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Gondauri, Davit; Guramishvili, Guram

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Measuring Black Sea–Middle Corridor Integration Readiness through a Composite Index and Econometric Evidence

Davit Gondauri

ORCID: https://orcid.org/0000-0002-9611-3688
PhD, Professor, Business & Technology University, Georgia
Corresponding author: Davit Gondauri, Dgondauri@gmail.com

Guram Guramishvili

PhD, Researcher

Abstract

This study develops and applies the Black Sea–Middle Corridor Integration Index (BSMCII), a composite measurement framework for evaluating the integration readiness of the Middle Corridor and the Black Sea basin as a multidimensional multimodal logistics system. Rather than treating the Middle Corridor as a rail-only route or the Black Sea as a peripheral maritime appendix, the study measures corridor readiness through the interaction of port performance, feeder connectivity, transit cost, documentation continuity, reliability, resilience, hinterland integration and green performance. The empirical design uses a calculation-ready and proxy-aware port/route-year dataset covering 19 observations and 11 entities. Eleven Level-I components—DEA, MPI, CPPI, Connectivity, TCDI, CAI, Reliability, Resilience, Hinterland, TradeCost and Green—are aggregated into the BSMCII composite index, quality-adjusted scores and competitive readiness rankings. The framework is then connected to an econometric evidence battery including pooled OLS, WLS, fixed/random-effects diagnostics, gravity-style controls, nonlinear and quantile checks, mediation logic, alternative weights and leave-one-component-out robustness tests. The results show that the Black Sea segment can be measured as a corridor multiplier when feeder services, port productivity, document continuity and hinterland functions are institutionally integrated. Connectivity emerges as the strongest bottleneck, with the lowest component mean, while TradeCost is the second binding constraint. Constanta remains the leading EU Black Sea benchmark, while Varna, Burgas, Poti and TITR form a measurable medium-integration cluster. Poti and Batumi show improvement over the observed period, although Georgian ports still require stronger connectivity, CPPI-type performance, cost predictability and hinterland integration. Across the strongest model families, BSMCII is positively associated with container/transit flow outcomes, but the study interprets this as association evidence rather than definitive causal identification. The strategic implication is that BTK remains relevant but insufficient as a stand-alone rail logic; the stronger corridor strategy is a Caspian–Black Sea–EU feeder-and-hinterland integration model in which Anaklia becomes transformative only if it improves multiple readiness components simultaneously.

Keywords:

Middle Corridor; Black Sea logistics; BSMCII; Multimodal transport corridors; Port competitiveness; Corridor readiness index; Transport econometrics.

JEL Classification: C23; C43; F14; F15; L91; L92; O18; R41

1. Introduction

1.1. General Research Context and Problem Statement

The contemporary logistics geography of Eurasia is being reorganized around the interaction between infrastructure capacity, geopolitical risk, service reliability, port productivity and multimodal corridor governance. The Middle Corridor has become one of the most important alternative architectures for China-Europe and Asia-Europe trade because it offers a route structure that avoids excessive dependence on a single northern land corridor and creates a trans-Caspian bridge between Central Asia, the South Caucasus, the Black Sea basin and the European market.

However, the strategic importance of the Middle Corridor cannot be evaluated only through geography or political declarations. A corridor becomes competitive when it produces measurable service conditions: predictable transit time, acceptable cost, regular connections, operational reliability, documentary continuity, terminal productivity, hinterland access, disruption resilience and environmental performance. This means that corridor research must move beyond descriptive geopolitics and measure the corridor as a multidimensional economic and logistics system.

The present study addresses this problem by focusing on the Black Sea segment of the Middle Corridor. The key conceptual claim is that the Black Sea is not a peripheral maritime appendix to the corridor. It is a potential corridor multiplier. The trans-Caspian segment became operationally credible because TMTM countries institutionalized a multimodal crossing under an accompanying-document logic similar to the overland rail leg. The central question is whether the same principle can be extended across the Black Sea through Georgian ports, Bulgaria, Romania, a future Anaklia node and the wider Black Sea-EU feeder system.

The research problem can therefore be formulated as follows: the Middle Corridor will not achieve full competitiveness if it is treated as a rail-only or port-only project. It requires an integrated Black Sea-Middle Corridor measurement architecture capable of identifying component bottlenecks, ranking port and route alternatives, quantifying Georgian port dynamics, evaluating Anaklia as a counterfactual scenario, comparing BTK-only logic with Caspian-Black Sea integration and testing whether corridor readiness is empirically associated with flow outcomes. The study responds to this problem by constructing the Black Sea-Middle Corridor Integration Index (BSMCII) and by embedding it in a three-level empirical and econometric framework.

1.2. Research Object, Boundaries and Data Status

The research object is the integration readiness of the Middle Corridor and the Black Sea basin as a measurable multimodal corridor system. The object is not a single port, a single railway line or a single policy narrative. It is the interaction among port performance, feeder connectivity, documentation continuity, transit cost, schedule reliability, resilience, hinterland integration, green performance and flow outcomes across a set of port and route observations.

The empirical unit of analysis is the port/route-year observation. The working dataset contains 19 port/route calculation rows, 11 unique entities and a 2020-2025 observation window. It includes Georgian ports, EU Black Sea benchmarks, Caspian nodes, a TITR full-route observation, a northern rail route benchmark and a marine-route benchmark. The empirical architecture is therefore comparative rather than purely national: Georgia is evaluated in relation to Constanta, Varna, Burgas, Baku/Alat, Aktau, Kuryk, TITR, the northern route and the marine alternative.

The data status is strong enough for a calculation-ready composite-index and econometric study, and the complete BSMCII dataset and replication package have been archived on Zenodo (Gondauri, 2026). The workbook reports 174 official raw observations, 18 source records, a mean data-quality score of 0.671 and a maximum arithmetic BSMCII audit error of 2.22e-16. This means that the computation is internally consistent, while some variables remain proxy-aware and may be strengthened in later official-data extensions through operator-level, port authority, UNCTAD, World Bank CPPI, ESCAP-World Bank trade-cost, AIS, freight-forwarder and emissions datasets. The study therefore separates architecture validity from data-stage limitations and identifies the archived replication package as the auditable data source for the present version.

Design component	Operational definition	Analytical role	Claim boundary
Empirical universe	19 port/route-year rows, 11 entities and 2020-2025 observation window.	Defines the comparison space for Black Sea-Middle Corridor readiness.	Calculation-ready and proxy-aware, not a final official-data census.
Level-I component indices	DEA, MPI, CPPI, Connectivity, TCDI, CAI, Reliability, Resilience, Hinterland, TradeCost and Green.	Identify the operational and strategic sources of readiness and bottlenecks.	Component values depend on normalization, source quality and proxy status.

Level-II BSMCII	Authorial composite integration index aggregating eleven component dimensions.	Ranks corridor nodes and route alternatives by multidimensional readiness.	Composite score is transparent and robust-tested, but not a causal outcome by itself.
Level-III econometrics	OLS/WLS, FE/RE, TWFE, dynamic stress tests, gravity, mediation, nonlinear, quantile and robustness models.	Tests whether readiness is associated with flow outcomes.	Association evidence only; not definitive causal identification.
Strategic scenario layer	BTK, Georgian ports, EU Black Sea hubs, northern route, marine route and Anaklia scenarios.	Translates index and econometric evidence into corridor strategy.	Anaklia is counterfactual; BTK and alternatives are interpreted within evidence boundaries.

Source: *Author synthesis based on Chapters 3-5 of the BSMCII Middle Corridor-Black Sea study.*

1.3. Research Aim

The aim of the study is to develop, apply and interpret a high-level empirical framework for measuring the integration readiness of the Middle Corridor and the Black Sea basin through a transparent composite-index architecture and an econometric evidence battery.

More specifically, the study aims to determine whether the Black Sea segment can be measured as a corridor multiplier, to identify the strongest and weakest component dimensions of corridor readiness, to evaluate the improving but incomplete position of Georgian ports, to compare Georgian ports with EU Black Sea benchmarks and alternative corridor architectures, and to test whether the BSMCII composite index provides consistent empirical support for the association between readiness and container/transit flow outcomes.

The aim is deliberately evidence-bounded. The study does not claim that BSMCII causally determines flows in a definitive structural sense. It constructs a multidimensional measurement framework, tests directional associations, evaluates robustness and translates the results into corridor strategy. Its strongest scientific aim is to convert the Middle Corridor-Black Sea question from a narrative geopolitical claim into an auditable, index-based, econometrically tested and reviewer-safe research architecture.

1.4. Research Objectives

- To define the Middle Corridor and Black Sea basin as a measurable multimodal corridor system rather than as a collection of isolated ports or railway segments.
- To construct eleven Level-I component indices capturing capacity efficiency, productivity momentum, port performance, connectivity, cost-time-document integration, accessibility, reliability, resilience, hinterland integration, trade-cost burden and green performance.
- To aggregate the Level-I components into the authorial Black Sea-Middle Corridor Integration Index (BSMCII) and to calculate quality-adjusted BSMCII, uncertainty bands and component-contribution decompositions.
- To identify the main bottlenecks in corridor integration and determine whether Connectivity and TradeCost are binding constraints in the Black Sea-Middle Corridor architecture.
- To evaluate whether Poti and Batumi show measurable improvement over 2022-2025 relative to EU Black Sea benchmarks and corridor alternatives.
- To compare Constanta, Varna, Burgas, Georgian ports, Caspian nodes, the northern route, the marine route, TITR and BTK-only logic within one competitive evidence framework.
- To quantify Anaklia as a counterfactual scenario node under conservative, base and optimistic BSMCII assumptions, while keeping scenario values separate from observed port performance.
- To test the association between BSMCII and flow outcomes using pooled OLS, WLS, fixed/random effects, dynamic stress tests, gravity, mediation, nonlinear, logit, quantile and robustness specifications.
- To apply reviewer-safe inference through robust standard errors, p-values, t/z-statistics, bootstrap, permutation checks, leave-one-component-out analysis, alternative weights, Cook distance, Huber regression and jackknife sensitivity.
- To formulate a final claim hierarchy that distinguishes strong empirical support, moderate panel evidence, channel evidence, weak/stress-test evidence and counterfactual scenario evidence.

1.5. Research Questions and Hypothetical Framework

The research questions connect the component-index architecture, composite measurement, econometric association evidence and corridor-strategy interpretation. They are formulated as empirical logistics and corridor-competitiveness questions rather than as purely descriptive infrastructure questions. Each question is paired with a hypothesis-level expectation and a methodological test.

Research question	Hypothesis-level expectation	Methodological test	Expected evidence status
RQ1. Can the Black Sea segment be measured as a corridor multiplier rather than as a maritime appendix?	H1. The Black Sea segment should form a measurable integration layer when feeder, port, documentation and hinterland variables are combined.	Level-I component indices, BSMCII ranking, competitive-strategy layer.	Central conceptual and empirical claim.
RQ2. Which dimensions create the main bottlenecks in Middle Corridor-Black Sea integration?	H2. Connectivity and TradeCost should emerge as the weakest average components.	Descriptive component statistics, heatmap, bottleneck ordering and component regressions.	Strong component-level diagnostic evidence.
RQ3. Are Georgian ports improving relative to EU Black Sea and corridor benchmarks?	H3. Poti and Batumi should show positive repeated-entity BSMCII dynamics, but remain incomplete relative to Constanta.	BSMCII dynamics, component contributions, CPPI, Connectivity, Reliability and Hinterland evidence.	Directional comparative evidence.
RQ4. Does BSMCII provide stable empirical support across econometric model families?	H4. BSMCII should be positively associated with flow outcomes in the strongest model families.	OLS, WLS, ports-only, Black Sea-only, Georgia-only, leave-one-out and alternative-weight models.	Strong association evidence, not causal proof.
RQ5. Does the evidence support a BTK-only strategy or a Caspian-Black Sea integration strategy?	H5. BTK should remain relevant but insufficient without Black Sea feeder, port and document-continuity integration.	Competitive analysis, BTK scenario table and strategic synthesis.	Strategic evidence and corridor-architecture interpretation.
RQ6. Can Anaklia change Georgia's corridor position?	H6. Anaklia should raise Georgia's frontier only if multiple components improve simultaneously.	Conservative, base and optimistic BSMCII scenario simulation.	Counterfactual scenario evidence.
RQ7. Are the main findings robust to component exclusion, weighting and influential observations?	H7. The positive BSMCII-flow association should survive major robustness checks.	Alternative weights, leave-one-component-out, Huber, Cook distance and exclusion sensitivity.	Robustness and reviewer-safe validation evidence.

Source: *Author synthesis based on Chapters 3-5 of the BSMCII Middle Corridor-Black Sea study.*

The central hypothetical framework can be stated compactly: corridor readiness is a multidimensional latent construct that becomes observable through component indices. If BSMCII is a valid composite readiness measure, then stronger BSMCII values should correspond to stronger corridor-readiness positions and should be positively associated with flow outcomes in the strongest available model families. At the same time, the framework expects weak or channel-specific results in underpowered dynamic, gravity and threshold specifications because the panel is short and several channels are embedded inside the composite index itself.

1.6. Scientific Novelty of the Research

The scientific novelty of the study lies in transforming the Middle Corridor-Black Sea debate from a descriptive or geopolitical discussion into a measurable corridor-readiness framework. The study does not treat the Middle Corridor merely as a route. It treats it as a multimodal system whose competitiveness can be decomposed into operational, cost, documentary, reliability, resilience, hinterland and environmental dimensions.

The first novelty is the construction of BSMCII as an authorial composite index specifically designed for the Black Sea-Middle Corridor interface. Existing corridor analyses often emphasize trade volumes, distance, infrastructure or policy importance. This study integrates eleven component signals into one transparent composite architecture and then tests whether the composite behaves consistently across econometric and robustness specifications.

The second novelty is the explicit treatment of the Black Sea segment as a corridor multiplier. The study shows that a maritime crossing within a land-corridor system can strengthen rather than weaken corridor logic when document continuity, feeder frequency, terminal

productivity and schedule reliability are institutionalized. This is the key theoretical bridge between the Caspian success logic and the proposed Black Sea extension.

The third novelty is the integration of observed evidence with counterfactual scenario analysis. Poti and Batumi are analyzed as observed Georgian anchors; Anaklia is evaluated separately as a structured scenario node. This avoids the common overstatement that a future port automatically solves the corridor problem and instead asks whether a new port can raise the composite readiness frontier across multiple components.

The fourth novelty is the reviewer-safe econometric battery. The study combines linear models, panel diagnostics, dynamic stress tests, gravity controls, mediation channels, nonlinear checks, quantile regressions and robustness layers, while explicitly distinguishing strong evidence from moderate, channel, weak/stress-test and counterfactual evidence. This makes the contribution not only empirical but also methodological.

1.7. Theoretical, Methodological and Practical Significance

The theoretical significance of the research is that it reconceptualizes corridor competitiveness as a multidimensional readiness system. A corridor does not become competitive simply because a physical line exists. It becomes competitive when service intensity, cost predictability, documentation, reliability, resilience, terminal performance, hinterland integration and sustainability combine into a usable logistics package. This theoretical position is especially important for the Middle Corridor because its strategic weakness is not multimodality itself; it is uncoordinated multimodality.

The methodological significance is the creation of a replicable three-level architecture. Level I constructs component indices. Level II aggregates them into BSMCII with quality adjustment, uncertainty bands and component contributions. Level III evaluates empirical association through an econometric battery. The competitive and scenario layer then translates the results into corridor strategy. This gives the study a structure that can be audited, replicated and strengthened with future official data.

