



*Research article*

## **Performance measurement and digitalization: Evidence from shipping companies**

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**Abstract:** In this study, we examined whether organizational maturity influences the adoption of modern performance measurement tools and digital performance management systems, as well as the perceived effectiveness of traditional financial ratios, in the shipping industry. Grounded in the Technology-Organization-Environment (TOE) framework and complemented by institutional and contingency perspectives, we assessed whether structural longevity drives modernization in performance infrastructures. Using survey-based evidence from 164 Greek shipping management firms, we estimated logistic models for adoption outcomes and OLS and ordered logit models for evaluative perceptions, supported by robustness checks and diagnostics. The findings indicated that organizational maturity, operationalized as years of operation, is negatively associated with the adoption of modern performance tools and digital systems, but shows no statistically significant relationship with the perceived effectiveness of traditional financial ratios. These results challenge the assumption that experience and historical presence inherently foster technological advancement. Instead, maturity appears to reflect institutional embeddedness and structural stability rather than readiness for innovation. By distinguishing structural longevity from adaptive capacity, we refine the organizational dimension of the TOE framework. Moreover, our work contributes to a more nuanced understanding of modernization trajectories in capital-intensive, institutionally embedded industries. The results further suggest that adoption behavior and evaluative practices may evolve asymmetrically, with implications for theory development and managerial strategies to upgrade performance management infrastructures.

**Keywords:** performance measurement; digitalization; shipping industry; technology-organization-environment; organizational maturity

**JEL Codes:** P47, L25, F

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## 1. Introduction

Shipping accounts for approximately 90% of global trade by volume and operates within one of the most capital-intensive and cyclically volatile sectors of the global economy. Successive disruptions over the past two decades, including the global financial crisis, the COVID-19 pandemic, and renewed geopolitical tensions, have intensified financial exposure and heightened strategic uncertainty. According to the United Nations Conference on Trade and Development (UNCTAD, 2025), maritime trade continues to expand despite recurrent shocks, yet growth patterns remain increasingly sensitive to macroeconomic and geopolitical instability. In such an environment, the capacity of firms to monitor performance, safeguard liquidity, and align strategic decisions with market conditions becomes structurally critical.

Performance measurement systems constitute a central mechanism through which shipping firms address these pressures. Traditional tools, particularly financial ratios and budgetary controls, remain deeply embedded in the sector, reflecting its reliance on debt financing and asset-based evaluation (Yang et al., 2022). Furthermore, modern performance frameworks and digital systems, including key performance indicators (KPIs), enterprise resource planning (ERP), and business intelligence (BI) platforms, promise greater integration, real-time oversight, and improved strategic coordination. Research highlights the accelerating role of digital transformation across maritime operations and shipping networks (Lambrou et al., 2019; Min, 2022; Yuen et al., 2024), while industry evidence underscores the growing strategic importance of digitalization, data interoperability, and sustainability reporting in global shipping markets (UNCTAD, 2024). Whether such modernization progresses systematically across firms, however, remains an open empirical and theoretical question.

To examine this issue, we adopt the Technology–Organization–Environment (TOE) framework as its primary theoretical lens (Tornatzky & Fleischer, 1990). TOE posits that organizational characteristics, including size and accumulated experience, influence innovation adoption by shaping resource availability and absorptive capacity. Furthermore, governance structures serve as contextual conditions that affect decision-making processes. From this standpoint, organizational maturity should facilitate the implementation of advanced performance and digital systems; Yet, this expectation may not hold in institutionally embedded and risk-intensive industries. Institutional theory suggests that maturity can reinforce established routines and path dependence, thereby constraining managerial change (Scott, 2014). In parallel, contingency theory emphasizes that the effectiveness of managerial systems depends on the alignment with environmental conditions; in highly volatile markets, firms may prioritize stability and risk containment over structural transformation (Donaldson, 2001). Together, these complementary perspectives introduce countervailing mechanisms that may attenuate, or even reverse, the positive relationship predicted by TOE.

This theoretical tension is particularly salient in the Greek shipping sector. Greece is one of the world's leading ship-owning nations; yet, concentrated ownership structures, strong family

governance traditions, and prolonged exposure to macroeconomic crises characterize its maritime cluster. While researchers have examined capital structure dynamics in shipping (Yang et al., 2022) and digital transformation in container lines (Yuen et al., 2024), limited empirical evidence exists regarding how organizational maturity interacts with performance measurement practices within family-dominated maritime contexts.

While Greece is one of the world's leading ship-owning nations, we do not treat the Greek shipping sector as statistically representative of global shipping firms. Instead, it is positioned as a theoretically salient institutional context characterized by concentrated ownership and historically embedded managerial practices. The findings contribute primarily to analytical generalization grounded in theory rather than to universal statistical generalization.

In this study, we investigate whether organizational maturity, defined as structural longevity proxied by firm age, influences the adoption of modern performance measurement tools and digital systems in Greek shipping companies. We also evaluate executives' perceived effectiveness of traditional financial ratios, thereby distinguishing adoption behavior and evaluative assessment. By positioning TOE as the dominant explanatory framework while incorporating institutional and contingency mechanisms as contextual constraints, we assess whether maturity-driven resource advantages translate into modernization or whether structural conservatism prevails.

Drawing on survey data from 164 Greek shipping management firms and employing multivariate regression techniques with robustness checks, the empirical analysis does not indicate a systematic positive association between organizational maturity and the adoption of modern tools or digital systems. Furthermore, financial ratios remain nearly universally used despite only moderate perceived effectiveness. These patterns suggest that accumulated organizational experience does not automatically lead to managerial modernization in capital-intensive, uncertainty-driven industries.

The study contributes to the literature in three interrelated ways. First, we refine the organizational dimension of the Technology-Organization-Environment framework by demonstrating that structural longevity does not uniformly enhance the adoption of innovation. By distinguishing organizational maturity as structural accumulation from adaptive readiness, the findings identify boundary conditions under which maturity may reinforce institutional stability rather than modernization. Second, we extend maritime management research by providing systematic, theory-driven empirical evidence on the interaction between organizational structure and the digitalization of performance systems within a capital-intensive, institutionally embedded industry. Third, it contributes to management accounting and digital transformation scholarship by showing that adoption behavior and evaluative perceptions may evolve asymmetrically, thereby challenging linear assumptions that organizational development automatically leads to technological upgrading.

In doing so, the study moves beyond descriptive accounts of digitalization in shipping and offers a theoretically grounded examination of how organizational structure conditions modernization trajectories. The remainder of the paper proceeds as follows: In Section 2, we develop the theoretical framework and hypotheses. In Section 3, we outline the methodology and data. In Section 4, we present the empirical results. In Section 5, we discuss the findings, and in Section 6, we conclude the paper.

