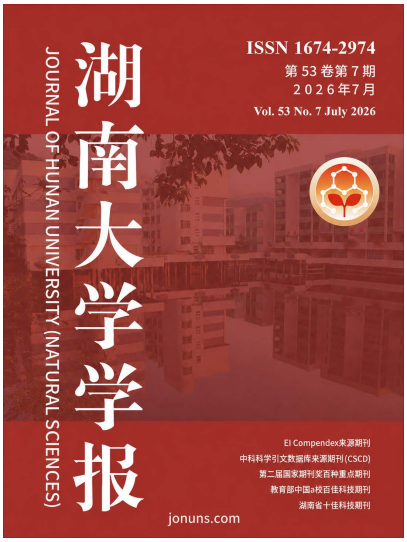

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Modeling ISO 9001, ISO 14001 and ISO 45001 Cross-Impacts on Port Performance

Mohamed SALHI [1*], Saadia MAROUANE [1], Abdallah RHIHIL [1]

[1] National School of Business and Management, Laboratory of Financial Engineering, Governance and Development (LifGod), University Hassan II of Casablanca, Casablanca, Morocco,

* Corresponding author: simousalhi1976@gmail.com, mohamed.salhi4-etu@etu.univh2c.ma

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Abstract: Port terminals are subject to converging normative demands spanning quality, environmental, and occupational health and safety management, driving the widespread parallel adoption of ISO 9001, ISO 14001, and ISO 45001 certifications. Despite the growing prevalence of co-certification in the port sector, the mechanisms through which these three standards interact, and the organizational conditions under which such interactions produce additive, synergistic, or compensatory performance effects, remain theoretically underdeveloped. This article presents a conceptual modeling study that constructs an integrated analytical framework for mapping the cross-impacts of ISO 9001, ISO 14001, and ISO 45001 on the operational, environmental, organizational, and social performance dimensions of port terminals. The methodology combines a structured literature synthesis, a contextual analysis of Moroccan port terminals drawing on secondary sources and official documentation, and a theoretical triangulation grounded in the Resource-Based View, stakeholder theory, and neo-institutionalism. The conceptual findings identify three interaction regimes, addition, synergy, and compensation, whose activation is moderated by integration maturity, governance structure, technological capability, institutional pressure, and cultural absorption capacity. Applied to six major Moroccan port terminals spanning from Optimization-level (Tanger Med) to Correspondence-level (Agadir) integration configurations, the model illuminates differentiated certification trajectories and their performance implications. Six testable research propositions are derived to guide empirical validation. This study contributes to the Integrated Management Systems (IMS) literature by operationalizing cross-certification dynamics within a port-specific and institutionally embedded North African context, while providing port managers with a

structured decision framework for optimizing certification integration strategies.

Keywords: Integrated management systems; ISO certifications; Port terminal performance; Cross-effects; Organizational performance; Managerial synergies; Moroccan port context.

ISO 9001、ISO 14001与ISO 45001对港口绩效交叉影响的建模研究

摘要：港口码头在质量、环境及职业健康安全管理领域面临日益趋同的规范压力，这一态势推动了ISO 9001、ISO 14001和ISO 45001认证的广泛并行采用。然而，尽管港口行业联合认证实践不断普及，三项标准在同步部署条件下的交互机制,， 及其在何种组织情境下产生叠加、协同或补偿绩效效应,， 在理论层面仍有待深入探讨。本文提出一项概念建模研究，构建了一个整合分析框架，系统描绘ISO 9001、ISO 14001和ISO 45001对港口码头运营绩效、环境绩效、组织绩效和社会绩效四个维度的交叉影响。研究方法综合运用三项互补支柱：以文献为基础的系统综述、以二手资料和官方文献为基础的摩洛哥港口码头情境分析，以及融合资源基础观、利益相关者理论与新制度主义的理论三角验证。研究结果揭示了三种交互机制,， 叠加效应、协同效应和补偿效应，其激活受整合成熟度、治理结构、技术能力、制度压力和文化吸收能力等调节因素的制约。将上述框架应用于整合配置涵盖优化级（丹吉尔地中海港）至对应级（阿加迪尔港）的六个主要摩洛哥港口码头，该模型揭示了差异化认证发展轨迹及其绩效影响。研究进一步推导出六条可检验的研究命题，以指引后续实证验证工作。

关键词：整合管理体系；ISO认证；港口码头绩效；交叉影响；组织绩效；管理协同；摩洛哥港口情境

1. Introduction

The transformation of global maritime trade has sharpened the competitive demands placed on port terminals, entities that were long treated as passive infrastructural nodes but are now recognized as strategically significant actors in the organization of international supply chains [14]. Container throughput has expanded at an average annual rate of approximately 5.8% over the past two decades, a sustained trajectory that compels terminals to continuously reconfigure their operational and managerial capacities. The regulatory environment has evolved in parallel, and in some respects faster: quality assurance requirements, environmental compliance obligations, and occupational health and safety mandates now converge on port operators through overlapping normative frameworks that siloed, uncoordinated management approaches can no longer adequately address.

ISO certifications have become central instruments in this regulatory reconfiguration. ISO 9001 for quality management, ISO 14001 for environmental management, and ISO 45001 for occupational health and safety management represent three structurally related frameworks whose simultaneous adoption has become increasingly common across the port sector. Their shared ISO Common High-Level Structure signals institutional recognition that these systems are designed to interact, not merely to coexist. What the standard-setting bodies have not fully resolved, however, is how these interactions unfold organizationally: whether co-deploying three ISO frameworks generates synergies that exceed the sum of their individual contributions, triggers compensatory trade-offs between competing performance dimensions, or simply accumulates benefits additively.

This question defines the theoretical gap motivating the present study. The Integrated Management Systems (IMS) literature, particularly foundational work by Bernardo et al. [2] and Nunhes et al. [15], has established robust conceptual vocabulary for thinking about multi-standard integration, yet port-specific applications remain sparse and engagement with the African institutional context is almost entirely absent. Individual certifications have attracted considerable attention: ISO 14001 in port environmental governance [4, 17], ISO 9001 in logistics performance [3, 7], and occupational safety management in maritime operations [8, 21]. The dynamics of their simultaneous integration, and particularly the moderating role of institutional, governance, and technological context, constitute an underexplored frontier.

Morocco provides an analytically productive setting for examining these dynamics. The kingdom's port sector has undergone deliberate and rapid modernization, culminating in the 2030 National Port Strategy, which explicitly incorporates operational excellence and normative compliance among its strategic priorities [20]. Tanger Med, among the most efficient container transshipment hubs in the Mediterranean basin, exemplifies the integration

potential achievable under favorable governance and technological conditions. Casablanca, Jorf Lasfar, Agadir, Mohammedia, and Safi represent more heterogeneous trajectories, differentiated by cargo specialization, organizational history, and integration maturity, collectively capturing the diversity of the Moroccan port landscape and, by extension, a broader set of institutional conditions relevant to emerging economies.

The objective of this article is to develop an original conceptual model mapping the cross-impacts of ISO 9001, ISO 14001, and ISO 45001 certifications on the key performance dimensions of port terminals. Drawing on theoretical triangulation between the Resource-Based View, stakeholder theory, and neo-institutionalism, the model articulates three interaction regimes, addition, synergy, and compensation, and identifies the explanatory and moderating factors that determine regime activation in a given organizational and institutional context. Six testable research propositions are derived from the model to guide future empirical investigation.

Section 2 details the methodological approach, positioning the study as a conceptual modeling contribution. Section 3 develops the theoretical framework. Section 4 situates the analysis within the Moroccan port context. Section 5 presents the conceptual results and discussion, encompassing direct certification impacts, the integrated cross-impact model, the research propositions, and the theoretical and managerial implications. Section 6 concludes with contributions, limitations, and research perspectives.