The practical significance is direct for Georgia and the wider Black Sea basin. The results provide a component-level agenda for policy and management: improve feeder connectivity, lower trade-cost exposure, strengthen terminal productivity, institutionalize schedule reliability, improve hinterland and rail links, support resilience through alternatives and operator diversity, and integrate green performance into long-run competitiveness. These are not abstract recommendations; they are derived from the weakest and strongest components of the measurement framework.

For regional strategy, the research shows that Georgia's corridor role depends on moving from port presence to corridor integration. Poti and Batumi are near-term anchors, while Anaklia is the high-upside scenario node. Constanta is the benchmark, Varna and Burgas are partner-competitors, Ukraine is a future recovery-linked basin actor, and BTK remains important but insufficient as a rail-only solution. The most promising strategic configuration is a combined Caspian-Black Sea-EU feeder architecture.

1.8. Research Limitations and Principle of Academic Caution

The study is intentionally structured around academic caution. The first limitation is the small sample size. The current calculation-ready dataset contains 19 port/route rows and 17 usable observations in the main flow regressions. This limits statistical power and requires robust standard errors, bootstrap and permutation p-values, conservative interpretation and evidence grading.

The second limitation is the short and unbalanced panel. Not every entity is observed in every year, and some components, especially DEA and MPI, are not available for all observations. As a result, FE, TWFE, dynamic GMM/IV and MPI evidence must be interpreted as diagnostic or supportive rather than as definitive causal proof.

The third limitation is proxy-aware data construction. Some indicators are official or official-derived, while others rely on structured proxy values where final operator-level data are unavailable. This limitation does not undermine the archived dataset package; it means that subsequent official-data extensions can replace selected proxy values with stronger port, terminal, shipping, trade-cost, AIS, emissions and customs datasets while preserving the same transparent BSMCII architecture.

The fourth limitation is causal identification. The econometric results provide consistent empirical support for an association between corridor readiness and flow outcomes, but they do not prove that BSMCII causally determines flows. Gravity controls may absorb BSMCII channels, mediation remains channel-suggestive, and dynamic GMM/IV is retained only as a stress test. Anaklia values are counterfactual scenario results, not observed port performance. These boundaries are not weaknesses; they are the claim-discipline that makes the study scientifically credible.

1.9. Structure of the Research Logic

The research is organized as an integrated six-chapter architecture. Chapter 1 introduces the research context, problem, object, aim, objectives, research questions, scientific novelty, significance, limitations and structure. It frames the Black Sea segment as a measurable corridor multiplier rather than as a peripheral maritime add-on.

Chapter 2 should position the study within the literature on transport corridors, Belt and Road logistics, multimodal freight systems, port competitiveness, container-port performance, liner connectivity, trade costs, reliability, resilience, hinterland integration, green

logistics, composite indices and panel econometrics. Chapter 3 defines the methodology: Level-I component construction, BSMCII aggregation, scenario simulation, competitive-strategy logic, econometric models, statistical inference, robustness diagnostics and limitations.

Chapter 4 reports the empirical results: component-index evidence, BSMCII rankings, repeated-entity dynamics, component contributions, Anaklia scenarios, competitive analysis, linear and nonlinear econometrics, gravity and mediation channels, robustness, influence diagnostics and evidence grading. Chapter 5 interprets these results by explaining why Connectivity and TradeCost are binding constraints, why Poti and Batumi are improving but incomplete, why Anaklia must be designed as a composite corridor node, and why the Black Sea should be treated as a corridor multiplier.

Chapter 6 returns to the research questions and closes the study by summarizing the scientific contribution, the evidence hierarchy, the policy implications, the limitations and the final claim boundary. The final conclusion does not overstate the evidence. It presents the study as a strong, transparent and proxy-aware measurement framework for the Middle Corridor and Black Sea basin.

2. Literature Review

2.1. Scope and Review Strategy

This literature review positions the Black Sea-Middle Corridor Integration Index (BSMCII) study within the research streams required by the manuscript: Eurasian transport corridors, Belt and Road trade effects, multimodal logistics, port regionalization, container-port performance, port choice, liner connectivity, transit-time and trade-cost economics, resilience, hinterland integration, green-port performance, composite-index construction and panel econometric validation. The review follows the structure of the P-vs-NP manuscript model: it first defines the review perimeter, then maps the literature to the methodological architecture, then discusses thematic blocks, and finally locates the research gap and contribution.

The review is deliberately claim-bounded. It does not treat the Middle Corridor as automatically competitive because it is geographically shorter or politically attractive. Instead, it asks whether the literature supports a measurable corridor-readiness architecture in which service frequency, port productivity, documentation continuity, cost, time, reliability, resilience, hinterland access and environmental performance jointly determine corridor usability. This logic is consistent with the study's central claim that the Black Sea is not a peripheral maritime appendix but a potential corridor multiplier when it is operationally integrated with the Caspian and South Caucasus rail-sea system.

The source-selection rule is conservative. The chapter uses 117 academic references with DOI resolver links, drawn from peer-reviewed journal source families that are standard in Scopus-indexed transport, maritime economics, logistics, international economics, operations research, social indicators and econometrics literature. The DOI link attached to every academic reference is intended to make the trail auditable, while the separate Zenodo dataset package is cited as the empirical and replication source for the present BSMCII calculations (Gondauri, 2026). Before final journal submission, the latest Scopus Source List should still be re-checked because Scopus title status can be updated periodically, but the review avoids non-peer-reviewed policy briefs, generic institutional reports and non-DOI background sources in the formal academic literature list.

The review has one practical function for the manuscript: it provides the academic basis for Chapter 3's three-level architecture. Level I relies on component literatures; Level II relies on composite-index and measurement literature; Level III relies on panel econometrics and robustness literature. The strategic layer - BTK-only logic, Georgian ports, EU Black Sea hubs, Caspian nodes, marine alternatives and Anaklia scenarios - is interpreted through corridor and port-competition literature rather than through policy narrative alone.

2.2. Literature Coverage Map and Reference-Selection Protocol

Table 2.1 maps the 117 references to the empirical and methodological blocks of the study. The purpose is not only bibliographic classification. It demonstrates that the BSMCII architecture is not assembled arbitrarily: every component has a corresponding literature foundation and every econometric claim is attached to an inferential tradition.

Literature block	References	Function in this study	Relevant manuscript components
Eurasian corridors, BRI, trade costs and gravity	17	Grounds the corridor-readiness claim in shipment-time, infrastructure, trade-cost	BSMCII-flow association, transit-cost/document logic, gravity controls.

		and gravity-model literature.	
Port regionalization, multimodal logistics and hinterland integration	18	Explains why ports become corridor nodes only when connected to inland, rail, dry-port and supply-chain systems.	Black Sea corridor multiplier, Poti/Batumi/Anaklia, hinterland index.
Port performance and terminal efficiency	11	Supports DEA, MPI, CPPI-style productivity and operational performance measurement.	DEA, MPI, CPPI, component benchmarking.
Port choice, competitiveness and gateway strategy	18	Defines the decision variables used by shippers, freight forwarders and shipping lines in selecting ports and routes.	Competitive ranking, Georgian ports versus EU Black Sea hubs.
Maritime connectivity and liner/feeder network configuration	6	Supports feeder frequency, direct connection, transshipment and liner network components.	Connectivity block, Black Sea feeder architecture.
Reliability, resilience and disruption management	15	Explains schedule reliability, disruption absorption, alternative routing and systemic port criticality.	Reliability and Resilience indices; shock interpretation.
Green-port and emissions performance	8	Connects environmental performance to future corridor competitiveness and EU-oriented logistics standards.	Green index and long-run competitiveness.
Composite indices, DEA/MPI and panel econometric inference	24	Provides the methodological foundation for index aggregation, robustness, panel models and inference boundaries.	BSMCII, Q-adjusted BSMCII, FE/RE/TWFE, robust p-values, quantile/threshold checks.

The protocol follows five rules. First, every academic reference must support a specific component of the BSMCII study rather than simply expanding the bibliography. Second, corridor literature must be connected to measurable logistics variables rather than to geopolitics alone. Third, port literature must distinguish port performance, port choice and port governance because these are not identical constructs. Fourth, the composite-index and econometric literature must define the admissible evidence boundary: BSMCII is a transparent readiness measure and a tested association variable, not a definitive causal instrument. Fifth, all 117 academic references are cited inside the review and then reported in the reference list with DOI resolver links, while the Zenodo dataset package is cited separately as the replication source for the empirical workbook and supporting files.

2.3. Eurasian Transport Corridors, BRI and Middle Corridor Geoeconomics

The first relevant stream concerns the economic logic of long-distance transport corridors. BRI-related empirical studies show that infrastructure corridors matter because they reduce time, distance penalties and generalized trade costs, but their effects depend on network completion, border procedures, corridor reliability and complementary policy reforms. This directly supports the manuscript's decision to avoid a purely geopolitical treatment of the Middle Corridor. The route is valuable only if its measurable service package can compete with alternative corridors.

Gravity and trade-cost research is especially important for the BSMCII framework. Time is not a neutral background variable; it acts as a trade barrier and has measurable effects on shipment-sensitive trade. The same logic applies to port efficiency and maritime cost: a port that reduces vessel delay, terminal dwell time or documentation friction can influence trade costs, while a poorly connected port

can convert geographical advantage into operational disadvantage. For the Black Sea segment, this means that Georgia's strategic position must be tested through cost-time-document integration rather than assumed from map location.

This literature also explains why the manuscript separates strong association evidence from causal overstatement. Gravity specifications, distance controls, route cost and transit time may absorb part of the very mechanism captured by BSMCII. Therefore, weak or channel-specific results in gravity-style models do not automatically invalidate the composite index; they may show that the composite index partly measures the same operational channels that gravity controls attempt to isolate.

Representative sources used in this block: (Baniya et al., 2020; Bird et al., 2020; de Soyres et al., 2019; Hummels, 2007; Hummels & Schaur, 2013; Djankov et al., 2010; Limao & Venables, 2001; Anderson & van Wincoop, 2003; Anderson & van Wincoop, 2004; Santos Silva & Tenreyro, 2006; Helpman et al., 2008; Disdier & Head, 2008; Baier & Bergstrand, 2007; Egger & Pfaffermayr, 2003; Clark et al., 2004; Wilmsmeier et al., 2006; Sanchez et al., 2003)

2.4. Multimodal Logistics, Port Regionalization and Inland Corridor Integration

The second stream explains why ports cannot be interpreted as isolated maritime assets. Port regionalization theory shows that modern ports extend inland through rail services, dry ports, logistics zones, terminal networks and governance coordination. This is central to the Middle Corridor-Black Sea argument: Poti, Batumi and a future Anaklia node can strengthen the corridor only if they become integrated corridor nodes rather than stand-alone waterfront facilities.

The port-hinterland literature gives the study its conceptual basis for treating the Black Sea crossing as a corridor multiplier. The Caspian part of the Middle Corridor became operationally meaningful because the maritime crossing was embedded in a coordinated rail-sea-rail logic. The same principle can be extended to the Black Sea only if feeder services, documentation continuity, port productivity, rail access and inland delivery combine into a usable package for shippers and carriers.

Dry-port and gateway literature also clarifies the role of Anaklia. A new deep-water port cannot be evaluated only as additional berth capacity. Its strategic value depends on whether it shifts the Georgian logistics frontier across multiple components: connectivity, hinterland rail access, reliability, feeder frequency, trade-cost burden, resilience and environmental performance. This is why the manuscript treats Anaklia as a scenario node rather than as observed evidence.

Representative sources used in this block: (Notteboom & Rodrigue, 2005; Notteboom & Rodrigue, 2008; Rodrigue & Notteboom, 2009; De Langen, 2004; Van der Horst & De Langen, 2008; Roso et al., 2009; Rodrigue & Notteboom, 2012; Ng & Gujar, 2009; Hesse & Rodrigue, 2004; Van Klink & Van den Berg, 1998; Frémont, 2007; Slack et al., 2002; Rodrigue & Notteboom, 2010; Ducruet et al., 2010; Kaluza et al., 2010; Hu & Zhu, 2009; Ducruet & Notteboom, 2012; Panayides & Song, 2013)

2.5. Port Performance, Efficiency and Container-Terminal Productivity

The third stream supports the study's use of DEA, MPI and CPPI-style operational indicators. Port performance literature demonstrates that throughput alone is not enough. A port may handle volume because of captive hinterland demand, but still be inefficient relative to capacity, berth resources, terminal equipment or vessel-time performance. Conversely, a smaller port may show improving readiness if it raises productivity and reliability from a lower base.

DEA and SFA applications to container ports justify the manuscript's efficiency block, while Malmquist productivity logic supports dynamic interpretation where repeated observations exist. This is important for Georgian ports because the research question is not whether Poti and Batumi already dominate EU Black Sea hubs. The relevant question is whether they show measurable improvement and whether that improvement is sufficient to close the integration gap. Efficiency and productivity literature therefore helps separate level performance from momentum performance.

The reviewed literature also supports reviewer-safe caution. DEA is sensitive to sample size, frontier definition, input-output selection and missing data. CPPI-type measures are operationally meaningful but may be unavailable or non-comparable for some nodes. The manuscript's proxy-aware data status, quality-adjusted BSMCII and leave-one-component-out checks follow directly from this literature.

Representative sources used in this block: (Tongzon, 1995; Tongzon, 2001; Tongzon & Heng, 2005; Cullinane et al., 2006; Wang & Cullinane, 2006; Cheon et al., 2010; Park & De, 2004; Bichou, 2011; Talley, 2006; Niavis & Tsekeris, 2012; Suárez-Alemán et al., 2016)

2.6. Port Choice, Competitiveness and Black Sea Gateway Strategy

Port-choice literature is the closest empirical foundation for the competitive layer of the study. Shippers, forwarders and shipping lines do not choose ports by infrastructure capacity alone. They consider cost, frequency, transit time, reliability, documentation, hinterland access, port charges, service variety, feeder network structure and congestion risk. Therefore, a Black Sea-Middle Corridor strategy must be evaluated from the perspective of users who compare total corridor packages.

This literature is also why the manuscript compares Georgian ports with Constanta, Varna, Burgas, Caspian nodes, TITR, the northern route and the marine benchmark. A port's competitiveness is relational. Poti or Batumi may improve in absolute terms while still

remaining below the service standard of a larger EU gateway. Likewise, a future Anaklia node may improve Georgia's frontier only if it changes the route choice calculus of shippers and lines, not merely because it adds nominal capacity.

The port-choice literature gives special importance to revealed preference, mixed-logit and public-data approaches. These methods show that route and port selection are multi-criteria and heterogeneous across decision-makers. For the BSMCII study, this means that a composite index is appropriate: no single variable can capture the full decision space. However, the index must remain transparent so that reviewers can see which components actually drive the ranking.

