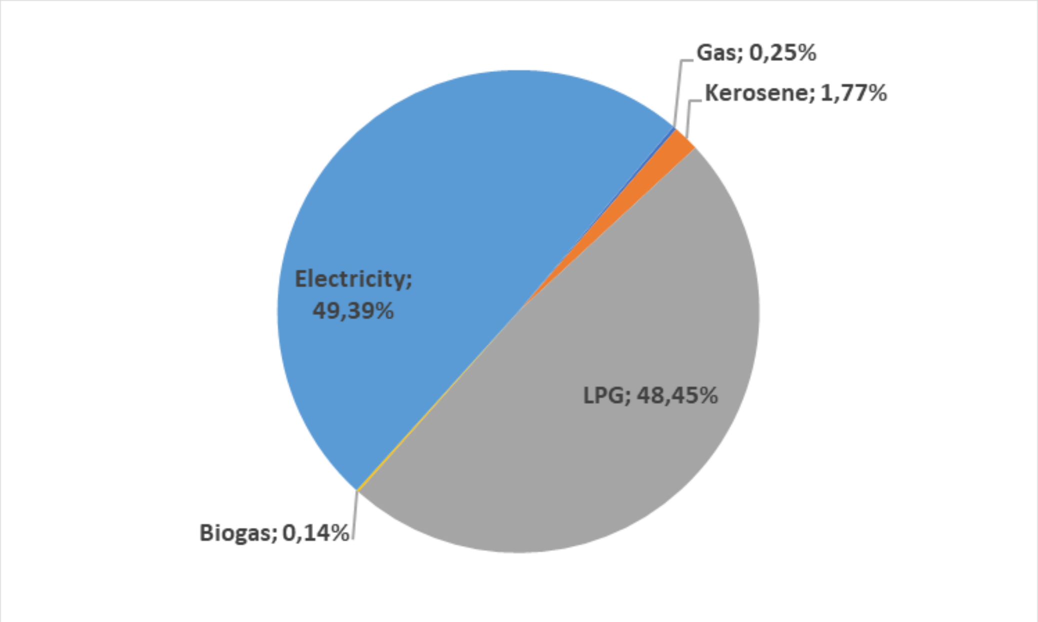


*Figure 2 – Share of Energy Consumption in Household Sector*

In the execution of infrastructure development within Pertamina, challenges often arise during the construction phase. These challenges result in cost and schedule overruns. Upon reviewing 15 sample projects within the National Oil & Gas Company with ongoing construction status in December 2023, experiencing cost/schedule overruns, 10 encountered scope creep. Scope Creep refers to the gradual progressive change (usually an addition to) of the project's scope such that the project management team or customer does not notice it. Typically occurs when the customer identifies additional, sometimes minor, requirements that, when added together, may collectively result in a significant scope change, resulting in cost and schedule overruns[5].

In resolving issues within a project cycle, it's essential to determine which phase the resolution of these problems significantly impacts. During the early stages of a project, such as feasibility studies, preliminary design, and even detailed design, the relative expenditures are relatively small compared to the project's overall scope. However, during the construction phase, effecting changes requires higher costs[6]. The illustration can be seen in Figure 3.

As the National Oil & Gas Company is the owner organization, adopting an asset-centric rather than a project management model is imperative. This model defines an asset across 7 Phases of the Asset Life Span (Figure 4), with Phase 4 marking the point where

[5] AACE International. (2023). AACE International Recommended Practice No. 10S-90 Cost Engineering Terminology
[6] Paulson, B. C. (1976). Designing to Reduce Construction Cost; Journal of The Construction Division, Vol. 102, Issue Number C04, retrieved from https://www.danieldavis.com/papers/boyd.pdf

the owner initiates contractor involvement. At each stage within Phase 1, there is a progression in the level of detail within the decision support package, one component of which includes the WBS (Work Breakdown Structure)[7].

The Work Breakdown Structure (WBS) is a fundamental tool in project management, breaking down intricate tasks into smaller, more manageable elements. It establishes a hierarchical structure for the project's scope, enhancing resource allocation, risk management, and progress tracking. Cost Breakdown Structure (CBS) complements the WBS by providing an intricate overview of project expenses and facilitating enhanced cost control, budget estimation, and financial transparency throughout the project's lifecycle. Moreover, the WBS can either adhere to established standard formats such as Norsok, CSI, OmniClass or be customized as a non-standard structure tailored to individual project specifications, offering flexibility to meet distinct project needs[8].

Upon completion of the engineering process and transitioning into the bidding phase, it is recommended that an owner takes responsibility for defining at least Level 3 of the Work Breakdown Structure (WBS). Ideally, the owner should aim for Level 4 of the WBS before initiating the bidding process. Once the winning contractor is chosen, they will further elaborate on the WBS and the Cost & Resource Loaded schedule, expanding it to Level 5 or even Level 6, ensuring a more comprehensive breakdown of the project elements and resources[9].

The National Oil & Gas Company has grown significantly, expanding the scope and complexity of its projects. Consequently, the imperative to bolster project management effectiveness has intensified. Employing methodologies like the WBS and CBS holds the potential to substantially elevate project planning, execution, and control processes within the company. This strategic approach ensures optimal resource utilization and the achievement of project objectives within predefined constraints[10].

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[7] Giammalvo, P.D. (2021). The Bigger Picture: Project Life Cycles from a Broader, Real-World Perspective; Commentary, PM World Journal, Vol. X, Issue VI, June
[8] 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, Vol. V, Issue XII, December
[9] Giammalvo, P.D. (2021). The Bigger Picture: Project Life Cycles from a Broader, Real-World Perspective; Commentary, PM World Journal, Vol. X, Issue VI, June
[10] Sukmono, C. (2023). Enhancing Project Management Efficiency in PERTAMINA through Work Breakdown Structure (WBS) and Cost Breakdown Structure (CBS) Integration; PM World Journal, Vol. XII, Issue IX, September

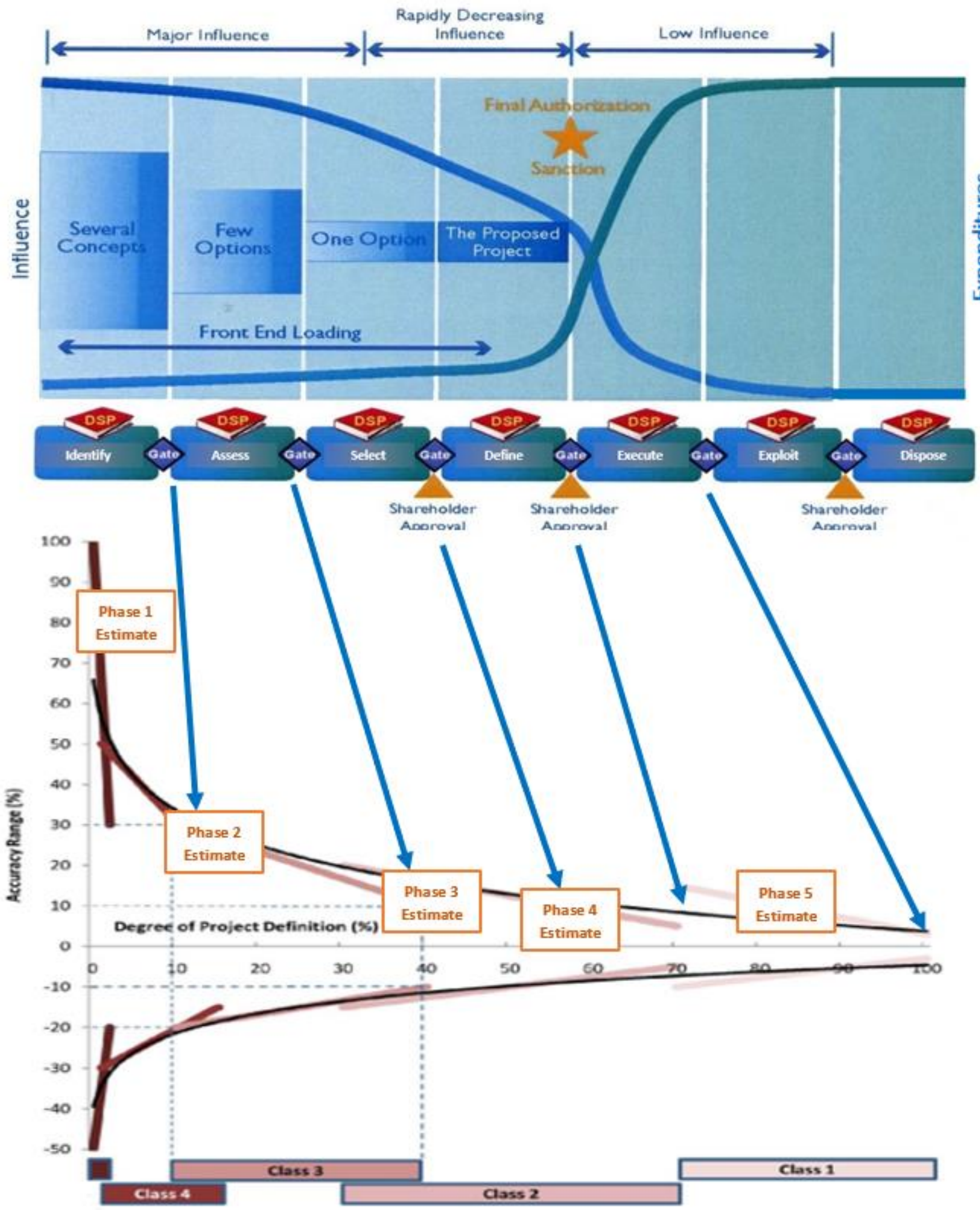


*Figure 3. Level of Influence on Project Cost* [11, 12]

[11] Paulson, B. C. (1976). Designing to Reduce Construction Cost; Journal of The Construction Division, Vol. 102, Issue Number C04, retrieved from https://www.danieldavis.com/papers/boyd.pdf
[12] U.S. Department of Energy. (2011). Cost Estimating Guide.

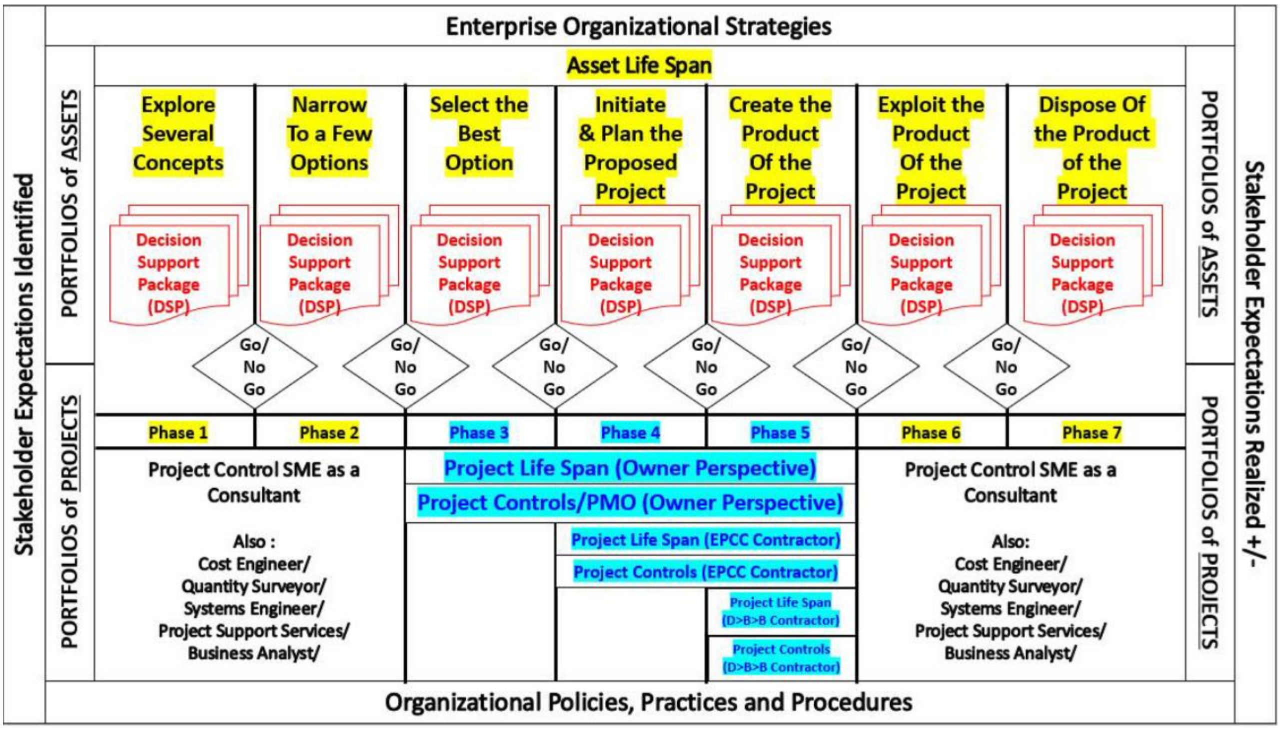


*Figure 4 - Integrated Asset, Portfolio, Program and Project Management Methodology*[13]

Establishing a standardized Work Breakdown Structure (WBS)/Cost Breakdown Structure (CBS) plays a pivotal role in fortifying the foundation of a robust database, particularly crucial for sustaining the progression of LPG Facility Construction initiatives within the National Oil & Gas Company. By implementing this standardized WBS/CBS, the company can efficiently gather and disseminate data across its programs. This streamlined approach facilitates more accurate cost estimations—an indispensable component of effective LPG Facility construction project management and enables National Oil & Gas Company to allocate resources more judiciously.

This accuracy in cost estimation is a catalyst, empowering National Oil & Gas Company to navigate resource allocation more efficiently, thereby mitigating the risk of budget overruns and significantly increasing the likelihood of completing projects within stipulated timeframes and financial parameters. Moreover, the seamless accessibility of shared data fosters an environment of enhanced communication and coordination among various departments. Such cohesion proves critical, especially within the expansive landscape of LPG Facility construction projects.

Consequently, the assimilation of a standardized WBS doesn't solely amplify project execution efficiency; it also fortifies the long-term sustainability of LPG Facility construction endeavors within the National Oil & Gas Company. This structured approach

[13] Giammalvo, P.D. (2021). The Bigger Picture: Project Life Cycles from a Broader, Real-World Perspective; Commentary, PM World Journal, Vol. X, Issue VI, June

ensures meticulous oversight and management across every stage of the projects, from their inception to ultimate fruition. Such meticulous oversight strengthens the company's proficiency in steering these pivotal infrastructure projects.

This paper aims to institute a standardized WBS/CBS for New LPG Facility Construction Projects that aligns with these core principles:

1. Provide an appropriate WBS/CBS for the LPG Facility Construction project that satisfies the entire entity and phase of the project so that many related stakeholders can use it for the cost-building and scheduling process.
2. Prepare a new "LPG Facility Construction" WBS architecture that can be easily implemented in the BIM system at the National Oil & Gas Company.

## METHODOLOGY

In writing this paper, the methodology employed will reference the Engineering Economic Analysis Procedure with 7 steps of analysis:

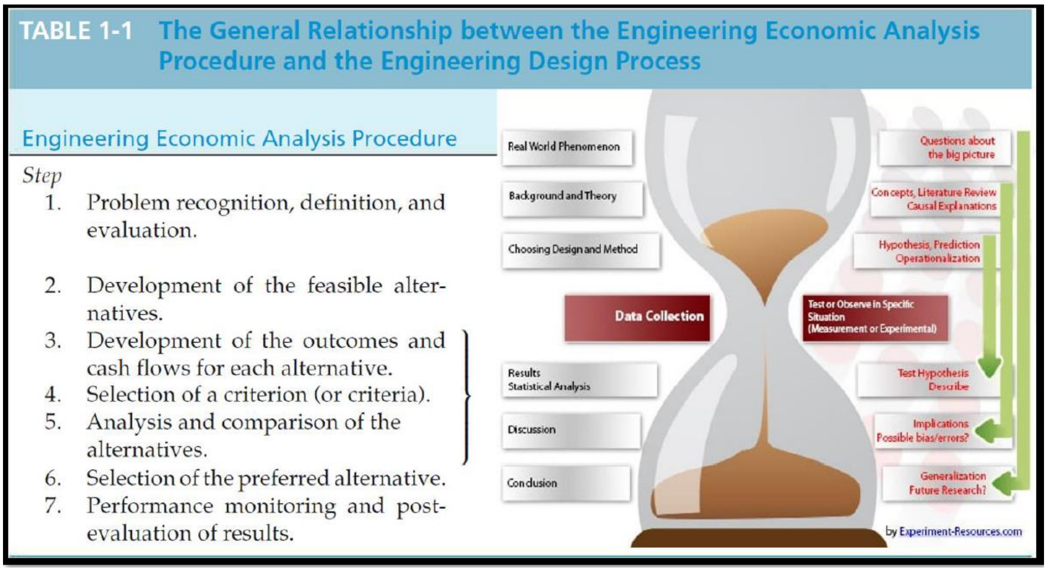
TABLE 1-1 The General Relationship between the Engineering Economic Analysis Procedure and the Engineering Design Process

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 5 – Engineering Economic Analysis Procedure*[14]

### Step 1 – Problem Definition

National Oil & Gas Company's existing project management procedures might encounter challenges that impede their overall efficiency and effectiveness. A lack of clear insight into the project's scope, responsibilities, timelines, and costs is among these potential obstacles, which could result in delays, exceeding budgets, and suboptimal resource utilization. Incorporating Work Breakdown Structure (WBS) and Cost Breakdown

[14] Sullivan, W. G., Wicks, E. M., & Koelling, C. P. (2020). Engineering Economy (Seventeenth Edition). Pearson Education Limited

Structure (CBS) methodologies into National Oil & Gas Company's project management practices is a viable solution to tackle these issues and enhance project management efficiency[15].

The development of standardized WBS/CBS poses a unique challenge for the National Oil & Gas Company as it represents a relatively novel concept, especially in the context of the LPG Facility Project. There are several commonly employed WBS standards globally in the construction and Oil & Gas industries. One recommended standard is Omniclass[16][17]

Implementing standardized WBS/CBS can assist in mitigating potential issues arising from scope changes that impact cost and schedule aspects [18].

Integrating cost and schedule control systems has been a significant challenge in the construction industry. Despite the potential benefits of this concept, its real-world implementation has not gained widespread popularity, limiting the full advantages it could provide. The primary obstacle is the substantial overhead effort required to gather and maintain detailed data. Figure 6 demonstrates that the stakeholders must answer the eight queries listed below.

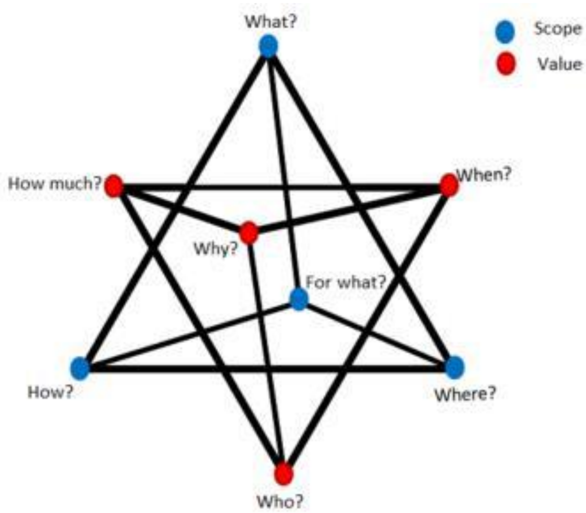


*Figure 6 - Stakeholders Needs*[19]

[15] Sukmono, C. (2023). Enhancing Project Management Efficiency in PERTAMINA through Work Breakdown Structure (WBS) and Cost Breakdown Structure (CBS) Integration; PM World Journal, Vol. XII, Issue IX, September
[16] Ibid
[17] Arba, D. (2020). Multi-dimensional Project Breakdown Structures to Ensure Efficient Delivery of Hospital Construction, PM World Journal, Vol. IX, Issue XI, November
[18] 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, Vol. V, Issue XII, December
[19] Arba, D. op. cit.