2. Methodological Approach

This study is designed as a **conceptual modeling study**, a recognized research design in organizational and operations management that constructs theoretically grounded frameworks capable of systematizing existing knowledge and orienting subsequent empirical inquiry [15]. No primary field data are reported; the study does not test its propositions against measurements collected directly from Moroccan port operators. Its epistemological ambition is structural rather than predictive: to map the causal architecture of cross-certification interactions with sufficient analytical precision to generate empirically tractable research propositions.

The methodology rests on three complementary pillars.

Structured literature synthesis. A systematic review of peer-reviewed publications was conducted across the following thematic domains: integrated management systems, ISO 9001, ISO 14001, ISO 45001, port performance, maritime terminal operations, organizational performance, and Moroccan logistics. Major academic databases, Scopus, Web of Science, and Google Scholar, were consulted, with an emphasis on publications from 2014 to 2024. Sources were selected on the basis of methodological rigor, disciplinary relevance, and direct engagement with multi-standard integration dynamics or port sector performance. The resulting corpus was distilled into the twenty-one references cited in this article, prioritizing sources with verified publication links and, where possible, DOI-indexed references.

Contextual analysis of Moroccan port terminals. Information on certification trajectories, integration levels, and sectoral profiles was compiled from secondary sources: official reports of the Agence Nationale des Ports (ANP), published academic studies on Moroccan port logistics [6, 20], and publicly available documentation from terminal operators and concessionaries. The integration levels attributed to each terminal in Table 1 are analytical classifications derived from a conceptual grading schema inspired by Bernardo et al. [2], distinguishing Correspondence (Level 1), Coordination (Level 2), Integration (Level 3), and Optimization (Level 4). These classifications represent analytical approximations of integration maturity based on available secondary evidence; they are not formally certified assessments issued by certification bodies or port regulatory authorities, and individual values should be treated as indicative pending primary fieldwork verification.

Theoretical triangulation. The model is constructed at the intersection of three complementary theoretical frameworks, the Resource-Based View [1], stakeholder theory [9], and neo-institutionalism [19], each illuminating a distinct causal dimension of the cross-certification phenomenon. The RBV explains the value-creation logic of integration; stakeholder theory maps the relational dynamics driving adoption and shaping performance expectations; neo-institutionalism contextualizes the institutional pressures that configure organizational behavior in the port normative field. The typology of interaction regimes, addition, synergy, and compensation, was constructed inductively, by cross-referencing IMS taxonomies [2, 15] with sector-specific performance frameworks [3, 11, 14] and the institutional characteristics of the Moroccan regulatory context.

This study explicitly prepares the ground for empirical validation. Future fieldwork targeting the ports of Casablanca and Tanger Med, two terminals that, by virtue of their contrasting integration trajectories, governance models, and technological configurations, represent complementary validation environments, will enable hypothesis testing of the six research propositions derived from the conceptual model. Mixed-method designs combining structured questionnaire surveys and in-depth managerial interviews are envisaged for this subsequent phase.

3. Conceptual and Theoretical Framework

3.1. Resource-Based View

The Resource-Based View, articulated by Barney [1] and subsequently extended by scholars in organizational strategy and operations management, provides the foundational rationale for treating integrated management systems as strategic assets rather than mere compliance instruments. According to the VRIO configuration, organizational resources generate sustainable competitive advantage when they are simultaneously valuable, rare, inimitable, and organizationally embedded. ISO certifications taken in isolation satisfy the first criterion, they generate value by structuring management processes and signaling commitment, but their accessibility undermines the rarity and inimitability conditions. Their genuine integration, by contrast, is a fundamentally different organizational achievement. The processes, cultural dispositions, cross-functional governance arrangements, and managerial routines required to fuse three normative frameworks into a coherent, transversal management architecture are path-dependent and socially complex. Shaped by each terminal's institutional history, stakeholder relationships, and accumulated organizational learning, they cannot be readily replicated, and no certification body can formally assess their depth.

In the port sector, this reasoning gains additional force from the density and diversity of stakeholder accountability. Port terminals must simultaneously satisfy the performance expectations of shipping lines, customs authorities, environmental regulators, labor organizations, local communities, and international benchmarking bodies. An IMS that credibly signals integrated managerial commitment across quality, environmental, and occupational health and safety dimensions addresses this stakeholder complexity in a register that sequential, uncoordinated certifications cannot match [3].

3.2. Stakeholder Theory

Freeman's [9] stakeholder theory shifts analytical focus toward the relational dynamics surrounding certification adoption in multi-actor organizational environments. Port terminals occupy a structurally complex position in which the expectations of commercial partners, regulatory authorities, labor organizations, and civil society actors are not merely additive but layered and occasionally contradictory. A shipping line's throughput priorities may conflict with environmental authority requirements for systematic waste auditing; labor union demands for procedural safety standards may impose operational constraints affecting cargo velocity.

ISO certifications function, in this framework, as organizational signaling mechanisms through which terminals communicate targeted commitments to distinct stakeholder audiences. ISO 14001 addresses environmental regulators and proximate communities; ISO 45001 speaks to labor inspectorates, insurers, and collective bargaining partners; ISO 9001 projects operational reliability to logistics integrators and commercial port authority stakeholders. When genuinely integrated, these signals reinforce one another, projecting a coherent image of comprehensive managerial competence across all three registers. The analytical risk is the reverse: resource competition between quality, environmental, and safety objectives may generate organizational tensions, what the model captures as compensatory interaction effects.

3.3. Neo-Institutionalism

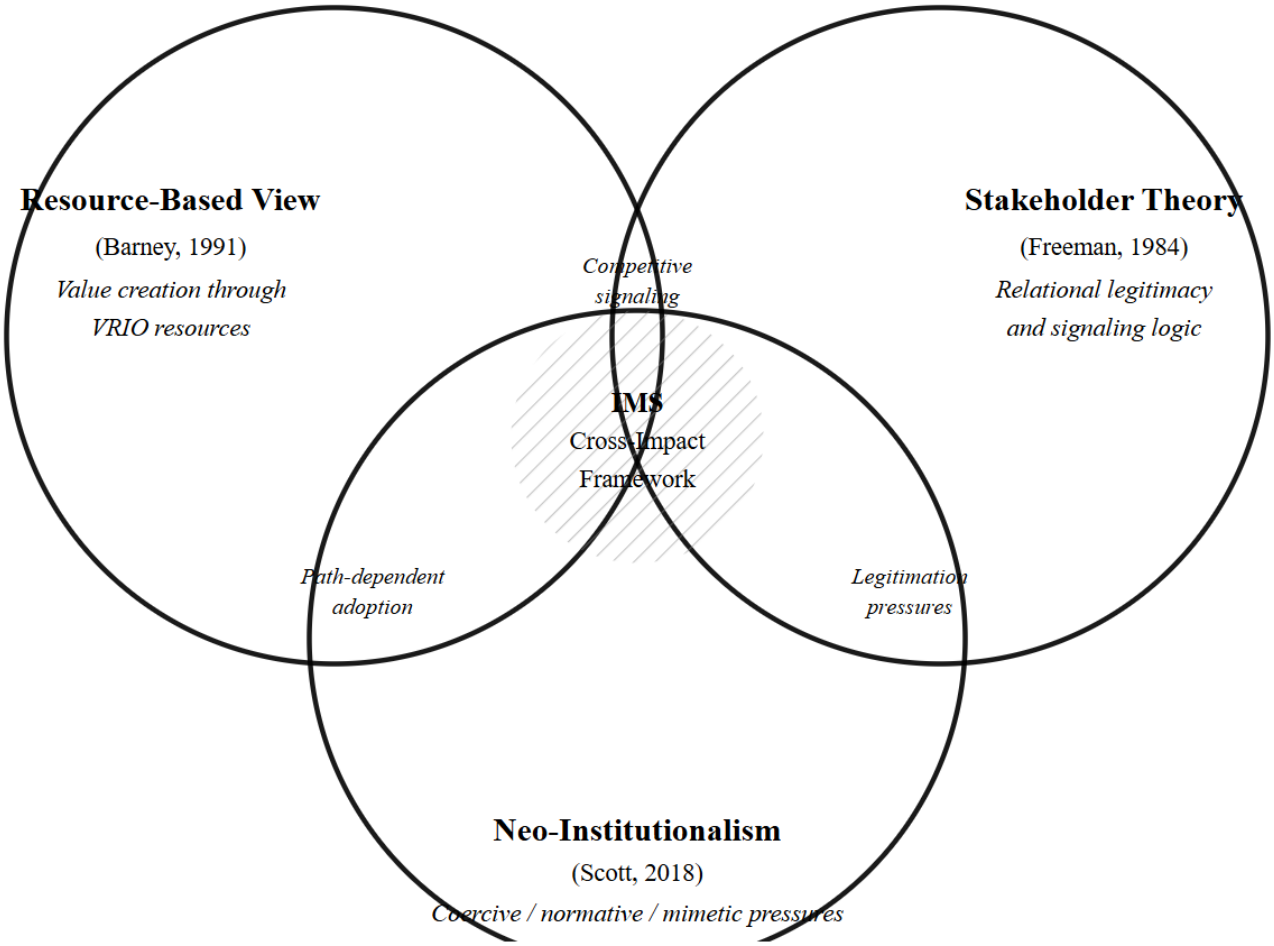
Scott's [19] neo-institutional framework situates certification adoption within the broader field of institutional pressures and organizational legitimation imperatives. Three institutional forces are operative: coercive pressures imposed through regulatory mandate, normative pressures diffused through professional networks and standard-setting bodies, and mimetic pressures arising from organizational imitation of legitimate models in conditions of uncertainty.

