Standardizing Bidding Templates for Storage Tank Repair Projects as a Basis for Database Automation [1,2]

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ABSTRACT

Storage tank repair projects are important for maintaining asset integrity, operational safety, and fuel distribution reliability, especially in Indonesia's downstream energy network. However, recurring repair projects often use bidding documents that are not fully standardized, resulting in inconsistent scope descriptions, varied cost breakdowns, weak WBS/CBS coding, and limited use of historical data for future estimating. This paper aims to develop a standardized bidding template for storage tank repair projects as a basis for database automation. The study uses a practice-based comparative approach by reviewing current bidding structures, API 650/API 653 logic, OmniClass-based WBS/CBS coding, National Park Service cost-estimating principles, and multiattribute decision-making analysis. The result shows that a multidimensional database-ready bidding template is the preferred alternative because it links technical scope, tank components, quantities, cost elements, QA/QC requirements, handover records, and actual project data. The proposed template can improve tender readiness, bid comparison, project control, asset integrity, and the development of a long-term cost database.

Keywords: Bidding template; database automation; storage tank repair; OmniClass; WBS/CBS

INTRODUCTION

A. Global and Indonesian Contexts: Importance of Storage Tank Integrity

Bulk oil storage tanks are a key element of downstream energy infrastructure, enabling the receipt, storage, quality control, and redistribution of fuel products before they are delivered to end users. The International Energy Agency (IEA) notes that "at the global level, energy security remains exposed to disruption because the global oil market

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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/

remains vulnerable to a wide range of risk factors".[3] Therefore, for oil and gas companies, storage tank integrity is directly related to supply continuity, emergency preparedness, operational safety, and environmental protection.

In Indonesia, this becomes a more strategic issue due to the country's geography and the scale of demand. Indonesia is the "world's largest archipelago" with more than 17,500 islands lying between the Pacific and Indian Oceans, according to the Food and Agriculture Organization.[4] The archipelagic nature creates long and dispersed fuel-distribution chains that require reliable terminals, marine facilities, road access, and storage capacity. At the same time, national demand is still high. "Indonesia's final energy consumption in 2023 is 1,220 million BOE, where the industrial sector is 45.60%, and the transport sector is 36.74%," the Ministry of Energy and Mineral Resources said.[5] The numbers show that the fuel storage infrastructure is not a peripheral facility, but a strategic buffer in the Indonesian energy supply system.

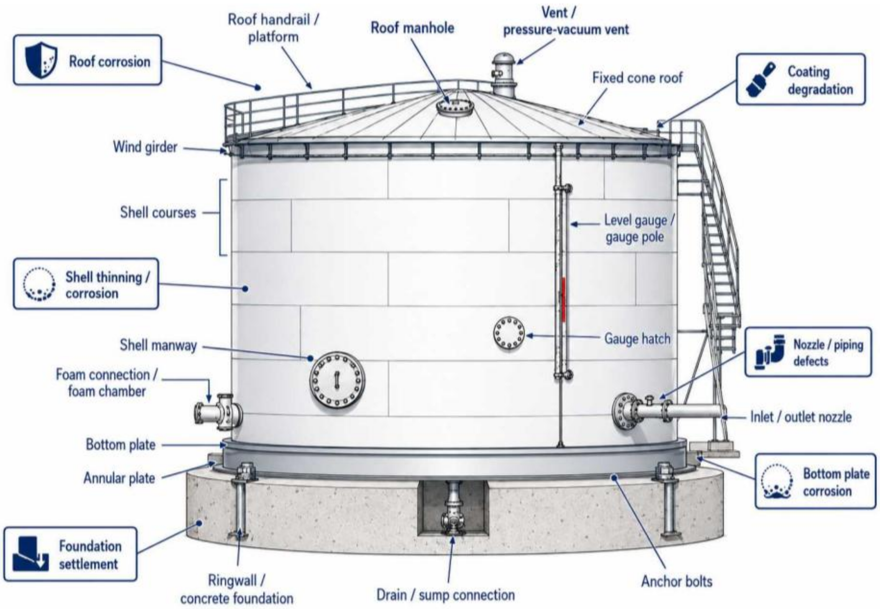

Figure 1. Typical bulk oil storage tank repair scope and common integrity threats[6]

[3] International Energy Agency. (n.d.). *Oil security and emergency response*. https://www.iea.org/about/oil-security-and-emergency-response
[4] Food and Agriculture Organization of the United Nations. (n.d.). Indonesia at a glance. https://www.fao.org/indonesia/about-us/indonesia-at-a-glance/en

[5] Ministry of Energy and Mineral Resources of the Republic of Indonesia. (2024). Handbook of energy & economic statistics of Indonesia 2023. https://www.esdm.go.id/assets/media/content/content-handbook-of-energy-and-economic-statistics-of-indonesia-2023.pdf
[6] By Author

B. Pertamina Downstream Distribution Context of Storage Tanks

In the case of PT Pertamina Patra Niaga, storage tanks are core assets for the downstream value chain as they support product receipt, inventory management, quality control, inter-terminal transfer, and final distribution to customers. The size of this downstream network was shown in Pertamina's public information during the 2024 Ramadan and Eid task-force period, where 115 fuel terminals, 30 LPG terminals, more than 7,400 SPBU, 723 SPBE, 48,207 LPG agents and outlets, and 71 aviation fuel depots were prepared and monitored through the Integrated Enterprise Data and Command Center.[7] That public release doesn't specify the number of storage tanks. Still, the number of terminals and aviation depots indicates that storage infrastructure is embedded within a large operating network.

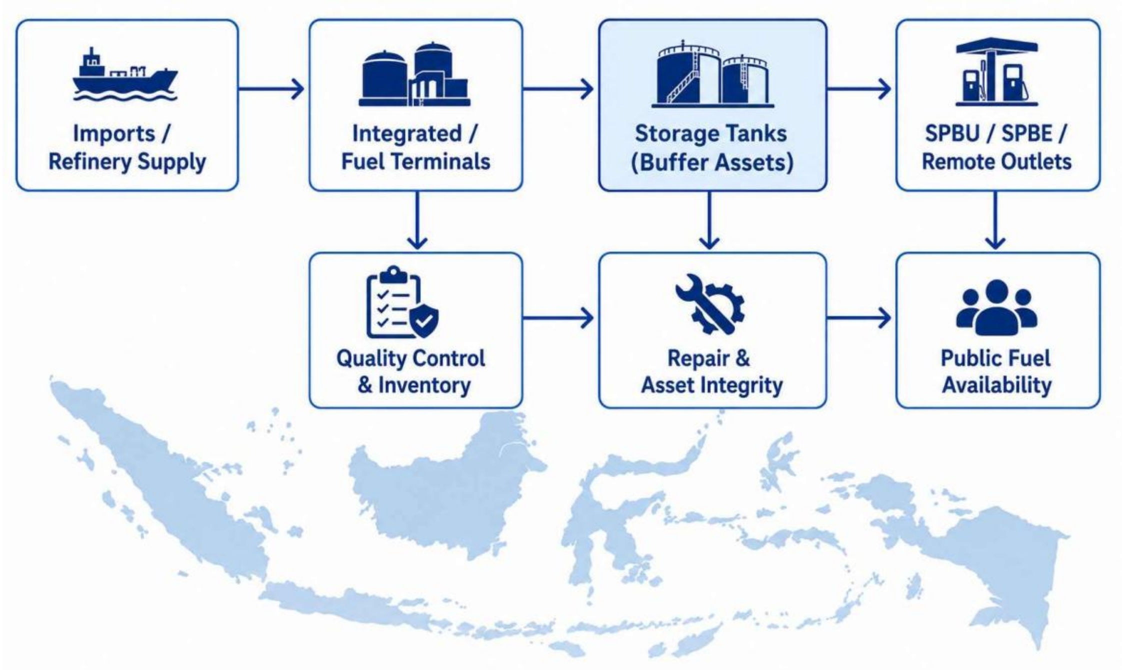

Figure 2. Indonesia's downstream fuel-distribution context and the role of storage tanks as buffer assets[8]

Pertamina Patra Niaga's public-service role is also reflected in the BBM Satu Harga program. BPH Migas stated that "until 2024, there are already 583 BBM Satu Harga distributors, 573 of them or 98.28% are operated by PT Pertamina Patra Niaga, which

[7] PT Pertamina (Persero). (2024, April 14). Pertamina memastikan distribusi energi lancar selama libur Lebaran 2024. Pertamina One Solution. https://onesolution.pertamina.com/Insight/Page/pertamina-memastikan-distribusi-enegeri-lancar-selama-libur-lebaran-2024
[8] By Author

contributes to the availability of affordable fuel in 3T areas and is expected to improve the quality of life, welfare, and local economy."[9] The same report, however, identified constraints to implementation related to access roads, jetties, ports, access to fuel distribution, security, geographical factors, and weather. This evidence proves the need for a reliable storage and distribution infrastructure for the Indonesian downstream fuel system.