## 2. Theory and hypothesis development

### 2.1. *The technology-organization-environment framework and innovation adoption*

The adoption of managerial and digital innovations at the firm level has been extensively examined through the Technology-Organization-Environment (TOE) framework (Tornatzky & Fleischer, 1990). TOE posits that innovation adoption is shaped by three interrelated dimensions: The technological characteristics of the innovation, the organizational attributes of the adopting firm, and the environmental conditions surrounding the organization. Unlike purely technological diffusion models, TOE explicitly recognizes that adoption decisions are embedded in organizational structure and resource configurations.

Within the organizational dimension, firm size, accumulated experience, managerial capabilities, and governance context influence the likelihood of adopting new systems by shaping resource availability, absorptive capacity, and decision-making processes (Oliveira & Martins, 2011). Larger and more mature firms are theorized to possess greater financial slack, formalized procedures, and specialized managerial expertise, thereby reducing implementation risk and facilitating the integration of complex performance management systems.

Organizational maturity is conceptualized here as structural longevity; the accumulation of routines, coordination mechanisms, and embedded evaluation practices developed over time. Maturity may operate through several mechanisms. First, structural formalization increases administrative coordination capacity, enabling cross-functional integration required for sophisticated performance infrastructures. Second, accumulated experience enhances absorptive capacity, enabling organizations to evaluate and implement complex managerial innovations more effectively. Third, longevity often generates reputational stability and resource slack, reducing perceived implementation risk. Through these mechanisms, maturity is theorized to enhance structural readiness for technological and managerial modernization.

However, institutional theory introduces a countervailing logic. As organizations age, they may become more deeply embedded in historically validated routines and legitimacy-seeking practices (Scott, 2014). Established evaluation systems can acquire institutional stability, reducing incentives for experimentation. In sectors characterized by concentrated ownership and tradition-oriented governance, longevity may reinforce continuity rather than transformation.

Contingency theory further suggests that organizational effectiveness depends on alignment between structure and environmental uncertainty (Donaldson, 2001). In highly volatile and capital-intensive industries such as shipping, firms may prioritize stability and liquidity management over disruptive system redesign. Thus, although TOE predicts a positive association between maturity and adoption, institutional embeddedness and environmental volatility introduce a theoretical tension that motivates empirical examination.

### 2.2. *Institutional embeddedness and organizational inertia*

While the TOE framework emphasizes resource availability and structural capacity as drivers of innovation adoption, institutional theory highlights the constraining influence of embedded norms, routines, and governance structures. Organizations do not operate solely as rational adopters of

efficiency-enhancing systems; they are also shaped by historically developed practices, legitimacy concerns, and path-dependent decision-making processes (Scott, 2014).

From an institutional perspective, organizational maturity may not uniformly promote innovation. As firms accumulate experience and develop more formalized administrative processes, they may also develop entrenched routines and established evaluation practices. These routines can generate stability and coordination benefits, but they may simultaneously reduce openness to managerial experimentation. Mature organizations often rely on historically validated systems that have proven effective under prior market conditions, thereby reinforcing continuity rather than transformation.

This dynamic is particularly relevant in sectors characterized by concentrated ownership and long-standing industry conventions. In family-dominated or closely held firms, strategic decision-making may be influenced by intergenerational continuity, reputational considerations, and informal coordination mechanisms. Such features can strengthen organizational cohesion, though they may also limit the perceived need to adopt externally developed performance frameworks or digital infrastructures. In this sense, maturity may be associated not only with structural capacity but also with institutional inertia.

Evidence from maritime research indicates that governance traditions and industry norms shape managerial choices and innovation trajectories. Studies of digital transformation in shipping suggest that internal resistance, organizational culture, and legacy systems can moderate the uptake of new technologies (Yuen et al., 2024). These findings underscore that innovation adoption is not determined solely by resource endowment but is also shaped by institutionalized patterns of behavior.

Accordingly, although organizational maturity may enhance absorptive capacity from a TOE standpoint, institutional embeddedness introduces a countervailing mechanism. Accumulated experience can reinforce established routines and legitimacy-seeking behavior, potentially constraining the adoption of novel performance measurement systems and digital tools. In the next section, we further consider how environmental volatility interacts with these organizational dynamics.

### *2.3 Environmental volatility and contingency constraints*

While the TOE framework emphasizes internal organizational capacity as a determinant of innovation adoption, contingency theory highlights the importance of alignment between managerial systems and environmental conditions. According to contingency logic, organizational effectiveness depends on the fit between structural arrangements and external uncertainty (Donaldson, 2001). In highly volatile industries, firms may prioritize stability, flexibility, and short-term risk containment over structural transformation.

The shipping industry provides a salient context of environmental turbulence. Freight rate fluctuations, cyclical demand patterns, geopolitical disruptions, and the capital-intensive financing structures typical of shipping firms expose organizations to persistent financial and strategic uncertainty (Yang et al., 2022). Under such conditions, managerial attention may shift toward liquidity management and operational resilience rather than long-term system redesign. The implementation of sophisticated digital infrastructures and modern performance frameworks often requires substantial coordination, upfront investment, and organizational disruption; conditions that may be perceived as risky in unstable environments.

Research underscores the systemic complexity of digital transformation in maritime ecosystems. Digitalization at the ship-port interface involves inter-organizational coordination, technological

interoperability, and evolving sustainability requirements (Del Giudice et al., 2022). Such complexity suggests that adoption decisions are shaped not only by internal readiness but also by environmental interdependencies and uncertainty. In contexts characterized by high volatility and capital constraints, firms may adopt a cautious approach toward large-scale digital or performance management transformations.

Accordingly, although organizational maturity may enhance structural capacity, environmental volatility introduces a contextual constraint. Mature firms operating in turbulent markets may rely on established routines and proven evaluation systems to maintain stability, rather than pursuing comprehensive modernization initiatives. Contingency theory suggests that the relationship between maturity and innovation adoption is conditional on environmental uncertainty.