In the Moroccan port environment, all three mechanisms operate simultaneously. Coercive pressure originates in national environmental legislation, occupational health and safety regulations, and ANP requirements that increasingly reference or condition port concession agreements on normative compliance. Normative pressure flows through Morocco's membership in international port associations, participation in Mediterranean benchmarking programs, and certification stipulations embedded in commercial agreements with European shipping clients. Mimetic pressure is visible in the certification timeline data of Table 1: Tanger Med's early and comprehensive certification strategy appears to have influenced the normative orientations of other Moroccan terminals, a diffusion dynamic consistent with the mimetic mechanism in a national port community of limited institutional scale [6].

3.4. Theoretical Convergence

The convergence of these three frameworks establishes a multidimensional analytical grid for the cross-certification phenomenon, illustrated in Figure 1. The RBV explains why integration creates strategic value; stakeholder theory clarifies for whom and through which relational channels; neo-institutionalism reveals the external forces that compel adoption and shape its organizational forms. Together, they enable a textured understanding of why some port terminals achieve genuine IMS synergies while others remain confined to sequential, functionally disconnected certification strategies, a distinction with direct and measurable consequences for performance outcomes.

Figure 1. Schema of Convergence of Theoretical Frameworks.



4. Moroccan Port Certification Context

4.1. Morocco's Strategic Positioning in Maritime Logistics

Morocco's port infrastructure occupies a distinctive position in both the African and Mediterranean maritime systems. The country's geostrategic location at the intersection of Atlantic and Mediterranean trade routes, combined with its proximity to European demand centers and growing commercial engagement with West African partners, has made port infrastructure a central instrument of national economic development policy. Successive port strategies have directed sustained public investment toward capacity expansion, technological modernization, and normative upgrading, producing a port system that, in its leading components, competes credibly with established European benchmarks [14].

The Agence Nationale des Ports (ANP), which coordinates port governance and regulatory oversight across the national system, has played a significant role in diffusing normative standards through its concession frameworks, performance monitoring mechanisms, and investment evaluation criteria. Its technical requirements and audit protocols increasingly reference international management standards as benchmarks for terminal quality, safety, and environmental management. The 2030 National Port Strategy explicitly incorporates operational excellence and compliance with international management standards among its strategic priorities, an orientation that has accelerated both formal certification adoption and, to varying degrees, genuine organizational integration.

4.2. Differentiated Certification Trajectories and IMS Institutionalization

Methodological Note on Table 1: The certification status, integration start years, and integration levels presented in Table 1 are compiled from secondary sources, including ANP official reports, published academic studies [6, 20], and publicly

available port operator documentation. The integration level classifications, Correspondence (Level 1), Coordination (Level 2), Integration (Level 3), and Optimization (Level 4), are analytical approximations derived from the conceptual grading schema proposed by Bernardo et al. [2]. These classifications are analytical reference points derived from secondary evidence, not formally certified assessments, and should be treated as approximations subject to validation through primary fieldwork.

Tanger Med, as Morocco's flagship container and transshipment complex, pursued a systemic certification trajectory from its inception, ISO 9001 obtained in 2008, ISO 14001 in 2009, ISO 45001 integration initiated in 2019, reaching an Optimization-level configuration that enables unified audit procedures, integrated risk governance, and transversal performance dashboards. This trajectory reflects deliberate governance choices and the availability of purpose-built technological infrastructure capable of sustaining data-intensive integration. As a new-generation terminal designed from the ground up for international-standard operations, Tanger Med avoided the institutional inertia that constrains older facilities.

Casablanca's profile is structurally different. As Morocco's oldest and most commercially diversified port, it carries significant historical institutional weight. Certification proceeded sequentially, ISO 9001 (2005), ISO 14001 (2012), ISO 45001 still ongoing as of 2023, yielding a Coordination-level integration that reflects genuine procedural harmonization without the process unification that synergy effects require. Sebbah and Boulahdour [20] document how this sequential pattern, while associated with deeper organizational learning within each individual system, tends to delay the emergence of cross-system synergies, a finding the present model explicitly theorizes.

Jorf Lasfar and Safi, both serving industrial cargo profiles with high environmental and safety risk exposure, have reached Integration-level configurations, driven in part by the acute coercive and normative pressures generated by their cargo typologies. Bulk chemical handling, phosphate processing, and hydrocarbon logistics create regulatory imperatives that accelerate ISO 14001 and ISO 45001 integration as much through institutional necessity as through voluntary strategic commitment. Agadir, specializing in perishable agricultural exports, and Mohammedia, handling hydrocarbons and industrial chemicals, occupy intermediate positions, Correspondence and Coordination levels respectively, reflecting the particular normative demands, organizational resources, and certification histories of their operational contexts.

Table 1. ISO Standards Applied in Moroccan Port Terminals: Certification Status and Integration Levels

Port Terminal	ISO 9001	ISO 14001	ISO 45001	Integration Start	Level Achieved	Sectoral Specificities
Tanger Med	Certified (2008)	Certified (2009)	Certified (2019)	2010	Optimization (Level 4)	Containers, transshipment, Mediterranean hub
Casablanca	Certified (2005)	Certified (2012)	Ongoing (2023)	2014	Coordination (Level 2)	Mixed traffic, historic port, regional services
Jorf Lasfar	Certified (2007)	Certified (2010)	Ongoing (2020)	2012	Integration (Level 3)	Solid/liquid bulk, industrial complex
Agadir	Certified (2011)	Ongoing (2024)	Not certified	2022	Correspondence (Level 1)	Citrus, perishables, sector specialization
Mohammedia	Certified (2006)	Certified (2016)	Ongoing (2024)	2016	Coordination (Level 2)	Hydrocarbons, chemicals, safety constraints
Safi	Certified (2013)	Certified (2018)	Certified (2022)	2019	Integration (Level 3)	Phosphates, fishing industry, dual specialization

Integration Level Definitions (adapted from Bernardo et al. [2]): Level 1 (Correspondence): Minimal documentary juxtaposition without procedural linkage. | Level 2 (Coordination): Partial harmonization of shared procedures. | Level 3 (Integration): Process unification, shared auditing, consolidated KPI frameworks. | Level 4 (Optimization): Fully transversal management with strategic-level performance convergence. Source: Authors' compilation from secondary sources, ANP official reports, El Merghadi et al. [6], Sebbah & Boulahdour [20], and publicly available port operator documentation. Integration levels are analytical approximations, not formally certified assessments.