The importance of storage tanks in strategic planning is further emphasized in national policy debates on the resilience of fuel stocks. In March 2026, the Cabinet Secretariat said "Indonesia's fuel reserves were in a safe condition", but also noted the statement by the Minister of Energy and Mineral Resources that "Indonesia's fuel storage capacity had long been limited to a maximum of 25 days".[10] In the same public statement, the President directed the development of new storage facilities to enhance national energy resilience. Although Indonesia is not an IEA member country and is not subject to the IEA 90-day stockholding obligation, the IEA framework is still useful as an international reference point and states that "it links oil security to the availability of stored crude oil and refined products".[11]

The national context makes the tank's integrity more relevant. Storage capacity only makes sense when the storage assets are safe, inspectable, maintainable, and available for operation. API Standard 653 and EEMUA Publication 159 offer internationally recognized guidance for the inspection, maintenance, repair, alteration, and reconstruction of aboveground storage tanks.[12,13] If tank integrity is not maintained, leakage, fire, explosion, environmental contamination, unplanned shutdown, product loss, and interruption of fuel-distribution continuity may expose the operator.

API 650 and API 653 are presented in this paper in a different but complementary way. API 650 establishes the technical basis for the construction of welded oil storage tanks.

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[9] Badan Pengatur Hilir Minyak dan Gas Bumi. (2025). Laporan kinerja BPH Migas tahun 2024. Kementerian Energi dan Sumber Daya Mineral Republik Indonesia. https://www.esdm.go.id/assets/media/content/content-laporan-kinerja-bph-migas-tahun-2024.pdf

[10] Sekretariat Kabinet Republik Indonesia. (2026, March 4). Cadangan BBM nasional aman, Presiden Prabowo perintahkan bangun storage baru perkuat ketahanan energi. https://setkab.go.id/cadangan-bbm-nasional-aman-presiden-prabowo-perintahkan-bangun-storage-baru-perkuat-ketahanan-energi/

[11] International Energy Agency. (n.d.). Oil security and emergency response. https://www.iea.org/about/oil-security-and-emergency-response

[12] American Petroleum Institute. (2020). API Standard 653: Tank inspection, repair, alteration, and reconstruction (5th ed., including applicable addenda). API Publishing Services. https://www.api.org/~/media/files/publications/whats%20new/653_e5%20pa.pdf

[13] Engineering Equipment and Materials Users Association. (2014). EEMUA Publication 159: Above ground flat bottomed storage tanks: A guide to inspection, maintenance and repair (4th ed.). EEMUA. https://www.eemua.org/storage-landing

It includes purchaser requirements, datasheet logic, materials, design, fabrication, erection, inspection, and documentation. API 653 is more directly related to in-service tank integrity because it deals with inspection, repair, alteration, reconstruction, examination, testing, recordkeeping, and owner/operator responsibility after a tank is placed in service. Thus, the proposed template is based on API 650 for the asset definition and API 653 for the repair governance.

This challenge is directly related to the case background of PT Pertamina Patra Niaga. In accordance with the Minutes of the Board of Directors Meeting No. RRD-016/PNA000000/2023-S0 dated July 5, 2023, and the Internal Memorandum of the Director of Engineering and Land Infrastructure No. 229/PNE000000/2023-S5 dated August 1, 2023, strategic directions were issued to expedite Asset Integrity programs for facilities classified as Safety Environment Critical Elements (SECE) at the regional level in 2023.[14,15] One of the key asset groups that needed acceleration was storage tank repair.

Storage tanks are strategic buffer assets, so their repair projects must be prepared and delivered quickly, consistently, and in a defensive manner. However, organizational learning and database automation based on recurring storage tank repair work can only be supported if its bidding data are structured in a repeatable WBS/CBS-coded format from the beginning of tender preparation.

C. Gap in Project Control in Current Bidding Practices

The main issue addressed in this paper is not the lack of technical standards for repairs, but rather the lack of a sufficiently standardized bidding structure for recurring storage tank repair projects that can be readily entered into databases. In practice, the scope descriptions in the bidding documents may be inconsistent, units of measurement may differ, work packages may be discipline-based rather than asset-based, assumptions and exclusions may be incomplete, and WBS/CBS coding may be non-uniform. When repair scopes are repeated but documented differently from project to project, the organization cannot consistently compare bids, normalize historical cost data, or convert procurement outputs into a reusable estimating database.

This is a big weakness from a project controls perspective. The purpose of front-end loading (FEL) is to define projects over time better until decisions are made to execute. As the project moves from concept development to execution readiness, the scope definition, WBS, CBS, estimating basis, schedule logic, and risk/opportunity analysis

[14] PT Pertamina Patra Niaga. (2023a, July 5). Minutes of the Board of Directors Meeting No. RRD-016/PNA000000/2023-S0. Internal company document.
[15] PT Pertamina Patra Niaga. (2023b, August 1). Internal Memorandum of the Director of Engineering & Land Infrastructure No. 229/PNE000000/2023-S5. Internal company document.

should become more mature and integrated. AACE International Recommended Practice 18R-97 similarly explains that "estimate classification is influenced by project definition maturity and the level of engineering information available".[16] Paul D. Giammalvo and PTMC (2021) also emphasize that "effective scope management depends on structured decomposition because the Work Breakdown Structure serves as the foundation for integrating scope, schedule, cost, risk, and project-control functions throughout the project lifecycle".[17] This means that uneven bidding structures can damage the continuity of FEL, estimation, procurement, execution control, and lessons learned.

D. Need for a Standardized and Database-Ready Bidding Template

The standard bidding template should not be seen as a simple administrative procurement form. It should be positioned as an integrated project-definition tool that links technical scope, WBS/CBS coding, quantity take-off, pricing format, assumptions, exclusions, procurement package structure, bid comparison, and future historical-data capture. When each work item, asset component, quantity, unit rate, cost element, and procurement package is coded consistently, bidding templates become a practical basis for database automation.

This logic is also compatible with BIM-based information management. BIM can support structured asset information, component identification, quantity traceability, and multidimensional coding in the project lifecycle. BIM is not only 3D modeling for storage tank repair, but also a disciplined information structure that links tank numbers, locations, components, inspection findings, repair methods, quantities, costs, codes, and execution records. In this sense, the proposed bidding template framework integrates FEL, WBS/CBS, BIM, estimating, procurement, and database automation.

[16] AACE International. (2020). AACE International Recommended Practice No. 18R-97: Cost estimate classification system – As applied in engineering, procurement, and construction for the process industries. AACE International. https://web.aacei.org/docs/default-source/toc/toc_18r-97.pdf
[17] Giammalvo, P. D., & PTMC. (2021). Unit 4 – Managing Scope. https://build-project-management-competency.com/1-4-1-4-unit-4/

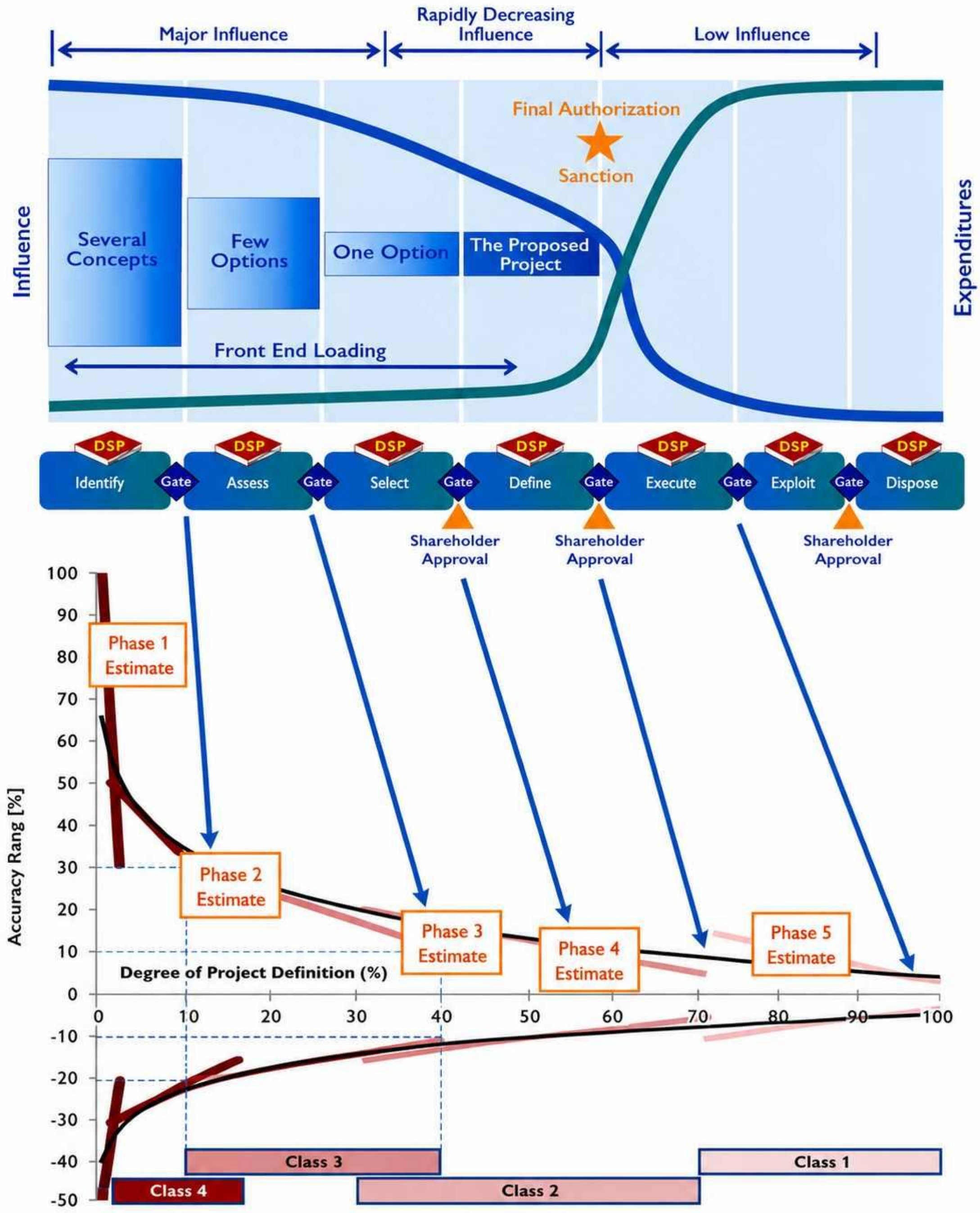

Figure 3. Influence of FEL and Project Definition Maturity on Cost and Schedule Uncertainty[18,19]

[18] 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
[19] U.S. Department of Energy. (2011). Cost Estimating Guide.

