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A Hybrid Conceptual Framework for Activity-Based Costing in Port Administrations

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Abstract

The increasing operational complexity of port authorities, combined with their high capital intensity and the strategic importance of these infrastructures within global logistics chains, requires costing systems capable of accurately representing cost formation and allocation. In this context, this study proposes a hybrid conceptual framework for activity-based costing in port administrations, integrating direct cost allocation, activity-based cost assignment, and the redistribution of support area costs within a unified analytical structure. The model is grounded in contingency theory and stakeholder theory, enabling the alignment of costing system design with organisational specificities while also addressing requirements of transparency, accountability, and decision support. The proposed operationalisation follows a sequential approach that links resources, activities, and cost objects through cost drivers and activity drivers. From a theoretical perspective, the study contributes to the management accounting literature by proposing a hybrid framework adapted to the port context. From a practical perspective, the model can support pricing decisions, cost control, and resource allocation by offering a more comprehensive representation of total cost formation in port environments.

Keywords: activity-based costing (ABC); conceptual model; cost management; cost drivers; management accounting; port administrations; port services; contingency theory; stakeholder theory

1. Introduction

Assuming a central role in the global economy and international logistics chains, maritime transport remains the dominant mode of freight movement worldwide. Despite the slowdown caused by the COVID-19 pandemic, the sector demonstrated high resilience, accounting for approximately 80% of global trade in 2023 [1]. In Portugal, the port sector has also shown consistent signs of recovery and growth. In 2024, the volume of goods handled in mainland ports reached approximately 88 million tonnes, reflecting the growing relevance of these infrastructures within the national logistics context [2].

In an increasingly competitive port environment, characterised by high operational complexity, strong capital intensity, and a significant proportion of indirect costs, it is essential to have costing systems capable of accurately representing the cost structure associated with different activities. However, traditional cost accounting methods, often based on aggregated and low-granularity allocation criteria, tend to exhibit limitations in representing complex operational contexts, which may compromise the quality of information provided to support decision-making [3,4].

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In this context, activity-based costing (ABC) emerges as a particularly relevant approach, as it enables cost allocation based on causal relationships between resources, activities, and cost objects. Despite its potential, the application of ABC in the port sector remains relatively underexplored in the literature.

According to Fioresi de Sousa et al. [5], the scarcity of detailed analyses of cost management models used by ports reveals a gap in the literature, particularly when considering the importance of this interface for port operational efficiency. Although some contributions exist within the Portuguese context [6,7], research still lacks structured models that allow the operationalisation of ABC in a way that is adapted to the specific characteristics of the sector.

Thus, the present study aims to propose a conceptual cost allocation model based on ABC principles, applicable to the port context. In this way, it seeks to contribute to a more structured understanding of cost formation in this sector and to provide an analytical basis for future empirical applications.

The present study is grounded in two complementary theoretical perspectives. Contingency theory, widely recognised for its relevance in analysing the fit between management accounting systems and the contextual specificities of organisations, posits that the effectiveness and design of accounting systems result from the interaction between internal and external factors such as strategy, environment, technology, and organisational structure [8,9]. On the other hand, stakeholder theory emphasises that organisations should adopt a relational and ethical perspective, with management responsible for balancing the interests of the various groups that influence, or are influenced by, the organisation [10,11]. In the field of management accounting, this theory highlights the importance of transparency and dialogue with stakeholders, recognising that accounting information plays a central role not only in internal decision-making, but also in accountability and institutional legitimacy [12].

The articulation of both theoretical lenses provides a more comprehensive and integrated understanding, enabling the simultaneous analysis of the suitability of accounting systems to organisational conditions and the need to respond to stakeholders' expectations, responsibilities, and interests.

Port administrations face a cost allocation problem involving shared infrastructure, heterogeneous operational activities, and support functions whose consumption is not always directly observable. The design challenge is to determine when costs should be traced directly, assigned through operational activities, or allocated through support functions, while documenting the basis of assignment and avoiding double counting.

This paper proposes a conceptual framework that makes these assignment decisions explicit through a hierarchical classification rule adapted to port administrations. Its contribution is an operational specification of how established costing mechanisms can be selected and integrated according to resource traceability, operational consumption, and support functions. The framework combines:

1. Direct tracing of costs that can be economically and observably associated with a final cost object;
2. Activity-based allocation of indirect operational costs through resource and activity drivers;
3. Separate allocation of support-function costs using documented allocation bases.

These mechanisms are not individually new, and their combination alone is not the claimed contribution. The proposed contribution is a port-oriented specification of assignment decisions: how mixed resources are partitioned, how competing assignment options are resolved, and how allocations are handled when consumption data are limited. These rules are brought together within a common three-pathway structure. The contribution

is therefore presented as a methodological refinement of established costing practices, whose practical usefulness remains to be assessed empirically. The article is structured as follows. Section 2 presents the literature review and theoretical framework. Section 3 describes the methodology used to develop the conceptual framework. Section 4 presents the proposed model and its three cost-allocation pathways: direct costs, ABC-based indirect operational costs, and support-area costs. Section 5 provides a conceptual discussion and expected managerial implications. Finally, Section 6 presents the conclusions, limitations, and avenues for future research.

2. Literature Review and Theoretical Framework

2.1. Activity-Based Costing

ABC emerged in the 1980s as a response to the significant increase in indirect costs relative to direct costs, highlighting the limitations of traditional costing systems. In this context, Cooper and Kaplan [13] introduced an innovative model at the time, centred on the relationship between resources, activities, and cost objects, establishing a more suitable methodological basis for the complexity of business operations.

The underlying logic of ABC is based on the premise that activities consume resources and that products or services consume those activities, with costs being allocated according to actual consumption [14]. The cost allocation process occurs in two main stages: in the first, costs are assigned to activities through cost drivers; in the second, these costs are transferred to cost objects based on activity drivers [15]. Although ABC is not a standardised model and may vary depending on the context in which it is implemented, its underlying logic remains consistent.

Since its initial formulation, ABC has evolved from an essentially conceptual framework into a widely applied and consolidated methodology across various organisational contexts. Its implementation spans multiple sectors, demonstrating the model's flexibility and ability to adapt to different operational realities and cost structures. The literature reports extensive applications of this approach in the manufacturing industry [16], in healthcare services [17–19] in the banking sector [20], in public administration [21] in agriculture [22] and in the port sector [6,23–25].

2.2. Factors Influencing the Adoption and Implementation of the ABC Method

The literature shows that the adoption and implementation of ABC is a process influenced by multiple factors of a strategic, organisational, behavioural, technological, and contextual nature, which may act either as facilitators or as barriers to its success [26–28].

2.2.1. Strategic Alignment and Cost Information Relevance

The relationship between organisational strategy and ABC adoption shows inconclusive empirical findings. Studies such as those by Elhamma and Yifei [29] indicate that there is no statistically significant relationship between strategy type and ABC adoption, suggesting that different strategic profiles may benefit from the model.

Despite this, the literature converges on the importance of alignment between ABC and strategic objectives. A lack of alignment may lead to underutilisation or abandonment of the system [27].

In parallel, the usefulness of cost information is a key determinant of the model's acceptance. Reliable and timely information improves decision-making and financial control [30,31], whereas delays and complexity reduce its practical value [26,32].

2.2.2. Organisational Structure, Resources and Economic Constraints

Organisational context plays a critical role in the implementation of ABC. The success of the system depends on top management involvement, the qualification of human resources, and the organisation's technical [33].

Organisations with more developed structures tend to cope better with the associated challenges, whereas limitations such as implementation costs, internal resistance, and weaknesses in control systems may compromise the process [28].

In addition, high initial and maintenance costs constitute one of the main barriers, especially in smaller organisations [26,34,35]. Although there is evidence of potential tax benefits in specific contexts, arising from a temporary increase in the cost of goods sold [36], these rarely offset the initial investment required for adoption.

2.2.3. Culture, Behaviour and Change Management

Behavioural and cultural factors are decisive for the success of ABC. Top management support, effective internal communication, and interdepartmental cooperation facilitate the acceptance of the system [37].

On the other hand, resistance to change, lack of commitment, and weak organisational involvement are recurring obstacles [38,39].

The implementation of ABC entails significant changes in processes and responsibilities, requiring structured change management with active leadership, continuous training, and strategic clarity [40,41]. The absence of these elements tends to compromise the success of implementation.

2.2.4. Technology, Knowledge and Organisational Learning

Technological infrastructure is a key factor in both the adoption and effectiveness of ABC. Advanced information systems facilitate data collection and analysis, reducing operational costs [42]. In contrast, technological limitations and incompatibilities with existing systems hinder implementation [38].

A lack of technical knowledge is equally critical. The absence of competencies in defining cost drivers and insufficient training can undermine the credibility of the system [43]. On the other hand, organisations with greater technical expertise implement ABC more efficiently and sustainably [27].

In practice, ABC can function as an organisational learning tool, enabling the identification of inefficiencies and non-value-adding activities [44]. However, without monitoring mechanisms and continuous improvement processes, the system tends to lose relevance over time [26].

Additionally, the perception of ABC as a "management fad" can reduce its legitimacy [45,46], although empirical evidence shows that, when adopted with a long-term perspective, it generates sustainable benefits [47].