5. Results and Discussion

5.1. Direct Performance Impacts of ISO Certifications

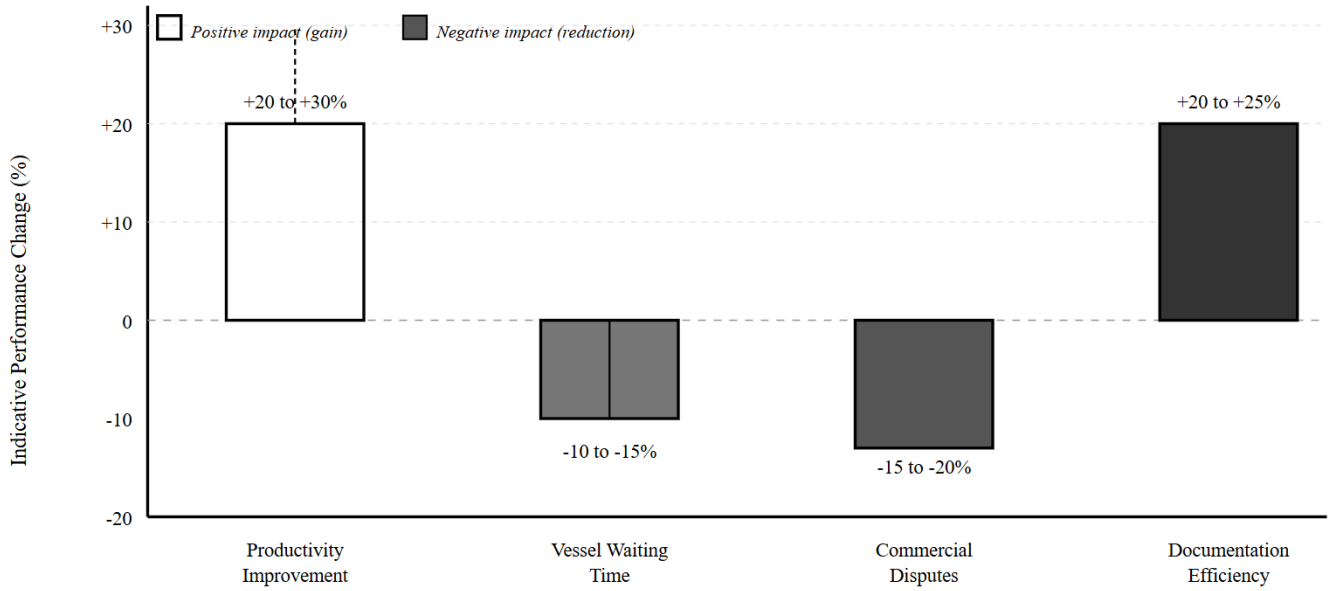
5.1.1. ISO 9001 and Operational Performance

ISO 9001's primary operational impact on port terminals flows through its process approach, which reconfigures port management logic from siloed functional units toward transversal, customer-value-oriented process chains. Standardization of task execution procedures reduces operational variability, a determinant of performance that matters acutely in port environments where unpredictable cycle times propagate through logistics chains and translate into vessel waiting costs, demurrage fees, and cascading client satisfaction penalties [3].

Note on Figure 2: The performance benchmarks presented in Figure 2 are literature-derived indicative values, compiled and adapted from empirical studies conducted in port and logistics contexts [7, 16]. They are presented as illustrative reference points reflecting the range of outcomes reported in prior research, and should not be construed as direct measurements from Moroccan port terminals. The caption of Figure 2 has accordingly been revised to read: "Literature-Based Indicative Benchmarks for ISO 9001 Operational Effects in Port Terminals."

Prior empirical studies in port and logistics operations suggest that ISO 9001 certification is associated with productivity improvements in the range of 20–30%, attributable primarily to procedural standardization and the formalization of responsibility assignments [16]. Reductions in vessel waiting times, a primary indicator in container terminal competitiveness benchmarking, appear linked to tighter coordination between documentation processing, resource scheduling, and quayside execution units. The resolution of commercial disputes benefits from ISO 9001's traceability requirements, which create a documentary evidentiary trail that facilitates liability assignment and claims management [7]. These effects, as the literature consistently notes, are contingent on implementation depth: terminals adopting ISO 9001 primarily as a commercial signaling credential, without restructuring their process architecture, capture only a fraction of its potential. This gap between formal adoption and genuine organizational appropriation is central to the moderating factor analysis developed in Section 5.2.2.

Figure 2. Literature-Based Indicative Benchmarks for ISO 9001 Operational Effects in Port Terminals.



Note: All performance benchmarks are literature-derived indicative values adapted from Feng et al. [7] and Prajogo et al. [16]. Source: Authors' elaboration, adapted from Prajogo et al. [16] and Feng et al. [7]

5.1.2. ISO 14001 and Environmental Performance

ISO 14001 organizes port environmental governance through a Plan-Do-Check-Act cycle that converts compliance from a reactive obligation into a proactive management routine. The standard's planning requirements, systematic identification, evaluation, and prioritization of significant environmental aspects, enable terminals to allocate improvement resources

according to impact severity rather than regulatory visibility alone, a rationalization that typically yields both better environmental outcomes and more efficient resource utilization.

Note on Table 2: The quantitative benchmarks presented in Table 2 are indicative values adapted from prior empirical literature on environmental management in port terminals [4, 17, 13]. They represent illustrative figures derived from research conducted in European and Mediterranean port contexts, and should not be interpreted as measurements from Moroccan port operators. Individual terminal performance will vary substantially depending on baseline environmental conditions, operational scale, cargo typology, and implementation depth.

Research on Mediterranean and European port terminals associates ISO 14001 certification with reductions in CO_2 emissions, lower generation of non-recovered waste, and decreased pollution incident frequency, effects most pronounced where certification accompanies operational electrification and equipment modernization programs [17]. The environmental co-benefits at the stakeholder interface, improved community relations, enhanced regulatory credibility, access to environmental performance recognition schemes, represent a category of value that the RBV framework captures but that standard environmental metrics tend to understate [4]. In Morocco's industrial port contexts, the risk assessment and emergency response planning provisions of ISO 14001 carry particular weight given the environmental risk profiles of bulk chemical and hydrocarbon cargo operations.

5.1.3. ISO 45001 and Organizational-Social Performance

ISO 45001, which superseded OHSAS 18001 as the international benchmark for occupational health and safety management systems in 2018, introduces a conceptually significant reorientation from reactive compliance to proactive risk governance. Its participatory requirements, which mandate worker consultation throughout hazard identification and risk assessment processes, carry the potential to reshape organizational culture in port terminals in ways that regulatory mandate alone rarely achieves. Culture, not procedure, is the ultimate determinant of safety outcomes in high-risk operational environments; this is the standard's most underappreciated lever.

Note on Figure 3: The performance indicators mapped in Figure 3 are literature-based indicative benchmarks, drawn and adapted from empirical research in port and construction occupational safety contexts [8, 21]. They are presented as illustrative reference values and should not be construed as direct measurements from Moroccan port terminals.

Prior research in comparable high-risk operational settings suggests ISO 45001 (and its OHSAS 18001 predecessor) can substantially reduce accident frequency rates through formalized hazard identification, structured corrective action protocols, and the institutionalization of proactive safety cultures [8]. The organizational co-benefits, improvements in worker engagement, reductions in absenteeism, and strengthened labor relations, reflect the standard's capacity to signal managerial concern for worker well-being in ways that contractual arrangements alone may not convey. In Morocco's port sector, where occupational safety governance is subject to both national regulatory oversight and international logistics operator expectations, these signaling benefits carry institutional resonance that reinforces the mimetic adoption dynamic described in Section 3.3 [20].