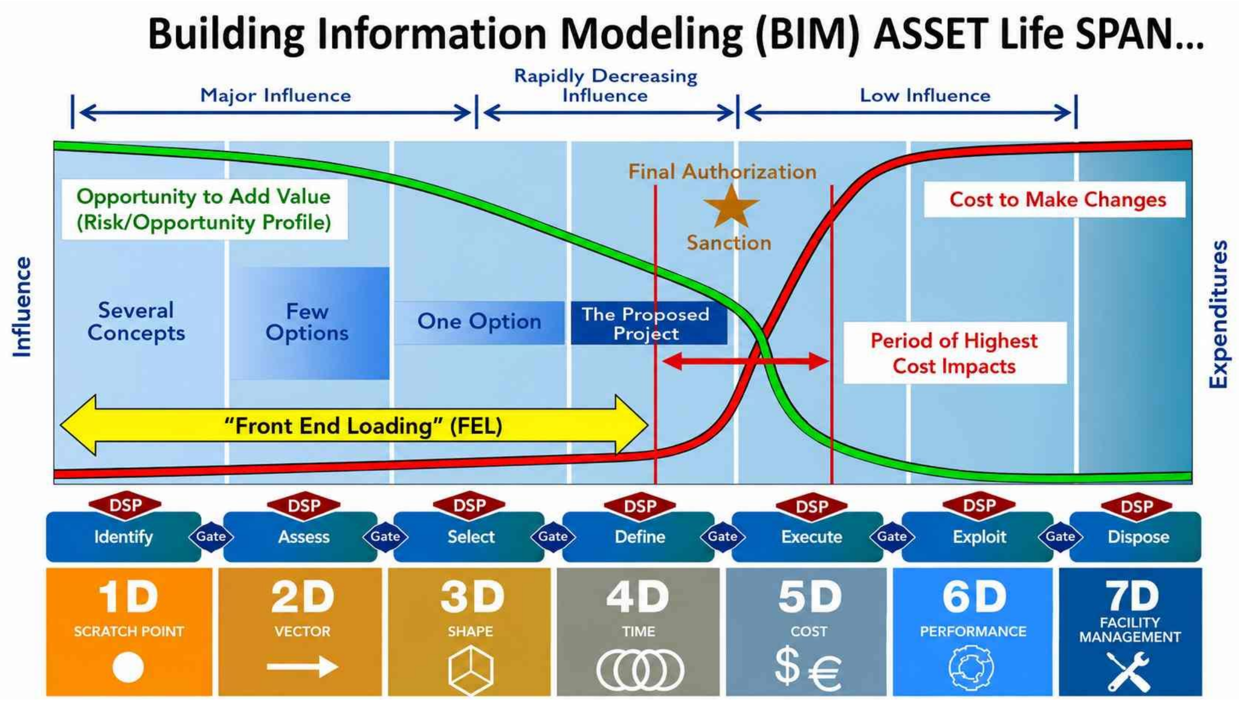

Figure 4. Illustration of FEL System and the evolution of WBS/CBS[20]

Benchmark references, such as the United States National Park Service Class A Construction Cost Estimate Template, can be a comparative model to overcome the disadvantages of traditional discipline-based bidding structures and promote a more standardized database-oriented structure.[21] The benchmark is not meant to be adopted as is. Instead, it provides a useful reference for organizing work items, cost information, and estimating documentation in a more structured way. The same logic can be adapted for repeat storage tank repair projects to align asset components, work packages, cost breakdown structures, and procurement requirements.

E. Owner Readiness, Contractor Support, and Research Focus

An equally important factor is that procurement performance is heavily influenced by how well the owner prepares the project itself. Contractors are generally able to perform more effectively when the owner can provide clear technical information, dependable quantity references, timely decisions, practical and constructible work packages, as well as responsive administrative coordination during project execution.

[20] Giammalvo, P. D., & PTMC. Loc. Cit.
[21] National Park Service. (2021, May 27). Class A Construction Cost Estimate Template. NPS.gov (U.S. National Park Service). https://www.nps.gov/dscw/publicforms.htm

For that reason, the proposed bidding template should not only be understood as a document prepared for contractors. It also serves as an internal management tool for the owner to improve scope definition, strengthen procurement readiness, support more consistent bid evaluations, and maintain better governance and control throughout the project lifecycle.

The research questions were generated from the previously identified gap between the repeated storage tank repair needs and a lack of a standardized database-ready bidding structure. The problem is not only in tender documentation. It includes scope definition, cost traceability, owner readiness, contractor communication, and use of long-term historical data. Therefore, the following introductory questions guide this paper:

1. What are the current weaknesses in the structure of a bidding document for storage tank repair projects?
2. Which benchmark elements should be adapted to develop a more standardized bidding template framework?
3. How will the resulting template improve the consistency of data for future estimating, procurement, and database automation decisions?

METHODOLOGY

The graphic below illustrates the methodology we are developing:

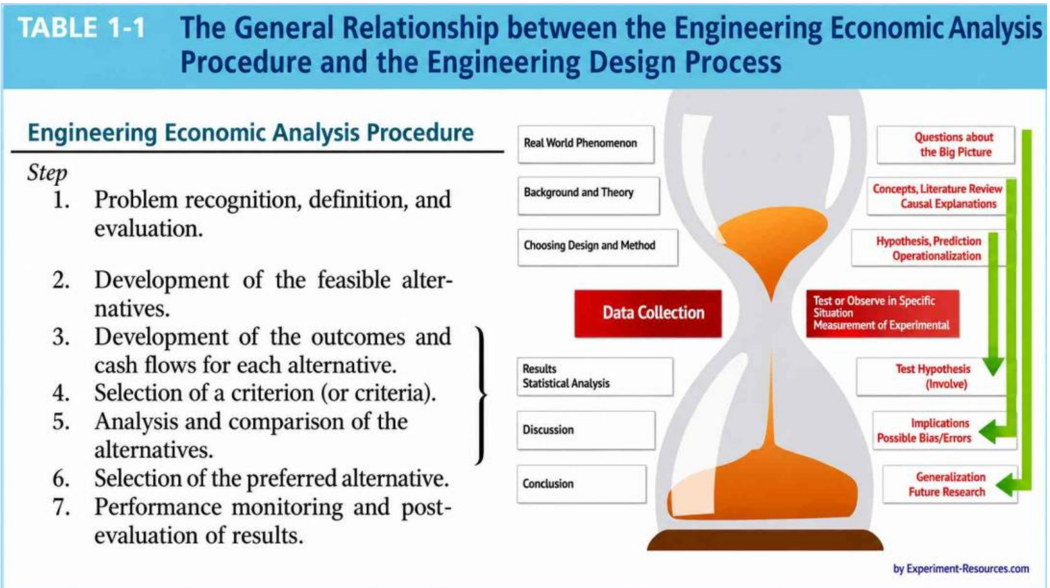

Figure 5. Engineering Economic Analysis Procedure[22] & Steps of the Scientific Process[23]

This study uses a practice-based comparative analysis of storage tank repair bidding structures, recurring work-package patterns, API 650/API 653 technical logic, and benchmark cost-estimating templates. The unit of analysis is the bidding template field structure, including work-package descriptions, tank-component coding, inspection basis, repair classification, cost-element separation, QA/QC and testing requirements, and close-out data fields. The objective is not to redesign procurement, but to identify which bidding template structure best supports project definition, bid comparison, cost tracking, and future database automation.

As part of the comparative analysis process, the author also developed several supporting working documents, such as an OmniClass-based WBS structure, a WBS/CBS coding dictionary, and bidding template worksheets organized by project phase: Engineering, Construction, and Handover activities. These documents were

[22] Sullivan, W. G., Wicks, E. M., & Koelling, C. P. (2020). Engineering Economy (Seventeenth Edition). Pearson Education Limited.
[23] Shuttleworth, M. (2008, February 2). What is research?. Retrieved from https://explorable.com/what-is-research.

primarily used to help structure and evaluate the analysis during the development of the study.