2.2.5. Technical and Structural Limitations of the ABC Method

Beyond the behavioral and economic barriers discussed earlier, ABC presents several structural weaknesses. Identifying genuine causal drivers is often a complex task, leading many organizations to fall back on arbitrary allocations and subjective criteria when forming cost pools. Another significant constraint is the handling of unused capacity, as traditional ABC frameworks tend to absorb idle costs into standard rates instead of isolating them explicitly [3,48]. Ultimately, this reliance on subjective allocations can generate an "illusion of precision", yielding highly detailed cost reports that lack robust empirical backing from the underlying data [45].

In the context of port authorities, these methodological constraints become even more pronounced. The extensive reliance on shared infrastructure, heavy capital equipment, and overlapping support functions complicates the mapping of clear operational drivers [5,6]. Consequently, applying a rigid, traditional ABC model to such a complex operational environment risks exacerbating these theoretical flaws. This specific challenge reinforces the argument for hybrid costing architectures, which are designed to simplify driver selection and restrict arbitrary distributions to non-operational support areas.

2.3. Empirical Evidence from the Port Sector

The international literature has highlighted the applicability and effectiveness of ABC in multiple logistics and port contexts, emphasising its strong adaptability to the operational specificities of each sector. Luo et al. [23] developed a cost management model for container terminals in China, using ABC as an empirical validation tool for the efficiency of resource allocation. In line with Ryu et al. [25], they demonstrated, in the South Korean context, that the model constitutes an effective management tool capable of identifying resource-intensive activities and eliminating non-productive costs. These authors also highlight the role of ABC in promoting transparency and cost control, enhancing operational efficiency, productivity, and the formulation of pricing policies aligned with the nature of operations. Elyass et al. [49] analysed the introduction of ABC in a Sudanese port corporation, highlighting its advantages, limitations, and implementation practices. On the other hand, Pehlivan and Çiçek [24] used a simulation-based approach to examine the costs associated with ship management on routes between Turkey and Italy, reinforcing the relevance of the model as a decision-support tool in maritime contexts characterised by high operational complexity.

In Portugal, Themido et al. [7] applied the model to determine the costs associated with providing logistics services to specific customers, demonstrating its potential for the individualisation and detailed analysis of costs per operation. In the same context, Martins et al. [6] developed a methodology based on ABC to support the definition of port tariffs, contributing to a more equitable, transparent, and technically robust tariff structure in national port administrations.

The incorporation of ABC in the port sector has emerged as a response to the growing complexity of operations and the diversification of services provided. In environments characterised by shared infrastructure and multiple stakeholders, the model enables a clear distinction between direct and indirect costs, promoting a more accurate and well-founded analysis of the cost structure and supporting management decisions based on reliable information [6,24]. In this context, maintenance costs play a particularly important role, representing a critical component of operational expenditure and directly influencing the efficiency and competitiveness of ports as strategic logistics infrastructures [50]. In the field of maintenance management, the application of ABC enables a deeper understanding of cost drivers and a more accurate allocation of resources, supporting strategic decisions oriented towards efficiency and sustainability, particularly through process optimisation and the implementation of performance-based maintenance models [50].

Recent empirical studies indicate a growing interest in the use of ABC in the port sector, where the method has been applied to support the analysis of operational costs [51]. The model enables the integrated identification of direct costs associated with activities such as container handling or inspection operations [24] and indirect costs related to equipment depreciation or infrastructure maintenance [6]. This analytical granularity provides managers with a holistic and accurate view of the cost structure, enabling the identification of critical areas and the development of more effective optimisation strategies [25].

Similarly, Campos et al. [52] demonstrate, through a comparative analysis of multiple studies conducted in port administrations, that the use of ABC contributes to reducing unit costs, identifying key activities, and strengthening the strategic competitiveness of port entities. The implementation of the model supports more informed pricing decisions and promotes management practices grounded in empirical evidence and highly reliable data. Martins et al. [53] further emphasise the contribution of ABC to economic sustainability by enabling the efficient allocation of resources and the systematic monitoring of financial, environmental, and social costs, thereby supporting the integration of sustainable development objectives into port management practices.

In summary, the literature converges in identifying ABC as a fundamental instrument for enhancing operational efficiency and strategic cost management, enabling the accurate allocation of resources to activities and facilitating systematic performance comparisons [54,55]. Previous studies suggest that ABC may help reduce some distortions associated with traditional costing systems and may support a more detailed analysis of unit costs [56,57], thereby promoting performance that is simultaneously efficient, transparent, and sustainable.

2.4. Competing Costing Approaches and Framework Justification

While alternative managerial accounting methodologies exist, each addresses specific cost allocation challenges rather than providing a universal solution for port administrations. Time-Driven Activity-Based Costing represents a strong direct alternative, calculating costs through resource capacity rates and time requirements while exposing idle capacity, as demonstrated in container terminal applications by Yaşar [58] and Ding et al. [59]. However, its limitation concerns scope rather than applicability: when port activities involve different causal drivers, such as time, space, infrastructure use, equipment, transactions, or cargo characteristics, an authority-wide model organized predominantly around time requires increasingly complex time equations. Evidence outside the port sector confirms that mixed resources involving both human and mechanical elements, alongside highly automated operations, make time measurement and modeling within such frameworks considerably more complex and error-prone [60].

Similarly, Resource Consumption Accounting offers a sophisticated treatment of resource consumption and capacity but demands highly granular relationships and an advanced information architecture. The literature on this method itself emphasizes that its suitability remains heavily contingent on organizational context and information system availability [61]. Capacity-based costing makes supplied, used, and unused capacity visible, yet functions more effectively as a complement to causal costing than as a complete authority-wide allocation architecture, given that port capacity can be simultaneously constrained by multiple dimensions including time, space, and volume [62]. Process costing, by contrast, relies on continuous processes and equivalent homogeneous output. Averaging becomes problematic when port services consume resources heterogeneously, requiring subjective judgment even in measuring equivalent completion units [63]. Finally, reciprocal allocation accurately recognizes mutual services between support departments, with modern matrix solutions rendering traditional objections regarding computational complexity largely unpersuasive [64]. Nevertheless, this approach resolves only the support allocation stage rather than the subsequent tracing of operational activities to final services and users.

The proposed framework is not presented as universally superior to alternative costing approaches. Its contribution lies in specifying the rules governing the use and integration of direct tracing, activity-based operational allocation, and support-cost allocation in port administrations. The choice between this configuration and alternative approaches depends

on the decision context, resource-consumption patterns, and available data. Unused-capacity mechanisms and reciprocal support-department allocation are not explicitly incorporated in the current specification and remain possible extensions.

A closely related contribution is the port-authority model of Sousa et al. [65] which combines direct assignment to cost objects with activity-based allocation and incorporates support functions within its activity structure. The present framework therefore does not claim novelty for combining direct tracing and ABC. Its proposed distinction is the separate specification of the support-cost pathway together with explicit rules for partitioning mixed resources, prioritising assignment routes, and documenting provisional classifications when data are insufficient. This distinction concerns the organisation and specification of the framework rather than demonstrated superiority in costing results.

2.5. Contingency and Stakeholder Theory's

Contingency theory constitutes one of the conceptual foundations of contemporary management accounting and has been widely used to explain the differences observed in the adoption, structure, and effectiveness of information and control systems across organisations [66]. This approach argues that there is no universally applicable management accounting model, as accounting practices should be adapted to the specific characteristics and conditions of each organisation [8]. Thus, factors such as organisational structure, the external environment, organisational size, technological complexity, and corporate strategy directly influence the design and performance of costing and control systems [30,67].

According to this theory, the effectiveness of a costing system depends on the degree of fit between the system adopted and the organisational context [68]. ABC fits particularly well within this contingency logic, as its success is influenced by variables such as the diversity of activities, cost structure, organisational size, and organisational culture [69]. By identifying and assigning costs to the activities that consume resources, ABC provides a more accurate and informative representation of business processes, flexibly adapting to the specific characteristics of each context.

In seaports, environments characterised by high operational complexity, a multiplicity of interdependent activities, and a demanding regulatory framework, ABC is of relevance [6,24]. Its application enables a deeper understanding of the cost structure of port operations and contributes to the establishment of fairer, more transparent tariffs aligned with operational reality [6]. Thus, ABC goes beyond its purely technical function, emerging as a contingency-based management tool capable of supporting strategic decision-making and promoting more efficient and context-sensitive management [50].

In addition, by recognising that organisational performance is determined by the interactions between the various groups that influence or are influenced by the organisation, stakeholder theory provides a relational and normative dimension that reinforces the contingency approach [10]. According to this theory, stakeholders include shareholders, customers, employees, suppliers, local communities, regulatory bodies, among others [11,70].

The articulation between ABC and stakeholder theory thus translates into a practice of collaborative governance, in which accounting information is used not only for internal management purposes but also as an instrument of communication, transparency, and legitimation towards stakeholders. Empirical evidence shows that stakeholder involvement in the design and use of information systems enhances the accuracy, credibility, and effectiveness of decision-making, while also fostering trust and inter-organisational cooperation [12,71].