## STEP 2 – Development of Feasible Alternatives

Work Breakdown Structure (WBS) must address eight questions our stakeholders may pose. One approach that could aid in resolving this is by employing Tesseract (Figure 7). In geometry, the Tesseract serves as the four-dimensional counterpart of the cube; it can be likened to how the cube relates to the square. Similar to the cube's six square faces, the hypersurface of the Tesseract comprises eight cubical cells (unfolded Tesseract). The described theoretical Tesseract is unfolded, allowing the view of the Tesseract from a contractor and stakeholder's perspectives[20]. The unfolded hypercube projects 8 High-Level Questions for Stakeholders, shown in Figure 8.

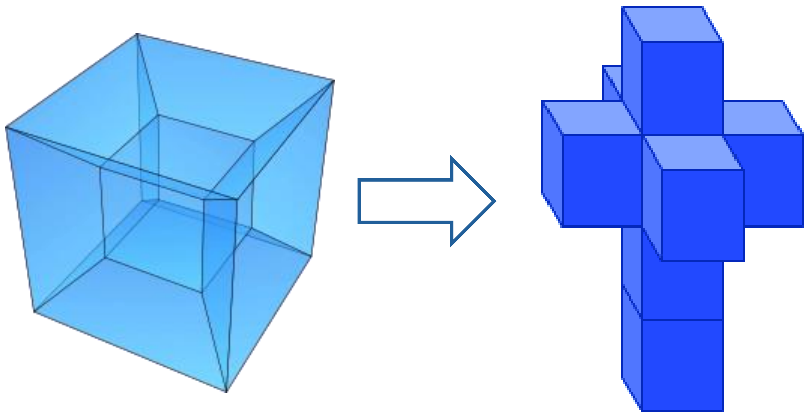

*Figure 7 – The Tesseract (The Folded Hypercube & 8 Cubical Faces The Unfolded Hypercube)*

[20] Leynaud, X., Giammalvo, P. D., Moine, J. Y. (2019). Multi-Dimensional Project Breakdown Structures - The Secret to Successful Building Information Modeling (BIM) Integration. DCB Publishing

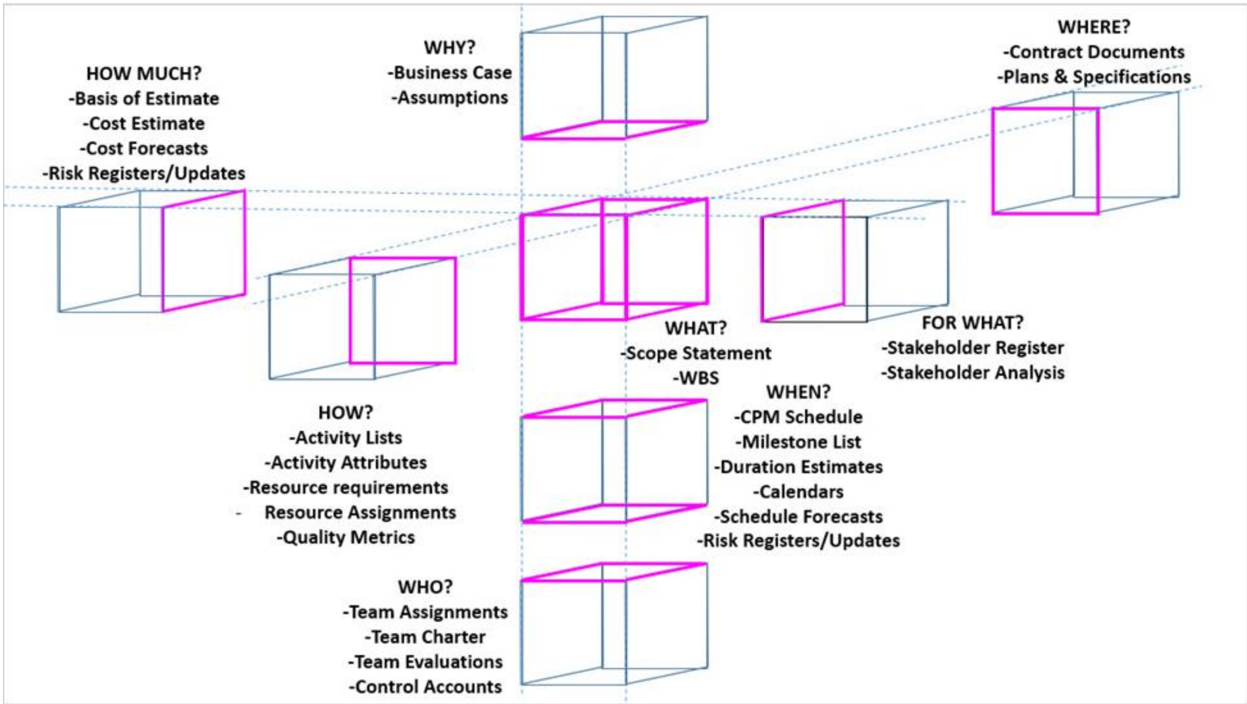


*Figure 8 – 8 High-Level Questions for Stakeholders*[21]

To address the question, it is essential to determine the appropriate project breakdown structure, particularly a structure that can be applied to the LPG Facility Project.

However, understanding the distinction between flat files and relational or object-oriented databases is crucial before the WBS is drafted. Flat file databases, which store data in a simple, unrelational format like a large table or text file, suffice for small-volume and straightforward data. However, they lack flexibility and efficiency as data volume and complexity increase[22]. In contrast, relational databases organize data into tables linked by foreign keys, enabling intricate relationships and efficient data retrieval while reducing duplication. Object-oriented databases enhance this approach by storing data as objects, incorporating attributes and methods. This facilitates a more natural and consistent data representation aligned with object-oriented programming, which is particularly valuable in modern applications requiring complex data modeling and versatile data handling capabilities[23].

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[21] Ibid
[22] Relational database vs flat file (Differences & similarities). (2023, January 24). Retrieved from https://databasetown.com/relational-database-vs-flat-file-differences-similarities/
[23] Flat file versus relational database (Comparison). (2020, February 23). Retrieved from https://www.relationaldbdesign.com/basic-sql/module3/relational-versus-flatfile.php

## 3 Dimensional WBS

The Product-Based Breakdown Structure (PBS) is formed through systems, sub-systems, products, and sub-products. It addresses the question, "What?". On the other hand, the Activity-Based Breakdown Structure (ABS), which addresses the question "How?", is constructed through phases, macro-activities, activities, and sub-activities[24]. The Zone-Based Breakdown Structure (ZBS) is physically functional and is divided into areas or sections. The ZBS can represent a topographic view of a project's construction site or functional zones, such as those for the design phase and commissioning phase. It answers the question "Where?". The "3D little cubes" within the WBS cube represent tasks or work packages of the project. Consequently, a work package in the 3D-WBS encompasses product, activity, and zone dimensions.

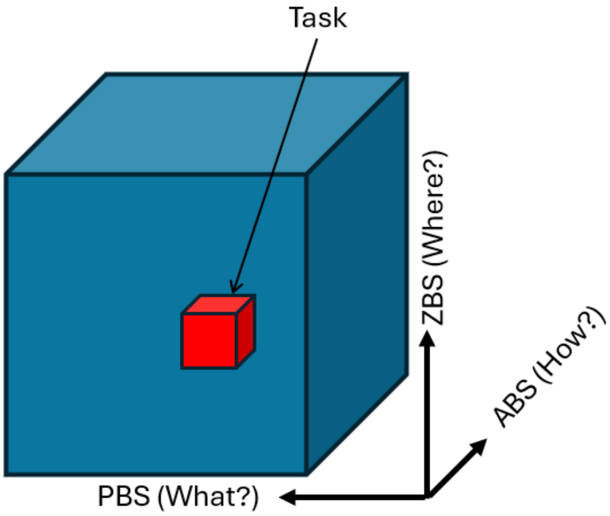



*Figure 9 – The WBS Cube*[25]

## Multi-Dimensional WBS (Not Limited to 3-D)

It is important to note that the WBS is not confined solely to the three-dimensional WBS. It extends beyond the limitations of the three combinations, namely the Product-Based Breakdown Structure (PBS), Activity-Based Breakdown Structure (ABS), and Zone-Based Breakdown Structure (ZBS). The WBS can be further developed into a multi-dimensional framework by incorporating other structures[26].

[24] Wain, Y. A. (2015). Implementation of 3-Dimensional Work Breakdown Structure in Engineering Design; PM World Journal, Vol. IV, Issue V, May
[25] Moine, J. Y. (2013). 3D Work Breakdown Structure method; PM World Journal, Vol. II, Issue IV, April
[26] Ibid

There are many hierarchical structures:

- GBS (Geographical Breakdown Structure),
- PBS (Product Breakdown Structure),
- SBS (Systems Breakdown Structure) or FBS (Functional Breakdown Structure),
- ABS (Activity Breakdown Structure),
- OBS (Organization Breakdown Structure),
- RBS (Resources or Risks Breakdown Structure),
- CWBS (Contract Work Breakdown Structure),
- etc.

Integrating these structures can elevate the 3D WBS into another multi-dimensional breakdown structure matrix while addressing eight stakeholder questions. Figure 11 presents a WBS in a complex context, similar to the Tesseract or 'Hypercube' concept in geometry. This approach expands WBS development to include dimensions like time, cost, risk, and resources, offering stakeholders diverse perspectives and enhancing project management for greater flexibility and effectiveness.

The collaboration among multi-dimensional tree structures aims to synergize efforts in supporting Virtual Reality (VR), Augmented Reality (AR), and Systems Dynamics (SD) models across different levels of Building Information Modeling (BIM), including 2D, 3D, 4D, and 5D BIM, and beyond (see Figure 10). Crafting multi-dimensional models for VR, AR, or SD necessitates grasping basic geometry concepts. For instance, a hypercube, a 3D projection of an 8-cell shape, results from animating a simple rotation around a plane, bisecting the figure from front-left to back-right and top to bottom. This sequence mirrors project Managers' typical steps, starting with creating databases to furnish essential productivity, cost, and resource data required by 3D BIM and VR software, transitioning 2D and 3D BIM designs into 4D BIM (schedule) and 5D BIM (cost) Models. As BIM software evolves, data integration expands to include 6D BIM (Sustainability Modeling) and 7D BIM (Facilities Operation and Management). Referring to the 3D WBS Method acknowledges the interrelationship of tree structures within the project, emphasizing a comprehensive approach[27].

The following are potential developments from the 3D WBS[28]:

[27] PTMC, & Giammalvo, P. D. (2021). 1.4.1.4 Unit 4 – Managing Scope. Retrieved from https://build-project-management-competency.com/1-4-1-4-unit-4/
[28] Leynaud, X., Giammalvo, P. D., Moine, J. Y. (2019). Multi-Dimensional Project Breakdown Structures - The Secret to Successful Building Information Modeling (BIM) Integration. DCB Publishing

- 5 Dimensional WBS Matrix

A 5-dimensional WBS matrix can be formulated by integrating the 3-dimensional WBS with combinations across three product categories. These categories include Products, Tools, and Materials .

- 6 D Matrix: WBS x CBS

The complete WBS and CBS codes are derived by intersecting the 5D WBS matrix with the CBS.

The Cost Structure (CBS) supplements the WBS by offering an intricate overview of project expenditures, facilitating enhanced control over costs, precise budget estimations, and heightened financial accountability across the project's entire lifecycle.

- 7 D Matrix: WBS x CBS x OBS

The WBS, CBS, and OBS codes are fully realized through the intersection of the 6D matrix with the OBS, as illustrated in Figure 12.

- 8 D Matrix: WBS x CBS x Performance (6D BIM)

The 8D matrix can be constructed by combining the 7D matrix with performance elements.

From the explanation of the multi-dimensional WBS above, the question arises: which option is the most suitable for implementation in the LPG Facility Construction as the project owner?

*Figure 10 - Virtual Reality in Engineering and Business Applications[29].*

[29] Virtual Reality in Engineering and Business Applications (19 February 2024). Retrieved from https://filmora.wondershare.com/virtual-reality/virtual-reality-use-in-engineering.html

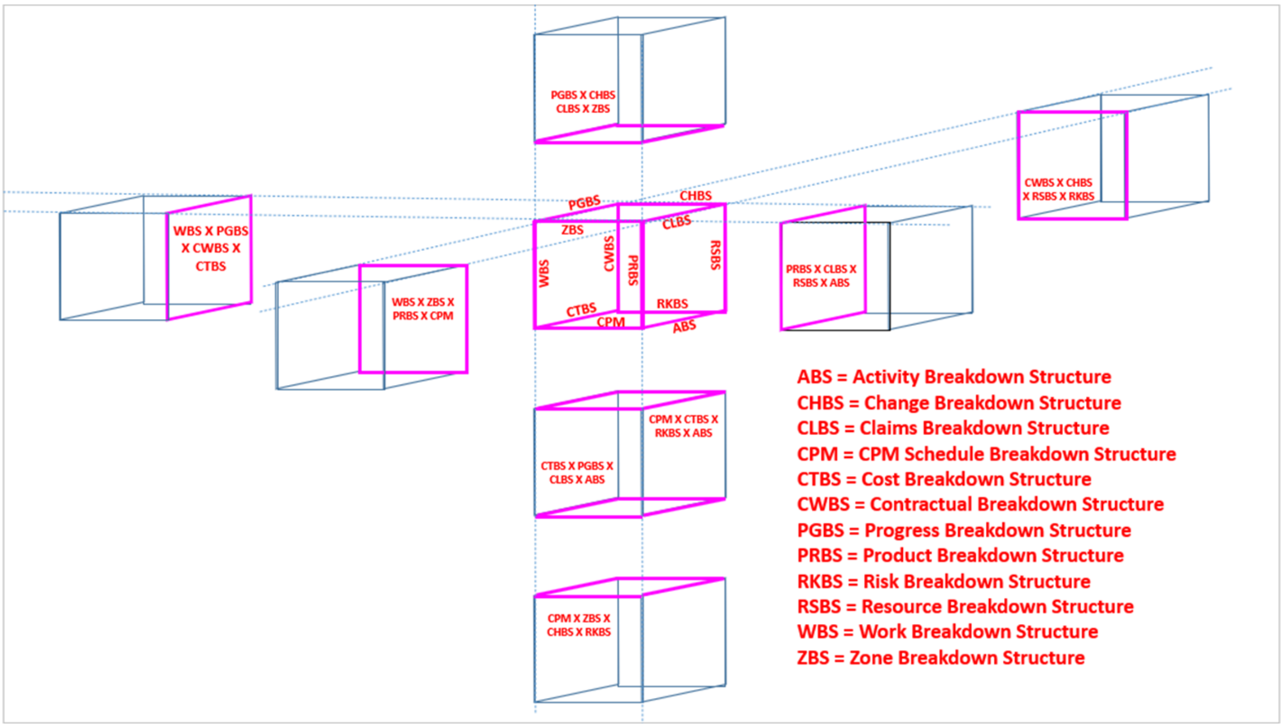



*Figure 11 - Multidimensional Work Breakdown Structures in Project Management[30].*

[30] Leynaud, X., Giammalvo, P. D., Moine, J. Y. (2019). Multi-Dimensional Project Breakdown Structures - The Secret to Successful Building Information Modeling (BIM) Integration. DCB Publishing

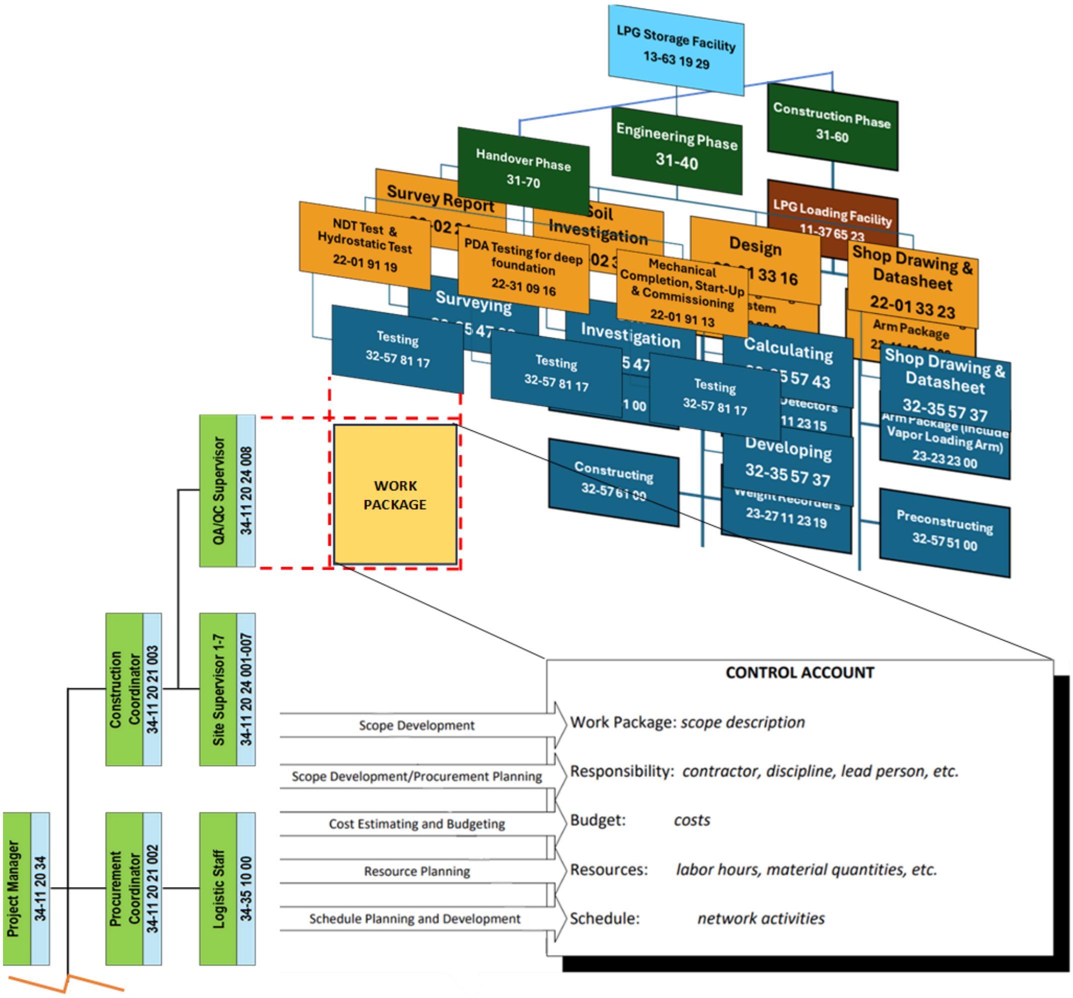



*Figure 12 –Intersection of the OBS with the WBS*[31]

Here are the alternatives to be discussed in this paper:

| Option | Type | WBS Level | | |
|---|---|---|---|---|
| | | Level 1 | Level 2 | Level 3 |
| 1 | 2D/Hierarchical | Area (ZBS) | Product (PBS) | Activities (ABS) |
| 2 | 3-Dimensional | Product (PBS) X-Axis | Activities (ABS) Y-Axis | Area (ZBS) Z-Axis |
| 3 | Multi-Dimensional (Not limited to 3-D) | | | |
| | 5-Dimensional | 3D WBS | Product or Tool or Material | |
| | 6-Dimensional | 5D Matrix | CBS | |
| | 7-Dimensional | 6D Matrix | OBS | |
| | 8-Dimensional | 7D Matrix | Performance | |

*Table 1 – Options, 2D and Multidimensional breakdown structure*[32]

[31] AACE International (2014). AACE International Recommended Practice No. 83R-13 Organizational Breakdown Structure and Responsibility Assignment Matrix
[32] Options, 2D and Multidimensional breakdown structure, by Author

## STEP 3 – Development of the Outcomes of Each Alternative

Among several feasible alternatives in Step 2, WBS is constructed with various dimensions as follows:

### Option 1 – Using 2 Dimensional/Hierarchical WBS

In Figure 13, a flat-file/2D WBS has been created for the LPG Facility Project using OmniClass. Each PBS (OmniClass Table 22) will have associated activities (ABS), constituting WBS Level 3. At this stage, the WBS is hierarchical.