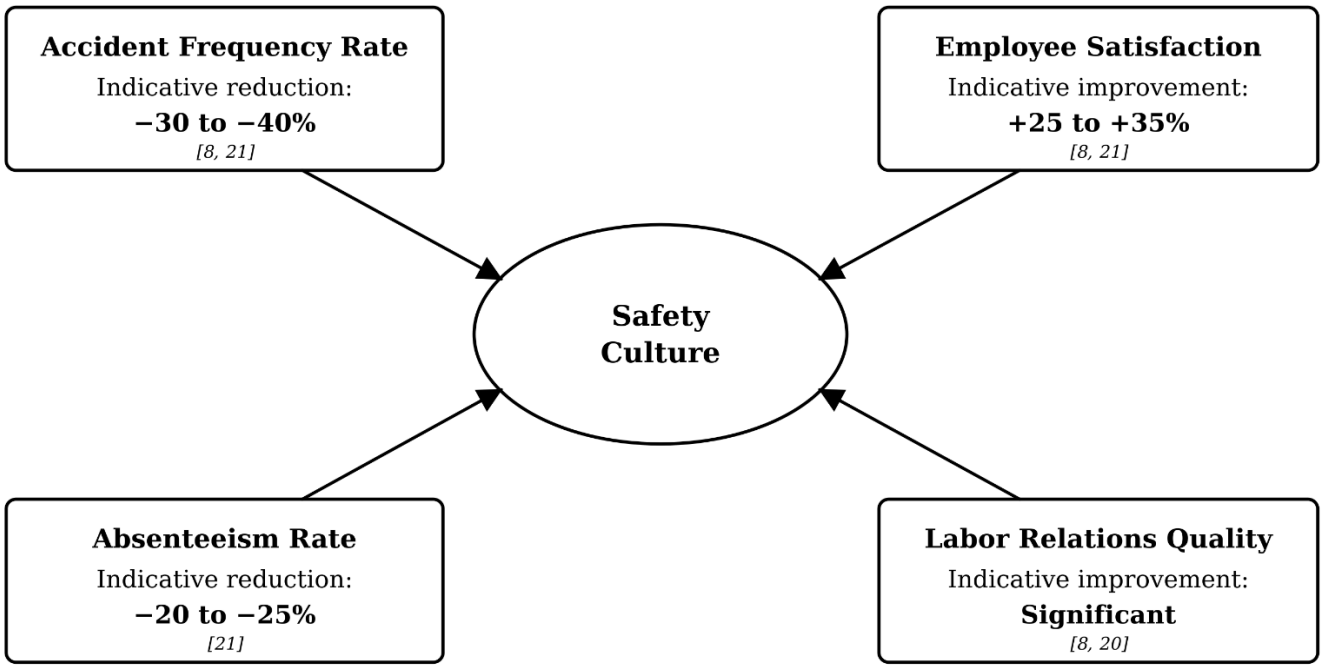
Table 2. Literature-Based Environmental Performance Benchmarks of ISO 14001 in Port Terminals

Environmental Dimension	Direct Impacts	Indirect Impacts	Impact Level	Indicative Benchmarks (Literature-Derived)
Greenhouse Gas Emissions	Equipment electrification; energy optimization; fleet renewal; renewable energy integration	Environmental image; anticipation of regulatory constraints; reduced carbon taxation	HIGH	∼−15 to −25% CO_2; ∼−10 to −18% NOx; +10–15% energy efficiency
Waste Management	Advanced selective sorting; waste recovery; reduction at source; hazardous waste traceability	Recycling partnerships; specialized training; cost savings through material recovery	HIGH	∼−25 to −35% non-recovered waste; +20–30% recycling rate; ∼−20% disposal costs
Marine Pollution	Hydrocarbon recovery; leak prevention; port water monitoring; spill response protocols	Cooperation with maritime authorities; response team training; ecological restoration	HIGH	∼−50 to −70% pollution incidents; +30–40% response speed; full regulatory compliance
Noise and Nuisances	Quieter equipment; night-time planning; acoustic screening; vibration prevention	Improved community relations; enhanced social acceptability; facilitated local negotiations	MEDIUM	∼−8 to −15 dB average noise; ∼−40% local complaints; +20–30% community satisfaction

Environmental Dimension	Direct Impacts	Indirect Impacts	Impact Level	Indicative Benchmarks (Literature-Derived)
Marine Biodiversity	Environmental impact assessments; ecological compensation; ecosystem monitoring	Scientific partnerships; marine research support; biodiversity awareness programs	MEDIUM	Maintenance or improvement of local species richness; documented ecosystem restoration
Natural Resource Consumption	Water optimization; rainwater harvesting; energy demand reduction; lean logistics	Innovation incentives; reduced operating costs; partial energy autonomy objectives	MEDIUM	∼−15 to −22% water use; ∼−12 to −18% energy use; +15–25% recycled input materials

Note: All quantitative benchmarks are indicative values derived from prior empirical studies in European and Mediterranean port contexts [4, 17, 13]. They are not measurements from Moroccan port terminals and should not be interpreted as locally established results. Source: Authors' elaboration, adapted from Puig et al. [17], Darbra et al. [4], and Mansouri [13].

Figure 3. ISO 45001 Social and Organizational Impact Mapping, Literature-Based Indicative Benchmarks.



Note: Performance indicators are literature-based indicative benchmarks adapted from Fernández-Muñiz et al. [8] and Yip et al. [21]. Source: Authors' elaboration, adapted from Fernández-Muñiz et al. [8] and Yip et al. [21]

5.2. Integrated Modeling of Cross-Certification Effects

5.2.1. Three Interaction Regimes

The conceptual core of this study lies in the systematic articulation of three distinct regimes through which co-deployed ISO certifications generate performance effects that differ fundamentally from what individual certification can achieve.

Addition effects characterize configurations where the three certifications generate independent, parallel improvements that accumulate without meaningful amplification. The Common High-Level Structure shared by ISO 9001, ISO 14001, and ISO 45001 reduces administrative redundancy when certifications are co-managed, documentation frameworks, PDCA cycles, and management review requirements can be partially consolidated, but performance gains in each dimension remain functionally autonomous. Addition is the baseline interaction regime: it reflects organizational maturity sufficient to manage multiple certifications concurrently without capturing their systemic interdependencies.