Thus, the integration of contingency theory and stakeholder theory provides a more comprehensive and holistic understanding of the application of ABC in the port context.

The former offers the analytical framework, explaining how systems should be adapted to specific structural and environmental conditions; the latter adds an ethical and relational dimension, emphasising the importance of stakeholder participation and the social legitimacy of decisions.

Accordingly, it is expected that the success of ABC implementation in a seaport depends not only on the alignment between organisational conditions and external factors such as the regulatory framework, competition, and environmental requirements but also on the active and continuous involvement of stakeholders in the design, validation, and interpretation of cost information. This integrated perspective is intended to support transparency, accountability, and context-sensitive cost management; however, its effects on efficiency, trust, competitiveness, and institutional legitimacy require empirical validation.

Building upon these theoretical foundations, this study anchors Model A explicitly in contingency and stakeholder principles. Rather than relying on these theories merely as general justifications, their tenets actively guide the architectural design of the model in two main ways.

- The first is through contingency theory, where key port contextual variables operate as structural determinants of the model's configuration:
- Service diversity determines the granularity of activity cost pools;
- Technological maturity and data availability dictate the selection and sophistication of cost drivers;
- Infrastructure sharing requires multi-layered allocation procedures;
- Regulatory requirements define the necessary level of detail for cost objects.

Second, stakeholder theory informs the intended uses and presentation of cost information. Port administrations may require detailed information on resources, activities, services, and terminals for budgeting and cost analysis. Concessionaires may require explanations of shared infrastructure and support charges affecting their operations. Government regulators may require reconciled cost statements, allocation methods, and assumptions relevant to tariff oversight. Shipping companies may require service-level explanations of the costs underlying charges. These needs may overlap, and the appropriate level of detail depends on the reporting purpose.

The proposed reporting approach distinguishes internal management reports from external disclosure. Internal reports may retain detailed activity costs, resource shares, allocation bases, and sensitivity analyses. Regulatory reports may aggregate this information into the required service or tariff categories while retaining reconciliation with internal totals and documentation of the allocation methods. Public or customer-facing disclosures may use a higher level of aggregation to protect commercially sensitive information, subject to applicable disclosure requirements. These reports draw on the same underlying cost assignments; their scope and level of detail differ. This is a proposed reporting arrangement rather than an implemented reporting system.

Finally, the architecture of Model A acknowledges that detailed cost data does not automatically create trust, accountability, or legitimacy. These outcomes should not be considered automatic consequences of the costing system. Rather, their achievement depends on the quality of the underlying data, the transparency of allocation rules, the governance arrangements adopted, and the way cost information is communicated and used by stakeholders.

3. Methodology for Framework Development

The Hybrid Conceptual Framework was developed through a targeted literature review. The review supported the identification of cost objects, activities, resources, and

allocation mechanisms relevant to port administrations and informed their organisation within the proposed framework.

3.1. Search Strategy and Data Collection

The literature search was conducted in Scopus, Web of Science, and Google Scholar, covering publications from 2000 to 2025. The search combined sector-related terms with the costing approach: ("Maritime ports" OR "Maritime Industry" OR "Ports" OR "Container Terminal") AND ("Activity-based costing" OR "ABC"). In Scopus, the search was restricted to the subject area "Business, Management and Accounting".

3.2. Literature Selection

The review considered full-text journal articles, conference proceedings, and academic theses addressing ABC, cost allocation, or costing practices in ports, maritime transport, and related logistics operations. Empirical, conceptual, and applied contributions were considered.

Publications were retained when they provided information relevant to the development of the proposed framework, including cost objects, activities, resources, allocation bases, cost-assignment mechanisms, or relevant managerial and regulatory considerations. Publications that did not provide information relevant to these dimensions were excluded.

The purpose of this selection was not to conduct a systematic literature review, but to identify relevant evidence that could inform framework development. The retained publications were therefore used according to their specific contribution: descriptions of costing mechanisms informed the technical components of the framework, while managerial and regulatory discussions provided contextual support.

3.3. Identification of Relevant Publications

The targeted literature search identified 30 records: seven from Scopus, three from Web of Science, and twenty from Google Scholar. After removing 12 duplicates, 18 publications remained and were assessed in full text for relevance to framework development. Nine publications were excluded because they did not provide information directly relevant to the costing mechanisms or contextual dimensions required for framework development, such as cost objects, activities, resources, allocation bases, or cost-assignment mechanisms. The remaining nine publications were retained and used as the principal literature base for framework development [6,7,23–25,49,52,65,72].

3.4. Data Extraction and Framework Development

The nine publications were examined through a structured qualitative extraction process. For each publication, information was extracted concerning cost objects, activities, resources, allocation bases, and cost-assignment mechanisms relevant to port administrations and related operational contexts. Rather than applying inductive thematic coding, the analysis used predefined extraction categories corresponding to the costing components required for framework development: cost objects, activities, resources, allocation bases, and cost-assignment mechanisms.

The extracted information was recorded and compared across the publications, as summarised in Table 1. Particular attention was given to distinguishing mechanisms involving direct assignment to cost objects, activity-based assignment, and the treatment of support costs.

Table 1. Literature evidence informing the development of the proposed framework.

Publication	Context and Study Type	Relevant Information Identified	Contribution and Limitations
Martins et al. [6]	Portuguese seaport sector; cost-accounting and tariff-regulation analysis.	Direct and indirect costs, intermediate centres or activities, tariff-related services, and common costs.	Informs cost assignment and its relationship with port tariffs. Does not establish the proposed three-pathway configuration.
Themido et al. [7]	Third-party logistics operator; ABC case study.	Stock entrance, storage, dispatching, and transport activities. Drivers include order lines, floor space, delivery stops, packages, and estimated management time.	Provides examples of resource and activity drivers, including overhead allocation. Concerns logistics services rather than a port administration.
Luo et al. [23]	Container-terminal operations; ABC illustration.	Labour, material, equipment, and subcontracting costs; terminal activities and yard-operation costs per move.	Informs operational activity costing. Does not specify a separate support-cost pathway.
Pehlivan and Çiçek [24]	Maritime transportation; simulation-based costing study.	Direct costs and activity-based assignment; activity centres covering customer, port, ship, inspection, and crewing operations.	Informs the treatment of direct and activity-related costs. Its shipping context requires adaptation to port administrations.
Ryu et al. [25]	Container terminal; ABC cost analysis.	Equipment-related activities, direct costs, and overheads. Allocation bases include cost proportions and container dwell time.	Provides examples of activity costing and overhead allocation. Direct assignment to equipment activities differs from direct assignment to final services.
Elyass et al. [49]	Sudanese port context; questionnaire-based study.	Perceived relevance of contemporary costing systems for planning, control, and decision-making.	Provides managerial context rather than a detailed implemented allocation model.
Campos et al. [52]	Comparative synthesis of costing studies.	Cost-object identification, cost classification, activity centres, resource drivers, activity drivers, and final assignment.	Helps organise framework components. Provides secondary evidence rather than an independent application of the mechanisms described.
Mthembu and Chasomeris [72]	South African port-pricing context; analysis of stakeholder submissions.	ABC, user-pays principles, tariff structures, and cross-subsidisation.	Informs the rationale for transparent port costing. Does not demonstrate the proposed allocation pathways.
Sousa et al. [65]	Brazilian port authority; applied action research.	Berths as cost objects; operational, administrative, and support activities; direct assignment and activity-based allocation. Bases include working hours, headcount, fixed-asset values, and electricity consumption.	Provides port-specific evidence of direct and activity-based assignment. Support costs are incorporated into the activity structure rather than a separate pathway equivalent to the one proposed here.

These three analytical categories were then used to organise the evidence and relate it to the proposed framework. Direct assignment was used to identify evidence concerning costs that can be traced directly to final cost objects; activity-based assignment captured evidence concerning the allocation of indirect operational costs through resources, activities, and drivers; and support-cost treatment captured evidence concerning the allocation and redistribution of administrative, shared, and support-function costs.

The resulting three-pathway configuration represents the authors' conceptual synthesis of the mechanisms identified in the literature. The reviewed publications do not all independently describe or validate this configuration. Instead, the framework integrates the different costing mechanisms identified across the selected publications into a single analytical structure adapted to the characteristics of port administrations.

3.5. Framework Development and Future Validation

The final structure of the framework resulted from the integration of the costing mechanisms identified in the literature with analytical reasoning regarding their applicability to port administrations. The resulting three-pathway configuration should therefore be understood as a conceptual proposition rather than an empirically validated model.

At this stage, the framework has not undergone expert consultation or empirical validation. Future case-study applications are required to assess the proposed allocation bases, data requirements, operational feasibility, and practical applicability of the framework in port administrations.

4. Conceptual Framework Development and Model Specification

A conceptual model can be understood as a structured theoretical representation that describes and organises the key concepts and the relationships between variables relevant to understanding a given phenomenon [73]. It consists of a coherent network of interconnected concepts, built on a solid theoretical foundation, aimed at supporting scientific reasoning and guiding empirical analysis. According to Miles and Huberman [74], conceptual models function as "cognitive maps" that clarify the theoretical framework of the research and systematically guide the processes of data collection, analysis, and interpretation.