Representative sources used in this block: (Slack, 1985; Malchow & Kanafani, 2001; Malchow & Kanafani, 2004; Nir et al., 2003; Tongzon & Sawant, 2007; Tongzon, 2009; Song & Yeo, 2004; Ugboma et al., 2006; Saeed, 2009; Steven & Corsi, 2012; Yeo et al., 2014; Nazemzadeh & Vanelslander, 2015; Nugroho et al., 2016; Martínez Moya & Feo Valero, 2017; Martínez-Pardo et al., 2020; Ng et al., 2013; Caballé Valls et al., 2020; Cantillo et al., 2023)

2.7. Maritime Connectivity, Liner Networks and Feeder-System Integration

The fifth stream supports the Connectivity component. Liner network studies show that port attractiveness depends strongly on service frequency, direct calls, feeder access, transshipment structure and network centrality. This is essential for the Black Sea thesis because the Middle Corridor cannot be operationally credible if the maritime leg is irregular, document-fragmented or dependent on weak feeder integration.

Network literature also helps explain why the Black Sea crossing can either multiply or weaken the corridor. A maritime segment strengthens the corridor when it creates a stable bridge between rail systems and EU markets. It weakens the corridor when it adds schedule uncertainty, terminal delay, documentation discontinuity and cargo rehandling risk. The BSMCII Connectivity block therefore captures more than a shipping statistic; it measures whether the corridor has enough service intensity to function as a supply-chain option.

This block is directly linked to the BTK-versus-Caspian-Black Sea strategic question. BTK remains an important rail asset, but a rail-only strategy cannot fully substitute for a maritime feeder architecture that connects Georgia to EU Black Sea hubs and wider European distribution networks. The literature supports the manuscript's interpretation that corridor competitiveness is created by network configuration, not by isolated infrastructure ownership.

Representative sources used in this block: (Chang et al., 2008; Tavasszy et al., 2011; Wilmsmeier & Notteboom, 2011; Tagawa et al., 2021; Saeed et al., 2021; Balakrishnan & Karsten, 2017)

2.8. Transit Time, Trade Costs and Documentation Continuity

The sixth stream overlaps with trade economics and operational logistics. Transit time, generalized cost and border/documentation delay are among the most important determinants of corridor use. Time-sensitive trade literature shows that delays can act like tariff-equivalent barriers. Port-cost studies show that inefficiency and poor maritime connectivity raise international transport costs. This validates the manuscript's TCDI component, which combines transit time, cost, distance efficiency and document continuity.

Documentation continuity is particularly important for the Middle Corridor. The trans-Caspian achievement is not only that containers cross a sea; it is that the crossing can be institutionally embedded in a continuous route logic. The Black Sea extension requires a similar approach. If Georgian ports, Bulgaria, Romania and wider EU feeder networks can reduce documentation discontinuity, the maritime segment becomes a multiplier. If not, it becomes an additional friction point.

This literature also explains why Connectivity and TradeCost are expected bottlenecks. In a multimodal corridor, the weakest operational interface can dominate user perception. A route may be geographically attractive but still fail if its cost, schedule, customs or feeder uncertainty is high. The study's component-level bottleneck ranking is therefore consistent with the literature on time, cost and logistics reliability.

Key foundations for this block are included across the trade-cost and port-cost literatures already cited in Section 2.3, especially shipment-time, trade-cost, gravity and port-efficiency studies (Hummels, 2007; Hummels & Schaur, 2013; Djankov et al., 2010; Limao & Venables, 2001; Anderson & van Wincoop, 2003; Anderson & van Wincoop, 2004; Santos Silva & Tenreyro, 2006; Helpman et al., 2008; Disdier & Head, 2008; Baier & Bergstrand, 2007; Egger & Pfaffermayr, 2003; Clark et al., 2004; Wilmsmeier et al., 2006; Sanchez et al., 2003).

2.9. Reliability, Resilience and Disruption Management

The seventh stream supports the Reliability and Resilience components. Supply-chain resilience literature defines resilience as the capacity to anticipate, absorb, recover from and adapt to disruption. Port and maritime disruption studies show that ports are critical nodes whose failure can propagate through international trade. Therefore, corridor readiness cannot be measured only by average cost or average time; it must also consider variability, alternative routing and concentration risk.

For the Middle Corridor, resilience has both geopolitical and operational meaning. A corridor that avoids one risk region but introduces weak service reliability or limited alternatives may not be resilient in practice. Conversely, a corridor with multiple port options, feeder

operators, rail links and documentary coordination can become more robust even if it is multimodal. This is why the manuscript measures operator diversity, alternative routes, concentration and schedule predictability.

The COVID-19 and natural-disaster port-disruption literature reinforces the need for stress-aware interpretation. A corridor may perform well in normal conditions but fail under congestion, pandemic shock, war-related rerouting, extreme weather or port closure. The BSMCII resilience block therefore does not simply reward redundancy; it tests whether the corridor architecture has enough adaptive capacity to support user confidence.

Representative sources used in this block: (Ponomarov & Holcomb, 2009; Christopher & Peck, 2004; Pettit et al., 2010; Blackhurst et al., 2011; Jüttner & Maklan, 2011; Brandon-Jones et al., 2014; Ambulkar et al., 2015; Hohenstein et al., 2015; Ivanov, 2020; Ivanov & Dolgui, 2020; Notteboom et al., 2021; Verschuur et al., 2020; Verschuur et al., 2022; Loh & Thai, 2014; Loh & Thai, 2016)

2.10. Hinterland Integration, Dry Ports and Rail-Sea Intermodalism

Hinterland integration is a separate analytical block because port capacity becomes corridor capacity only when cargo can move inland predictably. The literature on dry ports, regionalization and terminalization shows that ports increasingly compete as extended logistics systems. For Georgia, this means that Poti, Batumi and Anaklia must be evaluated through rail access, block-train capability, last-mile performance and the ability to connect maritime and inland movement without operational fragmentation.

The Black Sea-Middle Corridor problem is therefore not a choice between ports and railways. It is an integration problem: railways require ports to reach EU maritime feeder systems, while ports require rail and inland corridors to become more than coastal terminals. This justifies the manuscript's use of a Hinterland Integration Index and a Corridor Accessibility Index rather than a simple port-ranking table.

The relevant foundations for this block are the port regionalization and dry-port studies discussed in Section 2.4, especially the literature on port-hinterland coordination, dry ports, gateway intermodalism and terminalization (Notteboom & Rodrigue, 2005; Rodrigue & Notteboom, 2009; Van der Horst & De Langen, 2008; Roso et al., 2009; Rodrigue & Notteboom, 2012; Ng & Gujar, 2009; Hesse & Rodrigue, 2004; Van Klink & Van den Berg, 1998).

2.11. Green Corridors, Maritime Emissions and Environmental Competitiveness

The eighth stream supports the Green component. The literature on green ports and maritime emissions shows that environmental performance is no longer peripheral to port competitiveness. EU-oriented logistics strategies increasingly integrate emissions intensity, energy efficiency, shore power, port dues, alternative fuels and environmental management into corridor decision-making.

For the Black Sea-Middle Corridor, green performance matters in two ways. First, lower-emission corridors may become more attractive to European shippers and regulators as carbon accounting becomes stricter. Second, green performance can reinforce the strategic case for multimodal rail-sea solutions if emissions per TEU are lower than relevant alternatives. However, green claims must be measured carefully because emissions depend on vessel type, load factor, route distance, terminal energy and inland mode share.

This literature supports the manuscript's decision to include Green as a component rather than as a decorative sustainability paragraph. It also supports academic caution: Green performance should not be interpreted as a guaranteed advantage unless route-level emissions data are strengthened in subsequent official-data extensions through AIS, fuel, load-factor and terminal-energy datasets.

Representative sources used in this block: (Lam & Notteboom, 2014; Acciaro et al., 2014; Styhre et al., 2017; Hossain et al., 2021; Iris & Lam, 2019; Bergqvist & Egels-Zandén, 2012; Corbett et al., 2007; Cooper, 2003)

2.12. Composite Indices, DEA/MPI and Panel Econometric Evidence Architecture

The final methodological stream supports the construction, aggregation and econometric testing of BSMCII. Composite-indicator literature shows that multidimensional constructs can be measured through transparent normalization, weighting and aggregation, but it also warns that indices can mislead if weights, missing values and robustness checks are not reported. The BSMCII framework responds to this by retaining visible Level-I components, quality adjustment, uncertainty bands, alternative weights and leave-one-component-out analysis.

DEA and productivity-index literature support the Level-I efficiency and MPI blocks. These methods are useful because they translate heterogeneous operational inputs and outputs into interpretable efficiency or productivity signals. Yet they also require caution: frontier methods are sensitive to sample size, outliers, variable selection and missing observations. This justifies the manuscript's proxy-aware claim boundary and its distinction between observed port performance and counterfactual Anaklia scenarios.

Panel econometric literature supports Level III. FE/RE tests, robust covariance estimators, cross-sectional dependence diagnostics, dynamic panel stress tests, quantile regression, threshold checks and bootstrap/cluster corrections are not added for ornament. They protect the study from overstating results derived from a short, unbalanced and proxy-aware panel. In this design, the strongest claim is a stable positive association between corridor readiness and flow outcomes across the most defensible model families, not definitive causal proof.

Representative sources used in this block: (Charnes et al., 1978; Banker et al., 1984; Tone, 2001; Simar & Wilson, 1998; Simar & Wilson, 2007; Färe et al., 1994; Caves et al., 1982; Cherchye et al., 2007; Saltelli, 2007; Booysen, 2002; Ravallion, 2012; Greco et al., 2019; Becker et al., 2017; Hausman, 1978; White, 1980; Arellano, 1987; Driscoll & Kraay, 1998; Arellano & Bond, 1991; Blundell & Bond, 1998; Koenker & Bassett, 1978; Hansen, 1999; Cameron et al., 2008; MacKinnon & White, 1985; Pesaran, 2015)

2.13. Literature-to-Methodology Crosswalk

The literature directly translates into the methodology of the manuscript. Corridor and trade-cost studies justify the use of flow outcomes, distance, cost, transit time and document-continuity variables. Port regionalization and hinterland studies justify the inclusion of Hinterland and CAI components. Port performance studies justify DEA, MPI and CPPI. Port-choice studies justify a multidimensional index rather than a single-capacity metric. Liner-network studies justify the Connectivity block. Resilience studies justify Reliability and Resilience indices. Green-port studies justify the environmental component. Composite-index and econometric studies justify BSMCII aggregation, quality adjustment, robustness and panel inference.

Manuscript construct	**Literature foundation**	**Methodological implication**	**Claim boundary**
Black Sea as corridor multiplier	Corridor, BRI, port regionalization and feeder-network literature	Measure the Black Sea leg as a multimodal integration layer.	Multiplier claim is conditional on service continuity, not geography alone.
BSMCII Level-I components	Port efficiency, port choice, connectivity, resilience, green-port and trade-cost literature	Construct interpretable component indices.	Components depend on proxy strength and normalization.
BSMCII composite score	Composite-indicator literature	Aggregate only after transparent normalization and sensitivity checks.	Composite score is a readiness measure, not a causal mechanism by itself.
Econometric association tests	Gravity, panel, robust covariance, quantile and threshold literature	Use OLS/WLS, FE/RE, stress tests and robustness diagnostics.	Evidence is association-focused and small-sample cautious.
Anaklia scenario	Port regionalization and port-choice literature	Treat as counterfactual frontier node.	Scenario evidence is not observed performance.

2.14. Research Gap and Contribution Located by the Review

The review identifies a clear gap. Existing literature offers strong foundations for trade corridors, port efficiency, port choice, liner networks, hinterland integration, resilience, environmental performance, composite indicators and panel econometrics. However, these streams are usually treated separately. Corridor studies often remain at the level of infrastructure and trade costs. Port studies often focus on individual terminals or port-choice determinants. Resilience studies often examine disruption response without integrating port competitiveness. Composite-index studies often provide methodology without corridor-specific content. The BSMCII study connects these streams into one measurement architecture for the Black Sea-Middle Corridor interface.

The first contribution located by the review is conceptual. The Black Sea segment is reframed from a maritime add-on to a measurable corridor multiplier. The second contribution is methodological: eleven component indices are aggregated into BSMCII, quality-adjusted and then tested econometrically. The third contribution is empirical: Georgian ports, EU Black Sea benchmarks, Caspian nodes, route alternatives and Anaklia scenarios are placed in one comparative evidence framework. The fourth contribution is claim discipline: the study distinguishes strong association evidence, component bottleneck evidence, moderate panel evidence, weak stress-test evidence and counterfactual scenario evidence.

The literature therefore supports the final position of the manuscript: the Middle Corridor will not become fully competitive through route existence alone. It requires a coordinated Caspian-Black Sea-EU feeder architecture in which ports, railways, feeder lines, documentation, reliability, resilience and green performance are jointly improved. BSMCII provides a transparent way to measure that readiness and to identify the precise component bottlenecks that policy and operators must address.

Chapter 3. Methodology

3.1. Methodological Position and Research Design

This chapter defines the methodological architecture used to measure the integration readiness of the Middle Corridor and the Black Sea basin. The design is quantitative, composite-index based, comparative, panel-oriented and proxy-aware. It is not a purely descriptive logistics assessment; it combines operational indicators, composite index construction, scenario simulation, econometric association models, nonlinear diagnostics and robustness testing into one coherent empirical framework.

The methodology is deliberately three-level. Level I constructs and interprets eleven component indices. Level II aggregates those indicators into the authorial Black Sea-Middle Corridor Integration Index (BSMCII). Level III tests whether BSMCII and its components are empirically associated with corridor flow outcomes. A fourth strategic layer evaluates corridor alternatives such as BTK-only logic, EU Black Sea hubs, Georgian ports, the northern route, the marine route and Anaklia scenarios.

The unit of analysis is the port/route-year observation. The working empirical base contains 19 port/route calculation rows, 11 unique entities and a 2020-2025 observation window. The dataset is calculation-ready, publicly archived through the Zenodo replication package (Gondauri, 2026), and proxy-aware: several variables are official or official-derived, while others use structured proxy construction when final operator-level data are unavailable.

Layer	Methodological role	Main outputs
Level I: Component indices	Measures the operational, cost, reliability, resilience, hinterland and environmental dimensions of corridor readiness.	DEA, MPI, CPPI, Connectivity, TCDI, CAI, Reliability, Resilience, Hinterland, TradeCost and Green indices.
Level II: BSMCII	Aggregates the eleven dimensions into one composite integration-readiness score.	BSMCII, quality-adjusted BSMCII, uncertainty bands and component contribution analysis.
Level III: Econometrics	Tests whether index-based readiness is associated with corridor flow outcomes.	OLS/WLS, FE/RE, dynamic stress tests, gravity, mediation, nonlinear, quantile and robustness models.
Strategic layer	Translates empirical results into corridor competition and scenario logic.	Competitive comparison, Anaklia counterfactual scenarios and BTK versus Caspian-Black Sea integration logic.

3.2. Research Questions and Empirical Logic

The methodology is designed to answer four interrelated empirical questions:

- Can the Black Sea segment be measured as a corridor multiplier rather than as a maritime appendix?
- Which component dimensions create the main bottlenecks in Middle Corridor-Black Sea integration?
- Do Georgian ports show measurable improvement relative to EU Black Sea and corridor benchmarks?
- Does the composite BSMCII structure provide stable empirical support across linear, dynamic, nonlinear and robustness specifications?

The empirical logic is comparative rather than purely national. Georgian ports are evaluated relative to Constanta, Varna, Burgas, Caspian nodes, the TITR full route, the northern rail route and a marine-route benchmark. This allows the methodology to distinguish local improvement from system-level competitiveness.

3.3. Data Architecture, Observation Unit and Variables

The observation unit is defined as entity i in year t. An entity may be a port, a corridor segment or a route benchmark. The dataset includes port-year and route-year observations because the research question is not limited to individual ports; it concerns corridor competitiveness as a multimodal architecture.