However, the full set of working papers is not included as appendices in the final article to keep the paper concise and easier to follow. Instead, several selected tables are presented in the Methodology and Findings sections to illustrate the main concepts, structure, and the practical results generated by the study.

Step 1 - Problem Definition

This study was carried out using a practical comparative approach to review several storage tank repair bidding structures, recurring work-package arrangements, API 650/API 653 technical requirements, and commonly used cost-estimating templates. The review mainly focuses on how the bidding templates are organized, including work-package descriptions, tank component coding, inspection references, repair classifications, cost breakdown structures, QA/QC and testing requirements, and project close-out documentation fields. The purpose of this study is not to redesign the procurement process, but to understand which template structure can better support scope definition, bid comparison, cost tracking, and future database integration.

During the study, the author also prepared several supporting working documents, such as an OmniClass-based WBS structure, a WBS/CBS coding dictionary, and bidding template worksheets arranged according to the Engineering, Construction, and Handover phases. These documents were used internally to support the evaluation process and development of the proposed structure. To avoid making the paper unnecessarily long, the complete working papers are not attached as appendices. Instead, several selected tables are included in the Methodology and Findings sections to show the main structure, analytical logic, and practical results of the study.

The current bidding structure already contains detailed technical information, but it is still very much project-specific. Similar work items may be described at different levels of detail, with different quantity groupings, and with varying separation between material, service, equipment, inspection, and certification items. This causes a data problem. A BOQ can support one tender, but if not coded consistently, it cannot easily become a reusable historical database.

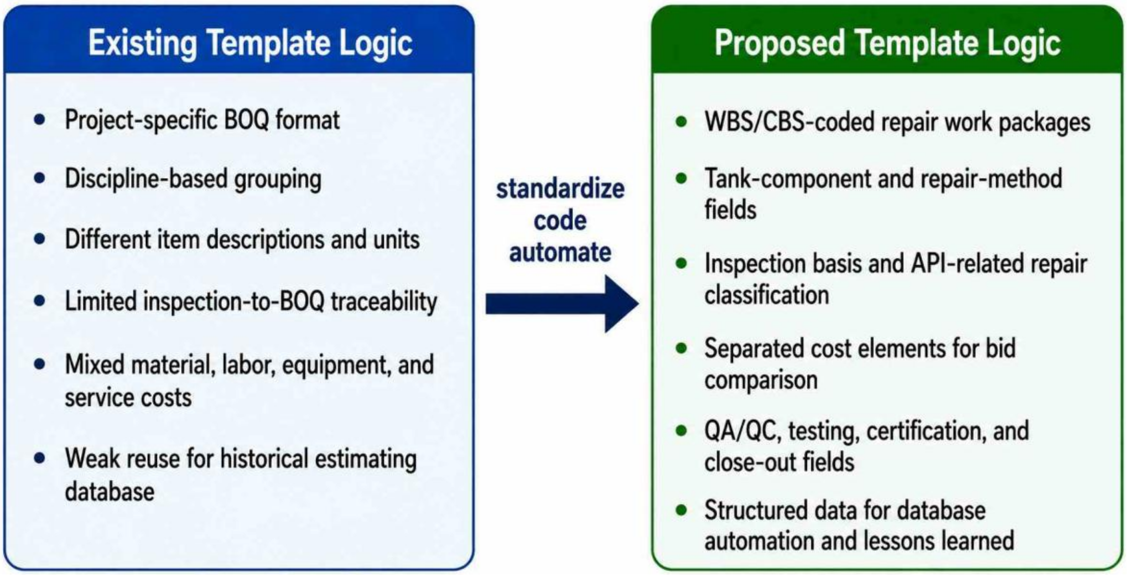

Figure 6. Existing vs proposed bidding template structure for storage tank repair projects[24]

From a cost-estimating standpoint, this problem is directly linked to the risk of failing to capture probable scope. Giammalvo and PTMC identified "Omit Probable Scope from Estimate and Omit Probable Risk from Analysis" as one of the common causes of estimate failure.[25] This is particularly true for repairs to storage tanks, where the scope of the repair may be dictated by inspection findings, hidden corrosion, field conditions, access constraints, and certification requirements.

Therefore, the main issue identified in this study is that existing storage tank repair bidding documents already contain a large amount of useful technical and commercial information, but the data is not yet organized in a consistent WBS/CBS-coded format ready for database integration. In practice, this makes bid comparisons more difficult, limits the use of historical cost data for normalization, reduces the accuracy of owner estimates, complicates change-order evaluations, and creates obstacles for future automation and database development initiatives.

[24] By Author
[25] Giammalvo, P. D., & PTMC. (2022). Unit 10 - Managing cost estimating and budgeting. https://build-project-management-competency.com/1-4-1-10-unit-10/

Problem Area	Observed Condition	Implication for the Bidding Template
Recurring but project-specific scope	Repeated work packages appear across cases, but are described and grouped differently.	A standardized work-package dictionary is needed.
Weak component-level traceability	Costs may not always be linked clearly to tank components such as bottom, annular, shell, roof, nozzle, or fire protection.	The template should use component-based WBS/CBS fields.
Limited cost-element visibility	Material, service, equipment, indirect cost, inspection, and certification may be mixed.	The template should separate cost elements for benchmarking.
Inspection and certification obligations	Repair completion depends not only on construction, but also on testing, certification, and operational readiness.	The template should capture QA/QC and certification fields.
Future database limitation	Project-specific BOQs are difficult to normalize into historical estimating data.	The template should be designed as structured data from the beginning.

Table 1. Summary of the problem recognized in the current storage tank repair bidding data.[26]

Step 2 - Identification of Feasible Alternatives

The logic for developing alternatives is that the bidding template should evolve from a mere pricing form into a structured project definition and data-capture tool. A standardized Work Breakdown Structure is useful because "WBS is a structure that breaks down the project into manageable work packages, components or WBS elements to provide a standard mechanism for scheduling scope, costs, distribution of responsibilities, communication, risk assessment, monitoring and control".[27,28]

The benchmark in this paper is not a direct copy of any external template. The National Park Service Class A Construction Cost Estimate Template is used as a reference instead, because it demonstrates how a cost estimate can systematically separate asset/service structure, material cost, labor cost, equipment cost, direct cost, and total cost.[29] This is useful in storage tank repair, where the aim is to make the bidding template more comparable, auditable, and reusable.

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[26] By Author
[27] Al Farizi, S., & Latief, Y. (2018). Development of a standardized WBS (Work Breakdown Structure) for planning the schedule based on risk in steel bridge construction projects. http://www.ieomsociety.org/ieom2018/papers/167.pdf
[28] Pragitatama, W. (2024). Building a standardized bidding template for jetty/pier project as the basis for database automation. PM World Journal, XIII(X). https://pmworldlibrary.net/
[29] National Park Service. (2021, May 27). Class A construction cost estimate template. NPS.gov. https://www.nps.gov/dscw/publicforms.htm

Four feasible alternatives are identified for subsequent comparison:

Alternative	Description	Expected Use in This Paper
Alternative 1 - Current BOQ format	Retains the current project-specific BOQ structure.	Baseline for identifying current strengths and limitations.
Alternative 2 - Discipline-based repair template	Groups work by civil, mechanical, piping, coating, inspection/testing, and finishing.	Improves technical review by discipline, but may not fully support component-level cost analysis.
Alternative 3 - WBS/CBS-based repair template	Groups work by tank component and repair work package, supported by WBS/CBS codes.	Improves scope and cost traceability for project control.
Alternative 4 - Multidimensional database-ready template	Adds asset identity, inspection basis, repair method, cost element, QA/QC, certification, and realization fields.	Best aligned with database automation and future historical estimating.

Table 2. Feasible alternatives for developing the storage tank repair bidding template.[30]

Alternatives are constrained by design to bidding template structures. The paper does not aim to redesign the entire procurement or contract management process. Instead, it centers on the practical interface of capturing technical scope, quantity, cost, schedule, quality, and future database fields before bid submittal.

Step 3 - Development of Feasible Alternatives

The main result expected from this study is a standardized bidding template that can make storage tank repair work easier to define, price, compare, control, and reuse for future projects. The intention is not only to improve procurement documentation but also to create a structure that supports more consistent project data management over time.

Alternative 1 is still used as the baseline because the existing BOQ format already contains considerable technical and commercial detail. However, problems start to appear when similar repair activities are described differently from one project to another. In many cases, the same component, inspection requirement, or repair method may use different wording depending on the project team or contractor. This makes the data difficult to standardize and limits its usefulness for automation or historical database development.

[30] By Author

Alternative 2 provides a cleaner and more organized layout because the work items are separated based on technical disciplines. From a review perspective, this structure can make the document easier to follow. However, the underlying database problem is still not fully addressed. In actual projects, one tank component is often connected to several types of work simultaneously.