The level of detail within the framework may be adjusted to organisational size, service diversity, technological maturity, and data availability. Simplification concerns the detail within each pathway while preserving the classification rules and the sequence of cost assignment. Direct tracing should be retained wherever it is observable and economically feasible.

For large, multi-terminal authorities with diverse services and detailed records, separate operational activity pools and support areas may be appropriate where consumption patterns differ. Smaller authorities with fewer services may group activities that have similar consumption patterns and can reasonably share a driver. Support functions may also be grouped where a common allocation basis is justified, while retaining the accumulation of support costs and their subsequent redistribution to operational areas.

Where information systems or consumption records are limited, broader activity pools and documented proxy drivers may be used where a reasonable relationship with resource consumption can be established. Limited data availability does not, by itself, justify moving operational costs to the support pathway. The level of detail needed for regulatory reporting should also be retained.

The effects of simplification should be examined by comparing selected service costs under more detailed and more aggregated configurations, where data permit, and by testing alternative plausible allocation bases for material cost pools. These comparisons may reveal differences obscured by aggregation. Where detailed data are unavailable, the resulting

uncertainty should be disclosed. These are proposed checks for future applications rather than procedures tested in this study.

Furthermore, the architectural design of Model A organically bridges contingency and stakeholder theories rather than applying them in parallel: operational contingency configurations dictate the internal technical design required to capture port complexity, while the resulting granular cost architectures directly serve as the analytical foundation for the external governance, accountability, and transparency demanded by stakeholder theory.

The Hybrid Conceptual Framework for ABC developed in this study is based on theoretical contributions and adapted to the specific reality of the port sector, focusing on the application of ABC in the context of maritime-port operations. Drawing on contingency theory, it is recognised that the effectiveness of the system depends on its fit with the organisation's internal and external conditions, ensuring more rigorous, transparent cost management aligned with strategic objectives.

Figure 1 presents the developed conceptual framework, structured into three distinct pathways corresponding to different levels of economic causality in cost formation.

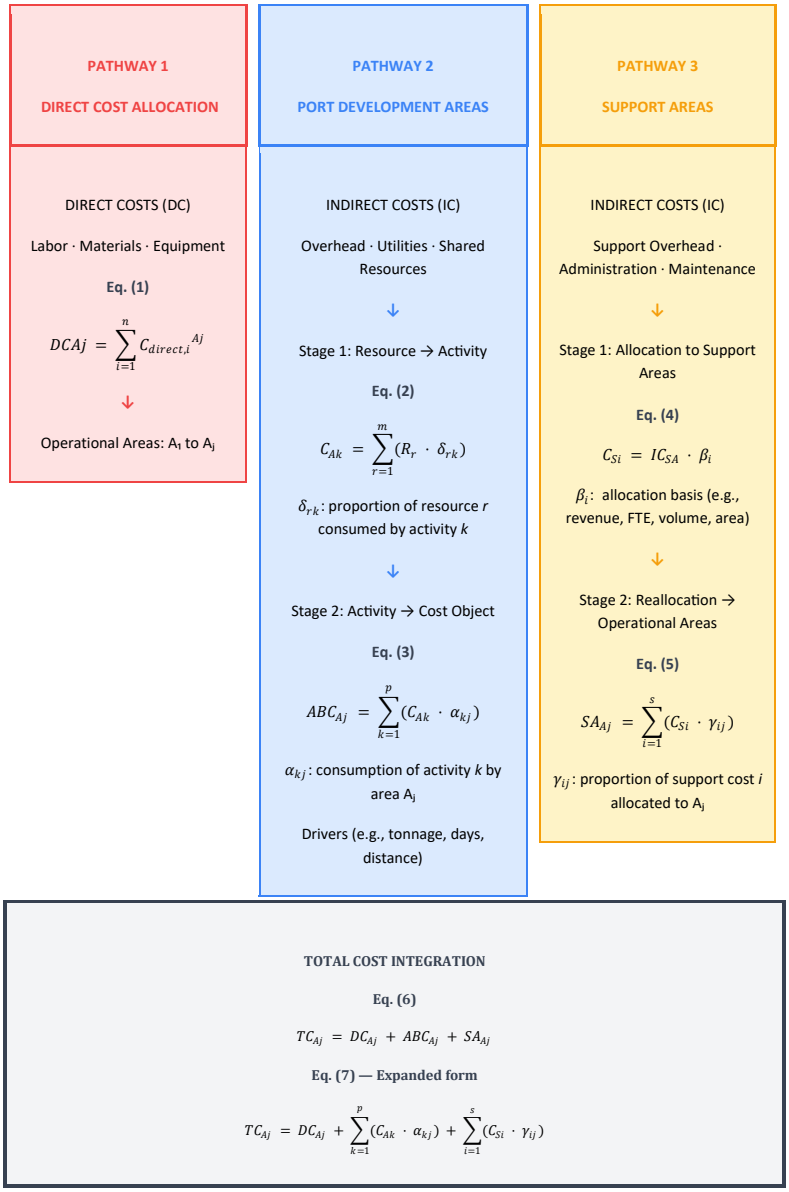


Figure 1. Conceptual framework: Activity-based costing in port operations and three-path cost allocation model for port development and support areas.

To facilitate the mathematical specification of these pathways and ensure clarity throughout the framework, Table 2 summarises the notation, variable types, and units of measurement used in the model.

Table 2. List of mathematical notation and variables.

Symbol/Index	Variable Name	Type/Nature	Unit of Measurement
i	Support area index	Index	Dimensionless
j	Operational area/final cost object index	Index	Dimensionless
k	Activity index	Index	Dimensionless
r	Resource index	Index	Dimensionless
DC_{Aj}	Direct cost allocated to area j	Cost	Monetary (€)
C_{Ak}	Cost of activity k	Cost	Monetary (€)
R_r	Resources consumed (indirect costs)	Cost/Resource	Monetary (€)
C_{Si}	Cost allocated to support area i	Cost	Monetary (€)
IC_{SA}	Total support area costs	Cost	Monetary (€)
q_{ij}	Raw operational driver quantity	Quantity	Operational units (hours, tonnes, calls, m^2)
α_{kj}/γ_{ij}	Allocation proportions or coefficients	Proportion	Adimensional $(\sum = 1)$
δ_{rk}	Resource consumption proportion	Proportion	Adimensional $(\sum = 1)$
β_i	Support area internal consumption criterion	Proportion/Weight	Adimensional $(\sum = 1)$

The framework uses a sequential classification rule to limit overlapping assignments. After partitioning mixed resources where feasible, each resulting cost share is assessed through the following tests. Where partitioning is not reasonably feasible, the fallback procedure described below applies:

- Direct Traceability Test (Pathway 1): The model first evaluates whether a resource cost can be traced directly and economically to a specific operational area or final cost object. If yes, it is classified exclusively as a direct cost.
- Operational Activity Test (Pathway 2): If it cannot be traced directly, the model tests whether the resource is consumed by an identifiable operational activity. If yes, it is routed through the activity-based pathway.
- Support Function Test (Pathway 3): A cost share relating to general support, administration, or shared infrastructure follows the support pathway when it does not meet the preceding tests. A lack of consumption data alone is not sufficient to classify a resource as support; uncertain cases follow the fallback procedure described below.

Before applying the classification tests, resources serving more than one function should be divided into separately identifiable cost shares where a reasonable basis is available. The proposed order of preference is: resource-specific consumption records; observable measures that approximate consumption; and, where neither is available, documented estimates. Examples include recorded working hours for labour, usage logs for information systems, and work orders or equipment hours for maintenance. Occupied

area is appropriate only where space use reasonably represents the consumption of the resource concerned.

The selection of a partitioning basis should consider its relationship with resource consumption, the availability and consistency of records, and the effort required to obtain the information relative to the importance of the cost. Where more than one basis is plausible, the choice should be explained. For material cost pools, the resulting allocations should be compared using an alternative plausible basis to assess their sensitivity to that choice.

Each partition should record the basis used, the source and period of the data, and any estimation assumptions. The resulting shares must sum to the original resource cost, and each share must enter only one pathway. These procedures are intended to limit and make visible the judgement involved, they do not eliminate subjectivity.

Where direct measures of resource consumption are unavailable, or obtaining them would involve disproportionate cost, partitioning may use a documented proxy or an estimate informed by staff familiar with the resource's use. The estimate should specify the functions served, the basis for the proposed shares, and the main uncertainty. Estimated shares must sum to the resource cost and follow the same classification tests as observed shares.

If no reasonable partition can be established, the proposed default is to retain the resource as a single pool and assign it according to its predominant function, supported by the available operational evidence. Predominantly operational resources follow Pathway 2, while predominantly administrative or support resources follow Pathway 3; Pathway 1 remains subject to the direct traceability test. Where the predominant function is also uncertain, the classification requires a documented judgement by the responsible managers and should be identified as provisional. This treatment preserves a single assignment of the cost but does not establish its causal accuracy. Material allocations should be reviewed using alternative plausible classifications or shares.

Mutual exclusivity applies to the cost amounts assigned, rather than to the original resource categories. Different shares of the same resource may follow different pathways, but each share is included only once. Where a cost is both directly traceable to the chosen cost object and associated with an activity, direct tracing takes priority under the sequential classification rule. Equation 6 integrates the amounts assigned through the three pathways.