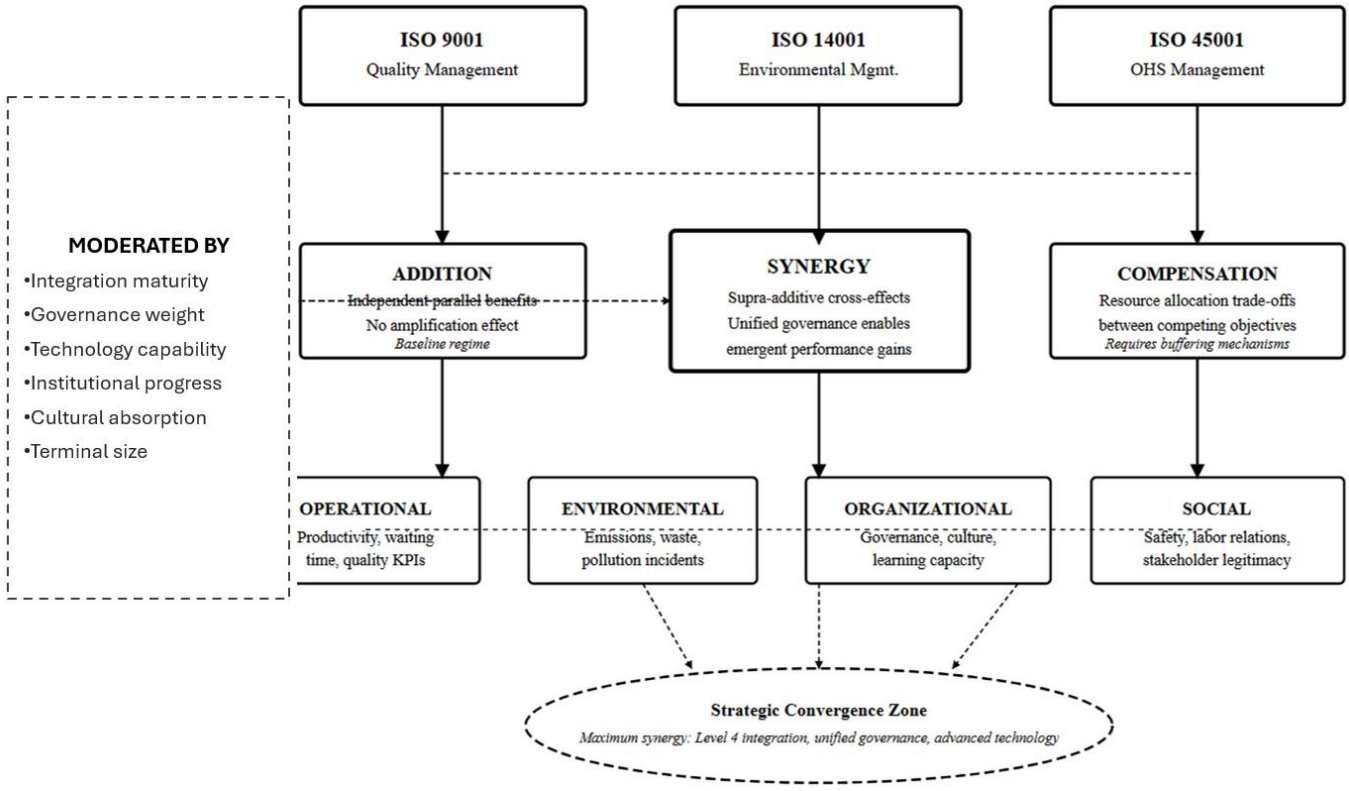
Synergy effects represent the most strategically significant interaction regime. Cross-system synergies emerge when the combination of certifications generates performance benefits exceeding the simple sum of their

individual contributions, supra-additive gains that the IMS literature identifies as the primary justification for integration investment [12, 15]. In port operations, synergies are most visible at performance intersections: a hazardous cargo incident is simultaneously a quality, environmental, and safety event, and an organization with genuinely integrated management can mobilize resources from all three frameworks in a coordinated response that outperforms any single-certification approach. Shared audit programs, consolidated performance dashboards, and cross-functional training are the organizational mechanisms through which synergies are actualized in practice.

Compensation effects arise when the simultaneous pursuit of quality, environmental, and occupational health and safety objectives generates resource allocation trade-offs and transient performance tensions. Pressure to maximize vessel turnaround speed may conflict with environmental waste handling protocols; cargo acceleration priorities may introduce occupational safety risks that demand immediate managerial reallocation. These tensions are not symptoms of integration failure, they are structurally inherent to the operational complexity of port terminals and must be anticipated through organizational buffering mechanisms: multi-criteria prioritization tools, cross-functional process redesign, and governance structures that weight all three performance dimensions in real time.

Figure 4 presents the integrated conceptual model, positioning the three interaction regimes within a four-dimensional performance space, operational, environmental, organizational, and social, and mapping the moderating factors that shape regime activation. The strategic convergence zone at the model's center designates the configuration space where synergies reach maximum intensity: high integration maturity, unified governance, advanced technology, and deep organizational appropriation of normative frameworks.

Figure 4. Integrated Conceptual Model of ISO 9001, ISO 14001 and ISO 45001 Cross-Effects on Port Terminal Performance.



5.2.2. Explanatory and Moderating Factors

The interaction regime prevailing in any given port terminal is determined not by the certifications themselves but by a set of structural and contextual factors that configure the organizational conditions under which integration unfolds [2, 12].

Note on Figure 5: The interaction intensity ratings presented in Figure 5 are analytical approximations derived from cross-referencing the IMS empirical literature with the contextual profiles of Moroccan port terminals described in Section 4. They are conceptual reference values, not primary field measurements, and are subject to empirical validation through the future fieldwork described in Section 2.

The **degree of IMS integration**, the primary explanatory factor, determines the structural conditions under which cross-effects can emerge. Bernardo et al.'s [2] four-level scale (Correspondence → Coordination → Integration → Optimization) maps a progression of integration depth that directly correlates with synergy potential: terminals at Correspondence level are structurally incapable of generating genuine synergy effects, while Optimization-level organizations have built the organizational architecture necessary for trans-system performance amplification.

Governance structure functions as the most influential moderating factor. Terminals with cross-functional governance mechanisms, where quality, environmental, and occupational health and safety management are coordinated through integrative committee structures or unified management offices rather than siloed departments, exhibit markedly stronger cross-effects across all performance dimensions. Fragmented governance, conversely, creates structural barriers to cross-system information flows that suppress synergy potential regardless of certification maturity [10].

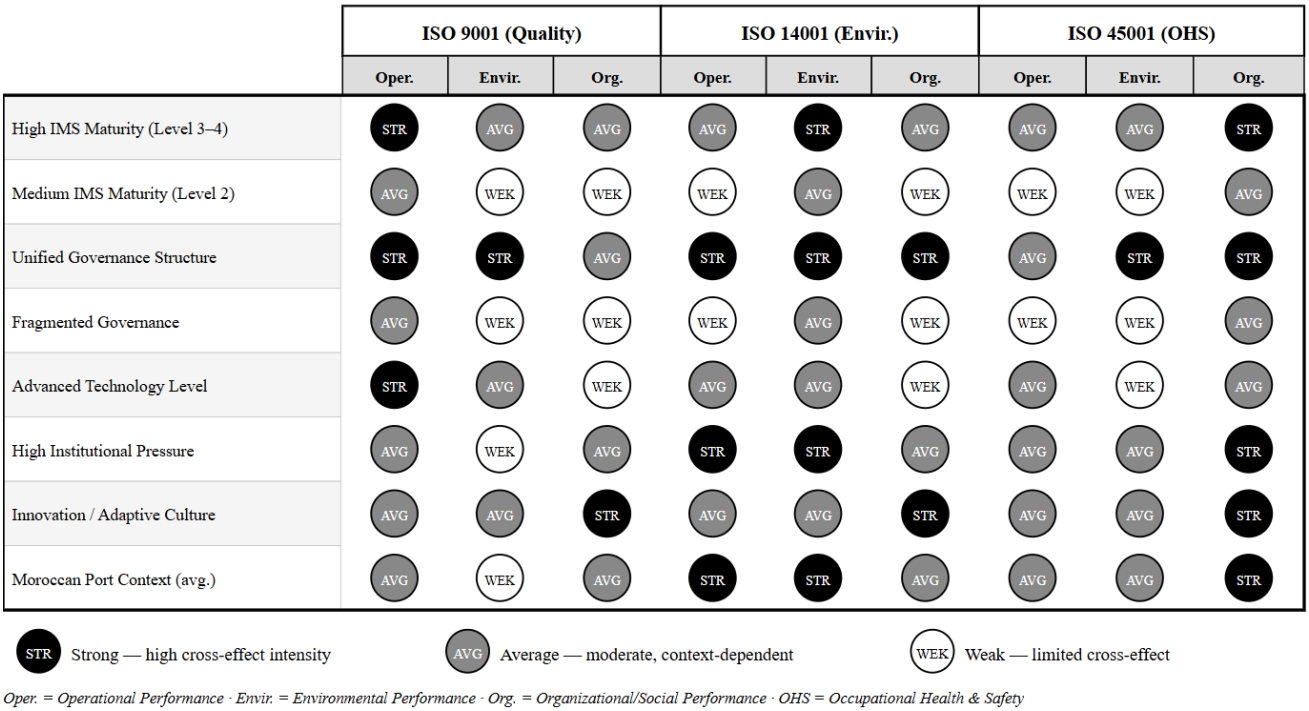
Technological maturity constitutes a second critical moderator. Terminals equipped with port community systems, automated performance tracking, and digital audit management platforms can identify cross-system performance data in real time and support adaptive management of trade-offs between interaction regimes. Less technically advanced organizations tend to administer each standard's requirements through separate administrative channels, limiting the cross-system visibility that synergy activation requires.