Equation (3.1). $O_{it} = \{entity_i, year_t, level_i, country_i, X_{it1}, X_{it2}, ..., X_{itK}\}$

O_{it} denotes one port/route-year observation and X_{itk} denotes a raw or proxy-coded variable used in component construction.

The principal outcome variable in the econometric section is the logarithm of container/transit flow. BSMCII and component indices are the main explanatory variables. Control variables include distance, cost, transit time, documentation-continuity score, port/route status, year trend and entity effects where the sample permits.

Variable group	Examples	Methodological role
Outcome	ln(TEU) or ln(flow)	Measures corridor or port flow intensity in the econometric models.

Main composite index	BSMCII	Captures multidimensional corridor readiness.
Level-I components	DEA, MPI, CPPI, Connectivity, TCDI, CAI, Reliability, Resilience, Hinterland, TradeCost, Green	Identify the channel through which corridor readiness is formed.
Gravity controls	lnDistance, lnCostFEU, transit time, document-continuity score	Separates composite readiness from distance, cost, time and documentary channels.
Panel identifiers	entity, year, country, level	Enable panel, subgroup and fixed/random-effects specifications.
Data-quality indicators	data-quality score, official/proxy status	Control weighting, interpretation and reviewer-safe limitations.

The archived Zenodo record contains the unified Excel workbook, CSV exports, source mapping, variable/codebook documentation, methodology and replication notes, metadata and replication script used to recompute and audit the BSMCII results: https://zenodo.org/records/21282793.

3.4. Data Processing, Normalization and Data-Quality Logic

Because the eleven components use different units and directions, all indicators are normalized before aggregation. The general rule is that higher normalized values must always represent stronger corridor readiness. Therefore, positive indicators use direct min-max normalization, while cost, delay and emissions indicators use inverse normalization.

Equation (3.2). $I_{itk} = (X_{itk} - \min(X_k)) / (\max(X_k) - \min(X_k))$

Direct normalization is used when a higher raw value means stronger performance, such as higher on-time performance or higher service intensity.

Equation (3.3). $I_{itk} = (\max(X_k) - X_{itk}) / (\max(X_k) - \min(X_k))$

Inverse normalization is used when a higher raw value means weaker performance, such as higher route cost, higher delay dispersion or higher emissions intensity.

Equation (3.4). $Z_{itk} = (X_{itk} - \text{mean}(X_k)) / \text{sd}(X_k)$

Z-score standardization is used in alternative composite-index robustness checks.

Equation (3.5). $M_{it} = \{k : I_{itk} \text{ is observed}\}$

M_{it} is the set of available component indices for observation i,t. It prevents missing components from being mechanically treated as zero.

Equation (3.6). $Q_{it} = \sum_s w_s * q_{its}$, where $\sum_s w_s = 1$ and $0 <= Q_{it} <= 1$

Q_{it} is the observation-level data-quality score. It summarizes whether the underlying information is official, official-derived, mixed or proxy-coded.

Algorithm 3.1. Data preparation and normalization pipeline

Step	Operation
1	Define each entity-year observation and classify it as port, route or scenario observation.
2	Collect raw variables for port statistics, CPPI-related performance, liner/connectivity, route cost/time, reliability, resilience, hinterland and green-performance indicators.
3	Assign data-quality status to each variable: official, official-derived, mixed or proxy-coded.
4	Normalize all variables so that higher values represent stronger corridor readiness.
5	Construct the eleven Level-I component indices and record missing components without converting them into artificial zeros.
6	Calculate BSMCII, quality-adjusted BSMCII, uncertainty intervals and econometric input variables.

3.5. Level-I Component Index Methodology

Level I converts heterogeneous logistics variables into eleven standardized index blocks. Each block is designed to capture a distinct corridor-readiness dimension. The methodological rule is interpretability: every component must correspond to a clear corridor function and must be capable of being audited through the archived replication package or replaced with stronger official data in subsequent source-strengthening exercises.

3.5.1. Data Envelopment Analysis (DEA)

DEA measures relative efficiency in transforming capacity and infrastructure conditions into throughput-oriented performance. The study uses DEA as an efficiency frontier device rather than as a final causal mechanism. The preferred orientation is output-oriented for corridor interpretation, because the policy problem is to expand usable throughput and corridor service performance from available capacity. Input-oriented interpretation is retained as a complementary reading when capacity utilization is the main concern.

Equation (3.7). P = {(x,y): x can produce y}

P denotes the production possibility set in DEA, where x is an input vector and y is an output vector.

Equation (3.8). max_phi phi subject to sum_j lambda_j y_j >= phi*y_i, sum_j lambda_j x_j <= x_i, lambda_j >= 0

This is the output-oriented CRS envelopment form. A higher phi indicates stronger output expansion potential from the same input bundle.

Equation (3.9). theta_i = 1 / phi_i

The DEA efficiency score is bounded between 0 and 1; values closer to 1 indicate stronger relative efficiency.

Equation (3.10). VRS condition: sum_j lambda_j = 1

The VRS version separates pure technical efficiency from scale effects when the sample permits.

3.5.2. Malmquist Productivity Index (MPI)

MPI captures within-entity productivity movement over time. It is valid only when repeated observations exist for the same entity. Therefore, MPI is used as a dynamic component and interpreted with caution in a short, unbalanced panel.

Equation (3.11). MPI_it = EC_it * TC_it

The Malmquist Productivity Index is decomposed into efficiency change and technical change.

Equation (3.12). EC_it = DEA_it / DEA_i,t-1

Efficiency change measures movement toward or away from the frontier.

Equation (3.13). TC_it = sqrt([D_t(x_i,t-1,y_i,t-1)/D_t(x_it,y_it)] * [D_t-1(x_i,t-1,y_i,t-1)/D_t-1(x_it,y_it)])

Technical change captures shifts in the frontier across periods. In the current dataset, the decomposition is interpreted as proxy-aware because the panel is short.

3.5.3. Container Port Performance Index (CPPI)

CPPI captures container-port operational performance. Because raw CPPI-type scores may have different signs and ranges, the index is normalized so that higher values mean stronger port performance.

Equation (3.14). CPPI_it = (Score_it - min(Score)) / (max(Score) - min(Score))

The normalization aligns CPPI-type scores with the direction of BSMCII. Sensitivity without CPPI is required because CPPI can be a strong differentiator across ports.

3.5.4. LSCI/LSBCI Connectivity Block

The Connectivity block measures liner and feeder-service intensity. It is central to the Black Sea thesis because the Middle Corridor can only become a multimodal Eurasian corridor if Black Sea feeder continuity is operationalized.

Equation (3.15). Connectivity_it = w1*LS_it + w2*DC_it + w3*WF_it

LS_it denotes normalized liner services, DC_it denotes normalized direct connections, WF_it denotes normalized weekly feeder calls, and weights sum to one.

3.5.5. Transit Cost and Document Integration Index (TCDI)

TCDI combines transit time, route cost, distance efficiency and documentation continuity. It captures whether the corridor can reproduce across the Black Sea the document-continuity logic already achieved across the Caspian Sea.

Equation (3.16). TCDI_it = a1*T_it_inv + a2*C_it_inv + a3*D_it_eff + a4*Doc_it

T_it_inv is inverse-normalized transit time, C_it_inv is inverse-normalized cost, D_it_eff is distance-efficiency score, Doc_it is documentation-continuity score, and weights sum to one.

3.5.6. Corridor Accessibility Index (CAI)

CAI evaluates whether a node is accessible in operational and institutional terms, not only geographically. It combines TCDI, document continuity, connectivity and reliability.

Equation (3.17). CAI_it = b1*TCDI_it + b2*Doc_it + b3*Connectivity_it + b4*Reliability_it

CAI is a joint accessibility block; a port or route must be serviceable, connected and reliable to be treated as accessible.

3.5.7. Reliability Index

Reliability measures schedule predictability. It combines on-time performance and delay dispersion. Higher values indicate greater predictability for container movement and feeder scheduling.

Equation (3.18). Reliability_it = c1*OnTime_it + c2*(DelaySD_it)_inv

OnTime_it is normalized on-time performance and (DelaySD_it)_inv is inverse-normalized delay dispersion.

3.5.8. Resilience Index

Resilience measures the ability of a corridor node to absorb disruptions through operator diversity, alternative services and lower route concentration.

Equation (3.19). HHI_it = sum_m s_mit^2

HHI measures concentration among services, operators or route options.

Equation (3.20). Resilience_it = d1*AlternativeRoutes_it + d2*OperatorDiversity_it + d3*(1 - HHI_it)

Higher values indicate lower concentration risk and greater disruption-absorption capacity.

3.5.9. Hinterland Integration Index

Hinterland integration measures the inland connection of the port or route node. For Georgian ports and a future Anaklia node, hinterland performance is critical because port capacity cannot become corridor capacity without rail, block-train and last-mile performance.

Equation (3.21). Hinterland_it = e1*RailAccess_it + e2*TrainPairs_it + e3*BlockTrain_it + e4*(LastMileHours_it)_inv

The index combines rail access, train-pair capacity, block-train availability and inverse-normalized last-mile time.

3.5.10. Trade-Cost Index

TradeCost is an inverse-normalized ad valorem or route-cost burden index. Higher values indicate lower relative cost burden and stronger competitiveness.

Equation (3.22). TradeCost_it = (max(Cost) - Cost_it) / (max(Cost) - min(Cost))

The TradeCost block is interpreted as one of the principal constraints on corridor competitiveness.

3.5.11. Green Performance Index

The Green index measures relative route-emissions performance. Higher values indicate lower emissions intensity per TEU and stronger long-term competitiveness under environmental-performance criteria.

Equation (3.23). Green_it = (max(CO2_per_TEU) - CO2_per_TEU_it) / (max(CO2_per_TEU) - min(CO2_per_TEU))

Green performance is a competitiveness dimension because EU-Asia logistics demand increasingly rewards lower-emission corridor packages.

Index	Core construct	Higher value means
DEA	Capacity-utilization efficiency	Closer to the usable efficiency frontier.
MPI	Productivity momentum	Improvement relative to prior observation.
CPPI	Container-port operational performance	Stronger terminal and vessel-time performance.
Connectivity	Liner/feeder service intensity	More direct connections and weekly feeder calls.
TCDI	Cost-time-document integration	More efficient transit package.
CAI	Operational accessibility	More accessible and institutionally serviceable node.
Reliability	Schedule predictability	Higher on-time rate and lower delay dispersion.
Resilience	Disruption absorption	More alternatives and lower concentration risk.
Hinterland	Rail/inland integration	Stronger rail, block-train and last-mile performance.
TradeCost	Relative cost burden	Lower effective trade-cost burden.
Green	Emissions performance	Lower CO2 per TEU.

3.6. Level-II BSMCII Composite Index Methodology

BSMCII aggregates the eleven component indices into a single authorial composite measure of Black Sea-Middle Corridor integration readiness. The index is intentionally transparent: each component remains visible and can be audited through descriptive statistics, component contribution tables, leave-one-component-out checks and alternative weighting schemes.

Equation (3.24). BSMCII_it = (1 / |M_it|) * sum_{k in M_it} I_itk

The baseline BSMCII is the missing-aware average of available normalized component indices.

Equation (3.25). QBSMCII_it = BSMCII_it * Q_it

Quality-adjusted BSMCII incorporates data-quality strength into the composite score.

Equation (3.26). Delta BSMCII_i = BSMCII_i,t2 - BSMCII_i,t1

This measures repeated-entity change over time.

Equation (3.27). Contribution_ik = I_i,t2,k - I_i,t1,k

Component contribution analysis decomposes observed BSMCII change by individual index movement.

Equation (3.28). CI_it = [quantile_0.025(BSMCII_it^b), quantile_0.975(BSMCII_it^b)]

Component-resampling uncertainty bands are obtained by resampling available components and recalculating BSMCII repeatedly.

Algorithm 3.2. BSMCII construction and audit

Step	Operation
1	Normalize all component indicators so that higher values mean stronger performance.
2	Create the set of available components M_it for each observation.
3	Compute BSMCII as a missing-aware average of available components.
4	Multiply BSMCII by the data-quality score to obtain quality-adjusted BSMCII.
5	Calculate component-resampling uncertainty intervals.
6	Check arithmetic consistency by comparing workbook and recomputed values; audit errors must be negligible.

3.7. Scenario and Competitive-Strategy Methodology

The methodology includes counterfactual scenario simulation because Anaklia is strategically central but not yet an observed operating port in the dataset. Scenario values are therefore treated as structured results simulation, not observed port performance.

Equation (3.29). BSMCII_scenario = (1 / K) * sum_{k=1}^K I_scenario,k

Scenario BSMCII is calculated from assumed component values for conservative, base and optimistic Anaklia cases.

Equation (3.30). Range_s = [BSMCII_s - m_s, BSMCII_s + m_s]

Scenario ranges reflect uncertainty around assumed component values.

The competitive layer compares BTK-only logic, Georgian Black Sea ports, EU Black Sea hubs, northern-route alternatives, marine-route benchmarks and Anaklia scenarios. This is not a narrative add-on; it is the strategic translation of the component and composite results.

Alternative class	Observed/scenario status	Methodological interpretation
BTK-only land rail logic	Observed strategic alternative	Tests whether land continuity alone is sufficient.
Constanta/Romania	Observed EU Black Sea benchmark	Defines the high-integration regional benchmark.
Varna/Burgas	Observed EU Black Sea alternatives	Defines medium-high EU comparator group.
Poti/Batumi	Observed Georgian Black Sea ports	Measures current Georgian corridor anchors.
Anaklia	Counterfactual scenario node	Evaluates future upside under conservative, base and optimistic assumptions.
Northern route	Route benchmark	Provides a land-route competitiveness comparator.
Marine route	Route benchmark	Provides a maritime scale/cost comparator.

3.8. Level-III Econometric Methodology

The econometric section tests whether corridor readiness measured by BSMCII and its components is associated with flow outcomes. The dependent variable is the logarithm of TEU/container/transit flow. The models are association models and must not be interpreted as full causal identification. The small and unbalanced panel requires robust standard errors, bootstrap/permutation checks and conservative interpretation.

Equation (3.31). y_it = ln(Flow_it)

The outcome variable is the logarithm of the available flow measure.

Equation (3.32). y_it = alpha + beta*BSMCII_it + eps_it

Baseline pooled OLS specification.

Equation (3.33). y_it = alpha + beta*BSMCII_it + gamma*t + eps_it

Pooled OLS with linear time trend.

Equation (3.34). y_it = alpha + beta*BSMCII_it + rho*PortRoute_i + eps_it

Pooled OLS with port/route dummy.

Equation (3.35). min sum_it w_it*(y_it - alpha - beta*BSMCII_it)^2

Data-quality weighted least squares, where w_it is linked to the data-quality score.

Equation (3.36). y_it = alpha_i + beta*BSMCII_it + eps_it

Entity fixed-effects specification.

Equation (3.37). y_it = alpha_i + lambda_t + beta*BSMCII_it + eps_it

Two-way fixed-effects approximation with entity and time components.

Equation (3.38). y_it = alpha + beta*BSMCII_it + u_i + eps_it

Random-effects / mixed-effects specification, where u_i is the entity-level random component.

Equation (3.39). Delta y_it = beta*Delta BSMCII_it + Delta eps_it

First-difference specification for repeated observations.