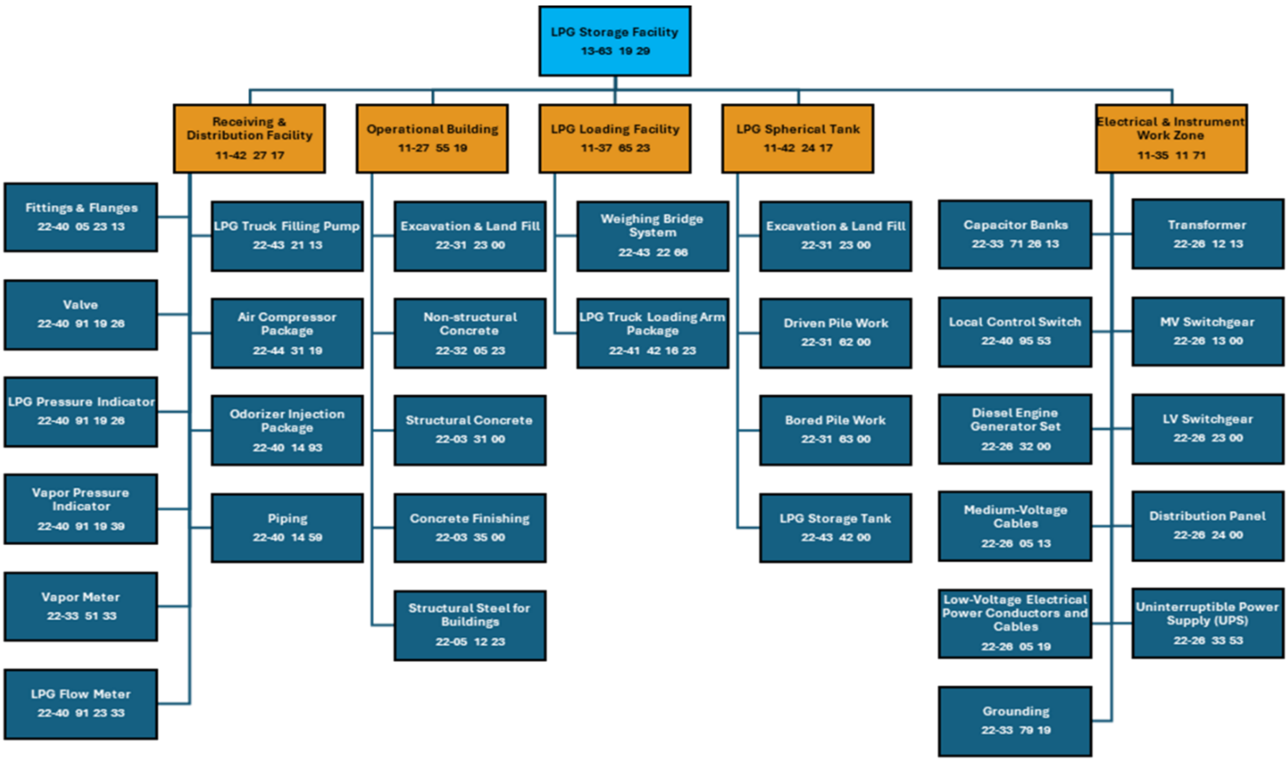



*Figure 13- Hierarchical Work Breakdown Structure*[33]

### Option 2 – Using 3 Dimensional WBS

#### a. 3 Dimensional WBS Using ISO 19008

In its formulation, ISO 19008 is an adaptation of Norsok Z-014, enabling it to encompass a multi-dimensional Work Breakdown Structure (WBS).

The PBS of NorSok Z-014/ISO 19008 can be compared to the PBS of 3-D WBS. The SAB of ISO 19008 can be compared to the ABS of 3-D WBS. The COR of ISO 19008

[33] Hierarchical Work Breakdown Structure, by Author

can be compared to the OBS/RBS of 3-D WBS. The 3-D WBS method can be based on ISO 19008, but zones must be added.

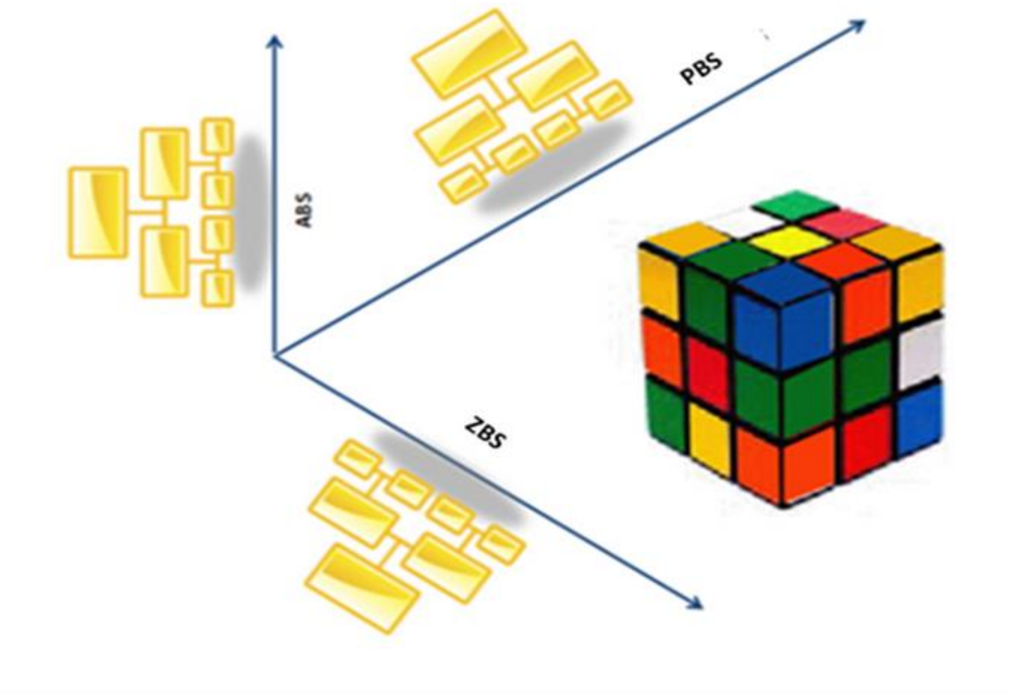



*Figure 14 – 3D Visualization Support Scope Definition*[34]

The ISO 19008:16 standard can be employed in formulating a 3-dimensional Work Breakdown Structure (WBS) for the LPG Facility Project. The "Name" provided by ISO 19008:2016 for PBS, SAB, and COR is well-suited for WBS applications in oil and gas projects.

The detailed 3D WBS using ISO 19008 Standard for the LPG Facility Project will be presented in Appendix 1.

### b. 3 Dimensional WBS using Omniclass

OmniClass is a means of organizing and retrieving information specifically designed for the construction industry. It comprises 15 hierarchical tables, with each one illustrating a distinct facet of construction information. Alternatively, entries can be merged with those from other tables to categorize more intricate subjects.

The 15 inter-related OmniClass tables are:

[34] PTMC, & Giammalvo, P. D. (2021). 1.4.1.4 Unit 4 – Managing Scope. Retrieved from https://build-project-management-competency.com/1-4-1-4-unit-4/

| Table | Description | Table | Description |
|---|---|---|---|
| Table 11 | Construction Entities by Function | Table 31 | Phases |
| Table 12 | Construction Entities by Form | Table 32 | Services |
| Table 13 | Spaces by Function | Table 33 | Disciplines |
| Table 14 | Spaces by Form | Table 34 | Organizational Roles |
| Table 21 | Elements (includes designed elements) | Table 35 | Tools |
| Table 22 | Work Results | Table 36 | Information |
| Table 23 | Products | Table 41 | Materials |
| | | Table 49 | Properties |

*Table 2 – The inter-related Omniclass*

The 3-D WBS is based on three main dimensions: Locations/Zone (LBS/ZBS), Products (PBS), and Activity (ABS) (Figure 15).

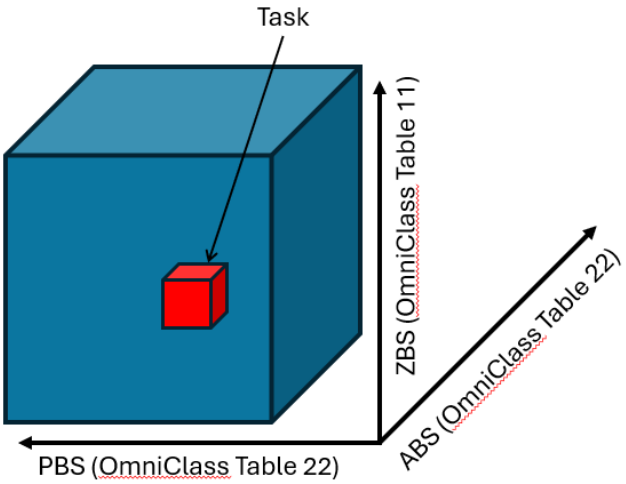



*Figure 15 – 3 Dimensional WBS Using Omniclass Table for LPG Facility*[35]

ZBS denotes the hierarchical arrangement of regions, sites, or geographical segments typically within a project. Following these definitions, the specific breakdown structure for LPG Facility projects can be derived using OmniClass Table 11 (Construction Entities by Function). This table comprehensively overviews general facility components for decomposing ZBS elements.

The product breakdown structure (PBS) dissects the project into tangible components, products, systems, or sub-systems. Following these definitions, a detailed PBS for LPG Facility Projects can be derived from OmniClass Table 22 (Work Result). This table specifically outlines LPG Facility components or facilities for decomposing PBS elements.

[35] 3 Dimensional WBS Using OmniClass Table, by Author

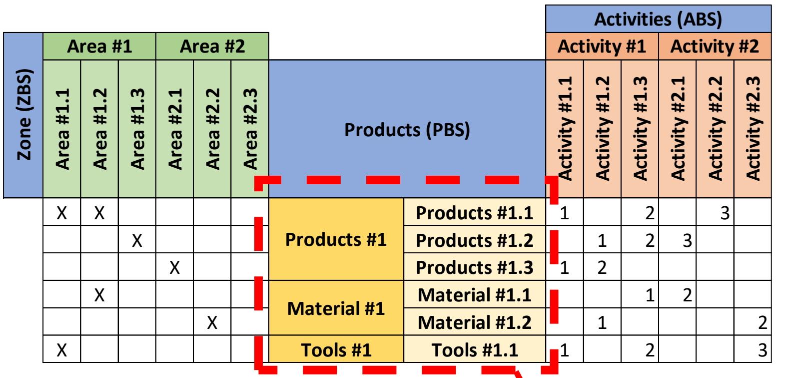
Activity Breakdown Structure (ABS) is the hierarchy of activities, phases, and sub-activities. In accordance with these definitions, detailed ABS for LPG Facility Projects can be extracted by OmniClass Table 32 (Service), which notes the project phase for decomposing ABS components.

The detailed table compiled for the LPG Facility Project will be presented in Appendix 2.

### Option 3 – Using Multi Dimensional WBS (Not Limited to 3D WBS)

#### a. 5 Dimensional WBS Matrix

The 5D WBS is formed by integrating the Product/Tool/Material elements into the 3D WBS. This can be illustrated for the LPG Facility Project as shown in Figure 16 (The product details will be documented in Appendix 3).




| Task | | |
|---|---|---|
| ZBS | PBS | ABS |
| Area #1.1 | Products #1.1 | Activity #1.1 |
| Area #1.1 | Products #1.1 | Activity #1.3 |
| Area #1.1 | Products #1.1 | Activity #2.2 |
| Area #1.2 | Products #1.1 | Activity #1.1 |
| Area #1.2 | Products #1.1 | Activity #1.3 |
| Area #1.2 | Products #1.1 | Activity #2.2 |
| Area #1.3 | Products #1.2 | Activity #1.2 |
| Area #1.3 | Products #1.2 | Activity #1.3 |
| Area #1.3 | Products #1.2 | Activity #2.1 |
| Area #2.1 | Products #1.3 | Activity #1.1 |
| Area #2.1 | Products #1.3 | Activity #1.2 |
| Area #1.2 | Material #1.1 | Activity #1.3 |
| Area #1.2 | Material #1.1 | Activity #2.1 |
| Area #1.2 | Material #1.1 | Activity #2.2 |
| Area #2.2 | Material #1.2 | Activity #1.3 |
| Area #2.2 | Material #1.2 | Activity #2.3 |
| Area #1.1 | Tools #1.1 | Activity #1.1 |
| Area #1.1 | Tools #1.1 | Activity #1.3 |
| Area #1.1 | Tools #1.1 | Activity #2.3 |

*Figure 16 – 5 Dimensional Matrix* [36]

[36] 5 Dimensional WBS, by Author

### b. 6 D Matrix: WBS x CBS

The comprehensive Work Breakdown Structure (WBS) and Cost Breakdown Structure (CBS) codes are derived by intersecting the 5D WBS matrix with the CBS .

Designing cost codes for accounting versus major projects involves a significant distinction. For major projects, the emphasis is on project-driven work and the completion of essential tasks and activities. Therefore, it is logical to align cost code buckets with specific tasks and work. Assigning cost codes to tasks is apt, given that tasks are measurable in terms of hours, materials, and equipment needed for completion. This facilitates the association of budget, costs, progress, and other metrics. Consequently, aligning the hierarchy of the WBS with a hierarchical CBS becomes essential. A well-designed WBS serves a dual purpose: organizing work and categorizing and organizing costs[37].

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 13-63 19 29 | LPG Facility | | | | | | | | | | |
| 31-60 | Construction Phase | | | | | | | | | | |
| 11-42 24 11 | Installation Gas Storage Facility | | | | | | | | | | |
| 22-43 21 13 | Centrifugal Liquid Pumps | | | | | | | | | | |
| 23-27 17 13 | Centrifugal Pumps | | | | | | | | | | |
| | Description | Crew Type | Daily Output per Unit | Labor Hours per Unit | Unit of Measure | Material Cost / Unit | Total Material Cost | Labor Cost | Equipment Cost / Unit | Total Equipment | Total Cost |
| 0010 | Installation of Centrifugal Pump 300 GPM | 34-35 15 27 | 0,33 | 48 | Set | 253.000.000 | 253.000.000 | 25.000.000 | 1.270.000 | 1.270.000 | 279.270.000 |

**WBS Code:**

**13-63 19 29 31-60 11-42 24 11 22-43 21 13 23-27 17 13 0010 - Installation of Centrifugal Pump 300 GPM**

*Table 3 – Integrating Cost With WBS for LPG Facility Project*

### c. 7 D Matrix: WBS x CBS x OBS

A project Organization Breakdown Structure (OBS) visually represents the organizational hierarchy of the project, outlining reporting relationships. It mirrors the functional organization of the project, offering a direct portrayal of entities contributing resources to execute the WBS. The OBS is integral to establishing an efficient organization, considering the availability and proficiency of management, technical staff, and subcontractors. It plays a crucial role in identifying responsibilities in the Responsibility Assignment Matrix (RAM) and RACI Matrix, ensuring the successful execution of the

[37] Should You Align Your CBS with Your WBS? (2019). 4castplus. retrieved from https://4castplus.com/should-you-align-your-cbs-with-your-wbs/

project. The following is the OBS taken from Omniclass Table 34 and the Standard Occupational Classification Manual (SOC) for the LPG Facility Project:

| Criterion Fulfilled | Omniclass Code | Unique Code | SOC 2018 | Unique Code |
|---|---|---|---|---|
| Project Manager | 34-11 20 34 | | 11-9020 | |
| Engineering Manager | 34-11 20 21 | 001 | 11-9021 | 001 |
| Procurement Coordinator | 34-11 20 21 | 002 | 11-9021 | 002 |
| Construction Coordinator | 34-11 20 21 | 003 | 11-9021 | 003 |
| QA/QC Supervisor | 34-11 20 24 | 008 | 47-1000 | 008 |
| Project Schedule & Cost Control | 34-11 20 31 | | 13-1082 | |
| Process Engineer | 34-20 11 21 | 001 | 17-2112 | |
| Mechanical Engineer | 34-20 11 21 | 002 | 17-2140 | |
| Piping Engineer | 34-20 11 21 | 003 | 17-2141 | |
| Instrument/Control Engineer | 34-20 11 21 | 004 | 17-2072 | |
| Electrical Engineer | 34-20 11 21 | 005 | 17-2071 | |
| Civil/Structure Engineer | 34-20 11 21 | 006 | 17-2050 | |
| Field/Project Engineer | 34-35 15 17 | 001-007 | 17-2199 | 001-007 |
| Site Supervisor | 34-11 20 24 | 001-007 | 47-1000 | 001-007 |
| Civil Inspector | 34-20 51 17 | 001 | 47-4010 | 001 |
| Mechanical Inspector | 34-20 51 17 | 002 | 47-4010 | 002 |
| Piping/Pipeline Inspector | 34-20 51 17 | 003 | 47-4010 | 003 |
| Instrument & Control Inspector | 34-20 51 17 | 004 | 47-4010 | 004 |
| Electrical Inspector | 34-20 51 17 | 005 | 47-4010 | 005 |
| Logistic Staff | 34-35 10 00 | | 13-1081 | |

*Table 4 – Table 34 Omniclass and SOC Code for LPG Facility Project*[38][39]

## d. 8 D Matrix: WBS x CBS x Performance (6D BIM)

Performance for the Work Breakdown Structure (WBS) can be elucidated using Omniclass Table 49, incorporating performance parameters as follows:

[38] OmniClass. (2020). Organizational Roles – Table 34. https://www.csiresources.org/standards/omniclass
[39] Executive Office of The President Office of Management and Budget (2018). Standard Occupational Classification Manual

| Table 49 - Properties | |
|---|---|
| **49-81 00 00** | **Performance Properties** |
| 49-81 11 00 | Testing Properties |
| 49-81 11 11 | Test Method |
| 49-81 11 15 | Pre-Test Conditions |
| 49-81 11 17 | Test Conditions |
| 49-81 11 19 | Reference Standard |
| 49-81 11 21 | Inspection Protocol |
| 49-81 11 23 | Factory Testing |
| 49-81 11 25 | Field Testing |
| 49-81 15 11 | Deflection Tolerance |
| 49-81 15 13 | Dimensional Tolerance |
| 49-81 15 15 | Shape Tolerance |
| 49-81 15 17 | Installation Tolerance |
| 49-81 15 19 | Plumbness |
| 49-81 21 15 | Method of Operation |
| 49-81 21 17 | Functional Capacity |
| 49-81 21 17 13 | Operational Capacity |
| 49-81 21 17 15 | Rated Capacity |
| 49-81 21 17 17 | Breaking Capacity |
| 49-81 21 25 | Serviceability |
| 49-81 21 29 | Workability |
| 49-81 31 00 | Strength Properties |
| 49-81 31 11 | Adhesion Strength |
| 49-81 31 27 | Compressive Strength |
| 49-81 31 43 | Flexural Strength |
| 49-81 31 85 | Tensile Strength |
| 49-81 31 87 | Ultimate Strength |
| 49-81 31 91 | Vibration |
| 49-81 31 93 | Wind Uplift Resistance |
| 49-81 31 95 | Yield Strength |
| 49-81 41 23 | Chemical Resistance |
| 49-81 41 25 | Corrosion Resistance |
| 49-81 41 57 | Microorganism Resistance |
| 49-81 51 00 | Combustion Properties |
| 49-81 51 27 | Flammability |
| 49-81 51 29 | Ignitibility |
| 49-81 51 41 | Explosion Proof |
| 49-81 51 43 | Fire Resistance |

*Table 5 – Table 49 Omniclass for LPG Facility Project*[40]

## STEP 4 – Selection of a Criteria

It is necessary to establish criteria for the Multi-Dimensional Work Breakdown Structure to ensure the development of a WBS structure that aligns with the needs of the LPG Facility Project. The following criteria will be tested against alternative dimensions of the WBS [41, 42]:

[40] OmniClass. (2020). Properties – Table 49. https://www.csiresources.org/standards/omniclass
[41] Leynaud, X., Giammalvo, P. D., Moine, J. Y. (2019). Multi-Dimensional Project Breakdown Structures - The Secret to Successful Building Information Modeling (BIM) Integration. DCB Publishing
[42] Kerzner, H. (2009). Project Management a Systems Approach to Planning, Scheduling, and Control. John Wiley & Sons, Inc.