Alternative 3 creates a repair template based on the WBS/CBS. This alternative treats the storage tank as an asset that can be decomposed into repairable components: foundation, bottom plate, annular plate, shell, roof, nozzle, maintenance hole, fire-protection facility, grounding, and coating. It also ties each component to work results and cost elements. This is more in line with the logic of Pradibta's storage tank WBS/CBS standardization. But it is adapted to repair rather than new tank construction.[31]

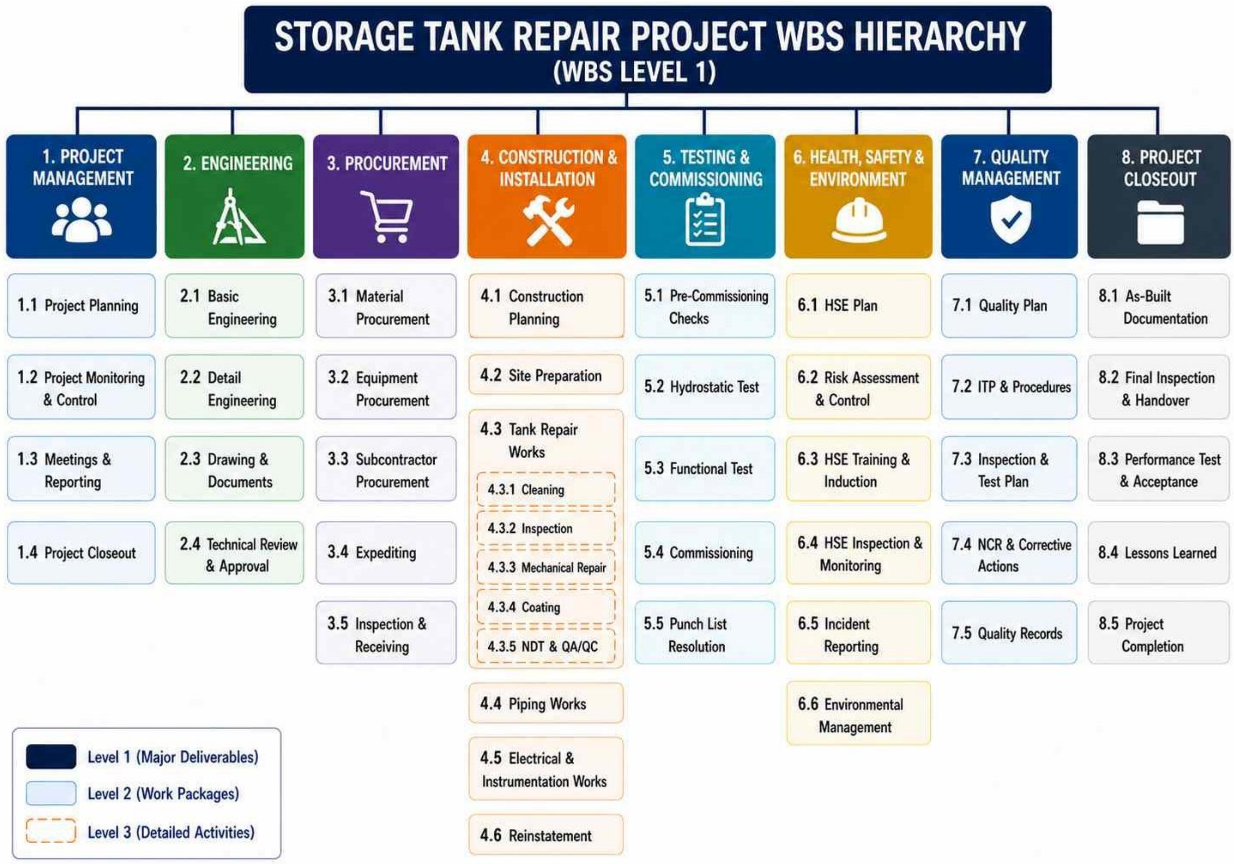

Figure 7. Storage tank repair project WBS hierarchy.[32]

[31] Pradibta, I. (2024). Developing a standardized, multidimensional WBS/CBS coding structure for storage tanks. PM World Journal, XIII(III). https://pmworldlibrary.net/
[32] By Author

Alternative 4 extends the WBS/CBS-based structure into a database-ready multidimensional template. This is the most complete expected result because it includes not only the BOQ item but also the data needed for future estimation, benchmarking, bid comparison, change order analysis, and lessons learned. The proposed logic is shown in Fig. 8.

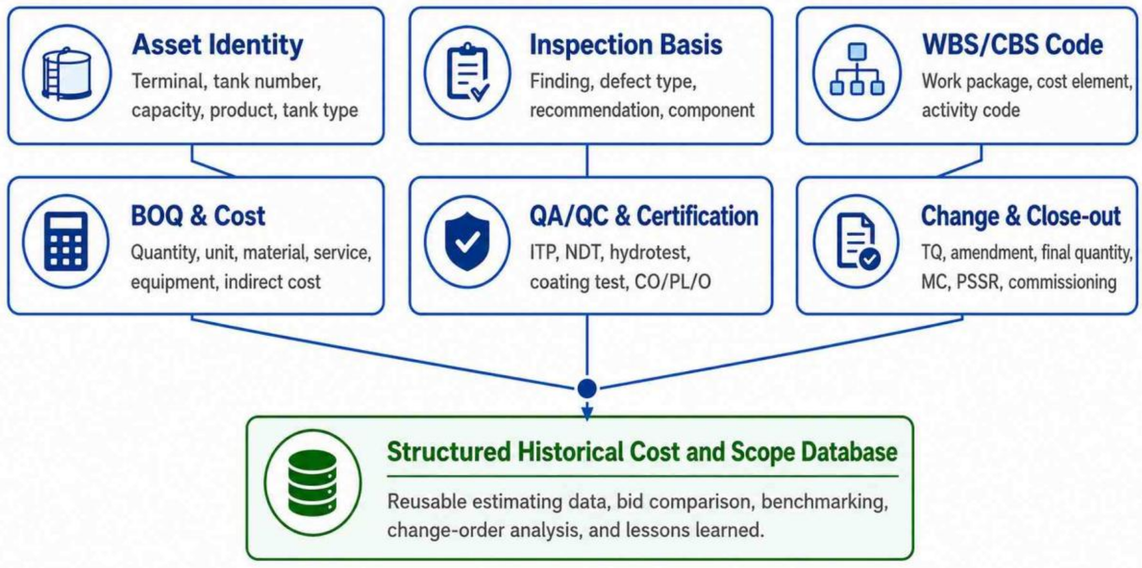

***Figure 8. Proposed database-ready bidding template logic.*[33]**

[33] By Author

Data Group	Example Fields	Reason for Inclusion
Asset identity	Terminal, tank number, capacity, product, tank type, year built	Links the work item to the operating asset.
Inspection basis	Inspection type, finding, defect type, recommendation, inspection reference	Connects repair scope to technical justification.
Tank component	Foundation, bottom, annular, shell, roof, nozzle, manhole, piping, foam chamber, sprinkler, grounding	Allows component-level cost and scope analysis.
Repair method	Replacement, welding, coating, jacking, NDT, hydrotest, calibration, commissioning	Captures how the scope is executed.
WBS/CBS coding	WBS code, CBS code, discipline, work package, cost element	Supports estimating, scheduling, and benchmarking.
BOQ and cost	Unit, original quantity, amended quantity, realized quantity, material cost, service cost, equipment cost	Enables cost traceability and bid comparison.
QA/QC and certification	ITP, DPT, vacuum test, RT, hydrotest, coating test, COI, PLO, MDR	Ensures the scope includes compliance and operational readiness.
Change and close-out	Technical query, amendment, final quantity, MC, PSSR, commissioning, completion record	Links bidding data to execution and final realization.

Table 3. Proposed data groups for the database-ready storage tank repair bidding template.[34]

The prospective outcome is therefore not restricted to a new BOQ layout. It is a structured data model. The template should enable the owner and contractors to communicate the same scope, using the same component names, cost elements, units, testing requirements, and close-out expectations. This should reduce ambiguity at the tender stage and make the final project data more useful for future projects.

This development approach is also consistent with the structure encouraged in API 650, particularly through its emphasis on data sheets and purchaser-defined requirements. In the context of a repair bidding template, this suggests that important information, such as asset identity, tank type, storage capacity, product service, design basis, reference drawings, technical assumptions, and documentation requirements, should be recorded in structured data fields rather than written only in narrative specifications. A more structured format makes the information easier to review, compare, and reuse across future projects.

API RP 575 and API Standard 2350 enhance the inspection-related basis for atmospheric and low-pressure storage tanks, respectively, and provide an operational-readiness perspective through overfill prevention requirements for petroleum storage tank facilities.