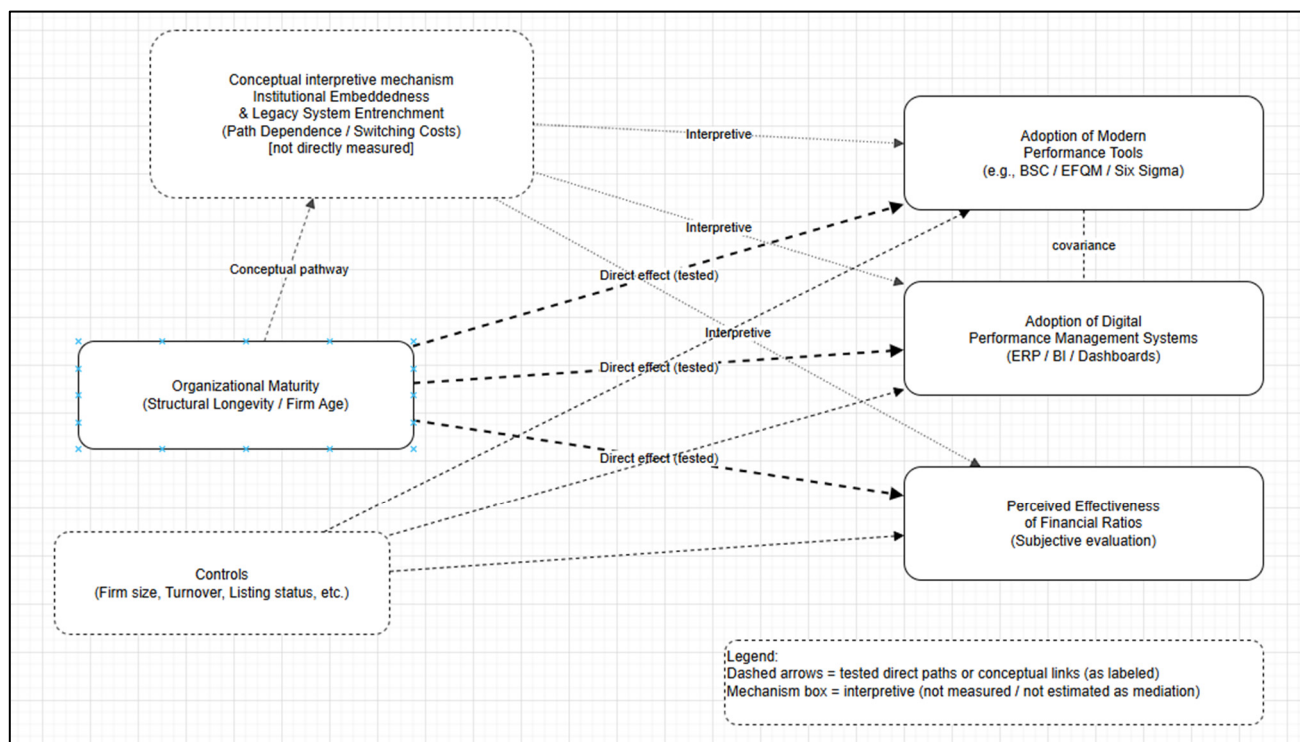
Moreover, maritime research increasingly situates digital transformation within broader dynamics of competitiveness and sustainability. Studies on shipping network optimization, operator competitiveness, and port integration highlight how digital infrastructures and data-driven coordination mechanisms reshape strategic positioning in global freight markets (Yu et al., 2025; Yu et al., 2024). Additional contributions further emphasize the strategic integration of digital analytics and sustainability reporting in maritime performance management (Gavalas et al., 2022; Min, 2022). While this literature centers on technological capability and market performance outcomes, comparatively less attention is devoted to how internal organizational characteristics condition firm-level adoption decisions. This study complements these perspectives by focusing on the structural and institutional determinants of modernization within shipping firms.

In the next section, we integrate these TOE-based expectations with institutional and contingency mechanisms to formally develop our hypotheses.

#### *2.4. Hypothesis development*

In the preceding sections, we developed a theoretically grounded tension. The TOE framework posits that organizational maturity enhances the adoption of innovation by increasing structural capacity, resource availability, and absorptive readiness. In contrast, institutional embeddedness and environmental volatility introduce countervailing forces that may reinforce stability-oriented behavior and constrain transformation. Building on this interplay, the following hypotheses are derived.

To clarify the underlying causal logic, it is necessary to specify the mechanisms by which organizational maturity may influence the adoption of performance infrastructure. Within the organizational dimension of TOE, maturity reflects the cumulative development of routines, administrative formalization, and coordination structures over time. These characteristics may operate through three major mechanisms. First, formalization enhances cross-functional coordination capacity, which is essential for implementing integrated performance systems. Second, accumulated experience strengthens absorptive capacity, enabling firms to evaluate and integrate complex managerial innovations more effectively. Third, organizational longevity may generate reputational stability and resource slack, thereby reducing perceived implementation risk associated with technological upgrading. Through these mechanisms, maturity may increase the likelihood of adopting modern performance infrastructures.



**Figure 1.** Conceptual SEM-style path model of organizational maturity and performance-system outcomes.

The model summarizes the hypothesized relationships between structural longevity and (i) adoption of modern performance tools, (ii) adoption of digital performance management systems, and (iii) perceived effectiveness of financial ratios. The mechanism box reflects the interpretive logic discussed in the text and does not imply formal mediation estimation. Dashed arrows denote tested direct effects and control-variable paths.

Note: The figure is conceptual and is provided to clarify theoretical directionality. The empirical analysis relies on multivariate regression models rather than structural equation modeling.

From a TOE perspective, mature firms may therefore possess accumulated resources and managerial expertise that facilitate the implementation of sophisticated performance measurement systems. Modern frameworks such as structured KPI systems and integrated performance dashboards require cross-functional coordination and sustained managerial commitment; attributes typically associated with more developed organizational structures. Furthermore, institutional theory suggests that as firms accumulate experience, they may rely more heavily on established routines and historically validated evaluation practices. In tradition-oriented, closely held sectors, long-standing managerial conventions can reduce the perceived need to adopt externally developed performance frameworks. Environmental volatility may further reinforce risk-averse behavior, shifting attention toward continuity rather than systemic redesign. Nevertheless, under the TOE framework's organizational dimension, structural capacity remains the dominant explanatory mechanism. Accordingly:

**H1a:** Organizational maturity is positively associated with the adoption of modern performance measurement tools.

Digital performance management systems, including ERP and business intelligence platforms, represent more technologically intensive forms of innovation. Their implementation typically requires financial investment, technical integration, and formalized decision-making processes. Therefore,

TOE predicts that firms with greater maturity are better positioned to adopt such systems due to accumulated experience and structural readiness. However, the presence of legacy infrastructure and institutionalized routines may dampen the incentive to pursue disruptive digital transformation, particularly in volatile environments where large-scale change is perceived as risky. Despite these countervailing dynamics, the primary theoretical expectation derived from TOE remains positive. Therefore:

**H1b:** Organizational maturity is positively associated with the adoption of digital performance management systems.

Organizational maturity may also influence how traditional financial indicators are evaluated. In capital-intensive industries, financial ratios play a central role in monitoring liquidity, leverage, and operational performance. From a TOE standpoint, accumulated experience may enhance analytical sophistication and interpretive capability, enabling more confident evaluation and utilization of established financial metrics. Conversely, institutional theory suggests that reliance on traditional financial measures may reflect path dependence rather than superior evaluative capacity; familiarity and historical validation can shape perceptions of effectiveness independently of objective performance outcomes. Balancing these perspectives, the dominant TOE-based expectation remains that maturity enhances evaluative capability. Accordingly:

**H2:** Organizational maturity is positively associated with the perceived effectiveness of traditional financial ratios.

Finally, organizational maturity may shape the relative orientation toward modern versus traditional performance systems. Under TOE logic, greater structural capacity should facilitate a shift toward integrated and digitally enabled performance architectures. Yet, institutional embeddedness and environmental uncertainty may reinforce continuity with established evaluation mechanisms. While these mechanisms introduce ambiguity, the TOE framework predicts that structural readiness supports modernization. Thus:

**H3:** Organizational maturity is positively associated with a greater relative orientation toward modern performance measurement and digital systems compared to traditional tools.