Reflects Exactly 100% of the Deliverables:

- Clearly outline the end product and all Work Packages for the project or program
- Contains at least three and preferably four levels of detail from the OWNER to the CONTRACTOR
- Demonstrates inclusivity and flexibility, adaptable to the program's specific needs
- Applies the 100 percent rule: the sum of the children "rolls up," equaling the parent's cost and duration

Utilizes a standardized coding structure to facilitate the collection of cost and productivity data for future project estimations .

- Is required so the 3D, 4D, 5D, and 6D apps can exchange data
- Is updated as changes occur and the program becomes better defined;
- Includes both OWNER and CONTRACTOR administrative (general condition) control accounts
- Is the starting point for developing the program's detailed schedule;
- Provides a framework for identifying and monitoring risks and the effectiveness of contingency plans;

Includes a dictionary elucidating each control account (planning or work package) and its hierarchical relationships, mapping to other tables.

- Clearly defines the inclusions in each element or component.
- Describes the necessary resources and functional activities required to produce the product.
- Establishes linkages between each element and other relevant technical documents.

The ability to address the eight questions on Stakeholders' Needs.

- Who
- What
- Why
- Where
- When

- How
- How Much
- For What Purpose

### STEP 5 - Analysis and Comparation Alternative

Based on the attributes indicated in Step 4, a check is conducted against the options available in the WBS matrix dimensions. Based on these criteria, Table 6 shows that a Multi-Dimensional WBS can meet the requirements for use.

| Criteria | 2D WBS | 3D WBS | 5D Matrix | 6D Matrix | 7D Matrix | 8D Matrix |
|---|---|---|---|---|---|---|
| **Reflects Exactly 100% of the Deliverables:** | | | | | | |
| **- Clearly outlines the end-product and all Work Packages for the project or program** | 1 | 1 | 1 | 1 | 1 | 1 |
| **- Contains at least three and preferably four levels of detail from the OWNER to the CONTRACTOR** | 1 | 1 | 1 | 1 | 1 | 1 |
| **- Demonstrates inclusivity and flexibility, adaptable to the program's specific needs** | | 1 | 1 | 1 | 1 | 1 |
| **- Applies the 100 percent rule: the sum of the children "rolls up," equaling the parent's cost and duration** | 1 | 1 | 1 | 1 | 1 | 1 |
| **Utilizes a standardized coding structure to facilitate the collection of cost and productivity data for future project estimations.** | | | | | | |
| **- is required so the 3D, 4D, 5D, and 6D apps can exchange data** | | 1 | 1 | 1 | 1 | 1 |
| **- is updated as changes occur and the program becomes better defined;** | | 1 | 1 | 1 | 1 | 1 |
| **- includes both OWNER and CONTRACTOR administrative (general condition) control accounts** | | | | | 1 | 1 |
| **- is the starting point for developing the program's detailed schedule;** | | 1 | 1 | 1 | 1 | 1 |
| **- provides a framework for identifying and monitoring risks and the effectiveness of contingency plans;** | | 1 | 1 | 1 | 1 | 1 |
| **Includes a dictionary elucidating each Control Account (planning or work package) and its hierarchical relationships, mapping to** | | | | | | |
| **- Clearly defines the inclusions in each element or component.** | | | 1 | 1 | 1 | 1 |
| **- Describes the necessary resources and functional activities required to produce the product.** | | | 1 | 1 | 1 | 1 |
| **- Establishes linkages between each element and other relevant technical documents.** | | 1 | 1 | 1 | 1 | 1 |
| | **3** | **9** | **11** | **11** | **12** | **12** |

*Table 6 – Analysis Using MADM*

However, a recheck of the 8 High-Level Questions is necessary. The question "What?" can be answered by creating a Product Breakdown Structure (PBS); the question "How?" can be addressed with Activities (ABS); the question "Where?" can be answered by specifying where the product/work results are installed (ZBS); the question "Who?" can be answered by identifying who performs the work (PBS); the question "When?" can be answered by considering the intersections between ZBS, PBS, ABS, and scheduled timing; the question "Why?" can be addressed by performing the project to obtain the required Product/Project or by using the OmniClass Table 11; the question "How Much?" can be answered by adding cost components (CBS); and the question "For What?" can be achieved by adding performance elements to the WBS.

| High Level Question | 2D WBS | 3D WBS | 5D Matrix | 6D Matrix | 7D Matrix | 8D Matrix |
|---|---|---|---|---|---|---|
| Who | | | | | 1 | 1 |
| What | 1 | 1 | 1 | 1 | 1 | 1 |
| Why | 1 | 1 | 1 | 1 | 1 | 1 |
| Where | 1 | 1 | 1 | 1 | 1 | 1 |
| When | 1 | 1 | 1 | 1 | 1 | 1 |
| How | | 1 | 1 | 1 | 1 | 1 |
| How Much | | | | 1 | 1 | 1 |
| For What | | | | | | 1 |
| | **4** | **5** | **5** | **6** | **7** | **8** |

*Table 7 – 8 High-Level Questions*

From the comparison against the eight high-level questions, it's evident that as the dimensions of the matrix increase, those questions are answered more effectively .

**STEP 6 - Selection of Preferred Alternative**

Based on the analysis in Step 5, it can be observed that utilizing a multi-dimensional WBS is the optimal option for the LPG Facility Project.

Next, in Step 6, a Multi-Dimensional WBS will be constructed for the LPG Facility Project.

Below is the list of WBS tables that will be used to develop the WBS for the LPG Facility Project [43, 44, 45,46, ,47,48,49] .

[43]OmniClass. (2020). Construction Entities by Function - Table 11. https://www.csiresources.org/standards/omniclass
[44] OmniClass. (2020). Construction Entities by Form - Table 12. https://www.csiresources.org/standards/omniclass
[45] OmniClass. (2020). Elements (includes Designed Elements) - Table 21. https://www.csiresources.org/standards/omniclass
[46] OmniClass. (2020). Work Results - Table 22. https://www.csiresources.org/standards/omniclass
[47] OmniClass. (2020). Products - Table 23. https://www.csiresources.org/standards/omniclass
[48] OmniClass. (2020). Phases - Table 31. https://www.csiresources.org/standards/omniclass
[49] OmniClass. (2020). Services - Table 32. https://www.csiresources.org/standards/omniclass

| Table ID | Name | Definition | WBS Usage |
|---|---|---|---|
| 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. | Zone |
| Table 13 | Spaces by Function | Spaces by Function are basic units of the built environment delineated by physical or abstract boundaries and characterized by their function or primary use. | Zone |
| 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. | Product |
| Table 23 | Products | Products are components or assemblies of components for permanent incorporation into construction entities | Resources |
| Table 31 | Phases | Life cycle phases are often represented by two terms used somewhat interchangeably in our industry. For the purposes of clarity and standardization, OmniClass™ defines these terms:<br>• 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.<br>• Phase: A portion of work that arises from sequencing work in accordance with a predetermined portion of a Stage.<br>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. | Phase |
| 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. | Activities |
| Table 34 | Organizational Roles | Organizational Roles are the technical 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. | Organizational |
| Table 49 | Properties | Properties are characteristics of construction entities. Property definitions gain meaning through reference to one or more construction objects to which they may be applied. | Performance |

*Table 8 – OmniClass Table for LPG Facility Project*

Using the OmniClass Table, the following WBS is constructed:

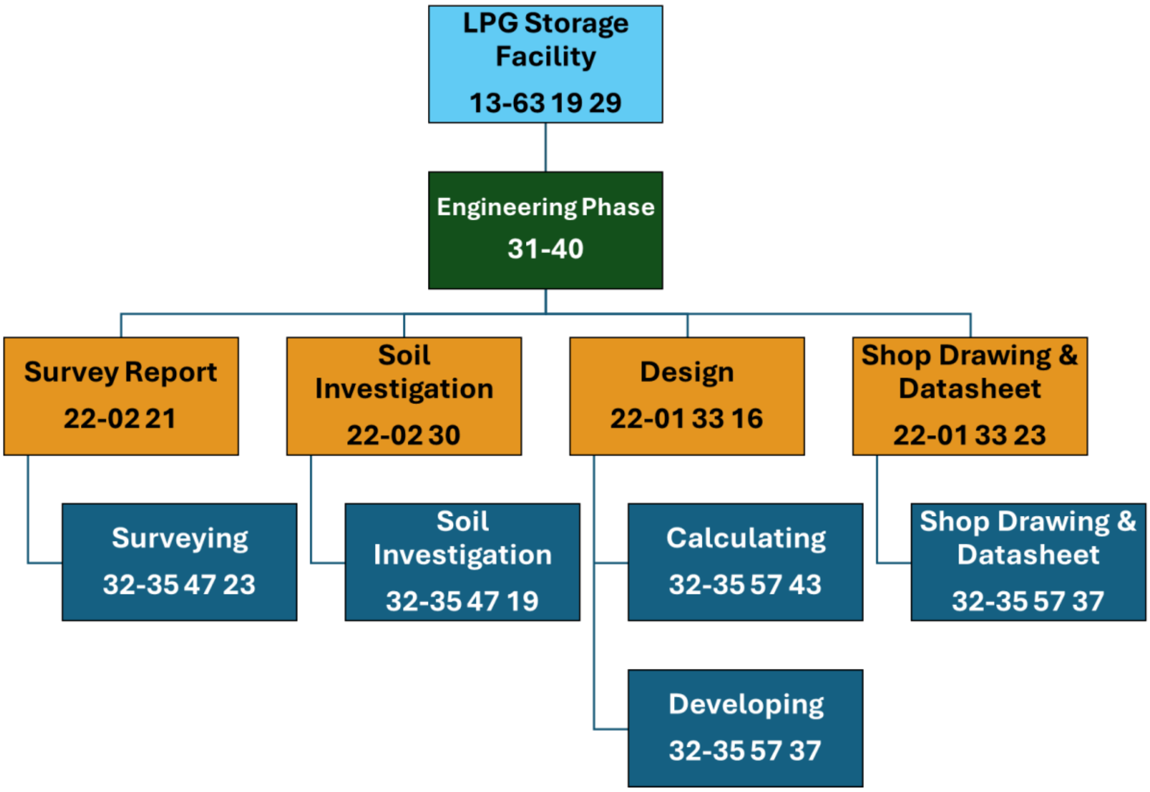



*Figure 17.A – Multi-Dimensional WBS for LPG Facility Project*

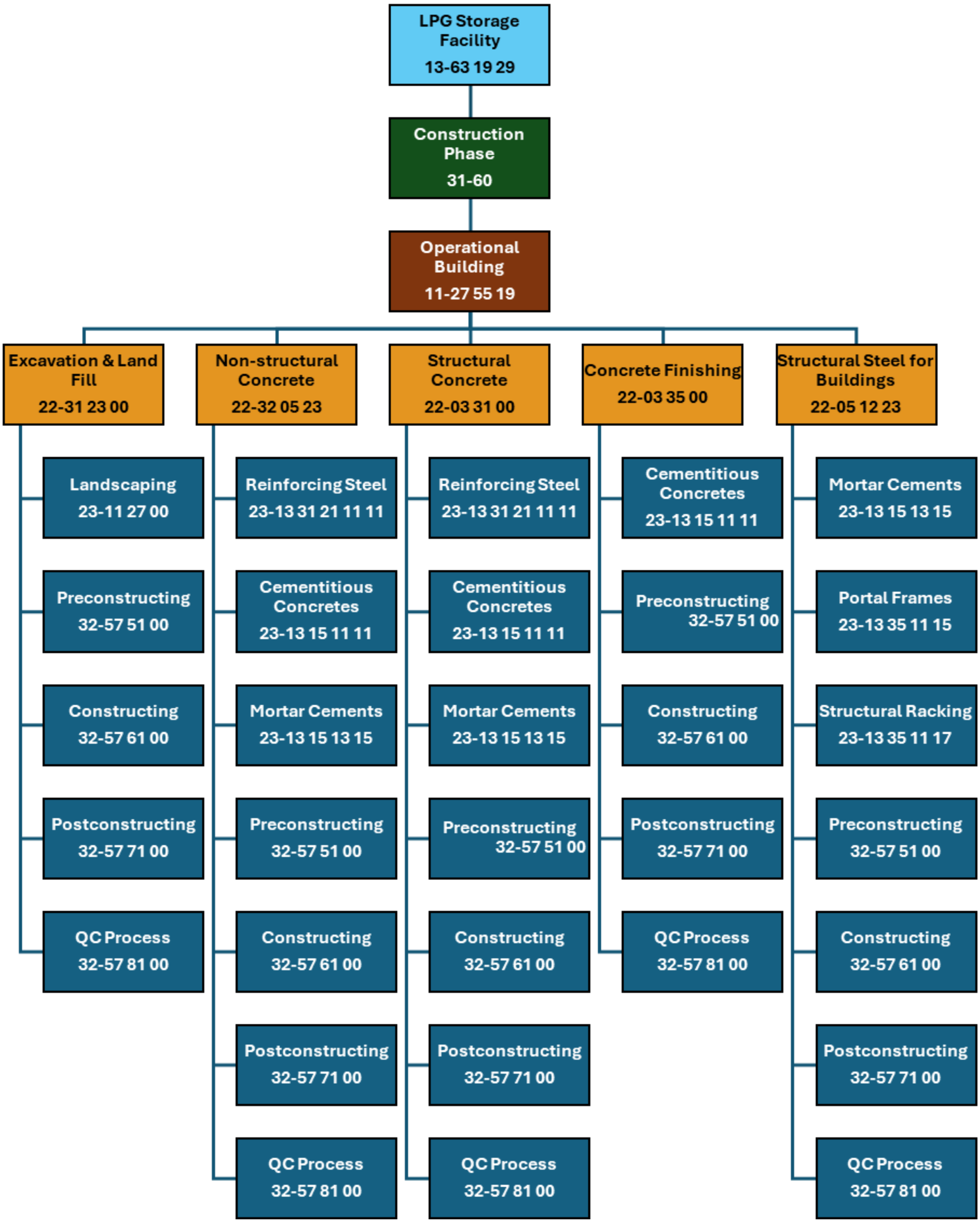



*Figure 17.B – Multi-Dimensional WBS for LPG Facility Project*

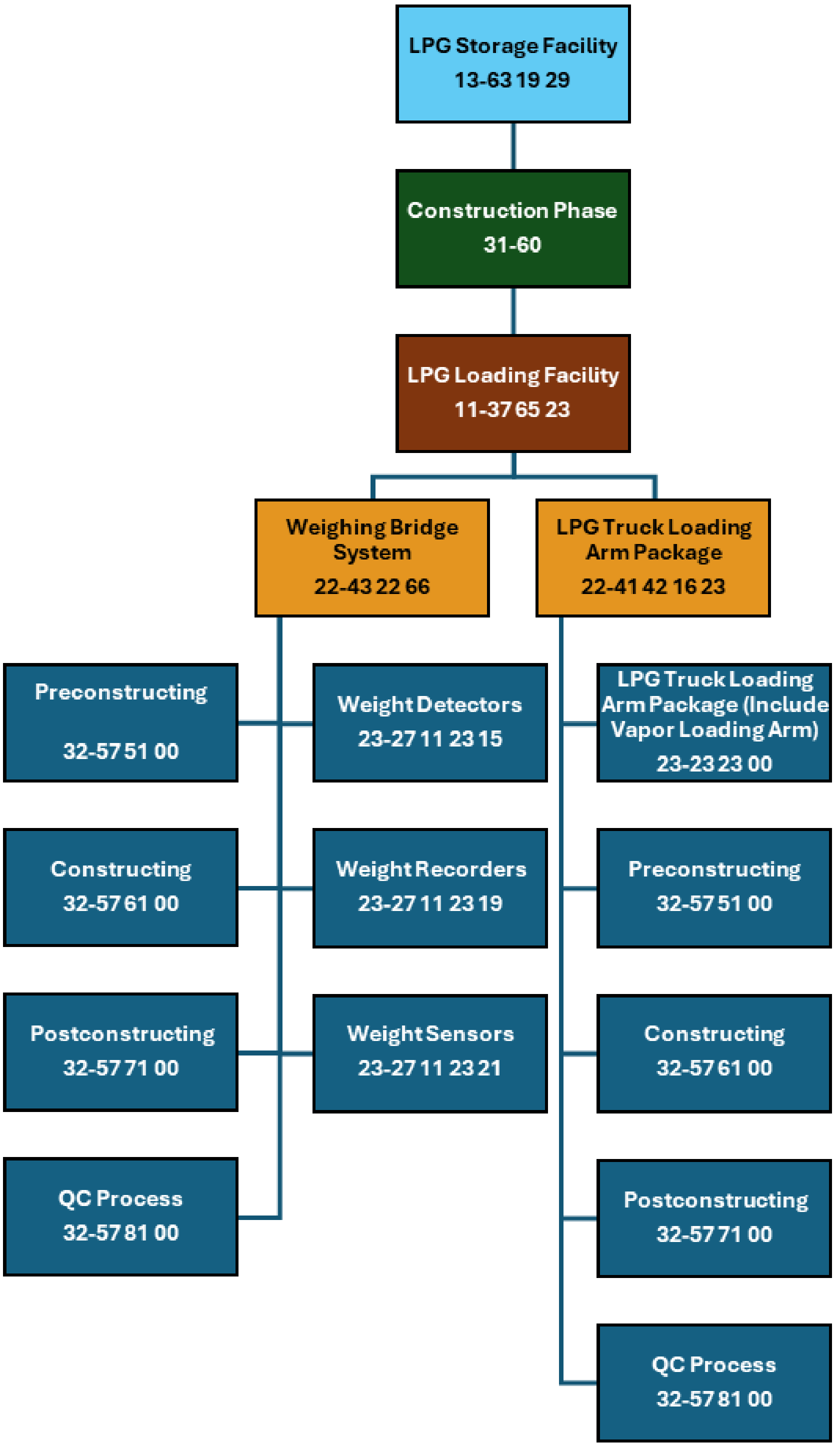



*Figure 17.C – Multi-Dimensional WBS for LPG Facility Project*

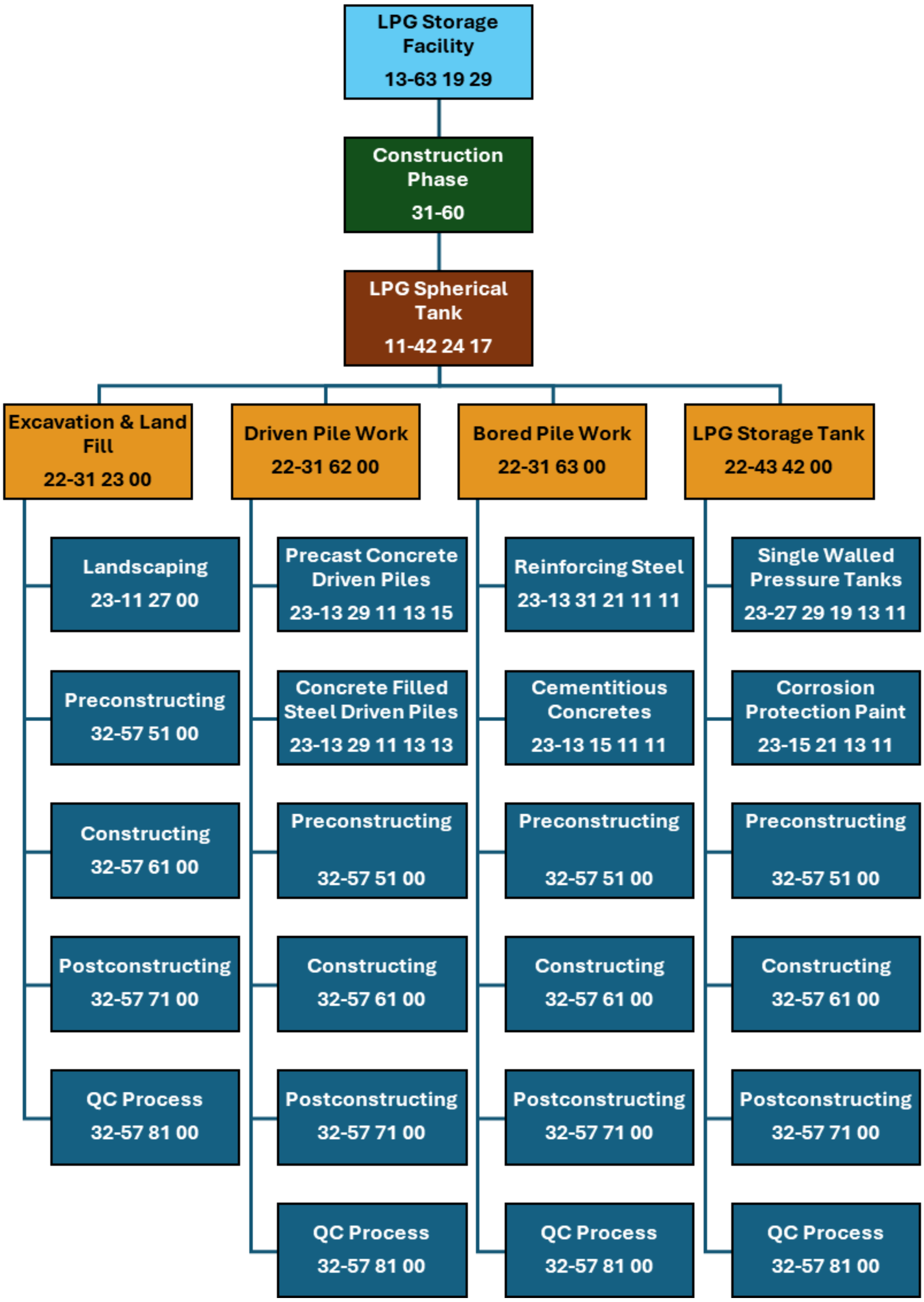



*Figure 17.D – Multi-Dimensional WBS for LPG Facility Project*

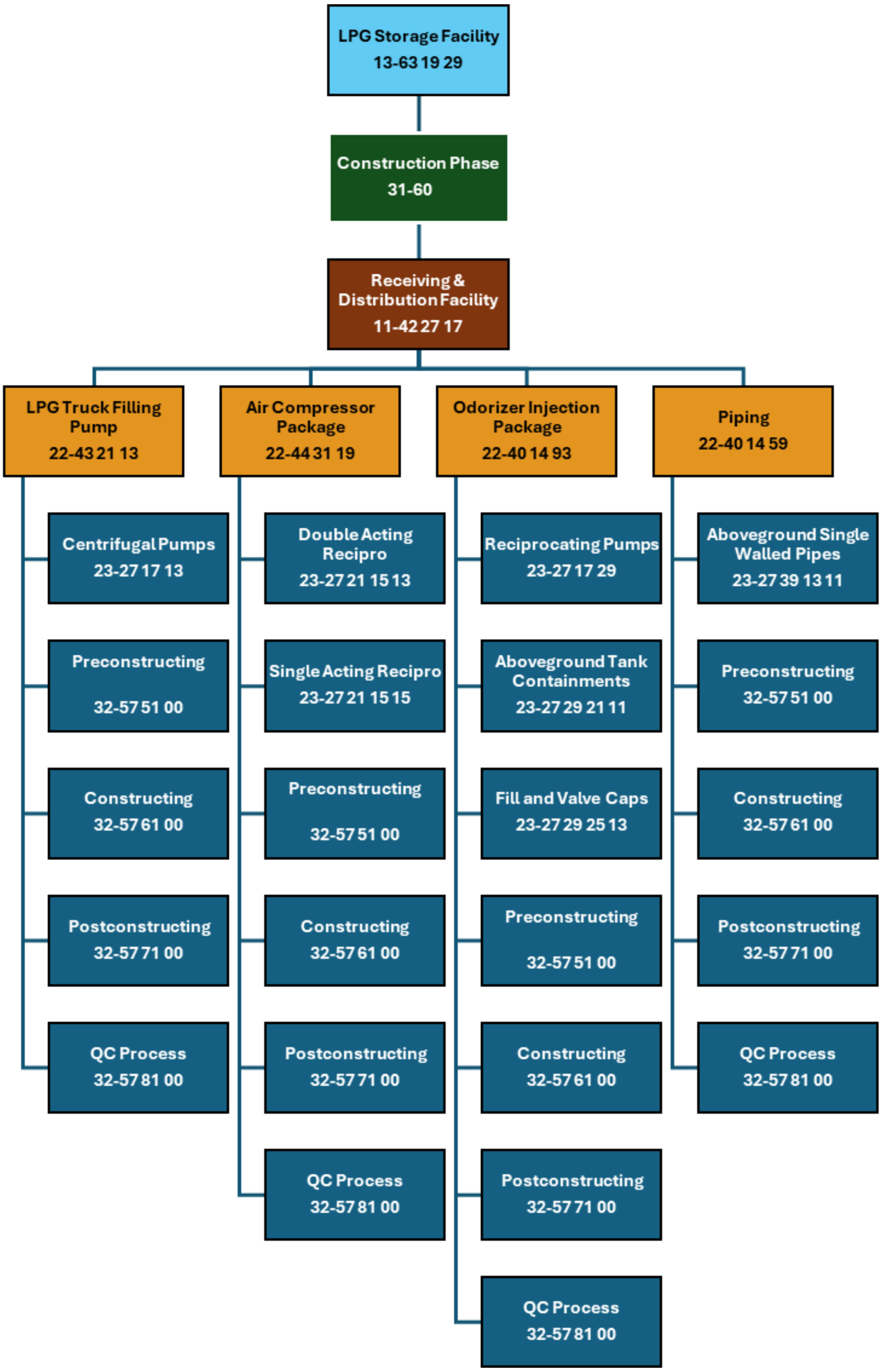



*Figure 17.E – Multi-Dimensional WBS for LPG Facility Project*

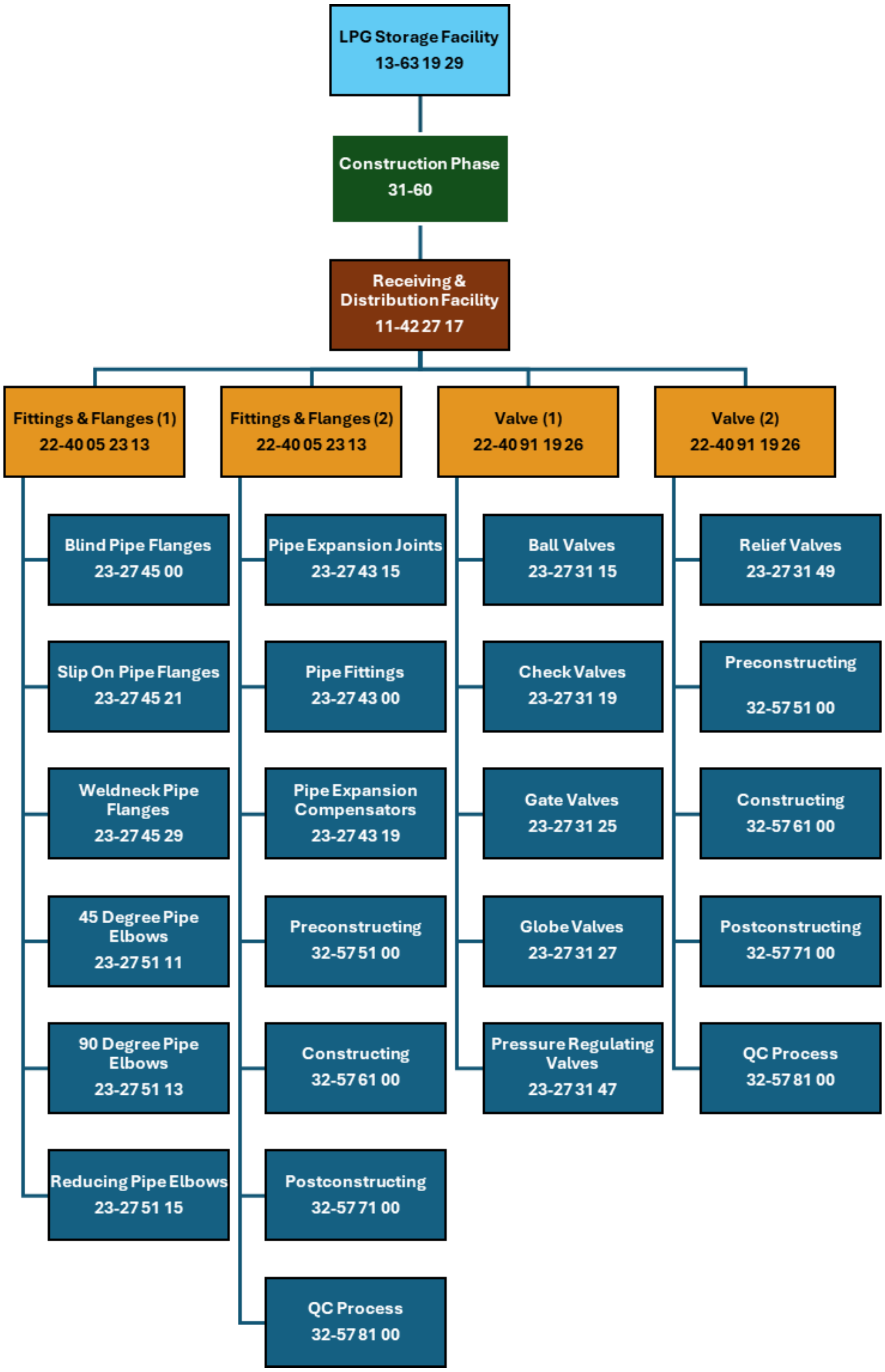



*Figure 17.F – Multi-Dimensional WBS for LPG Facility Project*

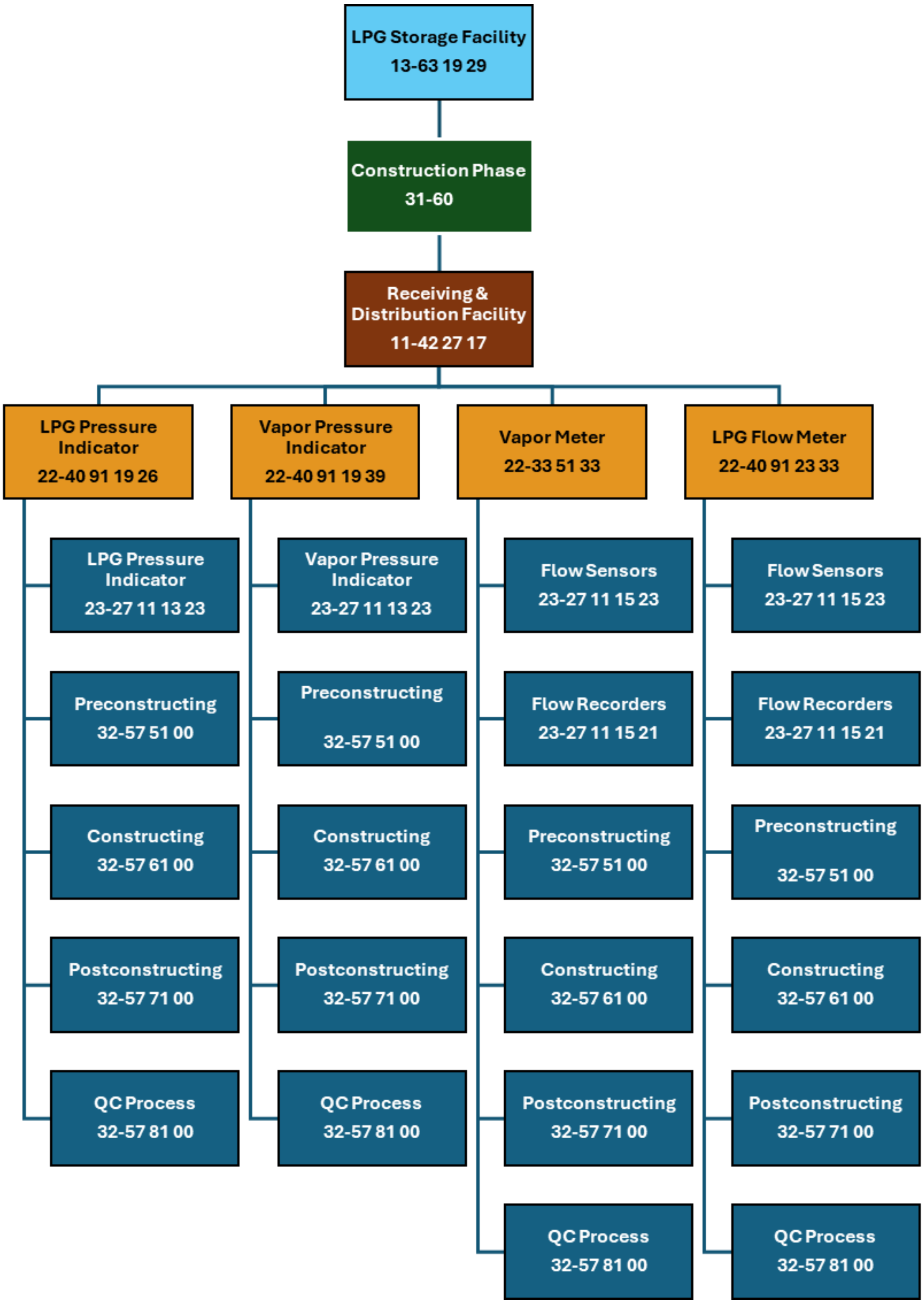



*Figure 17.G – Multi-Dimensional WBS for LPG Facility Project*

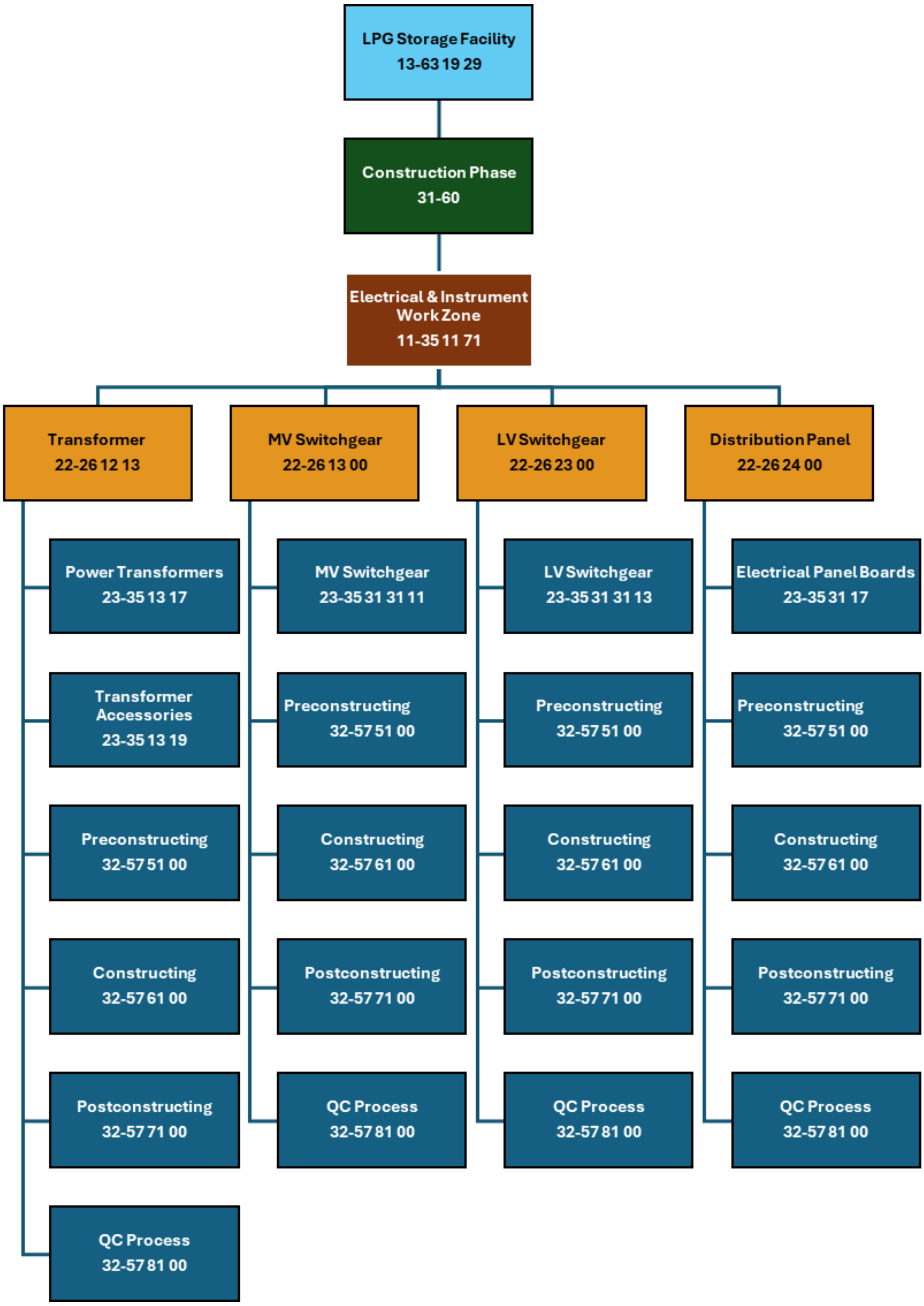



*Figure 17.H – Multi-Dimensional WBS for LPG Facility Project*

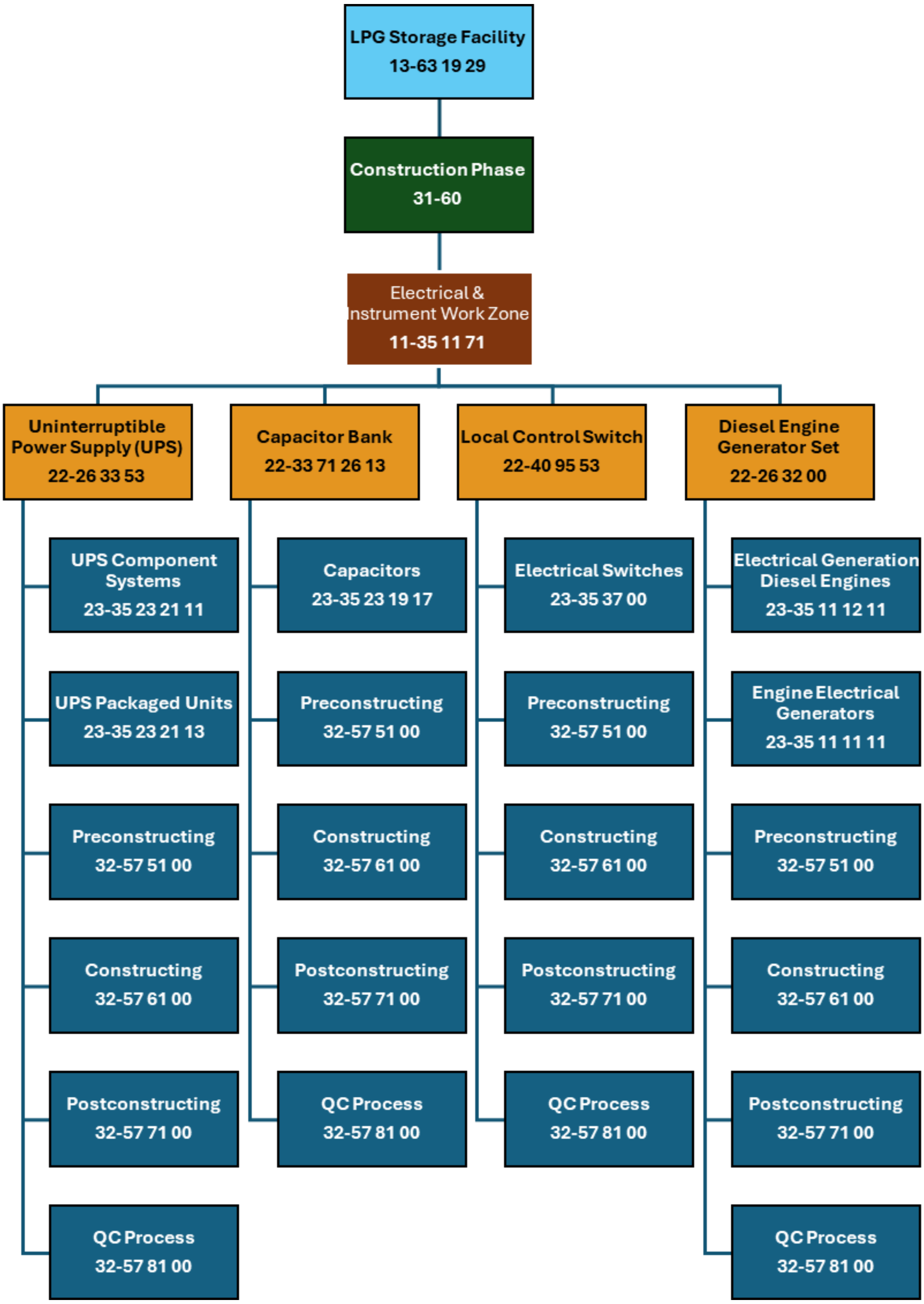



*Figure 17.I – Multi-Dimensional WBS for LPG Facility Project*

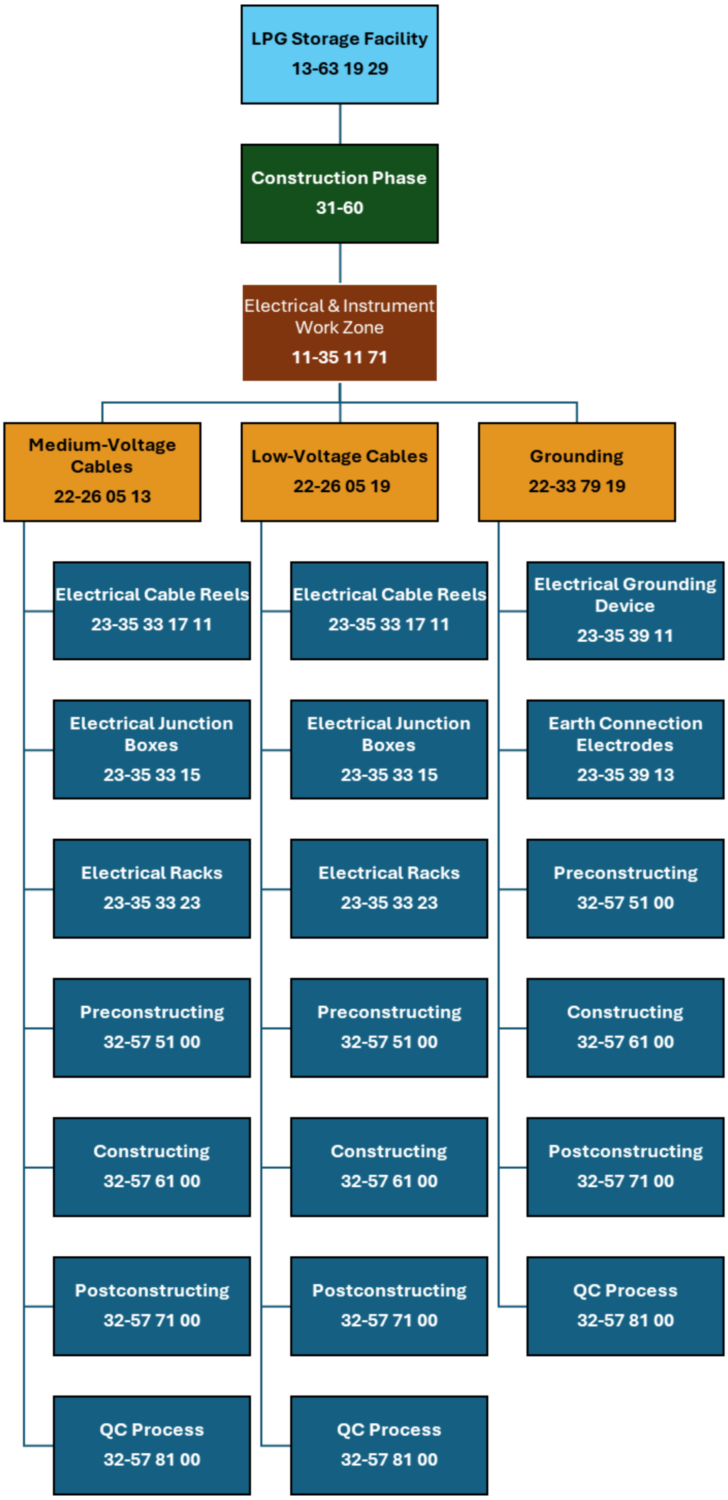



*Figure 17.J – Multi-Dimensional WBS for LPG Facility Project*

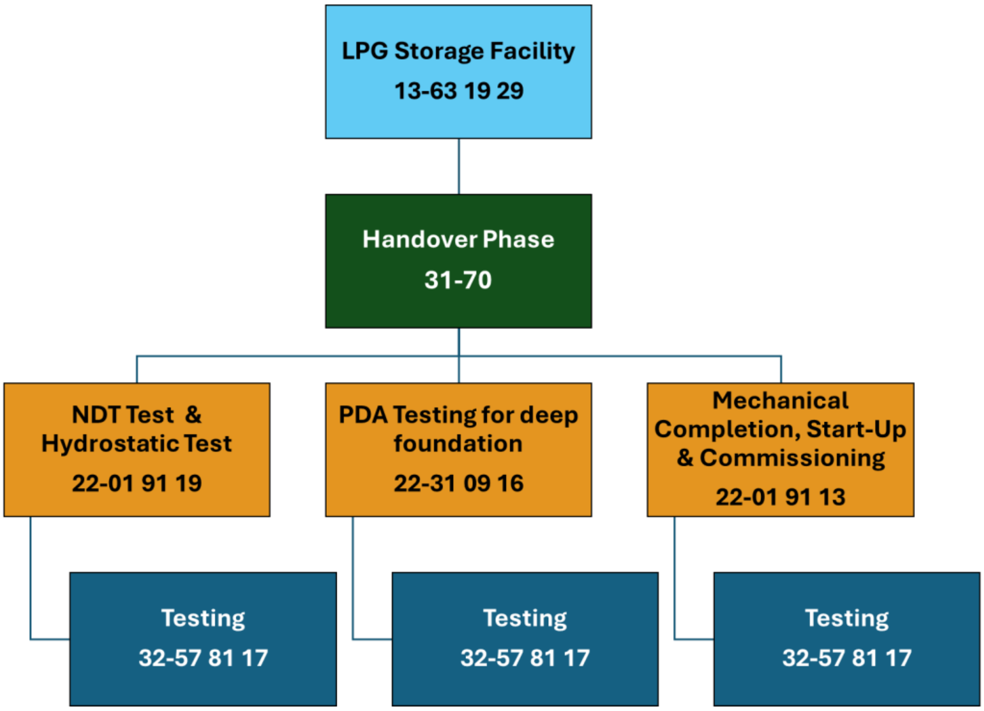



*Figure 17.K – Multi-Dimensional WBS for LPG Facility Project*

Once the Work Breakdown Structure (WBS) is established, the subsequent step involves assigning individuals to carry out the tasks. An Organizational Breakdown Structure (OBS) is utilized to indicate who is responsible for each task. To ensure accountability for every WBS element and its associated tasks, it is beneficial to establish levels of responsibility, known as control accounts, at the junctions between the OBS and the WBS.

Once the project's organizational structure is clearly defined, there is a shared understanding of the Organization Breakdown Structure (OBS) and its elements. The matrix that links responsibility to the scope of work is termed a Responsibility Assignment Matrix (RAM). This matrix displays the WBS on one axis and the OBS on the other. The intersection of these axes enables identifying individuals responsible for specific products or services. By marking the intersection of the WBS and the OBS with an "X", responsibilities are delineated.

Using OmniClass Table 34, the OBS is created in Figure 18.

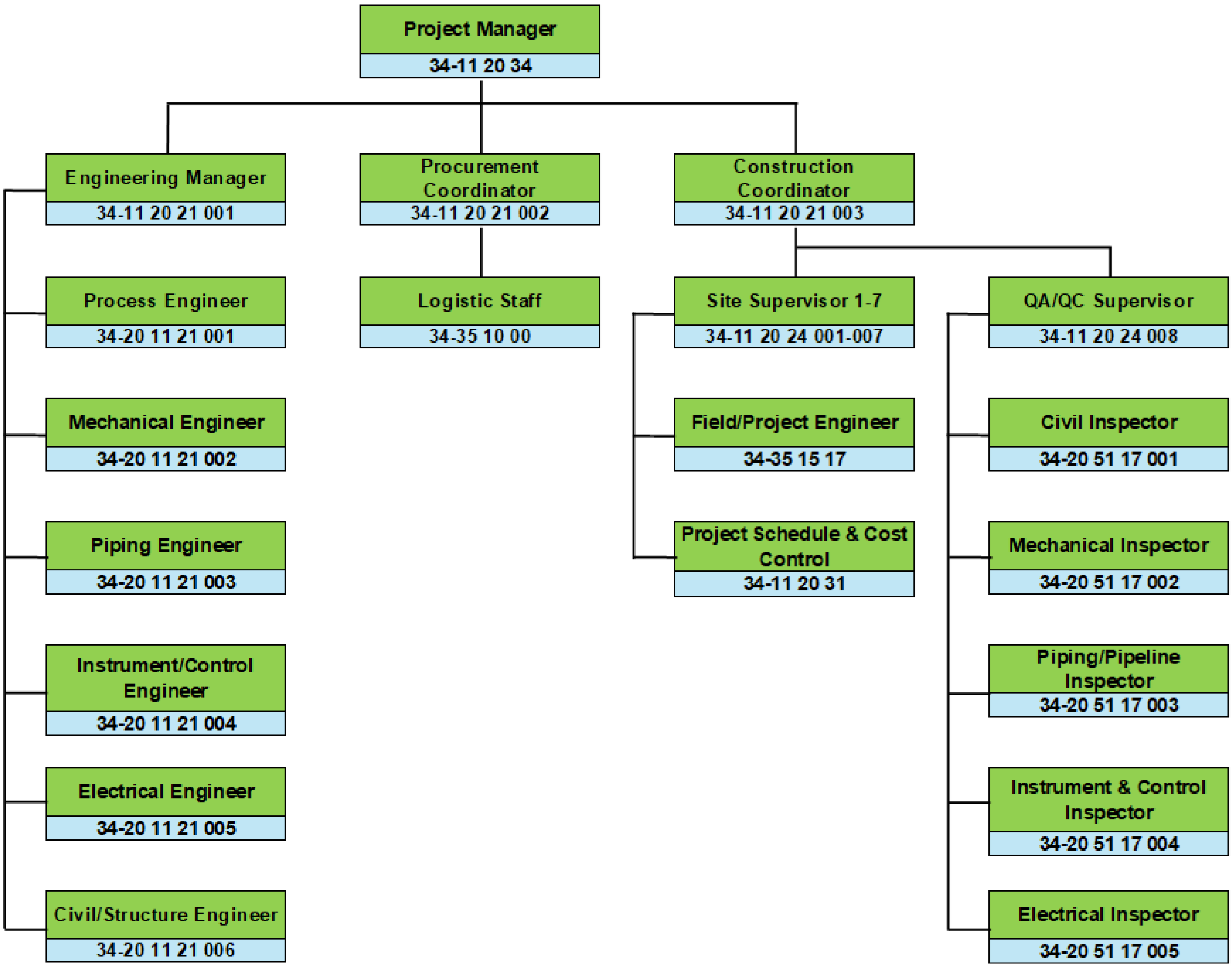



*Figure 18 – Organizational Breakdown Structure (OBS) for LPG Facility Project*

From the established OBS, a Responsibility Assignment Matrix (RAM) is formulated (See Appendix 4).

The performance elements, utilizing OmniClass Table 49 from Table 5, are assigned to each PBS item to evaluate the contractor's work results (from the owner's perspective). Table 9 exemplifies the integration of performance elements into the scope of the LPG Facility Project.

| Work Result | | Product | | Performance | |
|---|---|---|---|---|---|
| Structural Concrete | 22-03 31 00 | Reinforcing Steel | 23-13 31 21 11 11 | Tensile Strength | 49-81 31 85 |
| | | | | Yield Strength | 49-81 31 95 |
| | | | | Ultimate Strength | 49-81 31 43 |
| | | Cementitious Concretes | 23-13 15 11 11 | Compressive Strength | 49-81 31 27 |
| | | Mortar Cements | 23-13 15 13 15 | Adhesion Strength | 49-81 31 00 |
| LPG Truck Filling Pump | 22-43 21 13 | Centrifugal Pumps | 23-27 17 13 | Operational Capacity | 49-81 21 17 13 |
| | | | | Rated Capacity | 49-81 21 17 15 |
| | | | | Vibration | 49-81 31 91 |
| | | | | Explotion Proof | 49-81 51 41 |

*Table 9 – Performance from OmniClass Table 49 Combine With Product/Work Result*

## STEP 7 – Performance Monitoring and Post Evaluation of Result

To ensure the effectiveness of the Project Breakdown Structure developed for the LPG Facility Project, the following steps are necessary:

1. Establishing company procedures/standards as the basis for implementing the Multi-Dimensional WBS in the Front-End Loading of this project;
2. Providing training to engineers to prevent any misconceptions in WBS development, particularly emphasizing that the WBS should not be hierarchical but relational/object-oriented;
3. Integrating technology as standard tools that facilitate the creation of Multi-Dimensional WBS;
4. Standardizing the Bidding Template to enable contractors to submit bids that closely align with the actual project conditions;

These steps will help ensure that all elements of the LPG Facility Project are thoroughly addressed in the WBS, enabling more structured and efficient project management.

## CONCLUSION

The National Oil & Gas Company's project management procedures may encounter challenges that impede efficiency and effectiveness. A lack of clarity regarding scope, responsibilities, timelines, and costs could result in delays, budget overruns, and inefficient resource use. Developing WBS into the project management practices of the National Oil & Gas Company emerges as a feasible solution to address these challenges and improve the efficiency of project management.