[34] By Author

The National Park Service Denver Service Center cost-estimating requirements strengthen this development logic, emphasizing a consistent estimating format, WBS-based organization, asset-level cost breakout, Basis of Estimate documentation, labor/material/equipment breakdown, market-source documentation, variance reporting, and historical cost-database development.[35] In this paper, the same principles are adapted to storage tank repair by linking each bid item to asset identity, tank component, repair method, WBS/CBS code, cost element, QA/QC requirement, and close-out record. The WBS structure and WBS/CBS coding dictionary were developed as separate author working papers, while their essential logic is summarized in the main paper through condensed WBS and coding tables.[36]

[35] National Park Service, Denver Service Center. (2025, June 20). Construction Cost Estimating Requirements Handbook, Sections 1.2, 3.2, 3.3, 5.1, and 6.1.
[36] Construction Specifications Institute. (2020). OmniClass Construction Classification System. https://www.csiresources.org/standards/omniclass

Phase	Paper level WBS role	Essential work packages	Template / data link
Engineering	Defines scope and bid basis before tendering.	Inspection basis, repair design data, datasheets, MTO/QTO, and ITP/BOQ development.	Engineering template; inspection/design records.
Preparation	Makes the tank safe and ready for field execution.	Mobilization, tank cleaning and gas-freeing, temporary access, isolation, permits, HSE readiness, and laydown.	Construction template; readiness records.
Construction - Tank Repair	Executes component-level repair work packages.	Foundation, settlement, jacking, bottom and annular plate, shell, roof, nozzle, manhole, and welding.	Construction template; measured quantities.
Utilities/ Accessories	Captures interfaces needed for return-to-service.	Fire protection, foam chamber and piping, grounding, drainage, containment, instrumentation, and calibration support.	Construction template; interface records.
QA/QC Testing	Verifies technical and regulatory acceptance.	ITP, visual inspection, DPT/MPT/RT/UT, vacuum box, hydrotest or exemption, settlement, and coating tests.	Construction template; inspection/test reports.
Handover	Closes the project and returns the tank to service.	Mechanical completion, MDR, as-built dossier, PSSR, commissioning, operational certificate, final account, and database upload.	Handover template; close-out records.

Table 4. Condensed OmniClass-based WBS logic for the storage tank repair project.[37]

[37] By Author

Coding area	Essential information captured	Paper use
Engineering basis	Project identity, tank identity, design basis, inspection findings, repair recommendation, drawings, MTO/QTO, and approval readiness	Shows that bid items are derived from inspection/design records.
Preparation readiness	Mobilization, gas-freeing, access, isolation, permit, HSE readiness, and material receiving.	Clarifies readiness controls before field execution.
Tank repair construction	Foundation, settlement, jacking, bottom/annular plate, shell, roof, nozzle/manhole, welding, and repair quantities.	Supports bid comparison and historical quantity benchmarking.
Utilities and interfaces	Piping interface, fire protection, foam chamber, grounding, drainage/containment, instrumentation, and calibration support.	Prevents missed boundary-scope items.
QA/QC and testing	ITP, visual inspection, NDE, vacuum box, hydrotest/exemption, settlement, coating tests, and acceptance reports.	Supports On Specification and On Regulation.
Handover and feedback	MC, MDR, as-built, PSSR/commissioning, operational certificate, final account, lessons learned, and database upload.	Closes the feedback loop to future estimating data.

Table 5. Condensed WBS/CBS coding dictionary logic for standardized storage tank repair bidding templates.[38]

Step 4 - Selection of Decision Criteria

The National Park Service's cost-estimating guidance was also considered relevant to this study because it highlights the importance of well-structured estimate documentation. Pragitatama (2024) quotes these expected benefits as including that "Project costs can be better managed", "Project costs and scope changes will be easier to manage and track". Estimate documentation can "Facilitate development and maintenance of the company's cost database".[39] These benefits are directly aligned with this paper's database-automation objective.

For the comparative evaluation, each criterion was assessed on a scale from 1 to 5, where 1 indicates very weak support, and 5 indicates very strong support. Equal weighting was selected for the base-case analysis to avoid creating a misleading level of precision in the assessment. In addition, several sensitivity scenarios were explored within the author's supporting working papers to evaluate whether the preferred alternative would remain consistent under different stakeholder priorities and evaluation perspectives.

[38] By Author
[39] Pragitatama, W. (2024). Building a standardized bidding template for jetty/pier project as the basis for database automation. PM World Journal, XIII(X). https://pmworldlibrary.net/

Criterion	Definition	Link to the Paper Topic
Scope clarity	Ability to describe repair work without ambiguity.	Improves tender readiness and contractor understanding.
Inspection-to-BOQ traceability	Ability to link inspection findings and repair recommendations to BOQ items.	Connects asset-integrity evidence to bidding scope.
Cost traceability	Ability to separate material, service, equipment, indirect cost, profit/risk, and tax.	Supports benchmarking and owner-estimate development.
Bid comparability	Ability to compare bidders using consistent descriptions, units, and quantities.	Improves evaluation quality and commercial transparency.
WBS/CBS integration	Ability to connect work items to standardized work and cost breakdown codes.	Supports database automation and project-control integration.
Change-order readiness	Ability to identify change-sensitive items and link them to later change records.	Improves traceability of scope, cost, and schedule changes.
Schedule and execution readiness	Ability to capture duration-sensitive work, access constraints, jacking, hydrotest, coating, and commissioning.	Supports fast-track repair planning and owner readiness.
QA/QC and certification readiness	Ability to capture ITP, NDT, hydrotest, coating test, COI/PLO, MDR, MC, PSSR, and commissioning.	Ensures operational-readiness obligations are captured.
Database automation potential	Ability to convert template fields into structured historical project data.	Directly supports the title and research objective.
Ease of implementation	Ability to adopt the template without disrupting current procurement governance.	Keeps the proposed improvement practical.
OTOBOSOROR alignment	Ability of the template to support On Time, On Budget, On Specification, On Regulation, and On Return monitoring.	Connects bidding template design with final project-performance evaluation.

Table 6. Proposed decision criteria for evaluating bidding template alternatives.[40]

These criteria complete the methodology framework. They are used in the Findings section to compare the alternatives, rank the feasible solutions, and determine which template structure provides the best balance between practical implementation and long-term database automation.

FINDINGS

Step 5 - Analysis and Comparison of Alternatives

The alternatives are compared using a two-stage multiattribute decision-making process. First, a noncompensatory screening is used to determine whether each alternative satisfies minimum requirements for a storage tank repair bidding template. This screening is important because some requirements should not be traded away. A

[40] By Author

template that is easy to implement but cannot support WBS/CBS coding, inspection-to-BOQ traceability, or database automation cannot fully answer the research questions.

Alternative	Minimum WBS/CBS Support	Minimum Database Readiness	Minimum QA/QC Traceability	Screening Result
Alternative 1 - Current BOQ format	Weak	Weak	Moderate	Retained only as baseline
Alternative 2 - Discipline-based repair template	Moderate	Weak to moderate	Moderate	Feasible but incomplete
Alternative 3 - WBS/CBS-based repair template	Strong	Moderate to strong	Strong	Feasible
Alternative 4 - Multidimensional database-ready template	Strong	Strong	Strong	Preferred candidate

Table 7. Noncompensatory screening of bidding template alternatives[41]

Second, the feasible alternatives are evaluated and ranked using an additive weighted scoring approach adapted from Chapter 14 of Engineering Economy. This method was selected because the preferred bidding template cannot realistically be determined by a single criterion. Instead, the evaluation needs to balance several factors at the same time, including scope clarity, bid comparability, cost traceability, WBS/CBS integration, QA/QC readiness, ease of implementation, and long-term database automation potential.[42]

For the initial assessment, all 11 criteria were given equal weight to keep the evaluation simple and consistent. The detailed calculations, scoring logic, and sensitivity checks were documented separately in the author's supporting working papers for review purposes.

[41] By Author
[42] Sullivan, W. G., Wicks, E. M., & Koelling, C. P. (2020). Engineering Economy (17th ed.), Chapter 14: Decision Making Considering Multiattributes.

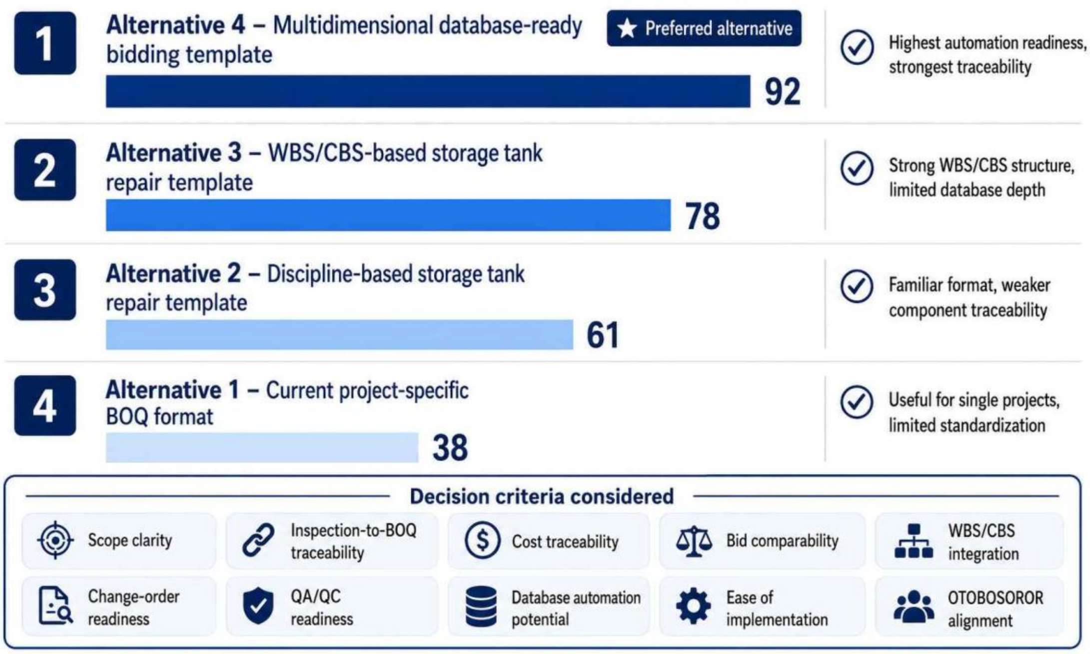

Figure 9. MADM ranking of bidding template alternatives.[43]

The ranking shows that Alternative 4 provides the strongest overall value. It does not merely reorganize BOQ line items. It transforms bidding data into structured project information by connecting asset identity, inspection basis, tank component, repair method, WBS/CBS code, cost element, QA/QC requirement, and close-out realization. Compared with the current BOQ format, Alternative 4 provides more than twice the relative score in the base model. This result supports the research argument that database automation requires more than a standardized price list; it requires a consistent data architecture from the beginning of tender preparation.