Table 3 clarifies the scope of the proposed configuration relative to ABC and TDABC. The comparison concerns their principal allocation logic and the choices made in the present framework; it does not imply that alternative approaches cannot be adapted to similar purposes.

Table 3. Comparison of the proposed hybrid framework with alternative costing approaches in port administrations.

Comparison Criteria	Proposed Hybrid Framework	Conventional ABC	Time-Driven ABC
Treatment of direct costs	Direct tracing where economically and observably feasible.	Activity-based allocation does not require directly traceable costs to be routed through activity pools; the activity-based mechanism addresses costs requiring assignment [4].	The time-driven mechanism estimates resource demands associated with transactions; it should not be interpreted as requiring every cost item to pass through a time equation [75].

Table 3. *Cont.*

Comparison Criteria	Proposed Hybrid Framework	Conventional ABC	Time-Driven ABC
Treatment of support functions	Separate allocation of identified support-function costs using documented bases.	Support work can be represented through defined activities and assigned according to consumption; its treatment depends on the model configuration [4].	Service-department resource costs can be assigned using capacity cost rates and estimated resource requirements [75].
Allocation logic	Direct tracing; resource-to-activity and activity-to-cost-object allocation; separate support-cost allocation.	Resources are assigned to activities, and activity costs are assigned to cost objects through consumption-related drivers [4].	Resource capacity cost rates are combined with estimated resource requirements for transactions or cost objects [75].
Treatment of unused capacity	Not explicitly modelled in the current specification; a possible extension where reliable capacity data are available.	In the conventional implementation illustrated by Kaplan and Anderson, assigning all resource costs through activity percentages does not separately identify unused capacity; this is not an unavoidable property of every ABC configuration [75].	Distinguishes supplied practical capacity from estimated capacity used, allowing unused-capacity costs to be identified [75].
Driver requirements	Resource and activity drivers, with documented support-allocation bases.	Resource drivers and activity drivers linking costs to consumption [4].	Estimated resource requirements, commonly expressed as unit times; other capacity measures may be used where appropriate [75].
Data requirements	Accounting costs, resource-consumption information, operational driver quantities, and support-allocation bases; detail depends on the chosen configuration.	Resource costs, activity definitions, resource-driver information, and activity consumption by cost objects [4].	Resource-group costs, practical-capacity estimates, unit resource requirements, and transaction quantities [75].
Intended managerial use	Intended to support port-service costing, tariff analysis, and resource-allocation decisions; benefits remain untested.	Cost analysis and support for operational decisions, including process improvement and capacity management [4].	Analysis of transaction costs and capacity utilisation to inform pricing and resource decisions [75].

Source: Authors' synthesis based on Gupta and Galloway [4] and Kaplan and Anderson [75]. The proposed-framework column describes the design developed in this study. The descriptions concern the allocation mechanisms discussed in these sources and do not imply that all implementations are identical or that the proposed framework demonstrated superior performance. Direct-cost treatment is presented as a clarification of scope, rather than as a distinctive capability of any one approach.

4.1. Pathway 1: Direct Cost Allocation

The first pathway corresponds to direct cost allocation, applicable whenever there is a clear and observable relationship between the consumed resource and the cost object. This type of cost includes, in the port context, resources that can be directly associated with a specific operation or an identifiable operational unit.

These typically include labour assigned to a specific terminal, equipment exclusively dedicated to certain operations (e.g., quay cranes or specialised handling equipment), and materials directly consumed in port operations or maintenance contracts dedicated to specific infrastructure.

Direct tracing is used whenever a resource can be economically and observably associated with a final cost object, thereby avoiding the need for an intermediate allocation criterion.

Direct allocation can be formally represented as follows:

$$DC_{Aj} = \sum_{i=1}^{n} C_{direct,i}^{Aj} \quad (1)$$

where

- DC_{Aj} represents the direct costs of area Aj;
- $C_{direct,i}^{Aj}$ corresponds to the different directly attributable cost components.

4.2. Pathway 2: Activity-Based Costing in Port Development Areas

The second pathway constitutes the analytical core of the model, based on the logic of ABC, and is particularly relevant in port contexts characterised by high levels of indirect costs and the sharing of resources across multiple operations.

In the first stage, indirect costs are assigned to relevant activities based on cost drivers that reflect the actual consumption of resources:

$$C_{Ak} = \sum_{r=1}^{m} R_r \cdot \delta_{rk} \quad (2)$$

where

- R_r represents the resources (indirect costs);
- δ_{rk} corresponds to the proportion of resource r consumed by activity k;
- C_{Ak} represents the total cost of the activity k.

Resources typically include technical and operational labour, energy, fuel, information systems, equipment maintenance, and the use of support vessels. Activities reflect the main port operational processes, including maritime operations, pilotage, tug services (Trem Naval), port supervision, and cargo handling.

The cost drivers associated with this stage include, for example, operating hours, equipment usage time, energy consumption, or number of maintenance interventions, depending on the nature of each activity.

In the second stage, activity costs are subsequently assigned to cost objects through activity drivers, which reflect the intensity of activity usage by each operational unit:

$$ABC_{Aj} = \sum_{k=1}^{p} C_{Ak} \cdot \alpha_{kj} \quad (3)$$

where

- α_{kj} represents the level of consumption of activity k by area Aj;
- ABC_{Aj} corresponds to the indirect cost allocated via ABC. The drivers used include, among others, tonnes handled, storage days, and distance travelled, allowing the effective consumption of activities to be reflected.

These drivers include, for example, number of ship calls, tonnes handled, number of cargo movements, storage days, or quay utilisation. The raw operational driver quantities (q_{ij}) collected from port databases, which serves as the quantitative basis to determine these consumption proportions.

This framework allows the capture of structural differences across the literature, where activities such as pilotage and towing tend to be associated with the number of vessels, while storage activities are more frequently related to dwell time or space occupancy.

4.3. Pathway 3: Allocation of Support Area Costs

The third pathway corresponds to the allocation of support area costs, whose cross-functional nature makes it difficult to establish direct causal relationships with specific operational activities. These areas typically include functions such as general administration, human resources, information systems, accounting, public procurement, legal services, and financial management.

Given this nature, support costs are distributed through a two-stage mechanism. In the first stage, total support overhead costs are allocated across specific support cost centers using internal organizational criteria, reflecting their internal structure of consumption:

$$C_{Si} = IC_{SA} \cdot \beta_i \quad (4)$$

where

- IC_{SA} represents the total cost of support areas;
- β_i corresponds to the allocation criterion associated with support area i;
- C_{Si} represents the cost allocated to the support area i.

This stage allows organisational costs to be distributed across the different support functions, reflecting their internal structure of resource consumption.

Equation (4) represents the allocation of the support-cost pool considered in the framework across support areas according to the selected allocation criteria. The current conceptual model focuses on this aggregate allocation mechanism and does not explicitly represent all internal cost–flow relationships among individual support departments.

In the second stage, these accumulated support costs are subsequently redistributed to the operational business areas using appropriate allocation bases. To operationalize this mechanism under a contingency theory perspective, the selection of these criteria cannot rely on a uniform approach; instead, the choice must be aligned with the operational nature and resource consumption patterns of each support activity. Table 4 outlines a situational selection guide, mapping each support cost pool to its preferred allocation criterion based on organizational conditions and its substantive impact on cost results.

Table 4. Situational selection guide for support cost allocation criteria.

Support Cost Pool	Preferred Allocation Criterion	Situational Conditions for Preference	Substantive Impact of Criterion Choice on Cost Results
Administrative & General Management	Headcount/Personnel Count	Services benefit personnel uniformly across departments; specific causal tracking is economically unjustified or unmeasurable.	Distributes overhead broadly as a structural baseline; minimizes administrative effort but risks cross-subsidizing heavy administrative users if headcount diverges from actual management demand.
Information Technology & Digital Systems	System Access/User Count or Processing Volume	IT resource consumption varies directly with digital interactions, terminal operating system logs, or user license intensity.	Reflects technological dependency accurately; prevents highly digitalized operational units from subsidizing manual back-offices, directly sharpening cost visibility for IT-heavy marine services.
Infrastructure Maintenance & Facilities	Occupied Area (Square Meters)/Asset Usage	Costs are driven by physical footprint, real estate occupation, and facility wear-and-tear across terminals and yards.	Imposes economic accountability on space-intensive operations (e.g., storage yards vs. administrative offices); prevents central yard costs from being uniformly spread across non-land-consuming maritime services.
Operational Support & Equipment Pools	Actual Operational Activity Volume (Hours/Moves)	Support units provide direct, variable operational inputs (e.g., tugboat maintenance, utility supplies) consumed proportionally by specific services.	Captures true operational causality; ensures that high-intensity operational services bear the proportional cost of dedicated support inputs, avoiding distortion in tariff-setting calculations.

Formally, this second-stage redistribution to the operational areas is represented as follows:

$$SA_{Aj} = \sum_{i=1}^{s} C_{Si} \cdot \gamma_{ij} \quad (5)$$

where

- γ_{ij} represents the proportion of support costs from area i allocated to operational area Aj;
- SA_{Aj} corresponds to the total allocated support costs. This approach ensures the incorporation of support costs while simultaneously maintaining the operational feasibility of the model.