This paper analyzes which WBS dimension is suitable and provides the most significant impact for the National Oil & Gas Company. Flat WBS / 2-dimensional / hierarchical WBS provides the slightest advantage, while Multi-Dimensional WBS is the best implementation option. The Multi-Dimensional WBS can be developed into an 8-D Matrix as it can meet the needs of the Front-End Loading process and answer the 8 High-Level Questions for Stakeholders.

Multi-Dimensional WBS is the most suitable approach to meet stakeholders' needs for achieving complete integration with BIM. It can be easily implemented in the BIM system at the National Oil & Gas Company.

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# APPENDICES

## APPENDIX 1 - 3 Dimensional WBS using ISO 19008:2016

PBS

| Code | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 |
|---|---|---|---|---|---|
| B | Onshore | | | | |
| BA | | Process, utilities and product handling | | | |
| BAC | | | Product handling | | |
| BACA | | | | Product Storage | |
| BACAA | | | | | Gas storage |
| BACB | | | | Product Metering | |
| BACBB | | | | | Weight metering |
| BACC | | | | Product loading | |
| BAB | | | Utilities | | |
| BABA | | | | Electrical power systems | |
| BABB | | | | Instrument systems | |
| BABH | | | | Chemical injection systems | |
| BABJ | | | | Fuel systems | |
| BABL | | | | Fire and safety systems | |
| BC | | Civil, Structures, Marine and Buildings | | | |
| BCA | | | Civil | | |
| BCB | | | Buildings | | |
| BCBB | | | | Control rooms and utility buildings | |
| BCBC | | | | Laboratories | |
| BCBE | | | | Other building facilities | |
| BD | | Transport systems | | | |
| BDA | | | Pipeline System | | |
| BDAC | | | | Pipeline | |
| BDAG | | | | Facilities | |

SAB

| Code | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 |
|---|---|---|---|---|---|
| B | Onshore | | | | |
| BA | | Process, utilities and product handling | | | |
| BAC | | | Product handling | | |
| BACA | | | | Product Storage | |
| BACAA | | | | | Gas storage |
| BACB | | | | Product Metering | |
| BACBB | | | | | Weight metering |
| BACC | | | | Product loading | |
| BAB | | | Utilities | | |
| BABA | | | | Electrical power systems | |
| BABB | | | | Instrument systems | |
| BABH | | | | Chemical injection systems | |
| BABJ | | | | Fuel systems | |
| BABL | | | | Fire and safety systems | |
| BC | | Civil, Structures, Marine and Buildings | | | |
| BCA | | | Civil | | |
| BCB | | | Buildings | | |
| BCBB | | | | Control rooms and utility buildings | |
| BCBC | | | | Laboratories | |
| BCBE | | | | Other building facilities | |
| BD | | Transport systems | | | |
| BDA | | | Pipeline System | | |
| BDAC | | | | Pipeline | |
| BDAG | | | | Facilities | |

## COR

| Code | Level 1 | Level 2 | Level 3 | Level 4 |
|---|---|---|---|---|
| B | Bulk materials | | | |
| BQ | | Civil works bulk | | |
| BQA | | | Concrete, cement, sand and aggregates | |
| BQB | | | Reinforcement bars/rods and pre-stressing cables | |
| BQC | | | Precast concrete elements | |
| BQD | | | Masonry | |
| BQE | | | Piles | |
| BQH | | | Ground materials | |
| BQZ | | | Other civil works bulk | |
| BL | | Piping bulk | | |
| BLA | | | Pipework | |
| BLB | | | Manually operated valves | |
| BLC | | | Supports | |
| BE | | Electrical bulk | | |
| BEE | | | Accessories | |
| BEA | | | Cables and cable accessories | |
| BJ | | Instrument bulk | | |
| BJA | | | Instruments | |
| BJB | | | Instrument valves | |
| BM | | Surface protection bulk | | |
| BMA | | | Paint | |
| BMB | | | Coating | |
| BMC | | | Anodes | |
| BN | | Structural bulk | | |
| BNA | | | Primary, secondary and outfitting structures | |
| BNZ | | | Other structural bulk | |
| E | Equipment | | | |
| ER | | Mechanical equipment | | |
| ERX | | | Miscellaneous package units | |
| ERXR | | | | Chemical injection packages |
| ERT | | | Storage tanks/containment equipment – atmospheric | |
| ERTA | | | | Storage tanks – cylindric |
| ERV | | | Vessels and columns – pressurised | |
| ERVQ | | | | Spheres |
| ERP | | | Pumps | |
| ERPA | | | | Centrifugal pumps |
| ERM | | | Material and product handling equipment | |
| ERMU | | | | Product loading and vapour return arms |
| EJ | | Instrumentation equipment | | |
| EJJ | | | Instrumentation equipment | |
| EJJV | | | | Weight scales |
| EJJI | | | | Gas metering package |
| EJJH | | | | Oil metering package |
| EE | | Electrical equipment | | |
| EEE | | | Electrical equipment | |
| EEET | | | | Transformers |
| EEEK | | | | Switchgear – above 1000 V |
| EEEH | | | | Switchgear – up to 400 V |
| EEED | | | | DC Distribution boards |
| EEEQ | | | | Uninterruptible power supply (UPS) |
| EEEG | | | | Generators |
| EEEP | | | | Earthing bars |
| Y | Land based plant and equipment | | | |
| YV | | Air compressors | | |
| YVI | | | Stationary air compressor (2000 cfm to 3000 cfm) | |