Because the scoring is intended to support decision-making rather than replace managerial judgment, the weighting and scoring should be validated through stakeholder review before company-wide implementation.

Step 6 - Selection of the Preferred Alternative

Applying the criteria from Step 4, the preferred alternative is Alternative 4, the multidimensional database-ready bidding template. This alternative is selected because it provides the most complete connection between the technical repair basis and the

[43] By Author

project-control data needed for estimating, procurement, construction control, and future benchmarking.

While Alternative 3 improves WBS/CBS-based scope and cost traceability, Alternative 4 is preferred because it extends the template into a multidimensional data-capture structure that also records API-based inspection basis, repair classification, QA/QC requirements, testing requirements, certification status, change records, handover documents, and actual execution data.

OmniClass WBS Code	Work/Item Name	Component	Method	Volume		Material Cost		Labor Cost		Equipment Cost		Total Direct Cost
				Qty	Unit	Per Unit	Total	Per Unit	Total	Per Unit	Total	
31-40 00 00 / 32-01	Project information and initation	General/ Project	Survey/ Assessment		lot							
12-14 21 17 / 22-02 21 00	Tank asset identification	General/ Project	Survey/ Assessment		lot							
22-01 33 16	Tank design and operating basis	General/ Project	Design/ Calculation		lot							
32-57 81 13	Inspection and condition assessment	General/ Project	Survey/ Assessment		lot							
32-35 47 23	Off-stream inspection findings	Tank Bottom	Survey/ Assessment		lot							
32-35 57 43	Fitness and repair recommendation	General/ Project	Design/ Calculation		lot							
32-35 57 37	Engineering deliverables	General/ Project	Design/ Calculation		set							
32-35 57 37 / 22-01 33 23	Repair drawings	General/ Project	Design/ Calculation		set							
32-35 57 43 / 32-35 57 37	Material take-off and quantity basis	General/ Project	MTO/BOQ Development		set							
32-35 57 37	Engineering review and approval	General/ Project	Survey/ Assessment		lot							

Table 8. Engineering Phase Bidding Template.[44]

[44] By Author

Phase	OmniClass WBS Code	Work/Item Name	Component	Volume		Material Cost		Labor Cost		Equipment Cost		Total Direct Cost
				Qty	Unit	Per Unit	Total	Per Unit	Total	Per Unit	Total	
Preparation	32-57 61 00	Mobilization and site readiness	General/ Project		lot							
Preparation	32-57 81 00 / 32-57 81	Tank cleaning and gas freeing	General/ Project		lot							
Preparation	22-05 51 19 / 32-57 61	Temporary access / scaffolding	General/ Project		lot							
Preparation	32-57 61 13	Isolation, permit, and safety preparation	General/ Project		lot							
Preparation	32-57 61 00	Material receiving and laydown	General/ Project		lot							

Table 9. Construction Phase Bidding Template-Preparation.[45]

[45] By Author

Phase	OmniClass WBS Code	Work/Item Name	Component	Volume		Material Cost		Labor Cost		Equipment Cost		Total Direct Cost
				Qty	Unit	Per Unit	Total	Per Unit	Total	Per Unit	Total	
Construction	22-31 / 32-35 47 23	Foundation and ringwall repair	Foundation		m3							
Construction	32-35 47 23	Settlement correction	Foundation		lot							
Construction	32-57 61 00	Tank jacking and temporary support	General/Project		lot							
Construction	22-08 54	Tank bottom plate	Tank Bottom		m2							
Construction	22-05 54 / 32-57 61 00	Bottom plate removal	Tank Bottom		m2							
Construction	23-13 19 13 / 11 19	Bottom plate replacement	Tank Bottom		kg							
Construction	32-57 61 00	Bottom plate welding	Tank Bottom		m							
Construction	22-05 54 / 23-13 19 13	Annular plate repair	Annular Plate		m2							
Construction	22-05 12 23	Shell plate repair	Shell		m2							
Construction	23-13 19 13 / 11 19 / 32-28	Shell patch/insert plate	Shell		each							
Construction	22-05 12 23 / 23-13 19	Roof repair	Roof		m2							
Construction	22-05 12 23 / 23-13 19	Floating roof repair	Floating Roof		m2							
Construction	22-08 17 13 / 23-17 11	Nozzle and manhole repair	Nozzle/Manhole		each							
Construction	22-23 11 00	Piping interface repair	Piping Interface		m							
Construction	09-90 / 23-15 21 13 11	Surface preparation	Coating/Lining		m2							
Construction	09-80 / 23-15 21 13 11	Internal/external coating	Coating/Lining		m2							

Table 10. Construction Phase Bidding Template-Construction.[46]

[46] By Author

Phase	OmniClass WBS Code	Work/Item Name	Component	Volume		Material Cost		Labor Cost		Equipment Cost		Total Direct Cost
				Qty	Unit	Per Unit	Total	Per Unit	Total	Per Unit	Total	
Utilities/ Accessories	22-21 05 / 23-29 33 13 21	Fire protection facility repair	Fire Protection		lot							
Utilities/ Accessories	22-23 10 62 / 29 33 13 21	Foam chamber and piping	Fire Protection		each							
Utilities/ Accessories	22-26 05 26 / 23-35 39 11	Grounding and lightning protection	Grounding/ Lightning		point							
Utilities/ Accessories	22-23 11 00 / 23-36 00 07	Drainage and containment interface	Foundation		m							
Utilities/ Accessories	22-28 40 / 23-27 11 11	Instrumentation and calibration support	Instrument/ Calibration		point							

Table 11. Construction Phase Bidding Template-Construction.[47]

[47] By Author

Phase	OmniClass WBS Code	Work/Item Name	Component	Volume		Material Cost		Labor Cost		Equipment Cost		Total Direct Cost
				Qty	Unit	Per Unit	Total	Per Unit	Total	Per Unit	Total	
QA/QC Testing	32-57 81 13	Inspection and test plan	Documentation		lot							
QA/QC Testing	32-57 81 13	Visual inspection	General/Project		lot							
QA/QC Testing	32-57 81 13	Dye penetrant testing	Tank Bottom		joint							
QA/QC Testing	32-57 81 13	Magnetic particle testing	Shell		joint							
QA/QC Testing	32-57 81 13	Radiographic or ultrasonic testing	Shell		joint							
QA/QC Testing	32-57 81 17	Vacuum box test	Tank Bottom		m2							
QA/QC Testing	32-57 81 17	Hydrostatic testing	General/Project		m3							
QA/QC Testing	22-15 21 13 / 11 / 32-57 61	Coating inspection	Coating/Lining		m2							
QA/QC Testing	22-28 40 / 32-27 11	Calibration	Instrument/ Calibration		point							

Table 12. Construction Phase Bidding Template-Construction.[48]

Consistent with ISO 21502:2020 project management guidance, this ownership should be treated as part of project governance rather than as an informal document control activity.

In practice, the template should have a clear owner: Technical Basis: Engineering; Tendering: Procurement; WBS/CBS and cost data consistency: Project Control; Testing and inspection records: QA/QC; Handover readiness and future usability: Operations/Maintenance

The selected template should be organized in three main phases based on packages. The Engineering Phase captures the inspection basis, repair recommendations, engineering assumptions, drawings, datasheets, method statements and quantity development logic. The Construction Phase includes the repair work packages, tank

[48] By Author

components, materials, labor, equipment, inspection/testing requirements, and direct cost elements. MDR is part of the Handover Phase, as well as as-built documentation, inspection reports, hydrotest or vacuum test results, coating test reports, calibration certificates, mechanical completion, PSSR, commissioning and final operational-readiness records.

Phase	OmniClass WBS Code	Work/Item Name	Component	Volume		Material Cost		Labor Cost		Equipment Cost		Total Direct Cost
				Qty	Unit	Per Unit	Total	Per Unit	Total	Per Unit	Total	
Handover	22-33 08 00	Mechanical completion	General/Project		lot							
Handover	22-01 33 23	Manufacturing data book	Documentation		set							
Handover	22-01 33 23	As-built documentation	Documentation		set							
Handover	22-33 08 00 / 32-57 81 17	PSSR and commissioning	General/Project		lot							
Handover	22-33 08 00	Operational readiness	Documentation		set							
Handover	22-01 33 23 / 32-57 81 17	Final account and actual quantity	Documentation		set							
Handover	32-57 81 17	Lessons learned and database	Documentation		lot							

***Table 13. Handover Phase Template.*[49]**

The Handover Phase template ensures that completed repair works are not closed only administratively, but are converted into validated asset records, final cost data, and lessons learned for future repair packages.