Using broader allocation bases may obscure differences in resource consumption. Their suitability should therefore be assessed against the available evidence and the intended use of the cost information. The current framework adopts a direct redistribution of support-area costs to operational areas. Reciprocal services among support departments are not explicitly modelled and constitute a possible extension for future empirical applications.

4.4. Cost Integration

The integration of the three pathways enables the construction of a multi-level cost structure, in which different degrees of economic causality coexist: direct, operational, and organisational.

Cost objects, typically container terminals, liquid bulk terminals, or other port operational units, simultaneously receive directly traceable costs, costs associated with the consumption of operational activities, and costs arising from support functions.

This structure reflects the evidence observed in the literature, where different studies recognise the coexistence of multiple levels of cost aggregation, albeit with varying degrees of formalisation, highlighting the need for integrated models that capture the full structure of port costs.

Formally, the total cost of each cost object can be expressed as follows:

$$TC_{Aj} = DC_{Aj} + ABC_{Aj} + SA_{Aj} \quad (6)$$

or, in its expanded form as follows:

$$TC_{Aj} = DC_{Aj} + \sum_{k=1}^{p} (C_{Ak} \cdot \alpha_{kj}) + \sum_{i=1}^{s} (C_{Si} \cdot \gamma_{ij}) \quad (7)$$

where

- TC_{Aj} represents the total cost of the area Aj.

This formulation shows that total cost results from the combination of different allocation mechanisms, reflecting multiple levels of economic causality. By integrating these three pathways into a single analytical framework, the model enables a more complete and structured representation of port cost formation.

To preserve total cost allocation within the proposed conceptual structure, the model assumes that the proportional allocation coefficients applied at each allocation stage sum to one:

- Resource allocation proportions: $\sum_j \delta_{rk} = 1$
- Activity-to-cost-object allocation proportions: $\sum_j \alpha_{kj} = 1$
- Support-cost allocation proportions: $\sum_j \gamma_{ij} = 1$ and $\sum_i \beta_i = 1$

Regarding the operationalization of the model's quantitative coefficients, namely the resource consumption ratio (δ), activity consumption coefficient (α), and support allocation

weights (β/γ), data collection relies on standard port management infrastructures, such as Terminal Operating Systems (TOSs), Enterprise Resource Planning (ERP) databases, and maintenance management logs. Furthermore, the framework's mathematical structure adapts dynamically to different port profiles: container terminals prioritize crane utilization and yard handling activity drivers; bulk terminals focus on static storage space occupancy and throughput tonnage; and passenger terminals emphasize terminal infrastructure occupation and passenger flow metrics. While the present study establishes the foundational theoretical architecture, these parameters define the operational pathway for future empirical implementations across diverse port typologies. The specific coefficient values are therefore context-dependent and should be estimated from the data available in each port application rather than treated as universal parameters. Raw driver quantities, such as labour hours, tonnes handled, number of calls, or occupied area, provide the empirical basis for determining the corresponding allocation proportions. In each application, these quantities are converted into relative shares according to the observed consumption of the relevant resource, activity, or support service.

To facilitate interpretation and operational understanding of the proposed framework, Table 5 synthesises the hierarchical structure of the ABC system in port environments.

Table 5. Summary of resources, activities, cost drivers, and cost objects in the ABC model.

Costing Level	Elements	Examples in Port Context
Resources	Inputs consumed by the organisation	Labour, energy, fuel, IT systems, maintenance, support vessels
Activities	Operational processes consuming resources	Maritime operations, pilotage, tug services (Trem Naval), port supervision, cargo handling, traffic management
Cost drivers (resource allocation)	Measures of resource consumption by activities	Labour hours, equipment usage time, fuel consumption, maintenance interventions, system usage
Activity drivers (cost assignment)	Measures linking activities to cost objects	Number of vessels, tonnes handled, cargo movements, storage days, berth occupancy, service calls
Cost objects	Final cost-bearing units	Container terminals, liquid bulk terminals, port service areas, operational concessions

This synthesis highlights the hierarchical nature of port cost formation, in which different levels of causality operate simultaneously, ranging from resource consumption to operational activities and final cost objects.

5. Conceptual Discussion and Expected Managerial Implications

Rather than imposing a rigid structure, the proposed framework organises cost accumulation into three layers (direct, activity-based, and support costs), allowing the organisation to adapt the system to its own technological complexity and operational scale [65].

Conceptually, the framework is intended to improve the visibility of how direct, activity-based, and support costs are accumulated and assigned to cost objects. The activity-based pathway may facilitate the identification of resource-intensive processes and the analysis of non-value-adding activities. Likewise, the separate treatment of support costs may reduce some allocation distortions when appropriate drivers are available. However, these potential benefits remain theoretical expectations and require empirical validation using actual port data [25]. This visibility is essential in a sector where technical efficiency

is a constant requirement for competitive survival. Furthermore, the explicit separation of support costs (such as administration and regulatory compliance) is intended to mitigate distortions commonly associated with traditional costing methods, in which these costs are often allocated arbitrarily, thereby compromising the assessment of the true profitability of each service [56].

From the perspective of Stakeholder Theory, the hybrid model may support transparency and accountability by making cost-allocation rules more explicit and traceable. This information may inform tariff-setting and capital-allocation discussions involving port administrations, concessionaires, and governmental entities [25,56]. However, data reliability, stakeholder trust, and institutional legitimacy are not automatic outcomes of the model; they depend on data quality, governance arrangements, disclosure policies, and how cost information is interpreted and communicated. Where environmental and regulatory costs can be identified, the framework may also support discussion of their contribution to the port's cost structure.

Because this study presents a conceptual framework rather than an empirical test, the benefits discussed above remain theoretical expectations. The framework may help port administrations examine their cost structure and the cost implications of changing operating conditions. Its usefulness for managerial decisions requires empirical assessment.

The following propositions are proposed for future empirical assessment.

Proposition 1: *Explicit resource-partitioning rules and assignment boundaries may improve the traceability of costs from resources to cost objects.*

Documenting how shared resources are divided and assigned may make individual allocations easier to follow and review. This proposition could be assessed by examining whether users can reconstruct cost assignments from the available records and allocation rules.

Proposition 2: *Distinguishing direct, activity-based, and support costs may help managers understand the composition of port service costs.*

This distinction makes the contribution of each cost category visible while retaining the total cost of each service. Future case studies could examine whether managers use this information to explain service costs and identify items requiring further analysis.

Proposition 3: *Documented allocation bases may support stakeholder discussions about cost allocation when the information and its underlying assumptions are accessible and understood.*

Explicit allocation bases may provide a reference for discussing how shared costs are distributed among services. Interviews or observations of tariff discussions could explore whether stakeholders understand and use this information, without assuming that it necessarily produces agreement or trust.

6. Conclusions

This study develops a hybrid conceptual model for cost allocation in port authorities by integrating three complementary mechanisms: direct cost attribution, indirect cost allocation based on activity-based costing, and the redistribution of support department expenses. Structuring the costing process across direct, operational, and organisational allocation mechanisms is intended to make the treatment of shared resources and heterogeneous services explicit within a single analytical framework.

From a conceptual perspective, the contribution lies in specifying how established costing mechanisms are selected and integrated in port administrations. The framework makes explicit the treatment of mixed resources, the assignment boundaries between the three pathways, and the documentation of uncertain allocations. It also connects alternative levels of costing detail with organisational conditions and stakeholder reporting needs. These specifications provide a basis for subsequent empirical assessment.

From a theoretical standpoint, the framework draws on contingency theory to recognize that accounting systems must adapt to the structural and operational specificities of individual organizations. Simultaneously, the stakeholder perspective highlights cost information as a vital instrument for transparency, accountability, and governance support. Blending these theoretical lenses frames the model as a conceptual support mechanism built to elevate information quality during institutional coordination processes.

Regarding prospective benefits, the architecture is designed to offer structural advantages rather than guaranteed operational outcomes at this stage of development. Successful future implementation is expected to provide a structured foundation for pricing decisions, cost control, and resource allocation through a more comprehensive representation of total cost formation in port environments. The framework is theoretically intended to enhance transparency in cost distribution and foster more informed decision-making in capital-intensive, shared infrastructure contexts. Because this research remains strictly conceptual, however, any claims regarding operational effectiveness, precision gains, or proven decision-making improvements must be viewed as theoretical expectations requiring empirical testing.

Limitations and Future Research

Several limitations accompany these contributions. First, as a purely conceptual model, its empirical validation in real port environments remains a task for future research, meaning its practical operational applicability, precision enhancements, and concrete performance are still untested. Second, the framework operates at an aggregate level of analysis, leaving out micro-organizational, behavioral, and institutional factors that often influence internal cost allocation dynamics within port authorities. Third, while tailored specifically for the port sector, the model has not yet been explored in other complex infrastructure contexts, which limits the immediate generalizability of its implications. Finally, the approach presupposes access to detailed, structured data regarding resource consumption and activities. We acknowledge the practical difficulties in selecting cost drivers, as a theoretically suitable driver may not always be available in a port's information system. Since the framework heavily depends on this accuracy, this data gap represents an important implementation issue. In practice, port administrators may need to rely on alternative proxy drivers when the required data is scarce, particularly in less digitized environments or organizations with lower data management maturity.