## APPENDIX 2 - 3 Dimensional WBS using OmniClass

PBS using OmniClass Table 22

| Criteria Fulfilled | Omniclass Title (Table 22 - Work Result) | OmniClass Number |
|---|---|---|
| Excavation & Land Fill | Excavation & Fill | 22-31 23 00 |
| Driven Pile Work | Driven Pile | 22-31 62 00 |
| Bored Pile Work | Bored Pile | 22-31 63 00 |
| Non-structural Concrete | Cement and Concrete for Exterior Improvements | 22-32 05 23 |
| Structural Concrete | Structural Concrete | 22-03 31 00 |
| Concrete Finishing | Concrete Finishing | 22-03 35 00 |
| Structural Steel for Buildings | Structural Steel for Buildings | 22-05 12 23 |
| Odorizer Injection Package | Packaged Odor Control Systems | 22-44 31 19 |
| LPG Storage Tank (Construction, Installation, Painting) | Pressurized Tanks and Vessels | 22-43 42 00 |
| LPG Truck Filling Pump | Centrifugal Liquid Pumps | 22-43 21 13 |
| LPG Truck Loading Arm Package (Include Vapor Loading Arm) | Truck Bulk Material Loaders | 22-41 42 16 23 |
| Air Compressor Package | Double-acting Reciprocating Compressors | 22-43 12 34 |
| Weighing Bridge System | Liquid Weigh Systems | 22-43 22 66 |
| Piping | Mixed Fuel Gases Piping | 22-40 14 93 |
| | Propane Fuel Gas Process Piping | 22-40 14 59 |
| | Butane Piping | 22-40 14 19 |
| Fittings & Flanges | Service Fittings and Accessories | 22-11 53 43 |
| Valve | Carbon Steel Process Valves | 22-40 05 23 13 |
| Transformer | Liquid-Filled, Medium-Voltage Transformers | 22-26 12 13 |
| MV Switchgear | Medium-Voltage Switchgear | 22-26 13 00 |
| LV Switchgear | Low-Voltage Switchgear | 22-26 23 00 |
| Distribution Panel | Switchboards and Panelboards | 22-26 24 00 |
| Uninterruptible Power Supply (UPS) | Static Uninterruptible Power Supply | 22-26 33 53 |
| Capacitor Banks | Capacitor Banks | 22-33 71 26 13 |
| Local Control Switch | Process Control Switches | 22-40 95 53 |
| Diesel Engine Generator Set | Packaged Generator Assemblies | 22-26 32 00 |
| Cable Works | Medium-Voltage Cables | 22-26 05 13 |
| | Low-Voltage Electrical Power Conductors and Cables | 22-26 05 19 |
| Grounding | Utilities Grounding | 22-33 79 19 |
| LPG Pressure Indicator | Liquid Pressure Process Measurement Devices | 22-40 91 19 26 |
| Vapor Pressure Indicator | Vapor Pressure Process Measurement Devices | 22-40 91 19 39 |
| Level and Temperature Indicator (Sensor & Transmitter) | Integrated Automation Sensors and Transmitters | 22-25 35 16 |
| Instrument Valve | Integrated Automation Control Valves | 22-25 35 19 |
| Vapor Meter | Natural-Gas Metering | 22-33 51 33 |
| LPG Flow Meter | Flow Process Measurement Devices | 22-40 91 23 33 |
| NDT Test & Hydrostatic Test | Facility Shell Commissioning | 22-01 91 19 |
| N2 Purging (For Storage Tank & Piping Sytem) | Non-Condensable Gas Purge Equipment | 22-23 61 13 13 |
| PDA Testing for deep foundation | Foundation Performance Instrumentation | 22-31 09 16 |
| Mechanical Completion, Start-Up & Commissioning | General Commissioning Requirements | 22-01 91 13 |

ABS using OmniClass Table 32

| Criteria Fulfilled | Omniclass Title (Table 32 - Services) | OmniClass Number |
|---|---|---|
| Preconstructing | Preconstructing | 32-57 51 00 |
| Constructing | Constructing | 32-57 61 00 |
| Postconstructing | Postconstructing | 32-57 71 00 |
| QC Process | Assuring | 32-57 81 00 |

ZBS using OmniClass Table 11

| Criteria Fulfilled | Omniclass Title (Table 11 - Construction Entities by Function) | OmniClass Number |
|---|---|---|
| Operational Building | Miscellaneous Operation Support Building | 11-27 55 19 |
| Electrical & Instrument Work Zone | Electrical Equipment or Appliance Manufacturing Facility | 11-35 11 71 |
| Tankyard | Installation Gas Storage Facility | 11-37 45 19 |
| LPG Loading Facility | Loading Platform/Ramp | 11-37 65 23 |
| Generator Set Room | Oil-Powered Electrical Generation Facility | 11-42 11 34 |
| LPG Spherical Tank | Gas Fuel Storage | 11-42 24 17 |
| Receiving & Distribution Facility | Pipe Line | 11-42 27 17 |

## APPENDIX 3 – PRODUCT (OmniClass Table 23) for LPG Facility Project

| PBS | Table 23 (Product) | OmniClass Number |
|---|---|---|
| Excavation & Land Fill | Landscaping | 23-11 27 00 |
| Driven Pile Work | Precast Concrete Driven Piles | 23-13 29 11 13 15 |
| | Concrete Filled Steel Driven Piles | 23-13 29 11 13 13 |
| Bored Pile Work | Reinforcing Steel | 23-13 31 21 11 11 |
| | Cementitious Concretes | 23-13 15 11 11 |
| Non-structural Concrete | Reinforcing Steel | 23-13 31 21 11 11 |
| | Cementitious Concretes | 23-13 15 11 11 |
| | Mortar Cements | 23-13 15 13 15 |
| Structural Concrete | Reinforcing Steel | 23-13 31 21 11 11 |
| | Cementitious Concretes | 23-13 15 11 11 |
| | Mortar Cements | 23-13 15 13 15 |
| Concrete Finishing | Cementitious Concretes | 23-13 15 11 11 |
| | Mortar Cements | 23-13 15 13 15 |
| Structural Steel for Buildings | Portal Frames | 23-13 35 11 15 |
| | Structural Racking | 23-13 35 11 17 |
| Odorizer Injection Package | Reciprocating Pumps | 23-27 17 29 |
| | Aboveground Tank Containments | 23-27 29 21 11 |
| | Fill and Valve Caps | 23-27 29 25 13 |
| LPG Storage Tank (Construction, Installation, Painting) | Single Walled Pressure Tanks | 23-27 29 19 13 11 |
| | Corrosion Protection Paint | 23-15 21 13 11 |
| LPG Truck Filling Pump | Centrifugal Pumps | 23-27 17 13 |
| LPG Truck Loading Arm Package (Include Vapor Loading Arm) | Loading Dock Equipment | 23-23 23 00 |
| Air Compressor Package | Double Acting Reciprocating Compressors | 23-27 21 15 13 |
| | Single Acting Reciprocating Compressors | 23-27 21 15 15 |
| Weighing Bridge System | Weight Detectors | 23-27 11 23 15 |
| | Weight Recorders | 23-27 11 23 19 |
| | Weight Sensors | 23-27 11 23 21 |
| Piping | Aboveground Single Walled Pipes | 23-27 39 13 11 |
| Fittings & Flanges | Blind Pipe Flanges | 23-27 45 00 |
| | Slip On Pipe Flanges | 23-27 45 21 |
| | Weldneck Pipe Flanges | 23-27 45 29 |
| | 45 Degree Pipe Elbows | 23-27 51 11 |
| | 90 Degree Pipe Elbows | 23-27 51 13 |
| | Reducing Pipe Elbows | 23-27 51 15 |
| | Pipe Fittings | 23-27 43 00 |
| | Pipe Expansion Joints | 23-27 43 15 |
| | Pipe Expansion Compensators | 23-27 43 19 |

| PBS | Table 23 (Product) | OmniClass Number |
|---|---|---|
| Valve | Ball Valves | 23-27 31 15 |
| | Check Valves | 23-27 31 19 |
| | Gate Valves | 23-27 31 25 |
| | Globe Valves | 23-27 31 27 |
| | Pressure Regulating Valves | 23-27 31 47 |
| | Relief Valves | 23-27 31 49 |
| Transformer | Power Transformers | 23-35 13 17 |
| | Transformer Accessories | 23-35 13 19 |
| MV Switchgear | Distribution Switchgear | 23-35 31 31 11 |
| LV Switchgear | Paralleling Switchgear | 23-35 31 31 13 |
| Distribution Panel | Electrical Panel Boards | 23-35 31 17 |
| Uninterruptible Power Supply (UPS) | Uninterruptible Power Supply Component Systems | 23-35 23 21 11 |
| | Uninterruptible Power Supply Packaged Units | 23-35 23 21 13 |
| Capacitor Banks | Capacitors | 23-35 23 19 17 |
| Local Control Switch | Electrical Switches | 23-35 37 00 |
| Diesel Engine Generator Set | Electrical Generation Diesel Engines | 23-35 11 12 11 |
| | Engine Electrical Generators | 23-35 11 11 11 |
| Cable Works | Electrical Cable Reels | 23-35 33 17 11 |
| | Electrical Junction Boxes | 23-35 33 15 |
| | Electrical Racks | 23-35 33 23 |
| Grounding | Electrical Grounding Device | 23-35 39 11 |
| | Earth Connection Electrodes | 23-35 39 13 |
| LPG Pressure Indicator | Pressure Sensors | 23-27 11 13 23 |
| Vapor Pressure Indicator | Pressure Sensors | 23-27 11 13 23 |
| Level and Temperature Indicator (Sensor & Transmitter) | Level Sensors | 23-27 11 21 23 |
| | Level Indicators | 23-27 11 21 19 |
| | Level Alarm Modules | 23-27 11 21 11 |
| | Temperature Sensors | 23-27 11 11 23 |
| | Temperature Recorders | 23-27 11 11 21 |
| Instrument Valve | Pressure Safety Valves | 23-27 31 53 11 |
| | Pressure Temperature Safety Valves | 23-27 31 53 13 |
| | Pressure Relief Valves | 23-27 31 49 11 |
| | Pressure Temperature Relief Valves | 23-27 31 49 13 |
| | Motor Operated Valve Actuators | 23-27 33 15 |
| Vapor Meter | Flow Sensors | 23-27 11 15 23 |
| | Flow Recorders | 23-27 11 15 21 |
| LPG Flow Meter | Flow Sensors | 23-27 11 15 23 |
| | Flow Recorders | 23-27 11 15 21 |

# APPENDIX 4 - Responsibility Assignment Matrix (RAM)

| Item | | Criterion Fulfilled | | Project Manager | Engineering Manager | Procurement Coordinator | Construction Coordinator | QA/QC Supervisor | Project Schedule & Cost Control | Process Engineer | Mechanical Engineer | Piping Engineer | Instrument/Control Engineer | Electrical Engineer | Civil/Structure Engineer | Field/Project Engineer | Site Supervisor | Civil Inspector | Mechanical Inspector | Piping/Pipeline Inspector | Instrument & Control Inspector | Electrical Inspector | Logistic Staff |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Omniclass Code | | 34-11 20 34 | 34-11 20 21 | 34-11 20 21 | 34-11 20 21 | 34-11 20 24 | 34-11 20 31 | 34-20 11 21 | 34-20 11 21 | 34-20 11 21 | 34-20 11 21 | 34-20 11 21 | 34-20 11 21 | 34-35 15 17 | 34-11 20 24 | 34-20 51 17 | 34-20 51 17 | 34-20 51 17 | 34-20 51 17 | 34-20 51 17 | 34-35 10 00 |
| | | Unique Code | | | 001 | 002 | 003 | 008 | | 001 | 002 | 003 | 004 | 005 | 006 | 001-007 | 001-007 | 001 | 002 | 003 | 004 | 005 | |
| Excavation & Fill | 22-31 23 00 | Preconstructing | 32-57 51 00 | X | X | X | | | X | | | | | | X | | | | | | | | X |
| | | Constructing | 32-57 61 00 | X | | X | X | | X | | | | | | | X | X | | | | | | X |
| | | Post Constructing | 32-57 71 00 | X | | | X | | X | | | | | | | X | X | | | | | | |
| | | Assuring | 32-57 81 00 | X | | | | X | X | | | | | | | | | X | | | | | |
| Driven Pile | 22-31 62 00 | Preconstructing | 32-57 51 00 | X | X | X | | | X | | | | | | X | | | | | | | | X |
| | | Constructing | 32-57 61 00 | X | | X | X | | X | | | | | | | X | X | | | | | | X |
| | | Post Constructing | 32-57 71 00 | X | | | X | | X | | | | | | | X | X | | | | | | |
| | | Assuring | 32-57 81 00 | X | | | | X | X | | | | | | | | | X | | | | | |
| Bored Pile | 22-31 63 00 | Preconstructing | 32-57 51 00 | X | X | X | | | X | | | | | | X | | | | | | | | X |
| | | Constructing | 32-57 61 00 | X | | X | X | | X | | | | | | | X | X | | | | | | X |
| | | Post Constructing | 32-57 71 00 | X | | | X | | X | | | | | | | X | X | | | | | | |
| | | Assuring | 32-57 81 00 | X | | | | X | X | | | | | | | | | X | | | | | |
| Cement and Concrete for Exterior Improvements | 22-32 05 23 | Preconstructing | 32-57 51 00 | X | X | X | | | X | | | | | | X | | | | | | | | X |
| | | Constructing | 32-57 61 00 | X | | X | X | | X | | | | | | | X | X | | | | | | X |
| | | Post Constructing | 32-57 71 00 | X | | | X | | X | | | | | | | X | X | | | | | | |
| | | Assuring | 32-57 81 00 | X | | | | X | X | | | | | | | | | X | | | | | |
| Structural Concrete | 22-03 31 00 | Preconstructing | 32-57 51 00 | X | X | X | | | X | | | | | | X | | | | | | | | X |
| | | Constructing | 32-57 61 00 | X | | X | X | | X | | | | | | | X | X | | | | | | X |
| | | Post Constructing | 32-57 71 00 | X | | | X | | X | | | | | | | X | X | | | | | | |
| | | Assuring | 32-57 81 00 | X | | | | X | X | | | | | | | | | X | | | | | |
| Concrete Finishing | 22-03 35 00 | Preconstructing | 32-57 51 00 | X | X | X | | | X | | | | | | X | | | | | | | | X |
| | | Constructing | 32-57 61 00 | X | | X | X | | X | | | | | | | X | X | | | | | | X |
| | | Post Constructing | 32-57 71 00 | X | | | X | | X | | | | | | | X | X | | | | | | |
| | | Assuring | 32-57 81 00 | X | | | | X | X | | | | | | | | | X | | | | | |
| Structural Steel for Buildings | 22-05 12 23 | Preconstructing | 32-57 51 00 | X | X | X | | | X | | | | | | X | | | | | | | | X |
| | | Constructing | 32-57 61 00 | X | | X | X | | X | | | | | | | X | X | | | | | | X |
| | | Post Constructing | 32-57 71 00 | X | | | X | | X | | | | | | | X | X | | | | | | |
| | | Assuring | 32-57 81 00 | X | | | | X | X | | | | | | | | | X | | | | | |
| Packaged Odor Control Systems | 22-44 31 19 | Preconstructing | 32-57 51 00 | X | X | X | | | X | X | X | | | | | | | | | | | | X |
| | | Constructing | 32-57 61 00 | X | | X | X | | X | | | | | | | X | X | | | | | | X |
| | | Post Constructing | 32-57 71 00 | X | | | X | | X | | | | | | | X | X | | | | | | |
| | | Assuring | 32-57 81 00 | X | | | | X | X | | | | | | | | | | X | | X | | |
| Pressurized Tanks and Vessels | 22-43 42 00 | Preconstructing | 32-57 51 00 | X | X | X | | | X | X | X | | | | | | | | | | | | X |
| | | Constructing | 32-57 61 00 | X | | X | X | | X | | | | | | | X | X | | | | | | X |
| | | Post Constructing | 32-57 71 00 | X | | | X | | X | | | | | | | X | X | | | | | | |
| | | Assuring | 32-57 81 00 | X | | | | X | X | | | | | | | | | | X | | X | | |
| Centrifugal Liquid Pumps | 22-43 21 13 | Preconstructing | 32-57 51 00 | X | X | X | | | X | X | X | X | | | | | | | | | | | X |
| | | Constructing | 32-57 61 00 | X | | X | X | | X | | | | | | | X | X | | | | | | X |
| | | Post Constructing | 32-57 71 00 | X | | | X | | X | | | | | | | X | X | | | | | | |
| | | Assuring | 32-57 81 00 | X | | | | X | X | | | | | | | | | | X | X | X | | |
| Truck Bulk Material Loaders | 22-41 42 16 23 | Preconstructing | 32-57 51 00 | X | X | X | | | X | | X | X | X | X | X | | | | | | | | X |
| | | Constructing | 32-57 61 00 | X | | X | X | | X | | | | | | | X | X | | | | | | X |
| | | Post Constructing | 32-57 71 00 | X | | | X | | X | | | | | | | X | X | | | | | | |
| | | Assuring | 32-57 81 00 | X | | | | X | X | | | | | | | | | | X | X | X | X | |
| Double-acting Reciprocating Compressors | 22-43 12 34 | Preconstructing | 32-57 51 00 | X | X | X | | | X | X | X | X | | | | | | | | | | | X |
| | | Constructing | 32-57 61 00 | X | | X | X | | X | | | | | | | X | X | | | | | | X |
| | | Post Constructing | 32-57 71 00 | X | | | X | | X | | | | | | | X | X | | | | | | |
| | | Assuring | 32-57 81 00 | X | | | | X | X | | | | | | | | | | X | X | X | | |
| Liquid Weigh Systems | 22-43 22 66 | Preconstructing | 32-57 51 00 | X | X | X | | | X | | X | | X | X | X | | | | | | | | X |
| | | Constructing | 32-57 61 00 | X | | X | X | | X | | | | | | | X | X | | | | | | X |
| | | Post Constructing | 32-57 71 00 | X | | | X | | X | | | | | | | X | X | | | | | | |
| | | Assuring | 32-57 81 00 | X | | | | X | X | | | | | | | | | X | X | | X | X | |

| Criterion Fulfilled | Omniclass Code | Unique Code | Mixed Fuel Gases Piping | | | | Propane Fuel Gas Process Piping | | | | Butane Piping | | | | Service Fittings and Accessories | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 22-40 14 93 | | | | 22-40 14 59 | | | | 22-40 14 19 | | | | 22-11 53 43 | | | |
| | | | 32-57 51 00 | 32-57 61 00 | 32-57 71 00 | 32-57 81 00 | 32-57 51 00 | 32-57 61 00 | 32-57 71 00 | 32-57 81 00 | 32-57 51 00 | 32-57 61 00 | 32-57 71 00 | 32-57 81 00 | 32-57 51 00 | 32-57 61 00 | 32-57 71 00 | 32-57 81 00 |
| | | | Preconstructing | Constructing | Post Constructing | Assuring | Preconstructing | Constructing | Post Constructing | Assuring | Preconstructing | Constructing | Post Constructing | Assuring | Preconstructing | Constructing | Post Constructing | Assuring |
| Project Manager | 34-11 20 34 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Engineering Manager | 34-11 20 21 | 001 | X | | | | X | | | | X | | | | X | | | |
| Procurement Coordinator | 34-11 20 21 | 002 | X | X | | | X | X | | | X | X | | | X | X | | |
| Construction Coordinator | 34-11 20 21 | 003 | | X | X | | | X | X | | | X | X | | | X | X | |
| QA/QC Supervisor | 34-11 20 24 | 008 | | | | X | | | | X | | | | X | | | | X |
| Project Schedule & Cost Control | 34-11 20 31 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Process Engineer | 34-20 11 21 | 001 | X | | | | X | | | | X | | | | X | | | |
| Mechanical Engineer | 34-20 11 21 | 002 | X | | | | X | | | | X | | | | X | | | |
| Piping Engineer | 34-20 11 21 | 003 | X | | | | X | | | | X | | | | X | | | |
| Instrument/Control Engineer | 34-20 11 21 | 004 | | | | | | | | | | | | | | | | |
| Electrical Engineer | 34-20 11 21 | 005 | | | | | | | | | | | | | | | | |
| Civil/Structure Engineer | 34-20 11 21 | 006 | | | | | | | | | | | | | | | | |
| Field/Project Engineer | 34-35 15 17 | 001-007 | | X | X | | | X | X | | | X | X | | | X | X | |
| Site Supervisor | 34-11 20 24 | 001-007 | | X | X | | | X | X | | | X | X | | | X | X | |
| Civil Inspector | 34-20 51 17 | 001 | | | | | | | | | | | | | | | | |
| Mechanical Inspector | 34-20 51 17 | 002 | | | | X | | | | X | | | | X | | | | X |
| Piping/Pipeline Inspector | 34-20 51 17 | 003 | | | | X | | | | X | | | | X | | | | X |
| Instrument & Control Inspector | 34-20 51 17 | 004 | | | | | | | | | | | | | | | | |
| Electrical Inspector | 34-20 51 17 | 005 | | | | | | | | | | | | | | | | |
| Logistic Staff | 34-35 10 00 | | X | X | | | X | X | | | X | X | | | X | X | | |