Equation (3.40). y_it = alpha + phi*y_i,t-1 + beta*BSMCII_it + eps_it

Dynamic lagged-dependent-variable model.

Equation (3.41). Delta y_it = phi*Delta y_i,t-1 + beta*Delta BSMCII_it + Delta eps_it

Difference-GMM/IV stress-test form. In this study, it is retained only as a dynamic stress test and must not be interpreted as causal evidence.

Equation (3.42). y_it = alpha + beta*BSMCII_it + delta1*lnDistance_it + delta2*lnCostFEU_it + delta3*TransitTime_it + delta4*Doc_it + eps_it

Gravity-type model separating BSMCII from distance, cost, time and document-continuity channels.

If BSMCII loses precision in the gravity-type model after adding distance, cost, time and documentation controls, the interpretation is not that BSMCII is rejected. Rather, it means that the composite index partly operates through those gravity and document-continuity channels.

3.8.1. Mediation and Channel Analysis

Mediation models are used to test whether Connectivity, TradeCost, Reliability or TCDI act as channels between BSMCII and flow outcomes. Because the sample is small, mediation is interpreted as channel-suggestive, not as definitive proof of causal mediation.

Equation (3.43). Mediator_it = a0 + a1*BSMCII_it + v_it

First mediation path: BSMCII to the mediator.

Equation (3.44). y_it = c0 + c_prime*BSMCII_it + b*Mediator_it + e_it

Second mediation path: mediator and BSMCII jointly explain flow.

Equation (3.45). IndirectEffect = a1*b

The indirect effect is calculated as the product of the first-stage and second-stage mediation coefficients.

Equation (3.46). CI_indirect = [quantile_0.025((a*b)^b), quantile_0.975((a*b)^b)]

Bootstrap confidence intervals are used for indirect-effect uncertainty.

3.8.2. Nonlinear, Threshold, Logit and Quantile Methods

Nonlinear methods are included to check whether the BSMCII-flow association changes across readiness regimes or quantiles. These models are diagnostic extensions and should be interpreted through the evidence grading table rather than as standalone causal estimates.

Equation (3.47). y_it = alpha + beta1*BSMCII_it + beta2*BSMCII_it^2 + eps_it

Quadratic OLS tests for curvature.

Equation (3.48). y_it = alpha + beta1*BSMCII_it + beta2*max(0, BSMCII_it - tau) + eps_it

Piecewise threshold model with threshold tau.

Equation (3.49). y_it = alpha + beta1*BSMCII_it + beta2*HighRegime_it + beta3*(BSMCII_it*HighRegime_it) + eps_it

Regime-interaction model.

Equation (3.50). Pr(HighFlow_it = 1) = Lambda(alpha + beta*BSMCII_it)

Logit high-flow probability model, where Lambda is the logistic cumulative distribution function.

Equation (3.51). Q_tau(y_it | X_it) = alpha_tau + beta_tau*BSMCII_it

Quantile regression estimates the BSMCII association at different parts of the conditional flow distribution.

3.8.3. Statistical Inference, p-values, t/z statistics and Small-Sample Tests

The inference strategy uses robust standard errors, p-values, small-sample checks, bootstrap p-values and permutation p-values. When the model is linear, coefficient significance can be read through t-statistics. In large-sample or logit-type settings the same coefficient-to-standard-error ratio is interpreted as a z-statistic.

Equation (3.52). t_j = beta_hat_j / SE(beta_hat_j)

The t-statistic measures the coefficient relative to its standard error in linear models.

Equation (3.53). z_j = beta_hat_j / SE(beta_hat_j)

The z-statistic is the analogous large-sample statistic used in logit and asymptotic settings.

Equation (3.54). p_j = 2 * Pr(|T| >= |t_j|)

Two-sided p-value for coefficient significance in a t-test framework.

Equation (3.55). SE_HC1 = sqrt(diag[(X'X)^(-1) X' diag(e_i^2) X (X'X)^(-1)] * n/(n-k))

HC1 robust standard errors correct heteroskedasticity in small samples.

Equation (3.56). p_boot = (1/B) * sum_b 1{|T_b| >= |T_obs|}

Bootstrap p-value based on resampled test statistics.

Equation (3.57). p_perm = (1/B) * sum_b 1{|T_perm,b| >= |T_obs|}

Permutation p-value based on randomly permuted outcome or treatment labels.

Model family	Purpose	Inference safeguard
Pooled OLS/WLS	Baseline association between BSMCII and flow.	HC1 robust SE, wild bootstrap and permutation p-values.
FE/RE/TWFE	Within/between panel diagnostics.	Hausman-type comparison and variance decomposition.
Dynamic LDV/GMM-IV	Persistence and dynamic stress testing.	Retained only as stress-test; no causal overclaiming.
Gravity model	Distance, cost, time and documentation channels.	Careful channel interpretation if BSMCII loses precision.
Mediation	Connectivity, TradeCost, Reliability and TCDI channels.	Bootstrap indirect-effect intervals.
Nonlinear/logit/quantile	Regime, classification and distributional effects.	Evidence grading; no overclaiming of weak models.

3.9. Robustness, Sensitivity and Diagnostics

Robustness testing is required because composite-index results may be sensitive to component selection, weighting, influential observations and small-sample noise. The study therefore applies several robustness layers.

Equation (3.58). BSMCII_it^(-k) = (1 / (|M_it|-1)) * sum_{j in M_it, j != k} I_itj

Leave-one-component-out BSMCII removes component k and recomputes the composite index.

Equation (3.59). Corr_k = corr(BSMCII_it, BSMCII_it^(-k))

Correlation with original BSMCII tests whether the composite architecture is stable after omitting one component.

Equation (3.60). BSMCII_it^W = sum_k w_k * I_itk

Alternative-weight BSMCII uses equal, PCA, entropy, quality-adjusted or expert weights.

Equation (3.61). w_k^entropy = (1 - E_k) / sum_j (1 - E_j)

Entropy weights assign greater weight to components with higher information content.

Equation (3.62). CookD_i = (e_i^2 / (k*MSE)) * (h_ii / (1 - h_ii)^2)

Cook distance identifies influential observations in the pooled model.

Equation (3.63). rho_delta(e) = 0.5*e^2 if |e|<=delta; delta*(|e|-0.5*delta) if |e|>delta

Huber loss reduces sensitivity to extreme residuals in robust regression.

Equation (3.64). beta_jackknife,i = beta_hat estimated after removing observation i

Jackknife sensitivity checks whether the sign and magnitude of the coefficient survive one-at-a-time exclusions.

Algorithm 3.3. Robustness and diagnostic pipeline

Step	Operation
1	Estimate the baseline BSMCII-flow association with robust standard errors.
2	Re-estimate the model with data-quality weights and subgroup samples.
3	Run HC1, wild bootstrap and permutation p-value checks.
4	Estimate FE, RE, TWFE and variance-decomposition diagnostics.
5	Rebuild BSMCII with alternative weights and leave-one-component-out variants.
6	Check influence using Cook distance, Huber regression, jackknife coefficients and sample-exclusion tests.
7	Classify every model result into strong, moderate, weak/stress-test or channel evidence.

3.10. Interpretation Rules and Reviewer-Safe Evidence Grading

The methodology uses strict interpretation rules to avoid overclaiming. The strongest evidence is assigned to models that are positive, statistically significant and stable across alternative specifications. Moderate evidence is assigned to models with stable sign but weaker precision. Weak or stress-test evidence is retained only to show that the result was examined, not to claim causal proof.

Evidence class	Criteria	Interpretation rule
Strong	Positive sign, conventional p-value support, robustness to weighting or sample variants.	Used as central empirical support.
Moderate	Stable sign but weaker precision or limited within variation.	Used as supportive but cautious evidence.
Channel evidence	Composite loses precision after controls but channels are meaningful.	Interpreted as evidence of transmission through cost, time, distance or document variables.
Weak/stress-test	Small N, weak precision, underpowered or scenario-only.	Reported transparently but not used for causal claims.
Counterfactual scenario	Anaklia or prospective infrastructure values.	Interpreted as structured simulation, not observed performance.

3.11. Methodological Limitations

The methodology is designed to be transparent and reviewer-safe, but it has clear limitations that must be acknowledged.

- Small sample size: the current calculation-ready dataset contains 19 port/route rows, which limits statistical power and makes small-sample inference essential.
- Unbalanced panel: not all entities are observed in all years; therefore, FE, TWFE, dynamic and MPI results must be interpreted cautiously.
- Proxy-aware data construction: some indicators rely on structured proxy values where official operator-level or downloadable raw data are not yet available.
- Composite-index sensitivity: BSMCII depends on normalization, weighting and component availability; this is mitigated through alternative weights, uncertainty bands and leave-one-component-out checks.
- Missing component observations: DEA and MPI are not available for all observations, and MPI requires repeated entity-year data.
- Causal identification is limited: the econometric models provide association evidence, not definitive causal identification.
- Dynamic GMM/IV is underpowered: the instrumented usable sample is too small for strong causal claims; it is retained only as a stress-test.
- Gravity controls may absorb BSMCII channels: when cost, distance, time and document-continuity variables are included, BSMCII may lose precision because the composite partly operates through those channels.
- Anaklia is counterfactual: Anaklia scenario values are structured simulations and should not be interpreted as observed port performance.
- External validity is limited: the current framework is designed for Middle Corridor and Black Sea basin applications and should be recalibrated before being applied to other corridors.

3.12. Replicability and Auditability Protocol

The methodology is constructed to be replicable. Every component has an explicit direction, normalization rule, formula and interpretation. Every composite score can be recalculated from normalized components. Every econometric result can be reproduced from the defined dependent variable, explanatory variables, sample filter and model specification. The complete BSMCII workbook, data exports, codebook, methodology notes and replication materials are archived on Zenodo as the dataset package for the present study (Gondauri, 2026).

Algorithm 3.4. Replication protocol

Step	Operation
1	Verify raw variables and assign data-quality status.
2	Normalize direct and inverse indicators according to Equations (3.2) and (3.3).
3	Construct all eleven Level-I indices using Equations (3.7)-(3.23).
4	Construct BSMCII and quality-adjusted BSMCII using Equations (3.24)-(3.25).
5	Run component-resampling uncertainty intervals using Equation (3.28).

6	Estimate the econometric model battery using Equations (3.31)-(3.51).
7	Compute statistical inference and small-sample checks using Equations (3.52)-(3.57).
8	Run robustness diagnostics using Equations (3.58)-(3.64).

3.13. Chapter Summary

The methodology combines index construction, composite measurement, panel econometrics, nonlinear diagnostics, scenario simulation and robustness testing. Its central contribution is the construction of a measurable Black Sea-Middle Corridor integration architecture. The framework is strong enough to identify component bottlenecks, compare port and route alternatives, simulate Anaklia as a future node and test whether readiness is associated with flow outcomes. At the same time, it remains conservative: it treats the archived dataset as calculation-ready and proxy-aware, avoids causal overclaiming and explicitly separates observed evidence from counterfactual scenario evidence.

Chapter 4. Research Results

Middle Corridor and Black Sea Basin Countries: Integrating the Middle Corridor with the Black Sea

The central result is strengthened as follows: the Black Sea segment is not a peripheral maritime appendix to the Middle Corridor. It is a corridor multiplier. When the document-continuity logic achieved across the Caspian Sea is extended to the Black Sea through Georgian ports, Bulgaria, Romania and a future Anaklia node, the Middle Corridor becomes a multimodal Eurasian logistics architecture rather than a single land-rail route.

4.0. Key Results Roadmap

The results are read through four evidence layers: component-index evidence, BSMCII composite evidence, econometric evidence, and competitive-strategy evidence. Together, these results show that the Black Sea segment functions as a corridor multiplier for the Middle Corridor rather than as a peripheral maritime add-on.

Top 5 Empirical Results

1. Connectivity is the strongest bottleneck in the Level-I evidence, with the lowest component mean (0.286).
2. TradeCost is the second binding constraint, confirming that cost predictability and border/waiting-cost reduction are central to competitiveness.
3. Poti and Batumi improve over 2022-2025, with Poti rising by +0.142 BSMCII points and Batumi by +0.106 points.
4. Constanta remains the leading EU Black Sea benchmark, while Varna, Burgas and Poti 2025 form the relevant medium-integration comparison cluster.
5. BSMCII provides consistent empirical support for the association between corridor readiness and flow outcomes across the strongest model families.

Table focus: This table concerns key results roadmap: hypotheses, evidence and strategic implications. It is included to show the empirical result directly before interpretation.

Table 4.1. Key results roadmap: hypotheses, evidence and strategic implications

Hypothesis / question	Index evidence	Econometric evidence	Strategic implication
H1: The Black Sea segment is a corridor multiplier, not a maritime appendix.	BSMCII ranks Constanta, Varna, Poti 2025, Burgas and TITR in a measurable integration cluster.	BSMCII is positive in pooled, WLS, ports-only, Black Sea-only and Georgia-only models.	Black Sea feeder integration can convert the trans-Caspian rail corridor into a multimodal Eurasian architecture.
H2: Connectivity and trade cost are the binding bottlenecks.	Connectivity has the lowest mean (0.286); TradeCost is second weakest (0.406).	Connectivity, TradeCost, Reliability, Resilience and Hinterland have positive single-component flow signals.	Policy should target feeder calls, direct services, cost predictability and documentation continuity.

Hypothesis / question	Index evidence	Econometric evidence	Strategic implication
H3: Georgian ports are improving but need hub-scale upgrading.	Poti grows by +0.142 BSMCII points and Batumi by +0.106 points over 2022-2025.	Georgia-only coefficient is positive and statistically significant but based on a small sample.	Poti/Batumi are near-term anchors; Anaklia is the high-upside scenario node.
H4: BTK alone is not sufficient for a 10/10 Middle Corridor strategy.	BSMCII competitiveness depends on feeder, port, document, reliability, resilience, hinterland and green blocks.	Composite robustness survives leave-one-component-out and alternative weights.	The optimal strategy is not rail-only but Caspian + Black Sea + EU feeder integration.

Note: This roadmap makes the evidence hierarchy explicit and prevents the chapter from becoming a list of disconnected tables.

The roadmap shows that the chapter's main finding is not based on one isolated indicator. The index evidence, econometric evidence and strategic implications point in the same direction: the Black Sea segment becomes a corridor multiplier when feeder services, document continuity, port productivity, reliability and hinterland access are combined into one integration package.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

4.1. Empirical Evidence Base of the Results

Table focus: This table concerns empirical sample coverage behind the results. It is included to show the empirical result directly before interpretation.

Table 4.2. Empirical sample coverage behind the results

Indicator	Value
Port/route calculation rows	19
Unique entities	11
Year range	2020-2025
Official raw observations in workbook	174
Source records in workbook	18
Mean data-quality score	0.671
Maximum arithmetic BSMCII audit error	2.22e-16

The results are built on 19 port/route calculation rows, 11 unique entities and a 2020-2025 observation window. The empirical workbook and replication files are archived in the Zenodo dataset package (Gondauri, 2026). The very small arithmetic audit error confirms that the BSMCII calculations are internally consistent, while the mean data-quality score of 0.671 signals that the results should be read as calculation-ready and proxy-aware rather than as a final official-data panel.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

4.2. Level I Results: Detailed Evidence from the Eleven Component Indices

The Level-I results identify where corridor integration is strongest and where it remains constrained. The strongest average dimensions are MPI, CPPI, Green and Resilience, while the binding constraints are Connectivity and TradeCost. This pattern supports the central result that feeder connectivity and cost predictability are the decisive gaps in the Black Sea-Middle Corridor architecture.