### 3. Materials and methods

#### 3.1. Research design and context

We employ a cross-sectional survey research design to examine whether organizational maturity influences (i) the adoption of modern performance measurement tools, (ii) the adoption of digital performance management systems, and (iii) executives' perceived effectiveness of traditional financial ratios in shipping firms. A survey approach is appropriate, given that several key constructs in this study, particularly tool adoption and perceived effectiveness, reflect internal managerial practices and judgments that are not consistently observable in archival sources within privately held shipping organizations.

The empirical setting is the Greek shipping sector. Greece constitutes a globally significant shipowning cluster and provides a theoretically salient context for studying adoption behavior under capital intensity and market turbulence. This setting aligns with the study's dominant TOE lens by enabling analysis of how organizational attributes (maturity and structural characteristics) relate to the uptake of managerial and digital innovations while enabling consideration of the institutional and environmental constraints developed in Section 2.

Although the empirical setting is nationally bounded, Greek shipping firms operate in global freight markets and face international competitive pressures. Nevertheless, governance traditions and ownership concentration specific to this maritime cluster may shape managerial practices. We adopt a contextualized analytical approach, focusing on theory testing within a distinctive institutional configuration rather than claiming statistical generalizability. Data are collected through a structured questionnaire administered to shipping management companies operating in Greece. The instrument is designed to capture firm characteristics, the adoption of performance measurement tools and digital systems, and perceived effectiveness ratings of financial ratios. The survey-based design supports our objective of testing the theoretically derived hypotheses by ensuring consistent measurement across firms and enabling multivariate analysis that controls for key organizational features.

### *3.2. Sample and data collection*

The target population comprised Greek shipping management companies listed in the Skolarikos Maritime Bureau Database (Skolarikos, 2020), which initially identified 764 firms. After excluding 213 firms due to invalid or incomplete electronic contact information, the final sampling frame consisted of 551 companies. The questionnaire was distributed electronically between February and April 2021.

To maximize participation, four reminder emails were sent at two-week intervals. A total of 164 valid responses were received, yielding a response rate of 29.76%. This response rate was comparable to those reported in prior maritime and shipping management surveys (Kuo et al., 2022).

Respondents were senior executives and financial managers directly involved in performance evaluation and strategic decision-making processes. The sample reflected the structural characteristics of the Greek shipping sector. Firm size was categorized according to combined guidelines from International Accounting Standards (IAS), Greek Accounting Standards (GAAP), and Directive 2013/34/EU, with fleet size as the primary criterion. The sample was dominated by very small and small firms (62.2%), followed by medium-sized (12.8%) and large firms (25.0%), consistent with the sector's structure. Descriptive statistics for firm characteristics, respondent profiles, fleet types, maturity distribution, turnover categories, and listing status are presented in Table 1.

**Table 1.** Descriptive statistics and key characteristics of the sample.

Characteristic	Category	Frequency	Percentage (%)
Gender	Male	156	95.4
	Female	8	4.9
Age group	16–24	5	3.0
	25–35	38	23.2
	36–45	74	45.1
	46–55	35	21.3
	>55	12	7.3
Education	Postgraduate	112	68.3
	Undergraduate	48	29.3
	Other	4	2.4
Experience (years)	1–5	18	11.0
	6–10	38	23.2
	11–15	68	41.5
	16–20	22	13.4
Position	>20	18	11.0
	CEO	33	20.1
	CFO	47	28.7
	Accounting Manager	84	51.2
	1–5	15	9.1
Firm maturity (years)	6–10	28	17.1
	11–19	32	19.5
	$\geq 20$	89	54.3
Fleet size (vessels)	1–3	20	12.2
	4–9	45	27.4
	10–24	53	32.3
	$\geq 25$	46	28.0
Employees (shore-based)	1–10	30	18.3
	11–50	62	37.8
	51–249	46	28.0
	$\geq 250$	26	15.9
Annual turnover (€ million)	$\leq 2$	25	15.2
	2–10	38	23.2
	11–49	21	12.8
Listed on the stock exchange	$\geq 50$	80	48.8
	Yes	23	14.0
	No	141	86.0

### 3.3. Variable operationalization

The study's dependent, independent, and control variables were operationalized in accordance with established practices in innovation, organizational research, and management accounting studies. Table 2 summarizes variable definitions, measurement scales, and coding schemes.

**Table 2.** Operational definitions, measurement scales, and coding of study variables.

Variable	Type	Measurement	Coding/Scale
Organizational Maturity	Independent	Firm age (years of operation), operationalized as an ordinal measure of structural longevity.	Standardized components aggregated; higher values indicate greater maturity.
Modern Performance Tools Adoption	Dependent	Use of structured KPIs and performance dashboards	Binary (1 = adoption; 0 = non-adoption)
Digital Performance Systems Adoption	Dependent	Use of ERP and/or BI systems	Binary (1 = adoption; 0 = non-adoption)
Perceived Effectiveness of Financial Ratios	Dependent	Executive assessment of effectiveness in decision-making	Ordinal scale (1–4 after exclusion of lowest category; N = 154)
Firm Size	Control	Fleet size category	Categorical
Turnover	Control	Annual turnover category	Categorical
Listing Status	Control	Publicly listed firm	Binary (1 = listed; 0 = private)
Fleet Type	Control	Dominant vessel type	Categorical

Organizational maturity served as the primary independent variable and reflected structural longevity within the organizational dimension of the Technology-Organization-Environment framework. Maturity was operationalized as firm age, measured in years of operation. Firm age captured the cumulative development of administrative routines, decision-making processes, coordination structures, and evolving embedded evaluation practices. In this sense, age functioned as a parsimonious proxy for structural accumulation and institutional embeddedness rather than merely chronological duration.

While governance configuration, ownership concentration, and capital market exposure could influence innovation orientation, these characteristics represented analytically distinct structural dimensions. To isolate the effect of structural longevity, governance-related factors such as listing status, firm size, and turnover were treated as control variables in the empirical models. This specification enabled the analysis to disentangle accumulated organizational routines from scale effects and formal market transparency pressures.

The first dependent variable captured the adoption of modern performance measurement tools. Firms were asked whether they systematically used structured performance systems, including Key Performance Indicators (KPIs), the Balanced Scorecard, Six Sigma, or the EFQM framework. A binary indicator was set to 1 if at least one of these tools was implemented, and 0 otherwise.

The second dependent variable captured the adoption of digital performance management systems, including enterprise resource planning (ERP) systems, business intelligence tools, and dashboard-based analytics platforms. This variable was coded as a binary indicator (1 = adoption; 0 = non-adoption), reflecting the presence of technologically intensive performance infrastructure. Binary coding was appropriate because the analysis concerned the structural decision to implement formalized performance systems rather than variation in usage intensity. Adoption reflected an organizational commitment to a specific performance infrastructure configuration. Robustness checks using alternative intensity specifications yielded substantively consistent results.