| Criterion Fulfilled | Omniclass Code | Unique Code | Carbon Steel Process Valves | | | | Liquid-Filled, Medium-Voltage Transformers | | | | Medium-Voltage Switchgear | | | | Low-Voltage Switchgear | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 22-40 05 23 13 | | | | 22-26 12 13 | | | | 22-26 13 00 | | | | 22-26 23 00 | | | |
| | | | 32-57 51 00 | 32-57 61 00 | 32-57 71 00 | 32-57 81 00 | 32-57 51 00 | 32-57 61 00 | 32-57 71 00 | 32-57 81 00 | 32-57 51 00 | 32-57 61 00 | 32-57 71 00 | 32-57 81 00 | 32-57 51 00 | 32-57 61 00 | 32-57 71 00 | 32-57 81 00 |
| | | | Preconstructing | Constructing | Post Constructing | Assuring | Preconstructing | Constructing | Post Constructing | Assuring | Preconstructing | Constructing | Post Constructing | Assuring | Preconstructing | Constructing | Post Constructing | Assuring |
| Project Manager | 34-11 20 34 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Engineering Manager | 34-11 20 21 | 001 | X | | | | X | | | | X | | | | X | | | |
| Procurement Coordinator | 34-11 20 21 | 002 | X | X | | | X | X | | | X | X | | | X | X | | |
| Construction Coordinator | 34-11 20 21 | 003 | | X | X | | | X | X | | | X | X | | | X | X | |
| QA/QC Supervisor | 34-11 20 24 | 008 | | | | X | | | | X | | | | X | | | | X |
| Project Schedule & Cost Control | 34-11 20 31 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Process Engineer | 34-20 11 21 | 001 | X | | | | X | | | | X | | | | X | | | |
| Mechanical Engineer | 34-20 11 21 | 002 | X | | | | | | | | | | | | | | | |
| Piping Engineer | 34-20 11 21 | 003 | X | | | | | | | | | | | | | | | |
| Instrument/Control Engineer | 34-20 11 21 | 004 | | | | | X | | | | X | | | | X | | | |
| Electrical Engineer | 34-20 11 21 | 005 | | | | | X | | | | X | | | | X | | | |
| Civil/Structure Engineer | 34-20 11 21 | 006 | | | | | | | | | | | | | | | | |
| Field/Project Engineer | 34-35 15 17 | 001-007 | | X | X | | | X | X | | | X | X | | | X | X | |
| Site Supervisor | 34-11 20 24 | 001-007 | | X | X | | | X | X | | | X | X | | | X | X | |
| Civil Inspector | 34-20 51 17 | 001 | | | | | | | | | | | | | | | | |
| Mechanical Inspector | 34-20 51 17 | 002 | | | | X | | | | | | | | | | | | |
| Piping/Pipeline Inspector | 34-20 51 17 | 003 | | | | X | | | | | | | | | | | | |
| Instrument & Control Inspector | 34-20 51 17 | 004 | | | | | | | | X | | | | X | | | | X |
| Electrical Inspector | 34-20 51 17 | 005 | | | | | | | | X | | | | X | | | | X |
| Logistic Staff | 34-35 10 00 | | X | X | | | X | X | | | X | X | | | X | X | | |

| Criterion Fulfilled | Omniclass Code | Unique Code | Switchboards and Panelboards | | | | Static Uninterruptible Power Supply | | | | Capacitor Banks | | | | Process Control Switches | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 22-26 24 00 | | | | 22-26 33 53 | | | | 22-33 71 26 13 | | | | 22-40 95 53 | | | |
| | | | 32-57 51 00 | 32-57 61 00 | 32-57 71 00 | 32-57 81 00 | 32-57 51 00 | 32-57 61 00 | 32-57 71 00 | 32-57 81 00 | 32-57 51 00 | 32-57 61 00 | 32-57 71 00 | 32-57 81 00 | 32-57 51 00 | 32-57 61 00 | 32-57 71 00 | 32-57 81 00 |
| | | | Preconstructing | Constructing | Post Constructing | Assuring | Preconstructing | Constructing | Post Constructing | Assuring | Preconstructing | Constructing | Post Constructing | Assuring | Preconstructing | Constructing | Post Constructing | Assuring |
| Project Manager | 34-11 20 34 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Engineering Manager | 34-11 20 21 | 001 | X | | | | X | | | | X | | | | X | | | |
| Procurement Coordinator | 34-11 20 21 | 002 | X | X | | | X | X | | | X | X | | | X | X | | |
| Construction Coordinator | 34-11 20 21 | 003 | | X | X | | | X | X | | | X | X | | | X | X | |
| QA/QC Supervisor | 34-11 20 24 | 008 | | | | X | | | | X | | | | X | | | | X |
| Project Schedule & Cost Control | 34-11 20 31 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Process Engineer | 34-20 11 21 | 001 | X | | | | X | | | | X | | | | X | | | |
| Mechanical Engineer | 34-20 11 21 | 002 | | | | | | | | | | | | | | | | |
| Piping Engineer | 34-20 11 21 | 003 | | | | | | | | | | | | | | | | |
| Instrument/Control Engineer | 34-20 11 21 | 004 | X | | | | X | | | | X | | | | X | | | |
| Electrical Engineer | 34-20 11 21 | 005 | X | | | | X | | | | X | | | | X | | | |
| Civil/Structure Engineer | 34-20 11 21 | 006 | | | | | | | | | | | | | | | | |
| Field/Project Engineer | 34-35 15 17 | 001-007 | | X | X | | | X | X | | | X | X | | | X | X | |
| Site Supervisor | 34-11 20 24 | 001-007 | | X | X | | | X | X | | | X | X | | | X | X | |
| Civil Inspector | 34-20 51 17 | 001 | | | | | | | | | | | | | | | | |
| Mechanical Inspector | 34-20 51 17 | 002 | | | | | | | | | | | | | | | | |
| Piping/Pipeline Inspector | 34-20 51 17 | 003 | | | | | | | | | | | | | | | | |
| Instrument & Control Inspector | 34-20 51 17 | 004 | | | | X | | | | X | | | | X | | | | X |
| Electrical Inspector | 34-20 51 17 | 005 | | | | X | | | | X | | | | X | | | | X |
| Logistic Staff | 34-35 10 00 | | X | X | | | X | X | | | X | X | | | X | X | | |

| Criterion Fulfilled | Omniclass Code | Unique Code | Packaged Generator Assemblies | | | |
|---|---|---|---|---|---|---|
| | | | 22-26 32 00 | | | |
| | | | 32-57 51 00 | 32-57 61 00 | 32-57 71 00 | 32-57 81 00 |
| | | | Preconstructing | Constructing | Post Constructing | Assuring |
| Project Manager | 34-11 20 34 | | X | X | X | X |
| Engineering Manager | 34-11 20 21 | 001 | X | | | |
| Procurement Coordinator | 34-11 20 21 | 002 | X | X | | |
| Construction Coordinator | 34-11 20 21 | 003 | | X | X | |
| QA/QC Supervisor | 34-11 20 24 | 008 | | | | X |
| Project Schedule & Cost Control | 34-11 20 31 | | X | X | X | X |
| Process Engineer | 34-20 11 21 | 001 | X | | | |
| Mechanical Engineer | 34-20 11 21 | 002 | | | | |
| Piping Engineer | 34-20 11 21 | 003 | | | | |
| Instrument/Control Engineer | 34-20 11 21 | 004 | X | | | |
| Electrical Engineer | 34-20 11 21 | 005 | X | | | |
| Civil/Structure Engineer | 34-20 11 21 | 006 | | | | |
| Field/Project Engineer | 34-35 15 17 | 001-007 | | X | X | |
| Site Supervisor | 34-11 20 24 | 001-007 | | X | X | |
| Civil Inspector | 34-20 51 17 | 001 | | | | |
| Mechanical Inspector | 34-20 51 17 | 002 | | | | |
| Piping/Pipeline Inspector | 34-20 51 17 | 003 | | | | |
| Instrument & Control Inspector | 34-20 51 17 | 004 | | | | X |
| Electrical Inspector | 34-20 51 17 | 005 | | | | X |
| Logistic Staff | 34-35 10 00 | | X | X | | |

| Criterion Fulfilled | Omniclass Code | Unique Code | Medium-Voltage Cables | | | | Low-Voltage Electrical Power Conductors and Cables | | | | Utilities Grounding | | | | Liquid Pressure Process Measurement Devices | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 22-26 05 13 | | | | 22-26 05 19 | | | | 22-33 79 19 | | | | 22-40 91 19 26 | | | |
| | | | 32-57 51 00 | 32-57 61 00 | 32-57 71 00 | 32-57 81 00 | 32-57 51 00 | 32-57 61 00 | 32-57 71 00 | 32-57 81 00 | 32-57 51 00 | 32-57 61 00 | 32-57 71 00 | 32-57 81 00 | 32-57 51 00 | 32-57 61 00 | 32-57 71 00 | 32-57 81 00 |
| | | | Preconstructing | Constructing | Post Constructing | Assuring | Preconstructing | Constructing | Post Constructing | Assuring | Preconstructing | Constructing | Post Constructing | Assuring | Preconstructing | Constructing | Post Constructing | Assuring |
| Project Manager | 34-11 20 34 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Engineering Manager | 34-11 20 21 | 001 | X | | | | X | | | | X | | | | X | | | |
| Procurement Coordinator | 34-11 20 21 | 002 | X | X | | | X | X | | | X | X | | | X | X | | |
| Construction Coordinator | 34-11 20 21 | 003 | | X | X | | | X | X | | | X | X | | | X | X | |
| QA/QC Supervisor | 34-11 20 24 | 008 | | | | X | | | | X | | | | X | | | | X |
| Project Schedule & Cost Control | 34-11 20 31 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Process Engineer | 34-20 11 21 | 001 | X | | | | X | | | | X | | | | X | | | |
| Mechanical Engineer | 34-20 11 21 | 002 | | | | | | | | | | | | | X | | | |
| Piping Engineer | 34-20 11 21 | 003 | | | | | | | | | | | | | | | | |
| Instrument/Control Engineer | 34-20 11 21 | 004 | X | | | | X | | | | X | | | | X | | | |
| Electrical Engineer | 34-20 11 21 | 005 | X | | | | X | | | | X | | | | | | | |
| Civil/Structure Engineer | 34-20 11 21 | 006 | | | | | | | | | | | | | | | | |
| Field/Project Engineer | 34-35 15 17 | 001-007 | | X | X | | | X | X | | | X | X | | | X | X | |
| Site Supervisor | 34-11 20 24 | 001-007 | | X | X | | | X | X | | | X | X | | | X | X | |
| Civil Inspector | 34-20 51 17 | 001 | | | | | | | | | | | | | | | | |
| Mechanical Inspector | 34-20 51 17 | 002 | | | | | | | | | | | | | | | | |
| Piping/Pipeline Inspector | 34-20 51 17 | 003 | | | | | | | | | | | | | | | | |
| Instrument & Control Inspector | 34-20 51 17 | 004 | | | | X | | | | X | | | | X | | | | X |
| Electrical Inspector | 34-20 51 17 | 005 | | | | X | | | | X | | | | X | | | | |
| Logistic Staff | 34-35 10 00 | | X | X | | | X | X | | | X | X | | | X | X | | |

| Criterion Fulfilled | Omniclass Code | Unique Code | Vapor Pressure Process Measurement Devices | | | | Integrated Automation Sensors and Transmitters | | | | Integrated Automation Control Valves | | | | Natural-Gas Metering | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 22-40 91 19 39 | | | | 22-25 35 16 | | | | 22-25 35 19 | | | | 22-33 51 33 | | | |
| | | | 32-57 51 00 | 32-57 61 00 | 32-57 71 00 | 32-57 81 00 | 32-57 51 00 | 32-57 61 00 | 32-57 71 00 | 32-57 81 00 | 32-57 51 00 | 32-57 61 00 | 32-57 71 00 | 32-57 81 00 | 32-57 51 00 | 32-57 61 00 | 32-57 71 00 | 32-57 81 00 |
| | | | Preconstructing | Constructing | Post Constructing | Assuring | Preconstructing | Constructing | Post Constructing | Assuring | Preconstructing | Constructing | Post Constructing | Assuring | Preconstructing | Constructing | Post Constructing | Assuring |
| Project Manager | 34-11 20 34 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Engineering Manager | 34-11 20 21 | 001 | X | | | | X | | | | X | | | | X | | | |
| Procurement Coordinator | 34-11 20 21 | 002 | X | X | | | X | X | | | X | X | | | X | X | | |
| Construction Coordinator | 34-11 20 21 | 003 | | X | X | | | X | X | | | X | X | | | X | X | |
| QA/QC Supervisor | 34-11 20 24 | 008 | | | | X | | | | X | | | | X | | | | X |
| Project Schedule & Cost Control | 34-11 20 31 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Process Engineer | 34-20 11 21 | 001 | X | | | | X | | | | X | | | | X | | | |
| Mechanical Engineer | 34-20 11 21 | 002 | X | | | | X | | | | X | | | | X | | | |
| Piping Engineer | 34-20 11 21 | 003 | | | | | | | | | | | | | | | | |
| Instrument/Control Engineer | 34-20 11 21 | 004 | X | | | | X | | | | X | | | | X | | | |
| Electrical Engineer | 34-20 11 21 | 005 | | | | | | | | | | | | | | | | |
| Civil/Structure Engineer | 34-20 11 21 | 006 | | | | | | | | | | | | | | | | |
| Field/Project Engineer | 34-35 15 17 | 001-007 | | X | X | | | X | X | | | X | X | | | X | X | |
| Site Supervisor | 34-11 20 24 | 001-007 | | X | X | | | X | X | | | X | X | | | X | X | |
| Civil Inspector | 34-20 51 17 | 001 | | | | | | | | | | | | | | | | |
| Mechanical Inspector | 34-20 51 17 | 002 | | | | | | | | | | | | | | | | |
| Piping/Pipeline Inspector | 34-20 51 17 | 003 | | | | | | | | | | | | | | | | |
| Instrument & Control Inspector | 34-20 51 17 | 004 | | | | X | | | | X | | | | X | | | | X |
| Electrical Inspector | 34-20 51 17 | 005 | | | | | | | | | | | | | | | | |
| Logistic Staff | 34-35 10 00 | | X | X | | | X | X | | | X | X | | | X | X | | |

| Criterion Fulfilled | Omniclass Code | Unique Code | Flow Process Measurement Devices | | | | Facility Shell Commissioning | | | | Non-Condensable Gas Purge Equipment | | | | Foundation Performance Instrumentation | | | | General Commissioning Requirements | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 22-40 91 23 33 | | | | 22-01 91 19 | | | | 22-23 61 13 13 | | | | 22-31 09 16 | | | | 22-01 91 13 | | | |
| | | | 32-57 51 00 | 32-57 61 00 | 32-57 71 00 | 32-57 81 00 | 32-57 51 00 | 32-57 61 00 | 32-57 71 00 | 32-57 81 00 | 32-57 51 00 | 32-57 61 00 | 32-57 71 00 | 32-57 81 00 | 32-57 51 00 | 32-57 61 00 | 32-57 71 00 | 32-57 81 00 | 32-57 51 00 | 32-57 61 00 | 32-57 71 00 | 32-57 81 00 |
| | | | Preconstructing | Constructing | Post Constructing | Assuring | Preconstructing | Constructing | Post Constructing | Assuring | Preconstructing | Constructing | Post Constructing | Assuring | Preconstructing | Constructing | Post Constructing | Assuring | Preconstructing | Constructing | Post Constructing | Assuring |
| Project Manager | 34-11 20 34 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Engineering Manager | 34-11 20 21 | 001 | X | | | | X | | | | X | | | | X | | | | X | | | |
| Procurement Coordinator | 34-11 20 21 | 002 | X | X | | | X | X | | | X | X | | | X | X | | | X | X | | |
| Construction Coordinator | 34-11 20 21 | 003 | | X | X | | | X | X | | | X | X | | | X | X | | | X | X | |
| QA/QC Supervisor | 34-11 20 24 | 008 | | | | X | | | | X | | | | X | | | | X | | | | X |
| Project Schedule & Cost Control | 34-11 20 31 | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Process Engineer | 34-20 11 21 | 001 | X | | | | X | | | | X | | | | | | | | X | | | |
| Mechanical Engineer | 34-20 11 21 | 002 | X | | | | X | | | | | | | | | | | | X | | | |
| Piping Engineer | 34-20 11 21 | 003 | | | | | X | | | | | | | | | | | | X | | | |
| Instrument/Control Engineer | 34-20 11 21 | 004 | X | | | | X | | | | | | | | | | | | X | | | |
| Electrical Engineer | 34-20 11 21 | 005 | | | | | X | | | | | | | | | | | | X | | | |
| Civil/Structure Engineer | 34-20 11 21 | 006 | | | | | X | | | | | | | | X | | | | X | | | |
| Field/Project Engineer | 34-35 15 17 | 001-007 | | X | X | | | X | X | | | X | X | | | X | X | | | X | X | |
| Site Supervisor | 34-11 20 24 | 001-007 | | X | X | | | X | X | | | X | X | | | X | X | | | X | X | |
| Civil Inspector | 34-20 51 17 | 001 | | | | | | | | X | | | | | | | | X | | | | X |
| Mechanical Inspector | 34-20 51 17 | 002 | | | | | | | | X | | | | | | | | | | | | X |
| Piping/Pipeline Inspector | 34-20 51 17 | 003 | | | | | | | | X | | | | | | | | | | | | X |
| Instrument & Control Inspector | 34-20 51 17 | 004 | | | | X | | | | X | | | | | | | | | | | | X |
| Electrical Inspector | 34-20 51 17 | 005 | | | | | | | | X | | | | | | | | | | | | X |
| Logistic Staff | 34-35 10 00 | | X | X | | | X | X | | | X | X | | | X | X | | | X | X | | |

## About the Author

**Mahesa Hidayat**

Makassar, Indonesia

**Mahesa Hidayat** is an engineer at the National Oil Company of Indonesia, possessing more than five years of professional expertise in the oil & gas sectors. Additionally, he has served as an inspector for downstream oil and gas projects and contributed as an engineer on projects dispersed across numerous provinces in Indonesia. He holds a bachelor's degree in Civil Engineering from Brawijaya University (UB). Currently, he is attending a distance learning mentoring course under the tutelage of Dr. Paul D. Giammalvo, CDT, CCE, MScPM, MRICS, GPM-m Senior Technical Advisor at PT Mitrata Citragraha, to attain Certified Cost Professional certification from AACE International.

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