Table focus: This table concerns descriptive statistics of the eleven level-i indices. It is included to show the empirical result directly before interpretation.

Table 4.3. Descriptive statistics of the eleven Level-I indices

Component	N	Missing	Mean	SD	Min	Median	Max	Best observation	Worst observation
DEA	16	3	0.508	0.202	0.192	0.479	0.843	Constanta 2023	Kuryk 2022

Component	N	Missing	Mean	SD	Min	Median	Max	Best observation	Worst observation
MPI	8	11	1.040	0.201	0.684	1.054	1.283	Poti 2023	Constanta 2024
CPPI	19	0	0.751	0.361	0.000	0.907	1.000	Constanta 2023	Poti 2024
Connectivity	19	0	0.286	0.243	0.117	0.200	1.000	Marine route 2020	Kuryk 2022
TCDI	19	0	0.580	0.091	0.333	0.612	0.699	Aktau 2022	Marine route 2020
CAI	19	0	0.538	0.094	0.385	0.542	0.719	Constanta 2024	Baku/Alat 2022
Reliability	19	0	0.556	0.114	0.275	0.579	0.700	Constanta 2024	Baku/Alat 2022
Resilience	19	0	0.670	0.145	0.500	0.669	0.940	Constanta 2024	Kuryk 2022
Hinterland	19	0	0.545	0.233	0.250	0.479	0.917	Constanta 2023	Marine route 2020
TradeCost	19	0	0.406	0.278	0.000	0.385	1.000	Marine route 2020	Kuryk 2022
Green	19	0	0.742	0.225	0.000	0.776	1.000	Kuryk 2022	Marine route 2020

Note: Connectivity is the lowest mean component (0.286), followed by TradeCost (0.406). Green (0.742) and Resilience (0.670) are the strongest average dimensions in the current workbook.

The descriptive statistics reveal the core component imbalance of the corridor system. Connectivity has the weakest mean score (0.286) and TradeCost is the second weakest block (0.406), while Green performance and Resilience are among the strongest dimensions. This pattern identifies the operational bottlenecks that the Black Sea feeder strategy must solve.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Figure focus: This figure concerns level-i heatmap of the eleven index components. It is included to show the empirical result directly before interpretation.

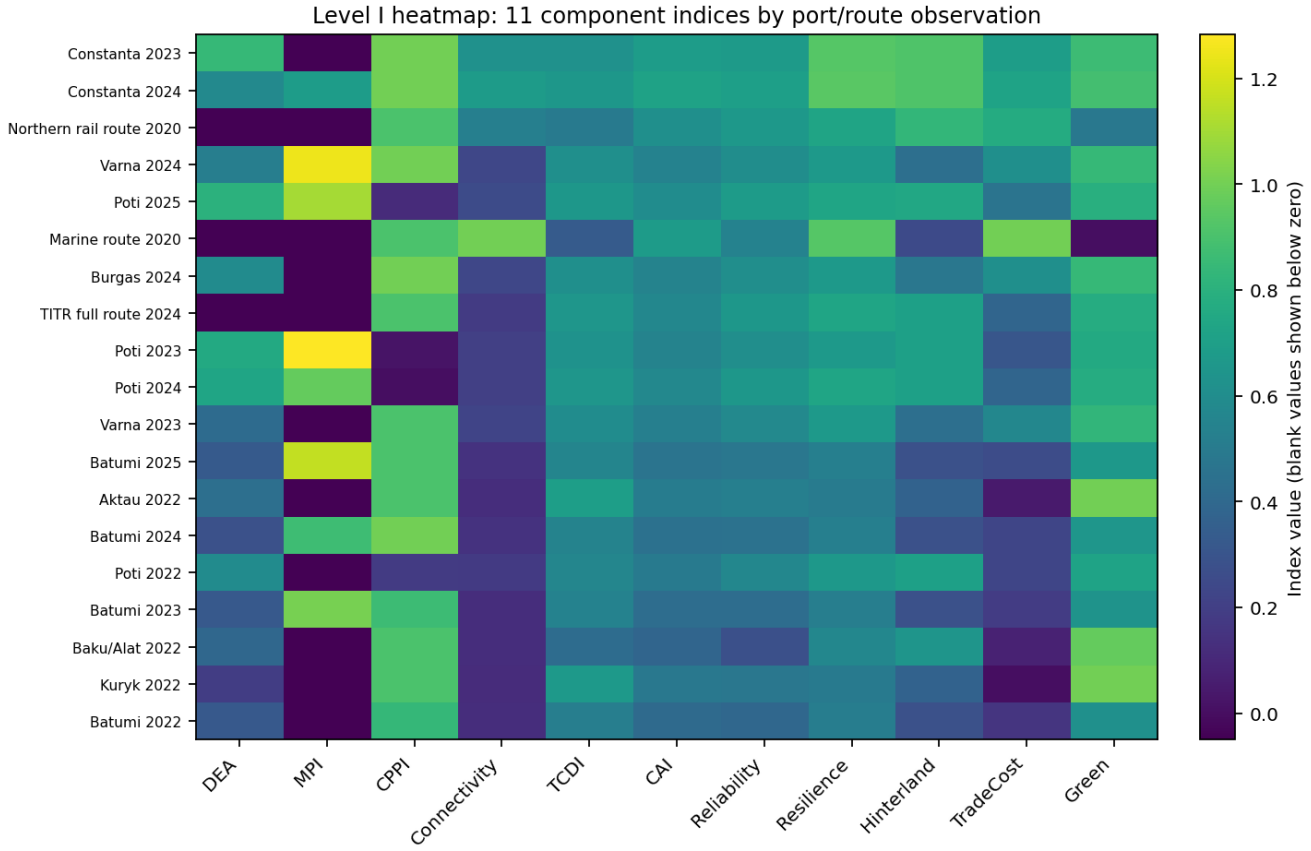


Figure 4.1. Level-I heatmap of the eleven index components

Note: Rows are sorted by BSMCII. Blank MPI/DEA cells are shown below zero only for visual separation; they are not treated as zeros in BSMCII.

The heatmap makes the component structure visible across all port and route observations. Darker low-value cells reveal the bottlenecks, while stronger cells show where an observation already has integration depth.

Source: Author's calculations and visualization based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Figure focus: This figure concerns mean component performance and bottleneck order. It is included to show the empirical result directly before interpretation.

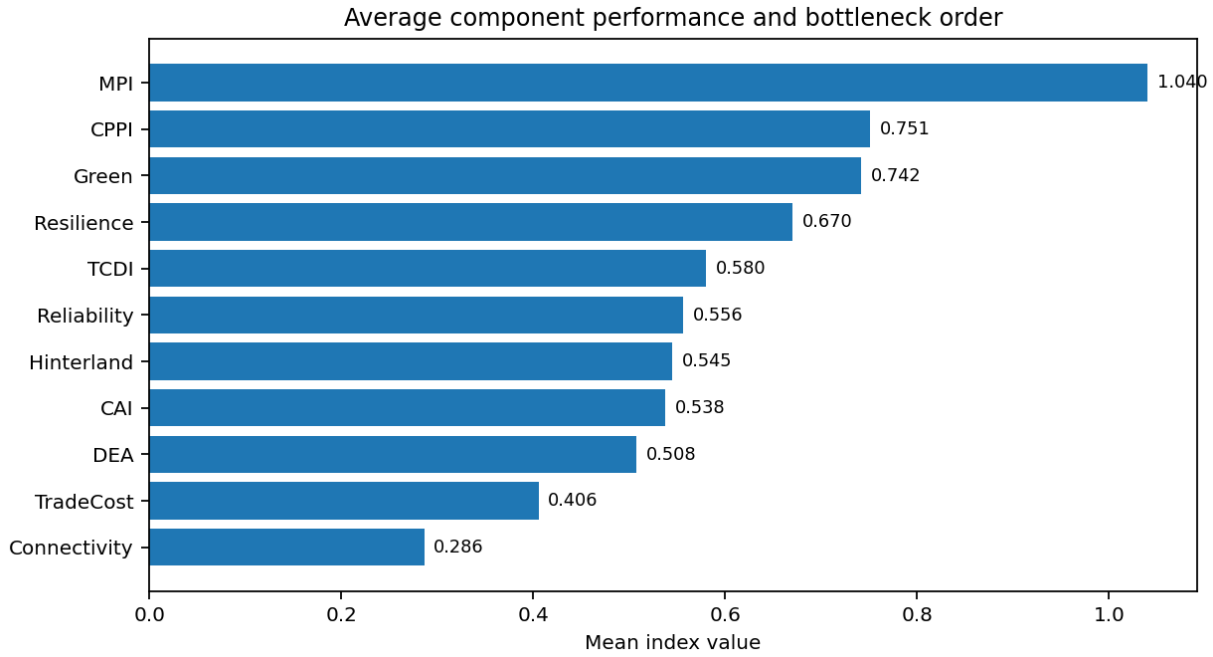


Figure 4.2. Mean component performance and bottleneck order

Note: The lowest bars identify the most binding integration constraints.

The bar chart ranks component means and visually confirms the main Level-I finding: Connectivity and TradeCost are the binding constraints, while MPI, CPPI, Green and Resilience form the stronger end of the component distribution.

Source: Author's calculations and visualization based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

4.2.1. Data Envelopment Analysis Efficiency Results

DEA results show the capacity-utilization side of corridor readiness. Higher DEA values indicate that a port or route observation is closer to its usable capacity frontier; lower values point to underused or structurally constrained throughput potential.

Table focus: This table concerns dea efficiency results: leading and weakest observations. It is included to show the empirical result directly before interpretation.

Table 4.4. DEA efficiency results: leading and weakest observations

label	country	level	DEA	BSMCII	data quality
Constanta 2023	Romania	Port	0.843	0.786	0.650
Poti 2025	Georgia	Port	0.809	0.632	0.650
Poti 2023	Georgia	Port	0.758	0.590	0.650
Kuryk 2022	Kazakhstan	Port	0.192	0.471	0.750
Batumi 2024	Georgia	Port	0.282	0.493	0.650
Batumi 2022	Georgia	Port	0.322	0.418	0.750

The DEA results show that Constanta 2023 and Poti 2025 occupy the highest efficiency positions, while Kuryk 2022 and Batumi 2022 remain at the lower end of the capacity-utilization distribution. This pattern confirms that port efficiency is not only a scale variable but also a corridor-readiness condition.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Table focus: This table concerns interpretive verdict for dea. It is included to show the empirical result directly before interpretation.

Table 4.5. Interpretive verdict for DEA

What it measures	What the result says	Meaning for Black Sea / Middle Corridor
Measures capacity-utilization efficiency relative to available port/route capacity.	Constanta 2023 and Poti 2025 are the strongest DEA observations; Kuryk 2022 is weakest.	Georgian port competitiveness depends on turning capacity into reliable throughput, especially before Anaklia is added as a prospective DMU.

The DEA verdict links capacity utilization directly to corridor competitiveness. The result indicates that Georgian port performance can move upward when available capacity is converted into reliable throughput, but the benchmark remains the higher-efficiency EU Black Sea hub represented by Constanta.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

4.2.2. Malmquist Productivity Index Results

MPI results show productivity momentum within repeated port observations. Values above 1 indicate improvement relative to the previous available observation, while values below 1 indicate normalization or decline from a stronger base.

Table focus: This table concerns mpi productivity results: leading and weakest observations. It is included to show the empirical result directly before interpretation.

Table 4.6. MPI productivity results: leading and weakest observations

label	country	level	MPI	BSMCII	data quality
Poti 2023	Georgia	Port	1.283	0.590	0.650
Varna 2024	Bulgaria	Port	1.250	0.666	0.650
Batumi 2025	Georgia	Port	1.158	0.524	0.650
Constanta 2024	Romania	Port	0.684	0.771	0.650
Batumi 2024	Georgia	Port	0.869	0.493	0.650
Poti 2024	Georgia	Port	0.968	0.580	0.650

The MPI results identify the strongest within-entity productivity momentum in Poti 2023, Varna 2024 and Batumi 2025. The result confirms that Georgian ports are not static observations in the panel; they show measurable improvement, even though the short time window limits the number of valid MPI observations.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Table focus: This table concerns interpretive verdict for mpi. It is included to show the empirical result directly before interpretation.

Table 4.7. Interpretive verdict for MPI

What it measures	What the result says	Meaning for Black Sea / Middle Corridor
Measures within-entity productivity momentum through year-on-year DEA-indicator change.	Poti 2023, Varna 2024 and Batumi 2025 show the strongest momentum; valid observations are limited because MPI requires a prior year.	The Georgian signal is dynamic: improvement is visible across the available port-year results.

The MPI verdict confirms that productivity momentum strengthens the dynamic side of the Georgian port story. Poti and Batumi improve across the observed port-year results, which supports the argument that the Georgian Black Sea segment is moving toward a higher integration class.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

4.2.3. Container Port Performance Index Results

CPPI results show how container-port operational performance differentiates the Black Sea ports. The sharp contrast between Constanta/Burgas/Varna and Poti's lower CPPI values confirms that Georgian port competitiveness requires terminal productivity and vessel-time improvement, not only geographic positioning.

Table focus: This table concerns cppi score and index results. It is included to show the empirical result directly before interpretation.

Table 4.8. CPPI score and index results

entity	country	year	CPPI score	CPPI rank	CPPI	BSMCII
Aktau	Kazakhstan	2022			0.907	0.513
Baku/Alat	Azerbaijan	2022			0.907	0.476
Batumi	Georgia	2022	-3.000		0.839	0.418
Batumi	Georgia	2023	-2.000		0.862	0.484
Batumi	Georgia	2024	4.000	206.000	0.998	0.493
Batumi	Georgia	2025	0.000	240.000	0.907	0.524
Burgas	Bulgaria	2024	4.100		1.000	0.620
Constanta	Romania	2023	4.100		1.000	0.786
Constanta	Romania	2024	4.100		1.000	0.771
Kuryk	Kazakhstan	2022			0.907	0.471
Marine route	Multi-country	2020			0.907	0.628
Northern rail route	Multi-country	2020			0.907	0.669
Poti	Georgia	2022	-32.000		0.181	0.490
Poti	Georgia	2023	-39.000		0.023	0.590
Poti	Georgia	2024	-40.000	346.000	0.000	0.580
Poti	Georgia	2025	-35.000	300.000	0.113	0.632
TITR full route	Multi-country	2024			0.907	0.618
Varna	Bulgaria	2023	0.000		0.907	0.575
Varna	Bulgaria	2024	4.100		1.000	0.666

The CPPI score block separates operationally stronger Black Sea benchmarks from lower-performing Georgian observations. Constanta, Burgas and Varna occupy the upper normalized range, while Poti's 2023-2025 values show that terminal productivity and vessel-time performance remain binding weaknesses despite Poti's broader BSMCII improvement.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Table focus: This table concerns cppi index: leading and weakest observations. It is included to show the empirical result directly before interpretation.