Moving past these limitations opens clear avenues for subsequent investigation. Future studies should prioritize validating the proposed conceptual framework empirically across diverse port authorities to evaluate its robustness, adaptability, and utility in varied institutional settings. Conducting comparative analyses between this hybrid model and traditional activity-based costing approaches will also be essential, focusing particularly on testing allocation accuracy and practical decision support. Another promising trajectory involves incorporating emerging digital technologies, such as port information systems and real-time data platforms, to refine cost drivers and sharpen allocation granularity. Finally, extending the model to adjacent infrastructure sectors, including airports, logistics terminals, and railway systems, could yield broader theoretical frameworks with cross-sector applicability.

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References

1. United Nations Conference on Trade and Development. *Review of Maritime Transport 2023—Towards a Green and Just Transition*; UN Trade and Development (UNCTAD): Geneva, Switzerland, 2023; Available online: https://unctad.org/publication/review-maritime-transport-2023 (accessed on 11 April 2025).
2. Governo de Portugal. Portos do Continente Crescem 6% em 2024, Atingindo 88 Milhões de Toneladas de Mercadorias. Available online: https://www.portugal.gov.pt/pt/gc24/comunicacao/comunicado?i=portos-do-continente-crescem-6-em-2024-atingindo-88-milhoes-de-toneladas-de-mercadorias (accessed on 7 April 2025).
3. Kaplan, R.S.; Cooper, R. *Cost & Effect: Using Integrated Cost Systems to Drive Profitability and Performance*; Harvard Business School: Brighton, MA, USA, 1998.
4. Gupta, M.; Galloway, K. Activity-Based Costing/Management and Its Implications for Operations Management. *Technovation* **2003**, *23*, 131–138. [CrossRef]
5. Fioresi de Sousa, E.; Kliemann Neto, J.F.; Fontoura Andriotti, R.; Rech Campagnolo, R. Proposta de Modelo de Gestão Estratégica de Custos Para Autoridades Portuárias: O Caso do Porto de Vitória. In Proceedings of the XXV Congresso Brasileiro de Custos, Vitória, Brazil, 12–14 November 2018.
6. Martins, A.; Jorge, S.; Sá, P. Price Regulation and Cost Accounting: The Case of the Portuguese Seaport Sector. *Int. J. Law Manag.* **2013**, *55*, 444–463. [CrossRef]
7. Themido, I.; Arantes, A.; Fernandes, C.; Guedes, A.P. Logistic Costs Case Study—An ABC Approach. *J. Oper. Res. Soc.* **2000**, *51*, 1148–1157. [CrossRef]
8. Otley, D. The Contingency Theory of Management Accounting and Control: 1980–2014. *Manag. Account. Res.* **2016**, *31*, 45–62. [CrossRef]
9. Chenhall, R.H. Management Control Systems Design within Its Organizational Context: Findings from Contingency-Based Research and Directions for the Future. *Account. Organ. Soc.* **2003**, *28*, 127–168. [CrossRef]
10. Freeman, R.E. *Strategic Management: A Stakeholder Approach*; Cambridge University Press: Cambridge, UK, 2010.
11. Friedman, A.L.; Miles, S. Developing Stakeholder Theory. *J. Manag. Stud.* **2002**, *39*, 1–21. [CrossRef]
12. Choi, J.; Wang, H. Stakeholder Relations and the Persistence of Corporate Financial Performance. *Strateg. Manag. J.* **2009**, *30*, 895–907. [CrossRef]
13. Cooper, R.; Kaplan, R.S. Measure Costs Right: Make the Right Decisions. *Harv. Bus. Rev.* **1988**, *66*, 96–103.
14. Stapleton, D.; Pati, S.; Beach, E.; Julmanichoti, P. Activity-Based Costing for Logistics and Marketing. *Bus. Process Manag. J.* **2004**, *10*, 584–597. [CrossRef]
15. Tsai, W.H.; Kuo, L. Operating Costs and Capacity in the Airline Industry. *J. Air Transp. Manag.* **2004**, *10*, 269–275. [CrossRef]
16. Gunasekaran, A.; Sarhadi, M. Implementation of Activity-Based Costing in Manufacturing. *J. Prod. Econ.* **1998**, *56–57*, 231–242. [CrossRef]
17. Hada, M.S.; Chakravarty, A.; Mukherjee, P. Activity Based Costing of Diagnostic Procedures at a Nuclear Medicine Center of a Tertiary Care Hospital. *Indian J. Nucl. Med.* **2014**, *29*, 241–245. [CrossRef]
18. Arnaboldi, M.; Lapsley, I. Activity based costing in healthcare: A UK case study. *Healthc. Financ. Manag.* **2005**, *10*, 61–75.
19. Conceição, A.; Major, M.; Clegg, S. Project ABC: Unanticipated Affinities and Affect in Hospital Health Care. *Financ. Account. Manag.* **2023**, *39*, 569–592. [CrossRef]

20. Soin, K.; Seal, W.; Cullen, J. ABC and Organizational Change: An Institutional Perspective. *Manag. Account. Res.* **2002**, *13*, 249–271. [CrossRef]
21. Vazakidis, A.; Karagiannis, I.; Tsialta, A. Activity-Based Costing in the Public Sector. *J. Soc. Sci.* **2010**, *6*, 376–382. [CrossRef]
22. Araújo, J.B.C.N.; Souza, A.N.; Joaquim, M.S.; Mattos, L.M.; Lustosa Junior, I.M. Use of the Activity-Based Costing Methodology (ABC) in the Cost Analysis of Successional Agroforestry Systems. *Agrofor. Syst.* **2020**, *94*, 71–80. [CrossRef]
23. Luo, J.X.; Ma, Z.; Fan, T.; Yang, J.; Hu, Y. Application of ABC for the Cost Management in Container Terminal. In *Proceedings of the 2009 International Conference on Information Management, Innovation Management and Industrial Engineering, ICIII*; IEEE: New York City, NY, USA, 2009; Volume 3, pp. 349–352. [CrossRef]
24. Pehlivan, D.; Çiçek, K. Simulation-Based Cost Evaluation of Maritime Transportation. *J. Eta Marit. Sci.* **2023**, *11*, 270–281. [CrossRef]
25. Ryu, D.-H.; Ahn, K.-M.; Yoon, Y.-S. A Study on the Cost Analysis for the Container Terminal Services Based on ABC Approach. *J. Navig. Port Res. Int. Ed.* **2011**, *35*, 589–596. [CrossRef]
26. Chea, A. Activity-Based Costing System in the Service Sector: A Strategic Approach for Enhancing Managerial Decision Making and Competitiveness. *Int. J. Bus. Manag.* **2011**, *6*, 3–10. [CrossRef]
27. Tran, U.; Tran, H. Factors of Application of Activity-Based Costing Method: Evidence from a Transitional Country. *Asia Pac. Manag. Rev.* **2022**, *27*, 303–311. [CrossRef]
28. Souza, D.S.; Cruz, J.E.; Carvalho, J.P.; Silva, A.Y.S. Dificuldades na Implementação do Custeio ABC nas Empresas. *Rev. Cient. Acertte* **2023**, *3*, 1–17. [CrossRef]
29. Elhamma, A.; Yifei, Z. The Relationship Between Activity Based Costing, Business Strategy and Performance in Moroccan Enterprises. *Account. Manag. Inf. Syst.* **2013**, *12*, 22–38.
30. Fei, Z.; Isa, C. Factors Influencing Activity-Based Costing Success: A Research Framework. *Int. J. Trade Econ. Finance* **2010**, *1*, 144–150. [CrossRef]
31. Kitsantas, T.; Vazakidis, A.; Stefanou, C.J. Factors That Facilitate and Motivate the Adoption and Implementation of Activity Based Costing in Greek Companies. *Adv. Bus. Relat. Sci. Res. J.* **2022**, *13*, 1–26.
32. Mahal, I.; Hossain, A. Activity-Based Costing (ABC)—An Effective Tool for Better Management. *Res. J. Finance Account.* **2015**, *6*, 66–74.
33. Quesado, P.; Lopes, M.C. Benefícios e Determinantes do Sistema de Custeio Baseado nas Atividades (ABC): Um Estudo de Caso. *Qual. Rev. Eletrôn.* **2016**, *17*, 37. [CrossRef]
34. Ferreira, D.; Caldeira, C.; Asseiceiro, J.; Vieira, J.; Vicente, C. *Contabilidade de Gestão: Estratégia de Custos e de Resultados*, 2nd ed.; Rei dos Livros: Lisbon, Portugal, 2019.
35. Oseifuah, E.K. Activity Based Costing (ABC) in the Public Sector: Benefits and Challenges. *Probl. Perspect. Manag.* **2014**, *12*, 581–588.
36. Dilley, S.C.; Jacobs, F.H.; Marshall, R.M. The Tax Benefits of ABC. *J. Account.* **1997**, *183*, 34–37.
37. Kitsantas, T.; Vazakidi, A.; Stefanou, C. Integrating Activity Based Costing (ABC) with Enterprise Resource Planning (ERP) for Effective Management: A Literature Review. *Tech. Rom. J. Appl. Sci. Technol.* **2020**, *2*, 160–178. [CrossRef]
38. Alsayegh, M.F. Activity Based Costing Around the World: Adoption, Implementation, Outcomes and Criticism. *J. Account. Finance Emerg. Econ.* **2020**, *6*, 251–262. [CrossRef]
39. Major, M.J.; Hopper, T. Managers Divided: Implementing ABC in a Portuguese Telecommunications Company. *Manag. Account. Res.* **2005**, *16*, 205–229. [CrossRef]
40. Askarany, D.; Smith, M. Diffusion of Innovation and Business Size: A Longitudinal Study of PACIA. *Manag. Audit. J.* **2008**, *23*, 900–916. [CrossRef]
41. Wahab, A.B.A.; Mohamad, M.H.S.; Said, J.M. The Implementation of Activity-Based Costing in the Accountant General's Department of Malaysia. *Asian J. Account. Gov.* **2018**, *9*, 63–76. [CrossRef]
42. Nair, S.; Tan, X. Factors Influencing the Implementation of Activity-Based Costing: A Study on Malaysian SMEs. *Int. Bus. Res.* **2018**, *11*, 133. [CrossRef]
43. Oseifuah, E.K. Activity Based Costing Approach to Financial Management in the Public Sector: The South Africa Experience. *Eur. Sci. J.* **2013**, *9*, 35–53.
44. Quesado, P.; Silva, R. Activity-Based Costing (ABC) and Its Implication for Open Innovation. *J. Open Innov. Technol. Mark. Complex.* **2021**, *7*, 41. [CrossRef]
45. Nørreklit, H.; Nørreklit, L.; Mitchell, F.; Bjornenak, T. The Rise of the Balanced Scorecard! Relevance Regained? *J. Account. Organ. Change* **2012**, *8*, 490–510. [CrossRef]
46. Piazza, A.; Abrahamson, E. Fads and Fashions in Management Practices: Taking Stock and Looking Forward. *Int. J. Manag. Rev.* **2020**, *22*, 264–286. [CrossRef]
47. Elias, H.; Mehrotra, A. Activity-Based Costing of Library Services in Universities—A Case Study of a Private University. *Econ. World* **2018**, *6*, 165–176. [CrossRef]