Institutional pressure and **cultural absorption capacity** complete the moderating architecture. Institutional pressure, whether coercive (ANP regulatory requirements), normative (industry professional standards and international association membership), or mimetic (Tanger Med's integration model as an observable benchmark for other Moroccan terminals), shapes the pace and depth of certification adoption throughout the national port system. Cultural absorption capacity, as theorized in the neo-institutional framework [19], refers to the organizational ability to transform international normative frameworks into authentic managerial routines embedded in everyday practice, rather than maintaining them as formal compliance facades. Sebbah and Boulahdour [20] document this distinction in the Moroccan port sector; its implications for synergy intensity are addressed directly in Research Proposition 5.

Table 3. Explanatory and Moderating Factors of ISO Cross-Certification Effects

Factor Type	Factor	Description and Operational Meaning	Key Reference
Explanatory Factor	Degree of IMS Integration	The primary structural determinant of cross-effect potential. Bernardo et al. distinguish four levels of integration (Correspondence, Coordination, Integration, Optimization) that progressively enable more intense cross-system interactions. Terminals at higher integration levels have unified audit procedures, consolidated KPI dashboards, and cross-functional management routines that create the organizational infrastructure necessary for synergy effects.	[2]
Moderating Factor	System Maturity	Mature systems, characterized by multi-year implementation experience and deep organizational appropriation, exhibit stronger cross-effects because procedures are genuinely embedded in operational routines rather than maintained as formal compliance artifacts. Maturity enables predictive rather than reactive cross-system management.	[2, 12]
Moderating Factor	Organizational Governance	Integrated governance structures, where quality, environmental, and OHS management are coordinated through unified committee structures or a single integrative management office, exhibit significantly stronger cross-effects. Fragmented governance creates structural barriers to cross-system information flows that suppress synergy potential regardless of certification maturity.	[10, 15]
Moderating Factor	Terminal Size	Large terminals benefit from economies of scale in integration, shared documentation systems, unified audit teams, consolidated training, but face greater challenges in sustaining organizational coherence across functionally complex operations. Smaller specialized terminals may achieve comparable integration intensity with fewer resources when governance is centralized.	[2, 14]
Moderating Factor	Technological Capability	Technologically advanced terminals equipped with port community systems, automated KPI tracking, and digital audit management platforms can identify and respond to cross-system performance data in real time, enabling adaptive management of interaction regimes. Less digitally integrated organizations tend to administer each standard's requirements through separate administrative channels.	[11, 14]
Moderating Factor	Institutional Pressures	The combination of coercive pressures (ANP regulatory requirements), normative pressures (professional standards, international association membership), and mimetic pressures (imitation of high-performing terminals such as Tanger Med) shapes both the pace of certification adoption and the depth of organizational appropriation. High institutional pressure can accelerate adoption without guaranteeing genuine integration.	[19, 20]

Figure 5. Analytical Matrix of ISO Cross-Certification Interaction Intensities.



5.3. Research Propositions

The conceptual model yields six research propositions that collectively define the empirical research agenda for subsequent fieldwork in Moroccan port terminals. Each proposition addresses a specific moderating relationship identified in Section 5.2.2 and connects the theoretical framework to testable empirical hypotheses.

Proposition 1. Higher IMS integration maturity, measured according to Bernardo et al.'s [2] four-level Correspondence-to-Optimization scale, increases the probability that synergy effects will dominate over additive or compensatory interaction regimes in ISO 9001, ISO 14001, and ISO 45001 co-deployment contexts within port terminal organizations.

Proposition 2. Fragmented governance structures, operationalized as the organizational separation of quality, environmental, and occupational health and safety management functions across distinct administrative units, increase the likelihood of compensatory interaction effects and reduce the intensity of synergistic cross-impacts on overall port performance.

Proposition 3. Technological capability, operationalized as the degree of digital integration of management information systems across quality, environmental, and occupational health and safety functions, positively moderates the intensity of cross-certification effects by enabling real-time cross-system performance visibility and adaptive resource allocation.

Proposition 4. Institutional pressure, whether primarily coercive, normative, or mimetic in its operative form, positively influences the adoption of ISO certifications in Moroccan port terminals; however, the performance consequences of adoption are contingent on the degree of local organizational appropriation of the adopted standards, rather than on formal certification status alone.

Proposition 5. Port terminals with higher cultural absorption capacity, defined as the organizational ability to transform international normative frameworks into embedded, operationally authentic managerial routines, achieve significantly more intense synergy effects from integrated ISO certification strategies than terminals where certifications remain primarily formal compliance instruments.

Proposition 6. Terminal size moderates the relationship between IMS integration maturity and port performance: large terminals benefit from economies of scale in integration but face greater challenges in sustaining organizational coherence across functionally differentiated operations, while smaller, specialized terminals may achieve comparable integration intensity with fewer resource commitments when governance is unified and operational scope is tightly bounded.

5.4. Theoretical and Managerial Implications

From a theoretical standpoint, this work advances the IMS literature in three substantive respects. First, it extends an empirical corpus that has been predominantly European in its institutional grounding toward a North African regulatory and organizational context, one characterized by a distinctive combination of rapid normative modernization, institutional plurality, and heterogeneous organizational capability. The

finding that the addition-synergy-compensation typology retains analytical purchase in this setting, albeit with context-specific moderating conditions, suggests that the framework carries transferable validity beyond its original European formulation.

Second, the systematic treatment of compensation effects as an analytically distinct interaction regime, rather than a failure state to be minimized, opens productive conceptual space for examining the conditions under which organizational trade-offs are managed, mitigated, or instrumentalized as diagnostic signals of integration challenges requiring governance attention. The IMS literature has historically privileged synergy dynamics; a more complete analytical picture requires accounting for the full distribution of interaction outcomes.

Third, the theoretical triangulation between RBV, stakeholder theory, and neo-institutionalism generates a multi-layered causal account of cross-certification dynamics that no single framework can independently provide. Their convergence is not an additive superposition of independent perspectives but a genuinely integrated reading of the same organizational phenomenon from three complementary epistemological vantage points.

On the managerial side, the decision framework synthesized in Figure 6 provides port operators with a structured analytical tool for selecting integration pathways suited to their organizational context. The framework differentiates between sequenced, simultaneous, and hybrid integration trajectories, mapped against the terminal's governance maturity, technology level, certification history, and operational load profile. Casablanca's sequential approach reflects a prudent response to institutional inertia and organizational learning constraints; it minimizes disruption risk but delays synergy emergence. Tanger Med's purpose-built simultaneous integration represents the upper bound achievable when institutional and technological preconditions are favorable. Terminals in intermediate positions, Jorf Lasfar, Mohammedia, Safi, might consider hybrid approaches that sequence the most procedurally demanding integration steps while pursuing cross-system procedural harmonization in parallel, balancing organizational learning requirements against the opportunity cost of delayed synergy activation.

The documentation rationalization benefits associated with IMS integration, estimated in the empirical literature at between 20% and 35% through process pooling and administrative consolidation [15], represent a concrete and monetizable argument for integration investment that can be presented to governing boards and port authority stakeholders in terms aligned with their financial oversight responsibilities.

Figure 6. Decision Tree for Strategic ISO Integration Pathway Selection in Port Terminals.