This structure is consistent with the NPS estimating principle that well-documented estimates should define the scope of work, identify cost-data sources, document assumptions, break costs into traceable line items, and support future cost-database

[49] By Author

development.[50] For storage tank repair, those principles are translated into phase-based bidding templates in Appendices 4, 5, and 6. Therefore, the recommended solution is not simply to revise the appearance of the BOQ, but to establish a repeatable data framework that can be used by Engineering, Procurement, Project Control, Construction, QA/QC, Operations, and Maintenance.

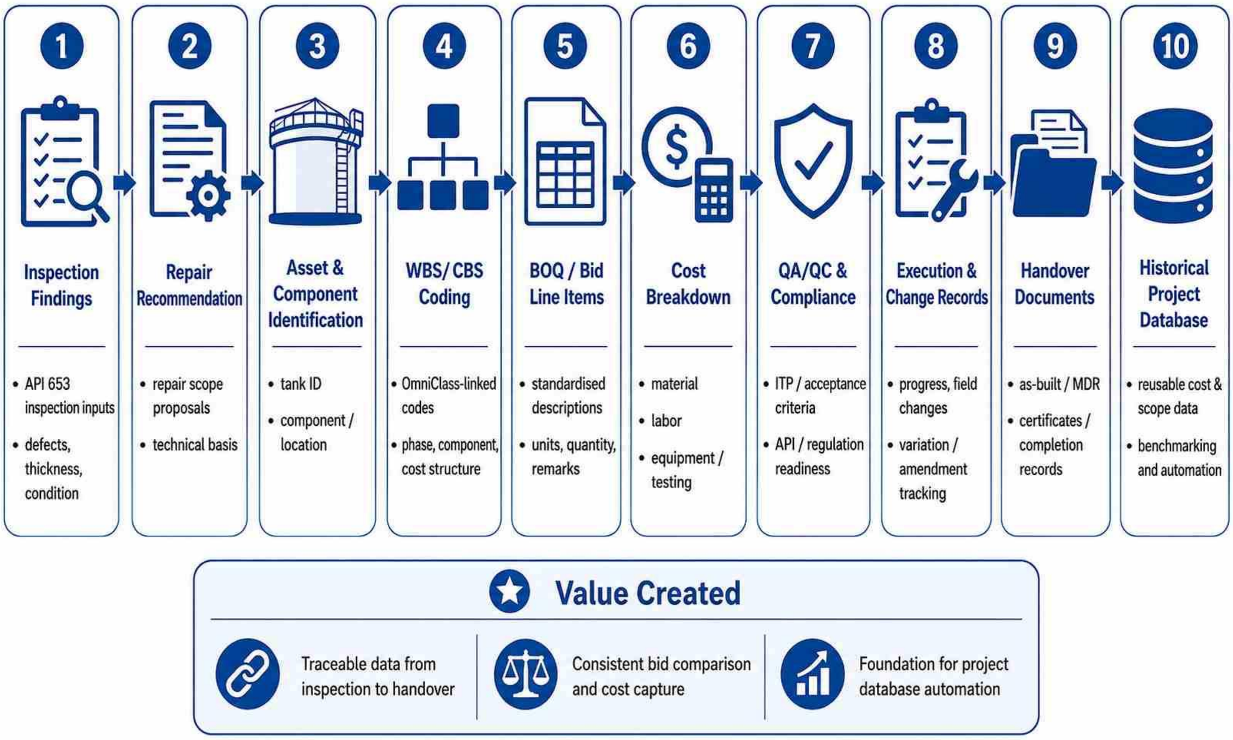

Figure 10. Data flow of the selected database-ready bidding template[51]

Step 7 - Performance Monitoring and Post-Evaluation

If the recommendation is accepted, the Company should monitor whether the new template improves actual project delivery. The post-evaluation should compare project performance before and after template implementation. The monitoring framework should not only measure whether the template was used, but also whether it improved tender readiness, bid evaluation, construction control, and data reuse.

[50] National Park Service, Denver Service Center. (2025, June 20). Construction Cost Estimating Requirements Handbook, Sections 1.2, 3.2, 3.3, and 6.2.
[51] By Author

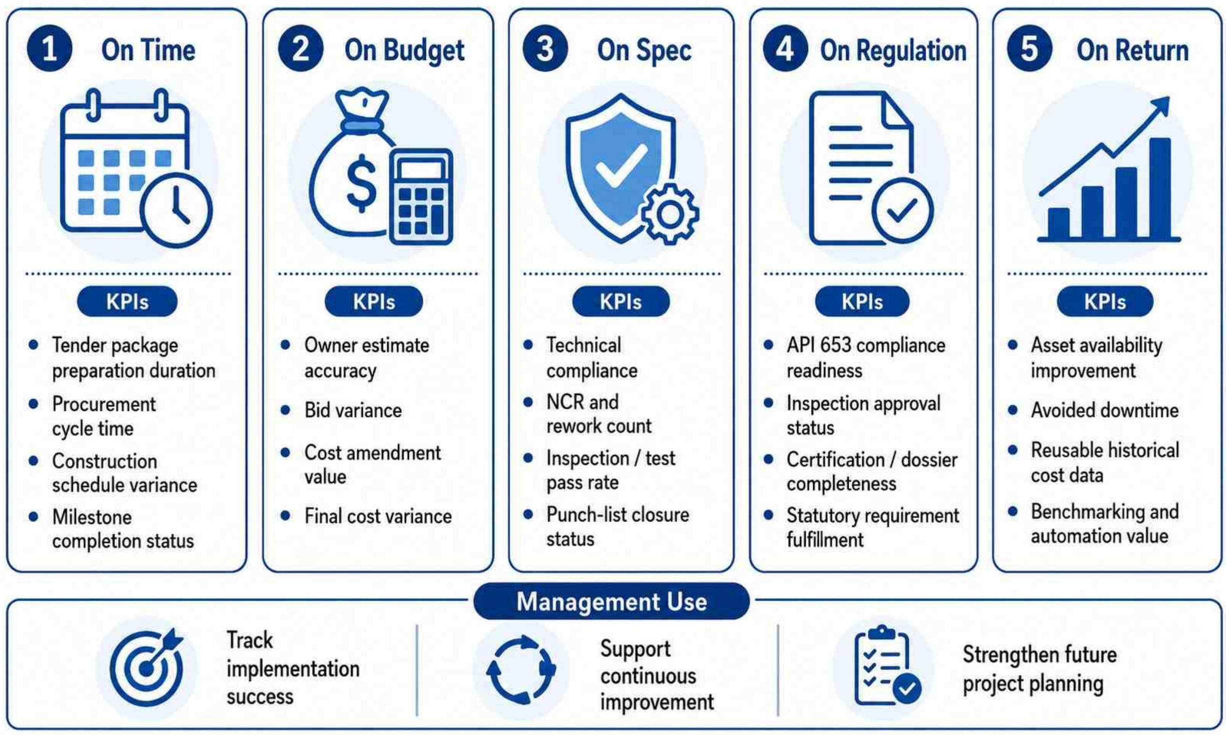

Figure 11. OTOBOSOROR monitoring framework for post-evaluation.[52]

The monitoring process should include a simple variance report for each implemented project. The report should compare the original bid template, awarded scope, approved changes, final quantities, final costs, schedule variance, and handover status. This aligns with the NPS variance-reporting concept, which documents major changes, additions, deletions, assumptions, and cost impacts between estimate versions.[53] In the context of storage tank repair, this variance information serves as a feedback loop that converts the bidding template into a living historical database.

[52] By Author
[53] National Park Service, Denver Service Center. (2025, June 20). Construction Cost Estimating Requirements Handbook, Chapter 5: Estimate Variance Reporting.

CONCLUSION AND RECOMMENDATIONS

The standardization of storage tank repair bidding documents was studied in this paper to speed up tender preparation, improve traceability for project control, and enable future database automation. The research was motivated by a practical problem: the current bidding documents are often disjointed and poorly aligned with the technical, cost, QA/QC, handover and benchmarking data needed for future estimating and procurement decisions.

The preferred solution is Alternative 4: a multidimensional database-ready bidding template, as demonstrated by the methodology and findings. This alternative addresses the first two research questions by identifying the current weakness as an integration issue, and by adapting benchmark elements from API 650/API 653 logic, OmniClass-based WBS/CBS coding, NPS estimating principles, project-governance ownership, and phase-based project delivery.

The proposed repeatable field structure addresses the third research question. Each tender package, by linking technical scope, component identity, quantities, cost elements, QA/QC and certification records, changing information, and handover documents, can serve as both a procurement document and a structured data-capture tool for estimating, project control, asset integrity, and database automation.

The significance of this research is that storage tank repair projects directly contribute to asset availability, safety, regulatory compliance, and fuel distribution reliability. It is recommended to pilot the structure on actual repair packages and to jointly review it by Engineering, Procurement, Project Control, QA/QC, Operations, and Maintenance before broader implementation. The pilot shall compare tender preparation cycle time, bid clarifications, quantity changes, schedule and cost variances, handover completeness, and data upload quality. Future research should develop a prototype digital database linked to historical cost and performance data.

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