48. Drury, C. *Management Accounting for Business*, 7th ed.; Cengage Learning: Independence, KY, USA, 2019.
49. Elyass, M.A.; Elshareef, A.M.; Abdullah, Y.A.G.S. The Role of Contemporary Cost Accounting Systems in Planning, Decision-Making and Controlling, in Sudanese Sea Port Corporation. *J. Sci. Technol.* **2022**, *3*, 1–20.
50. Munasir, K.; Misnan, M.S. The Need of Best Practices in Seaport Maintenance Management. *Int. J. Bus. Technol. Manag.* 2024. Available online: https://scispace.com/papers/the-need-of-best-practices-in-seaport-maintenance-management-2gahdopmqe (accessed on 2 April 2026). [CrossRef]
51. Martins, J.; Costa, A.; Campos, C.; Faria, I.; Sousa, A. Exploring Management Accounting Approaches in Port Pricing: A Scoping Review. In *The Challenges of Era 5.0 in Accounting and Finance Innovation*; Springer: Berlin/Heidelberg, Germany, 2024; Volume 28, pp. 333–345. [CrossRef]
52. Campos, C.; Martins, J.; Costa, A.; Sousa, A.; Faria, I. Exploring Activity-Based Costing Adoption in Seaports: A Comparative Study. In *Proceedings of the International Conference of Applied Business and Management (ICABM2024)*; ISAG European Business School: Porto, Portugal, 2024. [CrossRef]
53. Martins, J.; Costa, A.; Campos, C.; Sousa, A.; Faria, I. Strategic Management Control Tools for the Sustainability of Seaports: A Scoping Review. *Sustainability* **2024**, *16*, 9247. [CrossRef]
54. Lunkes, R.; Giner Fillol, A.; Ripoll Feliu, V.M.; Silva da Rosa, F. Distribuição de Custos: Um Estudo no Porto de Valência-Espanha. *Rev. ABCustos* **2015**, *10*, 1–19. [CrossRef]
55. Fillol, A.G.; Ubal, N.P.; Feli, V.R. Accounting Management and Technology Information: Empirical Evidence from the Port Authority of Valencia. *J. Inf. Syst. Technol. Manag.* **2008**, *5*, 469–482. [CrossRef]
56. Malla, L.N.M.; Narváez Zurita, C.I.; Erazo Álvarez, J.C. La Determinación de Costos a Través de la Metodología Abc/Abm Como Opción Estratégica en la Industria de Servicios Portuarios. *Cienciamatria* **2019**, *5*, 418–447. [CrossRef]
57. Pratiwi, N.; Sahade; Afiah, N. Analisis Penentuan Tarif Bongkar Muat Peti Kemas Dengan Metode Activity Based Costing. *Bongaya J. Res. Account.* **2023**, *6*, 39–51. [CrossRef]
58. Yasar, R. Zaman Esaslı Faaliyet Tabanlı Maliyetleme Yöntemi Ile Konteyner Terminallerinde Maliyet Analizi. *Muhasebe Finans. Dergis* **2017**, *73*, 203–228. [CrossRef]
59. Ding, Y.; Chen, K.; Wei, X.; Yang, Y. A Novel Cost-Management System for Container Terminals Using a Time-Driven Activity-Based Costing Approach. *Ocean Coast. Manag.* **2022**, *217*, 106011. [CrossRef]
60. Barros, R.S.; Da Costa Ferreira, A.M.D.S. Time-Driven Activity-Based Costing: Designing a Model in a Portuguese Production Environment. *Qual. Res. Account. Manag.* **2017**, *14*, 2–20. [CrossRef]
61. Perkins, D.; Scott Stovall, O. Resource Consumption Accounting Where Does It Fit? *J. Appl. Bus. Res.* **2011**, *27*, 41–52. [CrossRef]
62. Bell, J.; Hoque, Z.; Watts, T.; Baard, V.; Mcnair, C.J.; Polutnik, L. Structural Limits of Capacity and Implications for Visibility. *J. Account. Organ. Change* **2009**, *5*, 294–312. [CrossRef]
63. Guerreiro, R.; Cornachione, E.B.; Catelli, A. Equivalent Units of Production: A New Look at an Old Issue. *Manag. Audit. J.* **2006**, *21*, 303–316. [CrossRef]
64. Togo, D. Support Department Cost Allocations with a Matrix-Based Reciprocal Approach. *Adv. Account. Educ. Teach. Curric. Innov.* **2012**, *13*, 277–296. [CrossRef]
65. De Sousa, E.F.; Neto, F.J.K.; Andriotti, R.F.; Campagnolo, R.R. Activity-based costing: Uma proposta de modelo de gestão de custos portuários. *Rev. Eletrôn. Estratég. Neg.* **2024**, *16*, e13983. [CrossRef]
66. Su, S.; Baird, K.; Schoch, H. The Moderating Effect of Organisational Life Cycle Stages on the Association between the Interactive and Diagnostic Approaches to Using Controls with Organisational Performance. *Manag. Account. Res.* **2015**, *26*, 40–53. [CrossRef]
67. Sartorius, K.; Eitzen, C.; Kamala, P. The Design and Implementation of Activity Based Costing (ABC): A South African Survey. *Meditari Account. Res.* **2007**, *15*, 1–21. [CrossRef]
68. Drury, C. *Management and Cost Accounting*, 3rd ed.; Springer: Berlin/Heidelberg, Germany, 2013.
69. Abusalama, F.A. Barriers to Adopting Activity-Based Costing Systems (ABC): An Empirical Investigation Using Cluster Analysis. Ph.D. Thesis, Technological University Dublin, Dublin, Ireland, 2008. [CrossRef]
70. Mitchell, R.K.; Agle, B.R.; Wood, D.J. Toward a Theory of Stakeholder Identification and Salience: Defining the Principle of Who and What Really Counts. *Acad. Manag. Rev.* **1997**, *22*, 853–886. [CrossRef]
71. Wood, D.; Ross, D.G. Environmental Social Controls and Capital Investments: Australian Evidence. *Account. Finance* **2006**, *46*, 677–695. [CrossRef]
72. Mthembu, S.E.; Chasomeris, M. Revisiting Marine Services Pricing in South Africa's Ports. *WMU J. Marit. Aff.* **2023**, *23*, 5–24. [CrossRef]
73. Jabareen, Y. Building a Conceptual Framework: Philosophy, Definitions, and Procedure. *Int. J. Qual. Methods* **2009**, *8*, 49–62. [CrossRef]

74. Miles, M.B.; Huberman, M.A. *Qualitative Data Analysis: An Expanded Sourcebook*; SAGE Publications: Thousand Oaks, CA, USA, 1994.
75. Kaplan, R.S.; Anderson, S.R. Time-Driven Activity-Based Costing. *Harv. Bus. Rev.* **2004**, *82*, 131–138.

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