Table 4.9. CPPI index: leading and weakest observations

label	country	level	CPPI	BSMCII	data quality
Constanta 2023	Romania	Port	1.000	0.786	0.650
Burgas 2024	Bulgaria	Port	1.000	0.620	0.650
Constanta 2024	Romania	Port	1.000	0.771	0.650
Poti 2024	Georgia	Port	0.000	0.580	0.650
Poti 2023	Georgia	Port	0.023	0.590	0.650
Poti 2025	Georgia	Port	0.113	0.632	0.650

The CPPI index ranks Constanta, Burgas and Constanta 2024 at the top of the operational-performance block. Poti 2024, Poti 2023 and Poti 2025 remain at the weak end of this component, confirming that Georgian corridor strategy must include terminal-productivity upgrading, not only route positioning.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Table focus: This table concerns result sensitivity: bsmcii without cppi. It is included to show the empirical result directly before interpretation.

Table 4.10. Result sensitivity: BSMCII without CPPI

Omitted component	N	Coefficient	p-value	R2	Corr. with original BSMCII
CPPI	17	10.030	<0.001	0.490	0.943

Note: The leave-one-out result demonstrates that the BSMCII-flow association remains positive even when CPPI is removed.

The CPPI-exclusion check shows that the main BSMCII-flow association remains positive and statistically strong even after removing the most sensitive port-performance component. This result reduces the risk that the composite finding is driven only by CPPI normalization.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Table focus: This table concerns interpretive verdict for cppi. It is included to show the empirical result directly before interpretation.

Table 4.11. Interpretive verdict for CPPI

What it measures	What the result says	Meaning for Black Sea / Middle Corridor
Measures normalized container-port operational performance from CPPI-type scores.	The CPPI block sharply differentiates Constanta/Burgas/Varna from Poti 2023-2024.	Georgia cannot rely only on geography; terminal productivity, berth time and vessel-time performance must improve.

The CPPI verdict confirms that port productivity is a central competitive condition. The Georgian Black Sea ports cannot rely only on location; they must improve berth productivity, terminal throughput and vessel-time performance to approach the stronger EU Black Sea benchmarks.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

4.2.4. LSCI/LSBCI liner-shipping connectivity block

Connectivity results are central to the Black Sea thesis. The low mean connectivity score shows that feeder-service depth, direct connections and weekly calls are the most binding constraints for transforming the Middle Corridor into a reliable multimodal corridor.

Table focus: This table concerns liner and feeder connectivity results for key black sea ports. It is included to show the empirical result directly before interpretation.

Table 4.12. Liner and feeder connectivity results for key Black Sea ports

entity	country	year	liner_services	direct connections	weekly_feeder_calls	source IDs	Connectivity
Batumi	Georgia	2025	3	5	2	S13;S02	0.147
Burgas	Bulgaria	2024	5	8	3	S09;S03 indicator	0.233
Constanta	Romania	2024	13	26	9	S09;S10;S18	0.683
Poti	Georgia	2025	5	7	4	S12;S02;S07	0.253
Varna	Bulgaria	2024	5	8	3	S09;S17;S03	0.233

The connectivity table shows the service-intensity gap behind the Black Sea strategy. Constanta 2024 has the strongest observed service profile among the listed Black Sea ports, while Poti and Batumi remain materially weaker in liner services, direct connections and weekly feeder calls. This makes feeder development the most urgent operational result.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Table focus: This table concerns connectivity index: leading and weakest observations. It is included to show the empirical result directly before interpretation.

Table 4.13. Connectivity index: leading and weakest observations

label	country	level	Connectivity	BSMCII	data quality
Marine route 2020	Multi-country	Route	1.000	0.628	0.750
Constanta 2024	Romania	Port	0.683	0.771	0.650
Constanta 2023	Romania	Port	0.622	0.786	0.650
Kuryk 2022	Kazakhstan	Port	0.117	0.471	0.750
Batumi 2023	Georgia	Port	0.122	0.484	0.650
Batumi 2022	Georgia	Port	0.122	0.418	0.750

The Connectivity ranking confirms the lowest average component identified in the descriptive statistics. Marine route 2020 and Constanta lead the block, while Caspian and Georgian-port observations remain weaker. The result directly supports the argument that Black Sea feeder continuity is the missing integration layer.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Table focus: This table concerns interpretive verdict for connectivity. It is included to show the empirical result directly before interpretation.

Table 4.14. Interpretive verdict for Connectivity

What it measures	What the result says	Meaning for Black Sea / Middle Corridor
Measures liner/feeder service intensity through liner services, direct connections and weekly feeder calls.	Connectivity is the most severe bottleneck with mean 0.286.	The Black Sea thesis depends on feeder continuity: without direct/weekly services the corridor cannot reproduce the Caspian document-continuity success.

The Connectivity verdict is one of the strongest findings in the chapter. It shows that the Middle Corridor cannot reproduce the Caspian document-continuity success across the Black Sea unless direct services, feeder frequency and schedule coordination are strengthened.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

4.2.5. Transit Cost and Document Integration Index

TCDI results show the combined effect of transit time, route cost and distance efficiency. Higher TCDI observations indicate more efficient cost-time-document packages, which are crucial for extending the Caspian document-continuity logic across the Black Sea.

Table focus: This table concerns corridor cost and time results behind tcdi/tradecost. It is included to show the empirical result directly before interpretation.

Table 4.15. Corridor cost and time results behind TCDI/TradeCost

entity	country	year	cost (USD/FEU)	BCP cost (USD)	Residual corridor cost	BCP time (hours)	transit days	TCDI	TradeCost
Poti	Georgia	2022	4000	69	3931	12.900	17.000	0.559	0.231
Poti	Georgia	2023	3900	69	3831	12.900	13.000	0.628	0.308
Poti	Georgia	2024	3850	45	3805	14.200	12.000	0.648	0.385
Poti	Georgia	2025	3800	45	3755	14.200	12.000	0.655	0.462
Batumi	Georgia	2022	4300	69	4231	12.900	17.000	0.518	0.154
Batumi	Georgia	2023	4250	69	4181	12.900	16.000	0.539	0.185
Batumi	Georgia	2024	4200	45	4155	14.200	16.000	0.545	0.231
Batumi	Georgia	2025	4150	45	4105	14.200	15.500	0.559	0.262
Constanta	Romania	2023	3500	60	3440	8.000	15.000	0.626	0.692
Constanta	Romania	2024	3400	60	3340	8.000	14.000	0.653	0.723
Burgas	Bulgaria	2024	3600	55	3545	8.000	15.500	0.614	0.615

entity	country	year	cost (USD/FEU)	BCP cost (USD)	Residual corridor cost	BCP time (hours)	transit days	TCDI	TradeCost
Varna	Bulgaria	2023	3650	55	3595	8.000	16.000	0.598	0.569
Varna	Bulgaria	2024	3600	55	3545	8.000	15.500	0.612	0.615
Baku/Alat	Azerbaijan	2022	4200	97	4103	10.200	27.000	0.421	0.077
Kuryk	Kazakhstan	2022	4100	157	3943	9.200	12.000	0.665	0.000
Aktau	Kazakhstan	2022	4050	157	3893	9.200	10.000	0.699	0.046
TITR full route	Multi-country	2024	3850	45	3805	14.200	12.000	0.648	0.385
Marine route	Multi-country	2020	1750	0	1750	0.000	34.000	0.333	1.000
Northern rail route	Multi-country	2020	3000	50	2950	5.000	16.000	0.496	0.769

The cost-time table shows the operational burden behind the corridor. Poti improves between 2022 and 2025 through lower route costs and shorter transit time, while the marine and northern-route benchmarks retain important cost advantages. The result demonstrates why the Black Sea strategy must combine document continuity with cost predictability.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Table focus: This table concerns tcdi index: leading and weakest observations. It is included to show the empirical result directly before interpretation.

Table 4.16. TCDI index: leading and weakest observations

label	country	level	TCDI	BSMCII	data quality
Aktau 2022	Kazakhstan	Port	0.699	0.513	0.450
Kuryk 2022	Kazakhstan	Port	0.665	0.471	0.750
Poti 2025	Georgia	Port	0.655	0.632	0.650
Marine route 2020	Multi-country	Route	0.333	0.628	0.750
Baku/Alat 2022	Azerbaijan	Port	0.421	0.476	0.750
Northern rail route 2020	Multi-country	Route	0.496	0.669	0.750

The TCDI ranking places Aktau, Kuryk and Poti 2025 at the strongest end of the cost-time-document package, while the marine route and Baku/Alat are weaker in this normalized block. The result shows that cost-time performance can offset distance disadvantages when documentation and transit conditions are coordinated.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Table focus: This table concerns interpretive verdict for tcdi. It is included to show the empirical result directly before interpretation.

Table 4.17. Interpretive verdict for TCDI

What it measures	What the result says	Meaning for Black Sea / Middle Corridor
Measures transit time, cost and distance integration with higher values indicating a more efficient package.	Aktau/Kuryk and Poti 2025 lead the TCDI block; the marine route is lowest in this normalized package.	Cost-time-document integration can offset geography, but must be paired with feeder connectivity.

The TCDI verdict confirms that the Black Sea extension of the Middle Corridor depends on the combined cost-time-document package. Stronger TCDI values are valuable only when they are matched by feeder connectivity and schedule reliability.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

4.2.6. Corridor Accessibility Index

CAI results show whether a corridor node is accessible in operational terms. The index combines route efficiency, document continuity, connectivity and reliability into a single accessibility signal.

Table focus: This table concerns cai index: leading and weakest observations. It is included to show the empirical result directly before interpretation.

Table 4.18. CAI index: leading and weakest observations

label	country	level	CAI	BSMCII	data quality
Constanta 2024	Romania	Port	0.719	0.771	0.650
Constanta 2023	Romania	Port	0.686	0.786	0.650
Marine route 2020	Multi-country	Route	0.682	0.628	0.750
Baku/Alat 2022	Azerbaijan	Port	0.385	0.476	0.750
Batumi 2022	Georgia	Port	0.409	0.418	0.750
Batumi 2023	Georgia	Port	0.427	0.484	0.650

The CAI results show that accessibility is strongest for Constanta and the marine route, while Baku/Alat and Batumi remain weaker. This confirms that corridor accessibility is operational and institutional, not merely geographic.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Table focus: This table concerns interpretive verdict for cai. It is included to show the empirical result directly before interpretation.

Table 4.19. Interpretive verdict for CAI

What it measures	What the result says	Meaning for Black Sea / Middle Corridor
Measures corridor accessibility as a joint function of TCDI, documentation, connectivity and reliability.	Constanta and the marine route are strongest; Baku/Alat and Batumi 2022 are weakest.	A node is not strategic merely because it lies on the map; accessibility is operational and institutional.

The CAI verdict translates the accessibility evidence into a strategic result: a corridor node matters only when route efficiency, documentation, connectivity and reliability work together. Location alone is not enough to create corridor readiness.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

4.2.7. Schedule Reliability Index

Reliability results show the predictability of port, feeder and corridor operations. Higher values indicate stronger on-time performance and lower delay dispersion, which are necessary for scheduled container movement across the Black Sea.

Table focus: This table concerns reliability indicators and resilience results. It is included to show the empirical result directly before interpretation.

Table 4.20. Reliability indicators and resilience results

entity	country	year	on-time rate (%)	delay_sd_days	Reliability	Resilience
Poti	Georgia	2022	70	4.000	0.564	0.662
Poti	Georgia	2023	72	3.500	0.610	0.669
Poti	Georgia	2024	74	3.000	0.656	0.731
Poti	Georgia	2025	76	2.800	0.680	0.734
Batumi	Georgia	2022	58	5.500	0.397	0.517
Batumi	Georgia	2023	60	5.200	0.429	0.520
Batumi	Georgia	2024	62	5.000	0.453	0.523

entity	country	year	on-time rate (%)	delay_sd_days	Reliability	Resilience
Batumi	Georgia	2025	64	4.800	0.477	0.527
Constanta	Romania	2023	78	3.000	0.676	0.933
Constanta	Romania	2024	80	2.800	0.700	0.940
Burgas	Bulgaria	2024	72	3.500	0.610	0.672
Varna	Bulgaria	2023	70	3.800	0.579	0.666
Varna	Bulgaria	2024	72	3.600	0.603	0.669
Baku/Alat	Azerbaijan	2022	55	7.000	0.275	0.569
Kuryk	Kazakhstan	2022	60	4.500	0.479	0.500
Aktau	Kazakhstan	2022	62	4.000	0.524	0.507
TITR full route	Multi-country	2024	74	3.000	0.656	0.731
Marine route	Multi-country	2020	80	5.000	0.543	0.933
Northern rail route	Multi-country	2020	75	3.000	0.661	0.729

The reliability indicators show improving Georgian predictability, especially for Poti, where on-time performance rises and delay dispersion declines by 2025. Constanta remains the strongest benchmark, but Poti 2025 approaches the upper reliability group, which is important for scheduled feeder services.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Table focus: This table concerns reliability index: leading and weakest observations. It is included to show the empirical result directly before interpretation.

Table 4.21. Reliability index: leading and weakest observations

label	country	level	Reliability	BSMCII	data quality
Constanta 2024	Romania	Port	0.700	0.771	0.650
Poti 2025	Georgia	Port	0.680	0.632	0.650
Constanta 2023	Romania	Port	0.676	0.786	0.650
Baku/Alat 2022	Azerbaijan	Port	0.275	0.476	0.750
Batumi 2022	Georgia	Port	0.397	0.418	0.750
Batumi 2023	Georgia	Port	0.429	0.484	0.650

The Reliability ranking is led by Constanta 2024, Poti 2025 and Constanta 2023. The weakest observations remain Baku/Alat and early Batumi observations, showing that fixed schedules and delay control are critical for Black Sea corridor credibility.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Table focus: This table concerns interpretive verdict for reliability. It is included to show the empirical result directly before interpretation.

Table 4.22. Interpretive verdict for Reliability

What it measures	What the result says	Meaning for Black Sea / Middle Corridor
Measures schedule predictability through on-time performance and delay dispersion.	Constanta 2024, Poti 2025 and Constanta 2023 lead the reliability block.	The Black Sea segment requires fixed feeder windows, predictable terminal operations and documented delay monitoring.

The Reliability verdict shows that corridor integration requires predictable service, not only physical capacity. Fixed feeder windows, terminal discipline and documented delay monitoring are necessary for the Black Sea segment to function as a corridor multiplier.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

4.2.8. Operational Resilience Index

Resilience results show whether the corridor can absorb disruption through alternative routes, operator diversity and lower concentration risk. Higher resilience means the corridor is less dependent on a single operator or narrow path.

Table focus: This table concerns resilience index: leading and weakest observations. It is included to show the empirical result directly before interpretation.

Table 4.23. Resilience index: leading and weakest observations

label	country	level	Resilience	BSMCII	data quality
Constanta 2024	Romania	Port	0.940	0.771	0.650
Constanta 2023	Romania	Port	0.933	0.786	0.650
Marine route 2020	Multi-country	Route	0.933	0.628	0.750
Kuryk 2022	Kazakhstan	Port	0.500	0.471	0.750
Aktau 2022	Kazakhstan	Port	0.507	0.513	0.450
Batumi 2022	Georgia	Port	0.517	0.418	0.750

The Resilience results show that Constanta and the marine route have the strongest ability to absorb disruptions through alternatives and operator diversity. Kuryk, Aktau and Batumi 2022 sit at the weaker end, confirming that corridor resilience depends on diversified services rather than a single narrow path.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Table focus: This table concerns interpretive verdict for resilience. It is included to show the empirical result directly before interpretation.