The third dependent variable measured executives' perceived effectiveness of traditional financial ratios in supporting managerial decision-making. Respondents evaluated effectiveness on a five-point

ordinal scale ranging from “very low” to “very high.” For analytical consistency and to ensure adequate distribution across categories, observations in the lowest category were excluded, resulting in a four-category ordinal variable.

Importantly, we did not seek to assess the objective predictive validity or the impact of financial ratios on financial performance. Rather, we examined managerial evaluative perception as an organizational construct. Within organizational theory, perceived usefulness and interpretive legitimacy were analytically separable from objective performance outcomes. By focusing on perceived effectiveness, the analysis captured the extent to which traditional financial metrics retained evaluative legitimacy in managerial decision-making, regardless of their objective forecasting accuracy.

Although ordinal, the effectiveness variable was initially analyzed using ordinary least squares (OLS) regression, consistent with common empirical practice treating Likert-type scales as approximate intervals. Ordered logit models were also estimated to confirm that inference did not depend on linearity assumptions. Regarding measurement design, we prioritized construct clarity over scale expansion. Adoption variables were concrete managerial practices directly observable within firms, reducing ambiguity in interpretation. The questionnaire items reflected widely recognized performance frameworks and digital systems in the shipping and management accounting literature, thereby supporting content validity. Given the specificity and direct observability of these constructs, multi-item factor structures were not required to capture latent dimensionality.

### 3.4. Model specification

To test the hypotheses, multivariate regression models were estimated. Given the different measurement properties of the dependent variables, distinct estimators were employed.

The adoption of modern performance measurement tools (H1a) and digital performance management systems (H1b) was modeled using binary logistic regression, as both dependent variables were dichotomous. The general logit specification is as follows:

$$\text{logit}(P(Y_i = 1)) = \beta_0 + \beta_1 \text{Maturity}_i + \sum_{k=2}^K \beta_k \text{Controls}_{k,i} + \varepsilon_i \quad (1)$$

where  $Y_i$  denotes the adoption outcome for firm  $i$ , *Maturity* represents firm age as a proxy for organizational structural longevity, and *Controls* include firm size, turnover category, listing status, and fleet type.

Hypotheses H1a and H1b were tested using separate logistic regression models with the respective adoption variable as the dependent variable.

The perceived effectiveness of traditional financial ratios (H2) was initially examined using ordinary least squares (OLS) regression. The specification is:

$$\text{Effectiveness}_i = \alpha_0 + \alpha_1 \text{Maturity}_i + \sum_{k=2}^K \alpha_k \text{Controls}_{k,i} + u_i \quad (2)$$

Although the effectiveness variable was ordinal (four categories after recoding), OLS estimation was appropriate under the common assumption that Likert-type scales approximate interval properties. As a robustness check, ordered logit models were also estimated (reported in Section 3.5).

Hypothesis H3, which concerned the relative orientation toward modern versus traditional performance systems, was evaluated through comparative interpretation of the maturity coefficients across the adoption and perceived effectiveness models.

All models included the same set of control variables to ensure comparability across specifications. Statistical significance was evaluated at conventional levels ( $p < 0.10$ ,  $p < 0.05$ , and  $p < 0.01$ ). Multicollinearity diagnostics were assessed using variance inflation factors (VIF), which remained well below conventional thresholds, indicating no multicollinearity concerns.

### 3.5. Robustness and diagnostic tests

Several diagnostic procedures were conducted to assess data quality, measurement reliability, and the robustness of the empirical findings. To evaluate potential non-response bias, early and late respondents were compared across key firm characteristics and primary study variables using independent-samples t-tests. No statistically significant differences were observed ( $p > 0.05$ ), suggesting that systematic non-response bias was unlikely to materially affect the results. Considering the survey-based design, common method bias was assessed via Harman's single-factor test. The first unrotated factor accounted for 32.6% of the total variance, below the conventional 50% threshold; thus, non-response common method variance was unlikely to be a serious concern.

Reliability of multi-item constructs was assessed using Cronbach's alpha, with all relevant scales exceeding the commonly accepted threshold of 0.70. Split-half reliability tests yielded Spearman–Brown coefficients above 0.85, while the Kuder–Richardson (KR-20) coefficient for dichotomous items was 0.65, which was considered acceptable for exploratory organizational research. Responses were collected anonymously to further mitigate social desirability bias.

Multicollinearity diagnostics were conducted using variance inflation factors (VIF), which remained well below conventional thresholds ( $VIF < 1.5$ ) across all models. To assess the stability of the findings, two additional robustness checks were performed. First, ordered logit models were estimated for the perceived effectiveness variable to account for its ordinal nature; the results were substantively consistent with the OLS estimates in direction and statistical significance. Second, an alternative maturity index based on standardized component scores was constructed and re-estimated in all models. The substantive conclusions remained unchanged, indicating that the findings were not sensitive to the operationalization of organizational maturity.

## 4. Results

In this section, we present our empirical findings. We begin with descriptive evidence on adoption patterns and perceived effectiveness, followed by multivariate analyses testing the proposed hypotheses. Robustness analyses are then reported to assess the stability of the results.

### 4.1. Descriptive evidence

Table 3 reports the adoption frequencies of traditional and modern performance tools and digital systems, as well as the distribution of perceived effectiveness ratings across the 164 sampled firms. Traditional financial ratios remain nearly universal (94.5%), while more structured traditional tools, such as budget deviation analysis (74.4%) and benchmarking (65.9%), are also prevalent. Among modern performance measurement tools, KPI systems are adopted by 68.3% of firms, whereas more advanced frameworks such as the Balanced Scorecard (24.4%), EFQM (6.1%), and Six Sigma (7.9%) exhibit considerably lower diffusion rates.

**Table 3.** Adoption frequencies of traditional and modern performance tools and digital systems, and distribution of perceived effectiveness.

Tool/System	N Yes	% Yes
<b>Traditional Performance Tools</b>		
Financial Ratios (use ≠ “none”)	155	94.5
Budget Deviation Analysis	122	74.4
Benchmarking (industry comparison)	108	65.9
<b>Modern Performance Tools</b>		
Key Performance Indicators (KPIs)	112	68.3
Balanced Scorecard	40	24.4
EFQM Excellence Model	10	6.1
Six Sigma	13	7.9
<b>Digital Systems</b>		
Excel	146	89.0
Enterprise Resource Planning (ERP)	87	53.0
Dashboards	44	26.8
Business Intelligence (BI)	31	18.9
<b>Perceived Effectiveness of Financial Ratios</b>		
High / Very High	89	54.3
Average	54	32.9
Low / Very Low	21	12.8

Notes: N = 164 for all adoption variables. Perceived effectiveness was originally measured on a five-point scale; for multivariate analysis, the lowest category (“Very Low”, N = 10) is excluded, resulting in N = 154 for regression models.