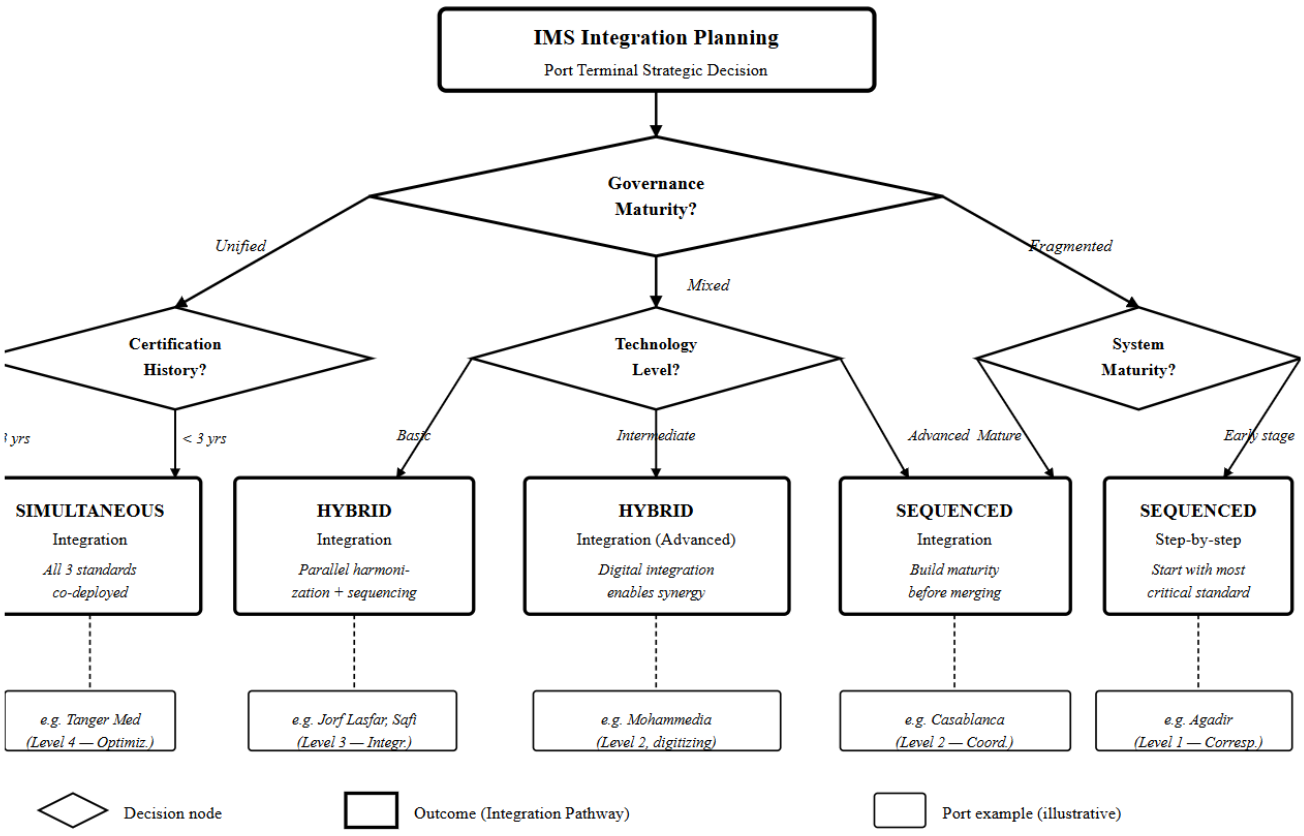


Table 4. Analytical Matrix of ISO Cross-Certification Interaction Intensities by Contextual Factor

Contextual Factor	ISO 9001 (Quality)			ISO 14001 (Environment)			ISO 45001 (OHS)		
	Op.	Env.	Org.	Op.	Env.	Org.	Op.	Env.	Org.
High Integration Maturity (Level 3–4)	STRONG	AVERAGE	AVERAGE	AVERAGE	STRONG	AVERAGE	AVERAGE	AVERAGE	STRONG
Medium Integration Maturity (Level 2)	AVERAGE	WEAK	WEAK	WEAK	AVERAGE	WEAK	WEAK	WEAK	AVERAGE
Unified Governance Structure	STRONG	STRONG	AVERAGE	STRONG	STRONG	STRONG	AVERAGE	STRONG	STRONG
Fragmented Governance Structure	AVERAGE	WEAK	WEAK	WEAK	AVERAGE	WEAK	WEAK	WEAK	AVERAGE
Advanced Technology (High Automation)	STRONG	AVERAGE	WEAK	AVERAGE	AVERAGE	WEAK	AVERAGE	WEAK	AVERAGE
Large Terminal Size (>20 M TEU equiv.)	STRONG	AVERAGE	AVERAGE	AVERAGE	STRONG	AVERAGE	AVERAGE	AVERAGE	STRONG
Innovation Culture (High Adaptability)	AVERAGE	AVERAGE	STRONG	AVERAGE	AVERAGE	STRONG	AVERAGE	AVERAGE	STRONG
High Institutional Pressure	AVERAGE	WEAK	AVERAGE	STRONG	STRONG	AVERAGE	AVERAGE	AVERAGE	STRONG
Moroccan Institutional Context	AVERAGE	WEAK	AVERAGE	STRONG	STRONG	AVERAGE	AVERAGE	AVERAGE	STRONG

Interaction Intensity Ratings: STRONG = high cross-effect intensity; AVERAGE = moderate, context-dependent; WEAK = limited or negligible cross-effect. Op. = Operational Performance; Env. = Environmental Performance; Org. = Organizational/Social Performance. OHS = Occupational Health and Safety. Note: Interaction intensity ratings are analytical approximations derived from cross-referencing the IMS empirical literature with Moroccan port terminal contextual profiles. Source: Authors' elaboration, inspired by López-Fresno [12], Bernardo et al. [2], Santos et al. [18], and Gianni et al. [10].

6. Conclusion

This article has proposed an integrated conceptual model of the cross-impacts of ISO 9001, ISO 14001, and ISO 45001 certifications on port terminal performance. Three analytically distinct interaction regimes, addition, synergy, and compensation, are organized within a four-dimensional performance framework encompassing operational, environmental, organizational, and social dimensions. Six moderating factors, integration maturity, governance structure, technological capability, institutional pressure, and cultural absorption capacity, are identified as the primary determinants of regime activation in a given organizational and institutional context.

The study's principal theoretical contribution lies in its synthesis of three complementary frameworks, the Resource-Based View, stakeholder theory, and neo-institutionalism, into a coherent cross-certification analytical architecture, applied to a port sector and institutional context that remain underrepresented in the IMS literature. The Moroccan port system provides a nationally coherent but internally heterogeneous validation setting: from Tanger Med's Optimization-level integration to Agadir's Correspondence-level configuration, the national port landscape embodies the full range of integration trajectories that the model theorizes.

Several limitations of the present study must be clearly acknowledged. As a conceptual modeling contribution, it reports no primary field data; the quantitative benchmarks drawn from the literature to illustrate performance dimensions are indicative and have not been validated against Moroccan port

conditions. The integration level classifications attributed to Moroccan terminals in Table 1, while grounded in secondary source compilation, represent analytical approximations that require primary fieldwork verification. The theoretical triangulation, while analytically productive, involves depth-of-engagement trade-offs with each individual framework that focused single-theory studies avoid.

Future research should move toward empirical validation of the six propositions derived from the model. A multi-site mixed-methods study, combining structured questionnaire surveys targeting quality, environmental, and occupational health and safety managers across the ANP port network with in-depth case studies at Casablanca and Tanger Med, would provide the comparative depth needed to test the moderating hypotheses. Longitudinal data collection, tracking cross-certification effects as integration matures over time, would enable causal inference that cross-sectional designs cannot support. Extensions toward the West African port context, where ISO certification adoption is accelerating under combined pressures from infrastructure investment programs, European trade agreements, and continental logistics integration imperatives, would assess the model's geographic transferability and contribute to a genuinely African body of IMS theory.

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