Digital systems exhibit a similar pattern of heterogeneity. While Excel-based systems are widely used (89.0%), adoption rates decline for more integrated systems such as ERP (53.0%), dashboards (26.8%), and business intelligence platforms (18.9%). These descriptive patterns suggest that although foundational digital and performance infrastructures are present in many firms, advanced formalized systems remain unevenly distributed across the sector.

Perceived effectiveness of traditional financial ratios is rated high or very high by 54.3% of respondents, with 32.9% rating it average and 12.8% rating it low or very low. For multivariate analysis, the lowest response category (N = 10) is excluded to ensure distributional balance, resulting in N = 154 observations for the effectiveness models.

As shown in Table 4, adoption patterns are disaggregated by firm size and listing status. Larger firms exhibit significantly higher adoption rates of KPI systems (80.8% vs. 62.5%,  $p = 0.031$ ) and ERP systems (65.4% vs. 47.3%,  $p = 0.047$ ), suggesting scale-related differences in formalization and digital integration. Similarly, listed firms demonstrate substantially higher adoption of KPI systems (100.0% vs. 62.3%,  $p < 0.001$ ) and ERP systems (80.8% vs. 47.8%,  $p = 0.004$ ), consistent with greater institutional exposure and reporting pressures. Differences in business intelligence and dashboard adoption are not statistically significant.

Overall, the descriptive evidence reveals substantial heterogeneity in the adoption of modern performance and digital systems, while traditional financial metrics remain broadly embedded in managerial practice. These preliminary patterns motivate the multivariate hypothesis testing that follows.

**Table 4.** Adoption rates of modern performance tools and digital systems by firm size and listing status.

Tool/System	Small/Medium Firms (n=112)	Large Firms (n=52)	Chi-square p (Size)	Non-Listed (n=138)	Listed (n=26)	Chi-square p (Listed)
KPIs	62.5% (70/112)	80.8% (42/52)	0.031	62.3% (86/138)	100.0% (26/26)	< 0.001
Balanced Scorecard	20.5% (23/112)	32.7% (17/52)	0.136	21.0% (29/138)	42.3% (11/26)	0.038
ERP	47.3% (53/112)	65.4% (34/52)	0.047	47.8% (66/138)	80.8% (21/26)	0.004
BI	16.1% (18/112)	25.0% (13/52)	0.252	18.1% (25/138)	23.1% (6/26)	0.749
Dashboards	23.2% (26/112)	34.6% (18/52)	0.179	25.4% (35/138)	34.6% (9/26)	0.462

Notes: Adoption rates are reported as percentages of firms within each category. Firm size classification follows the combined criteria of IAS, Greek GAAP, and Directive 2013/34/EU. p-values are derived from chi-square tests of independence. Statistical significance levels: \* $p < 0.10$ ; \*\* $p < 0.05$ ; \*\*\* $p < 0.01$ .

#### 4.2. Hypothesis testing

Consistent with Table 5, the logistic regression estimates examine the association between organizational maturity and (i) adoption of modern performance measurement tools and (ii) adoption of digital performance management systems.

We first tested H1a, which posits that organizational maturity is positively associated with the adoption of modern performance tools. As reported in Model 1 of Table 5, maturity is negatively associated with adoption ( $\beta = -0.660$ ,  $p = 0.003$ ; OR = 0.517), indicating that higher levels of organizational maturity are linked to lower odds of adopting modern tools, controlling for firm size, turnover, and fleet composition. Turnover exhibits a positive and significant association ( $\beta = 0.538$ ,  $p = 0.014$ ; OR = 1.712). Thus, H1a is not supported.

We next examined H1b, which predicts a positive association between organizational maturity and digital system adoption. Model 2 of Table 5 similarly shows a negative and statistically significant maturity effect ( $\beta = -0.527$ ,  $p = 0.006$ ; OR = 0.591). Turnover is marginally significant ( $p = 0.089$ ), while listing status is not statistically significant in the multivariate specification. Therefore, H1b is not supported.

To examine H2, we estimated an OLS regression model assessing the association between organizational maturity and the perceived effectiveness of traditional financial ratios (Table 6;  $N = 154$ ). The maturity coefficient is negative but statistically insignificant ( $\beta = -0.066$ ,  $p = 0.350$ ), indicating no systematic relationship between years of operation and the evaluation of traditional financial metrics. In contrast, listing status is positively and significantly associated with perceived effectiveness ( $\beta = 0.389$ ,  $p = 0.031$ ), suggesting that publicly traded firms may place greater emphasis on formal financial reporting structures. The remaining control variables do not exhibit statistically significant effects. Overall, the results provide no empirical support for H2.

To account for the ordinal nature of the dependent variable, we additionally estimate an ordered logit model, reported in Table 7. The ordered logit results confirm the OLS inference for maturity (non-significant), while listing status remains positively associated with perceived effectiveness ( $\beta = 0.994$ ,  $p = 0.028$ ; OR = 2.703).

**Table 5.** Logistic regression results examining the association between organizational maturity and adoption of modern performance measurement tools and digital performance management systems.

Predictor	Model 1: Modern tools adoption (Logit)			Model 2: Digital systems adoption (Logit)		
	Coef (SE)	p	OR	Coef (SE)	p	OR
Maturity (years-of-operation, 1–4)	−0.660 (0.221)	0.003	0.517	−0.527 (0.192)	0.006	0.591
Firm size (ordinal)	0.083 (0.206)	0.686	1.087	0.258 (0.201)	0.200	1.294
Turnover (ordinal)	0.538 (0.220)	0.014	1.712	0.364 (0.214)	0.089	1.439
Listed	—	—	—	0.921 (0.707)	0.192	2.512
Bulk present	0.002 (0.383)	0.995	1.002	−0.318 (0.371)	0.391	0.727
Tanker present	0.004 (0.421)	0.993	1.004	0.465 (0.406)	0.252	1.592
Container present	1.028 (0.829)	0.215	2.794	1.280 (0.823)	0.120	3.596

Model fit: McFadden pseudo- $R^2 = 0.117$  (Modern tools); 0.163 (Digital systems).

Notes: Logistic regression coefficients with standard errors in parentheses; OR =  $\exp(\beta)$ . Model 1 excludes listing status because of complete separation (all listed firms report adopting modern tools). Two-tailed tests; \* $p < 0.10$ ; \*\* $p < 0.05$ ; \*\*\* $p < 0.01$ .

**Table 6.** OLS regression results examining the association between organizational maturity and perceived effectiveness of traditional financial ratios.

Predictor	Coef	Robust SE (HC3)	p
Maturity (years-of-operation, 1–4)	−0.066	0.071	0.350
Firm size (ordinal)	0.021	0.059	0.714
Turnover (ordinal)	−0.038	0.089	0.666
Listed	0.389	0.180	0.031
Bulk present	0.001	0.141	0.996
Tanker present	0.048	0.139	0.728
Container present	0.157	0.186	0.398

Model fit:  $R^2 = 0.051$

Notes: OLS coefficients with HC3 robust standard errors in parentheses.  $N = 154$  after excluding the lowest response category. Two-tailed tests; \* $p < 0.10$ ; \*\* $p < 0.05$ ; \*\*\* $p < 0.01$ .

Having examined the direct effects of maturity across adoption and effectiveness models, we next assessed the comparative prediction advanced in H3 by comparing the maturity coefficients across the two models. In Table 5, the maturity is negatively associated with the adoption of modern performance tools and digital systems. In contrast, it is not statistically significantly associated with the perceived effectiveness of traditional financial ratios (Table 6–Table 7). This pattern suggests that greater

organizational maturity, as proxied by years of operation, is not associated with a stronger orientation toward modern performance infrastructures, nor does it substantially alter firms' evaluation of traditional financial metrics. Rather, maturity appears to be linked to a lower propensity to adopt new systems without fundamentally reshaping perceptions of existing financial practices. Consequently, the comparative evidence does not support H3 in its proposed direction.

The negative association between organizational maturity and modernization adoption warrants further interpretation. Rather than indicating resource deficiency, the pattern suggests that structural longevity may be linked to greater reliance on established administrative routines. Younger firms may exhibit greater structural flexibility and fewer legacy constraints, facilitating the redesign of performance infrastructure. The results point toward a differentiation between accumulated organizational experience and adaptive openness, reinforcing the theoretical tension between structural capacity and institutional embeddedness developed earlier.

**Table 7.** Ordered logit robustness estimates for perceived effectiveness of traditional financial ratios.

Predictor	Coef	SE	p-value	OR = exp( $\beta$ )
Maturity (years-of-operation, 1–4)	−0.183	0.158	0.249	0.833
Firm size (employees, ordinal)	0.471	0.268	0.079	1.602
Turnover (ordinal)	−0.301	0.209	0.151	0.740
Listed	0.994	0.452	0.028	2.703
Bulk present	0.130	0.328	0.692	1.138
Tanker present	0.174	0.327	0.596	1.190
Container present	0.205	0.456	0.653	1.228

**Notes:** Ordered logit coefficients with standard errors in parentheses; OR = exp( $\beta$ ). Cutpoints omitted. Two-tailed tests; \*p < 0.10; \*\*p < 0.05; \*\*\*p < 0.01.

#### 4.3. Robustness analyses

We conducted additional robustness analyses to assess the stability of the empirical findings across alternative operationalizations and in the presence of potential multicollinearity. First, we re-estimated the adoption and effectiveness models using alternative age categorizations of organizational maturity. The direction and statistical significance of the maturity coefficient remain substantially unchanged, reinforcing the stability of the results.

Table 8 further confirms that the negative association between maturity and both modern and digital system adoption remains statistically significant in the logistic specifications. In contrast, the relationship between maturity and perceived effectiveness remains statistically insignificant in the OLS model. The consistency of coefficient direction and statistical inference across alternative operationalizations suggests that the measurement of maturity does not drive the major findings.

Second, we examined multicollinearity diagnostics. Table 9 reports the variance inflation factors (VIF) for all explanatory variables included in the multivariate models. All VIF values remain well below commonly accepted thresholds, indicating that collinearity is not a concern and that overlapping explanatory effects do not distort coefficient estimates.

**Table 8.** Robustness analysis using standardized organizational maturity (adoption and effectiveness models).

Outcome/Model	Maturity (standardized) Coef	SE	p-value	OR = exp( $\beta$ )
Modern tools adoption (Logit)	-0.768	0.231	0.001	0.464
Digital systems adoption (Logit)	-0.560	0.199	0.005	0.571
Perceived effectiveness (OLS, HC3)	-0.094	0.075	0.209	—

Notes: Logit models report OR = exp( $\beta$ ). OLS uses HC3 robust standard errors. Two-tailed tests; \*p < 0.10; \*\*p < 0.05; \*\*\*p < 0.01. (Listing is excluded from the modern-tools logit due to perfect prediction, consistent with the main specification.)

**Table 9.** Variance inflation factors (VIF) for multicollinearity diagnostics.

Variable	VIF
Maturity	1.111
Firm size	1.785
Turnover	1.818
Listed	1.244
Bulk present	1.095
Tanker present	1.081
Container present	1.109

Notes: All VIF values are below conventional thresholds, indicating no multicollinearity concerns.

To address potential concerns about information loss from binary coding of adoption variables, we also constructed adoption intensity indices that capture the number of modern performance tools (KPIs, Balanced Scorecard, Six Sigma, and EFQM) and digital systems (ERP, business intelligence tools, and dashboards) implemented by each firm. Re-estimation using these count-based specifications yields substantively consistent results: Organizational maturity remains negatively associated with modernization intensity, while no statistically meaningful association emerges for perceived effectiveness. These findings suggest that the binary specification does not drive the major conclusions.

Finally, given the widespread use of KPI-based systems, we re-estimated the modern adoption models, excluding KPI-only implementation from the classification of modern tools, focusing solely on integrated formal frameworks (Balanced Scorecard, Six Sigma, and EFQM). The direction of the maturity coefficient remains unchanged, although statistical significance is attenuated due to lower adoption frequency. This sensitivity analysis suggests that the major findings are not driven exclusively by KPI prevalence. Across alternative specifications and operationalizations, the substantive pattern of results remains stable, reinforcing confidence in the robustness of the reported relationships.

## 5. Discussion

In this study, we examined whether organizational maturity is associated with the adoption of modern performance measurement tools and digital performance management systems, as well as with the perceived effectiveness of traditional financial ratios, within the shipping industry. Contrary to expectations derived from the organizational dimension of the Technology-Organization-Environment (TOE) framework, organizational maturity, operationalized as structural longevity, is negatively

associated with the adoption of modern and digital systems, while showing no statistically significant relationship with the perceived effectiveness of traditional financial ratios.

The initial hypothesis was grounded in the organizational dimension of the TOE framework, which links accumulated resources and absorptive capacity to a greater likelihood of adopting innovation. Contrary to this expectation, the findings indicate that structural longevity is negatively associated with modernization. This rejection does not invalidate the theoretical premise but suggests that maturity may operate differently under institutional embeddedness. Rather than enabling adaptive flexibility, accumulated routines and legacy infrastructure may constrain strategic reconfiguration. Organizational maturity thus reflects a tension between capacity-based readiness and path-dependent stability, thereby refining the TOE framework by distinguishing structural accumulation from adaptive flexibility.

One plausible mechanism concerns the entrenchment of legacy systems. Firms with longer operational histories may have accumulated customized reporting infrastructures and informal coordination practices that function adequately within established routines. The organizational and cognitive switching costs associated with adopting integrated digital platforms may therefore be higher for mature firms. By contrast, younger organizations may face fewer legacy constraints and may embed digital systems during formative stages of structural development.

Institutional theory provides additional interpretive depth. As firms age, established evaluation systems and historically validated practices may acquire legitimacy independent of technological sophistication. Such stability can reduce incentives to adopt externally developed performance frameworks, particularly in sectors characterized by concentrated ownership and tradition-oriented governance. Modernization is therefore not solely a function of structural capacity but also of organizational willingness to disrupt embedded routines.

These results extend prior research on maritime digital transformation, which emphasizes managerial support and organizational readiness as drivers of adoption (Yuen et al., 2024). The findings suggest that structural longevity may operate as a boundary condition under institutional embeddedness, where accumulated routines temper modernization incentives. Organizational maturity thus emerges as a potential constraint rather than a uniform enabler of technological upgrading. In doing so, the study complements perspectives on technological optimization and competitiveness by highlighting the organizational determinants of digital adoption in shipping firms.

Contingency considerations further contextualize the findings. Shipping operates in a capital-intensive, volatility-prone environment characterized by cyclical freight rates, geopolitical uncertainty, and financing constraints. Under such conditions, risk containment and liquidity preservation may take precedence over disruptive digital transformation, reinforcing stability-oriented governance logics over innovation propensity.

Governance configuration also warrants consideration. Greek shipping is characterized by concentrated ownership and limited capital market exposure. Although governance differences could potentially explain the observed pattern, listing status, firm size, and turnover are explicitly controlled in the multivariate models, and the negative association between maturity and modernization persists. Organizational longevity thus appears to shape adoption behavior independently of formal capital market governance.

The absence of a significant association between maturity and perceived effectiveness of financial ratios underscores the resilience of traditional evaluative practices. Financial metrics remain broadly legitimate across firms regardless of age, indicating that modernization of performance infrastructure

and evaluative perception may evolve asymmetrically. Adoption behavior and interpretive orientation do not necessarily shift in tandem.

KPI systems account for a substantial share of modern tool adoption. While structured, KPIs vary in their degree of formal integration and technological sophistication. Sensitivity analyses excluding KPI-only adoption confirm that the negative maturity effect persists when focusing on more integrated frameworks, indicating that the relationship reflects a broader modernization orientation rather than a definitional effect driven by KPI prevalence. The coexistence of widespread use and only moderate perceived effectiveness further suggests that financial ratios function as institutionalized evaluation norms sustained by legitimacy and comparability considerations rather than by superior analytical differentiation. This distinction reinforces the separation between evaluative legitimacy and infrastructure modernization.

These findings should be interpreted in light of the institutional configuration of the Greek maritime cluster. While Greek firms operate globally, concentrated ownership and historically embedded governance practices may shape modernization behavior. This study contributes to analytical generalization by refining theoretical expectations regarding organizational maturity under institutional embeddedness rather than advancing claims of universal statistical generalization across shipping contexts.

Several limitations merit consideration when interpreting the findings. Organizational maturity is proxied by firm age, which captures structural longevity within the organizational dimension of the Technology–Organization–Environment framework, but does not directly observe governance configuration, managerial cognition, or the depth of institutional embeddedness. As a result, elements of path dependence and rigidity are inferred from structural accumulation rather than measured directly. The cross-sectional survey design further limits causal interpretation. While statistically significant associations emerge between maturity and modernization adoption, the direction of influence cannot be established with certainty, and it remains possible that firms characterized by more conservative modernization strategies persist under particular structural conditions rather than maturity constraining digital transformation. The empirical focus on the Greek shipping cluster enables analytical generalization within institutionally embedded, capital-intensive environments. Still, it does not support universal statistical generalization across heterogeneous maritime governance regimes. In addition, adoption is measured as the formal implementation of performance and digital systems rather than the depth of integration, intensity of use, or performance consequences, and perceived effectiveness reflects evaluative legitimacy rather than objective predictive validity. These boundary conditions indicate that future research would benefit from multidimensional maturity constructs, longitudinal designs, and the integration of archival performance data to more precisely examine how the organizational dimension of TOE interacts with institutional stability and environmental volatility in shaping modernization trajectories.

## 6. Conclusions

In this study, we examined the relationship between organizational maturity and the adoption of modern performance measurement tools and digital management systems within the shipping industry. The findings indicate that structural longevity is negatively associated with modernization adoption, while exhibiting no statistically significant relationship with the perceived effectiveness of traditional financial ratios. The results reveal an asymmetry between evaluative legitimacy and infrastructural

modernization: Mature firms continue to rely on established financial metrics, yet appear comparatively less inclined to redesign their performance architectures.

Theoretically, the study refines the organizational dimension of the Technology-Organization-Environment framework by distinguishing structural capacity from adaptive flexibility. While TOE predicts that accumulated resources and absorptive readiness facilitate the adoption of innovation, the evidence suggests that organizational maturity may serve as a boundary condition under institutional embeddedness. Structural longevity can reinforce path-dependent routines and legacy system entrenchment, tempering modernization incentives even in resource-capable firms. By identifying organizational maturity as a potential constraint rather than a uniform enabler of technological upgrading, the study contributes to research on digitalization and innovation in capital-intensive industries characterized by strong governance traditions and institutional continuity.

From a managerial perspective, the findings imply that modernization challenges in mature maritime firms may not primarily reflect financial or technical constraints, but rather organizational inertia and switching costs embedded in long-standing routines. Effective digital transformation strategies should therefore address institutionalized evaluation practices and legacy infrastructures, complementing technological investment with organizational change mechanisms. The persistence of traditional financial ratios further suggests that executives should differentiate symbolic modernization and substantive integration of performance systems, ensuring that digital initiatives are embedded in decision-making structures rather than layered onto existing routines.

At the industry and policy levels, the results underscore the importance of institutional configuration in shaping modernization trajectories. In maritime clusters characterized by concentrated ownership and stability-oriented governance, digital transformation may require more than technological diffusion; it may depend on incentive structures, governance reforms, and collective learning mechanisms that reduce institutional inertia. Accordingly, initiatives aimed at accelerating digital adoption in shipping should account for organizational embeddedness and legacy structures, rather than assuming uniform readiness across firms of different maturity levels.

Overall, the study advances an analytically grounded understanding of how organizational maturity interacts with institutional context to shape the evolution of performance systems. Rather than offering claims of universal statistical generalization, it contributes to theory-driven analytical generalization by clarifying the conditions under which structural longevity constrains modernization within globally operating yet institutionally embedded maritime firms.

### **Author contributions**

Vasilios-Christos Naoum: Conceptualization, Writing - Review & Editing, Supervision, Project administration

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Kalliafas Dimitrios: Conceptualization, Methodology, Investigation, Writing, Original Draft

### **Use of AI tools declaration**

The authors declare that no artificial intelligence (AI) tools or AI-assisted technologies were used in the conception, design, data collection, analysis, interpretation, writing, editing, or preparation of this manuscript.

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## Conflict of interest

The authors reported no potential conflicts of interest.

## Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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