Table 4.24. Interpretive verdict for Resilience

What it measures	What the result says	Meaning for Black Sea / Middle Corridor
Measures alternatives, operator diversity and low route concentration.	Constanta and the marine route dominate resilience; Kuryk and Aktau are weakest.	Corridor competitiveness rises when alternative routes, operators and services reduce concentration risk.

The Resilience verdict confirms that competitiveness rises when operators, alternative services and route options reduce concentration risk. This result supports a multi-node Black Sea architecture rather than a single-line corridor strategy.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

4.2.9. Hinterland Integration Index

Hinterland results show how port performance is linked to rail access, block-train capacity and last-mile efficiency. For Georgia, this result is decisive because Poti, Batumi and Anaklia cannot function as corridor multipliers without strong rail and inland connections.

Table focus: This table concerns hinterland integration indicators. It is included to show the empirical result directly before interpretation.

Table 4.25. Hinterland integration indicators

entity	country	year	rail access	train pairs/day	block train	last-mile hours	Hinterland	BSMCII
Poti	Georgia	2022	1	30	1	8	0.708	0.490
Poti	Georgia	2023	1	30	1	8	0.708	0.590
Poti	Georgia	2024	1	30	1	8	0.708	0.580
Poti	Georgia	2025	1	30	1	6	0.750	0.632
Batumi	Georgia	2022	1	7	0	12	0.279	0.418

entity	country	year	rail access	train pairs/day	block train	last-mile hours	Hinterland	BSMCII
Batumi	Georgia	2023	1	7	0	12	0.279	0.484
Batumi	Georgia	2024	1	7	0	12	0.279	0.493
Batumi	Georgia	2025	1	7	0	12	0.279	0.524
Constanta	Romania	2023	1	60	1	4	0.917	0.786
Constanta	Romania	2024	1	60	1	4	0.917	0.771
Burgas	Bulgaria	2024	1	25	0	6	0.479	0.620
Varna	Bulgaria	2023	1	20	0	7	0.438	0.575
Varna	Bulgaria	2024	1	20	0	7	0.438	0.666
Baku/Alat	Azerbaijan	2022	1	25	1	10	0.646	0.476
Kuryk	Kazakhstan	2022	1	8	0	8	0.367	0.471
Aktau	Kazakhstan	2022	1	8	0	8	0.367	0.513
TITR full route	Multi-country	2024	1	30	1	8	0.708	0.618
Marine route	Multi-country	2020	0	0	0	0	0.250	0.628
Northern rail route	Multi-country	2020	1	40	1	4	0.833	0.669

Note: For Anaklia, the next workbook version should add rail-connection design, block-train frequency, last-mile hours and expected train-pair capacity.

The hinterland indicators show that Constanta and the northern rail route hold strong rail and inland-access positions, while Batumi remains constrained by lower train-pair capacity and weaker block-train availability. Poti's 2025 improvement in last-mile hours strengthens its corridor position.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Table focus: This table concerns hinterland index: leading and weakest observations. It is included to show the empirical result directly before interpretation.

Table 4.26. Hinterland index: leading and weakest observations

label	country	level	Hinterland	BSMCII	data quality
Constanta 2024	Romania	Port	0.917	0.771	0.650
Constanta 2023	Romania	Port	0.917	0.786	0.650
Northern rail route 2020	Multi-country	Route	0.833	0.669	0.750
Marine route 2020	Multi-country	Route	0.250	0.628	0.750
Batumi 2025	Georgia	Port	0.279	0.524	0.650
Batumi 2023	Georgia	Port	0.279	0.484	0.650

The Hinterland ranking confirms Constanta as the main benchmark, with the northern rail route also strong. Batumi and the marine route remain at the lower end of the index, showing that port competitiveness requires rail access, block-train capacity and last-mile efficiency.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Table focus: This table concerns interpretive verdict for hinterland. It is included to show the empirical result directly before interpretation.

Table 4.27. Interpretive verdict for Hinterland

What it measures	What the result says	Meaning for Black Sea / Middle Corridor
Measures rail access, train-pair capacity, block-train availability and last-mile efficiency.	Constanta is the leading benchmark; Northern rail route is strong; marine route is weak by construction.	For Georgia, Anaklia/Poti/Batumi competitiveness is inseparable from rail and last-mile performance.

The Hinterland verdict is especially important for Georgia. Poti, Batumi and a future Anaklia node can become corridor multipliers only if they are connected to efficient rail, block-train and inland distribution systems.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

4.2.10. Trade-Cost Index

TradeCost is the inverted normalized ad valorem trade-cost block. It captures the cost burden of moving through the corridor.

Table focus: This table concerns tradecost index: leading and weakest observations. It is included to show the empirical result directly before interpretation.

Table 4.28. TradeCost index: leading and weakest observations

label	country	level	TradeCost	BSMCII	data quality
Marine route 2020	Multi-country	Route	1.000	0.628	0.750
Northern rail route 2020	Multi-country	Route	0.769	0.669	0.750
Constanta 2024	Romania	Port	0.723	0.771	0.650
Kuryk 2022	Kazakhstan	Port	0.000	0.471	0.750
Aktau 2022	Kazakhstan	Port	0.046	0.513	0.450
Baku/Alat 2022	Azerbaijan	Port	0.077	0.476	0.750

The TradeCost ranking shows that the marine route and northern rail route retain strong cost advantages, while Caspian link nodes are weaker in the current workbook. This result explains why the Middle Corridor must reduce tariffs, border costs, waiting costs and cost uncertainty.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Table focus: This table concerns interpretive verdict for tradecost. It is included to show the empirical result directly before interpretation.

Table 4.29. Interpretive verdict for TradeCost

What it measures	What the result says	Meaning for Black Sea / Middle Corridor
Measures inverted ad valorem trade cost; higher values mean lower relative trade costs.	Marine route and Northern rail route are strongest; Caspian link nodes are weakest in the current workbook.	The Middle Corridor must reduce tariffs, border costs, waiting costs and uncertainty to compete with mature alternatives.

The TradeCost verdict identifies the second major binding constraint after Connectivity. The Middle Corridor can compete only if cost predictability improves alongside service frequency and document continuity.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

4.2.11. Green Performance Index

Green results show the relative emissions profile of corridor observations. Higher Green values indicate lower route-emission intensity and strengthen the long-term competitiveness of the corridor under environmental performance criteria.

Table focus: This table concerns route-distance and co2/teu results for the green index. It is included to show the empirical result directly before interpretation.

Table 4.30. Route-distance and CO2/TEU results for the Green index

entity	country	year	distance_km	sea_nm	CO2 kg/TEU	Green	BSMCII
Poti	Georgia	2022	4500	750	1450	0.724	0.490

entity	country	year	distance_km	sea_nm	CO2 kg/TEU	Green	BSMCII
Poti	Georgia	2023	4500	750	1400	0.759	0.590
Poti	Georgia	2024	4500	750	1375	0.776	0.580
Poti	Georgia	2025	4500	750	1350	0.793	0.632
Batumi	Georgia	2022	4550	720	1600	0.621	0.418
Batumi	Georgia	2023	4550	720	1580	0.634	0.484
Batumi	Georgia	2024	4550	720	1560	0.648	0.493
Batumi	Georgia	2025	4550	720	1540	0.662	0.524
Constanta	Romania	2023	5200	650	1250	0.862	0.786
Constanta	Romania	2024	5200	650	1220	0.883	0.771
Burgas	Bulgaria	2024	5000	600	1280	0.841	0.620
Varna	Bulgaria	2023	5050	620	1300	0.828	0.575
Varna	Bulgaria	2024	5050	620	1280	0.841	0.666
Baku/Alat	Azerbaijan	2022	3800	250	1100	0.966	0.476
Kuryk	Kazakhstan	2022	3200	250	1050	1.000	0.471
Aktau	Kazakhstan	2022	3200	250	1050	1.000	0.513
TITR full route	Multi-country	2024	4500	1000	1375	0.776	0.618
Marine route	Multi-country	2020	12000	0	2500	0.000	0.628
Northern rail route	Multi-country	2020	10000	0	1800	0.483	0.669

The Green-index input table shows how distance, sea-leg exposure and CO2 per TEU translate into the environmental-performance block. Caspian nodes record the strongest relative emissions positions under the available indicators, while the long marine route remains weakest.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Table focus: This table concerns green index: leading and weakest observations. It is included to show the empirical result directly before interpretation.

Table 4.31. Green index: leading and weakest observations

label	country	level	Green	BSMCII	data quality
Aktau 2022	Kazakhstan	Port	1.000	0.513	0.450
Kuryk 2022	Kazakhstan	Port	1.000	0.471	0.750
Baku/Alat 2022	Azerbaijan	Port	0.966	0.476	0.750
Marine route 2020	Multi-country	Route	0.000	0.628	0.750
Northern rail route 2020	Multi-country	Route	0.483	0.669	0.750
Batumi 2022	Georgia	Port	0.621	0.418	0.750

The Green ranking is led by Aktau, Kuryk and Baku/Alat, while the marine route is the weakest observation in the current indicator structure. This confirms that environmental performance may become a strategic differentiator in future EU-Asia logistics decisions.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Table focus: This table concerns interpretive verdict for green. It is included to show the empirical result directly before interpretation.

Table 4.32. Interpretive verdict for Green

What it measures	What the result says	Meaning for Black Sea / Middle Corridor
Measures inverted CO2 per TEU; higher values indicate lower emissions intensity.	Kuryk/Aktau/Baku are strongest under the current indicator; marine route is weakest.	Future EU-Asia logistics demand may increasingly reward lower-emission corridor packages, and the current result identifies the route observations with the strongest relative Green performance.

The Green verdict shows that future corridor competitiveness will increasingly depend on combining time, cost and emissions performance. Lower-emission corridor packages can strengthen the Middle Corridor's long-run position if they are integrated with reliable feeder and hinterland services.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

4.3. Level II Results: BSMCII Composite Integration Index

Level-II results aggregate the eleven component signals into BSMCII. The ranking shows which ports and routes are closest to corridor-readiness and which observations remain below the integration frontier.

Table focus: This table concerns recalculated bsmcii ranking with quality-adjusted score. It is included to show the empirical result directly before interpretation.

Table 4.33. Recalculated BSMCII ranking with quality-adjusted score

Rank	entity	country	year	level	BSMCII	Data quality	Quality-adj. BSMCII	interpretation
1	Constanta	Romania	2023	Port	0.786	0.650	0.511	High integration
2	Constanta	Romania	2024	Port	0.771	0.650	0.501	High integration
3	Northern rail route	Multi-country	2020	Route	0.669	0.750	0.502	Medium integration
4	Varna	Bulgaria	2024	Port	0.666	0.650	0.433	Medium integration
5	Poti	Georgia	2025	Port	0.632	0.650	0.411	Medium integration
6	Marine route	Multi-country	2020	Route	0.628	0.750	0.471	Medium integration
7	Burgas	Bulgaria	2024	Port	0.620	0.650	0.403	Medium integration
8	TITR full route	Multi-country	2024	Route	0.618	0.650	0.402	Medium integration
9	Poti	Georgia	2023	Port	0.590	0.650	0.384	Medium integration
10	Poti	Georgia	2024	Port	0.580	0.650	0.377	Medium integration
11	Varna	Bulgaria	2023	Port	0.575	0.650	0.374	Medium integration
12	Batumi	Georgia	2025	Port	0.524	0.650	0.341	Low-medium integration
13	Aktau	Kazakhstan	2022	Port	0.513	0.450	0.231	Low-medium integration

Rank	entity	country	year	level	BSMCII	Data quality	Quality-adj. BSMCII	interpretation
14	Batumi	Georgia	2024	Port	0.493	0.650	0.320	Low-medium integration
15	Poti	Georgia	2022	Port	0.490	0.750	0.367	Low-medium integration
16	Batumi	Georgia	2023	Port	0.484	0.650	0.315	Low-medium integration
17	Baku/Alat	Azerbaijan	2022	Port	0.476	0.750	0.357	Low-medium integration
18	Kuryk	Kazakhstan	2022	Port	0.471	0.750	0.353	Low-medium integration
19	Batumi	Georgia	2022	Port	0.418	0.750	0.313	Low-medium integration

The BSMCII ranking places Constanta 2023 and 2024 at the top, followed by the northern rail route, Varna 2024 and Poti 2025. Poti 2025 enters the upper-middle integration cluster, which is the strongest observed Georgian result and a key empirical support for the Black Sea multiplier thesis.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Figure focus: This figure concerns bsmcii ranking: strongest observations. It is included to show the empirical result directly before interpretation.

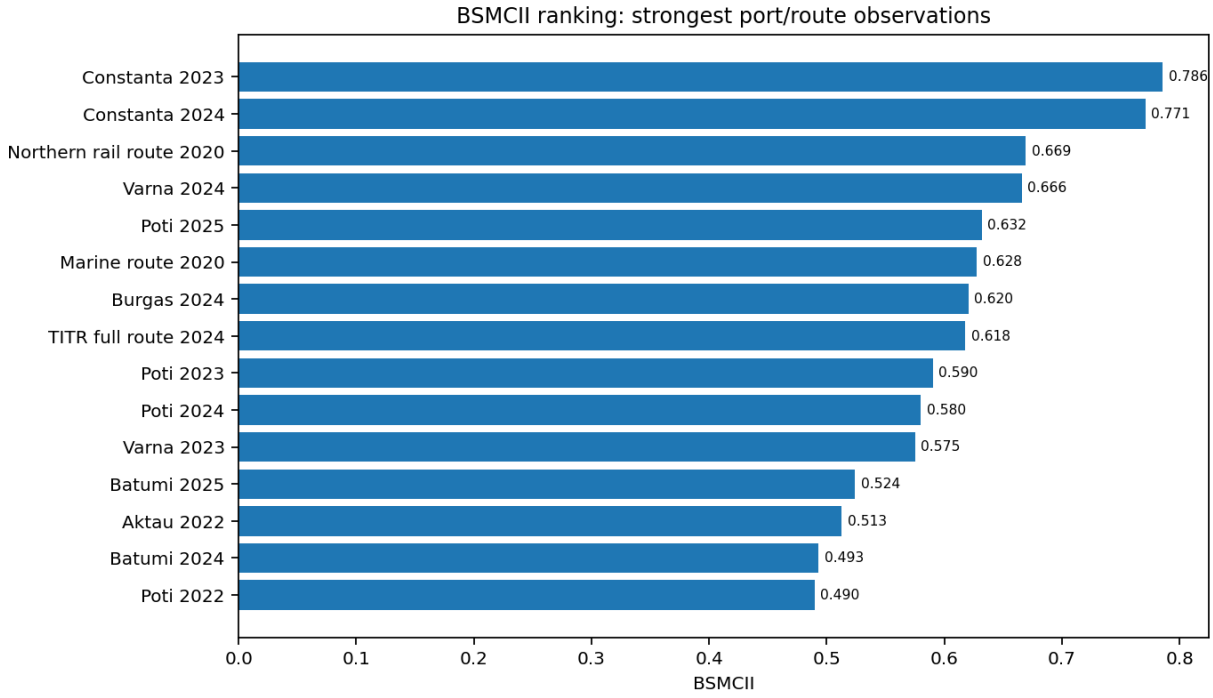


Figure 4.3. BSMCII ranking: strongest observations

Note: Constanta is the strongest EU Black Sea hub observation; Poti 2025 reaches the upper-middle group and stands close to the TITR full-route benchmark.

The ranking chart makes the corridor-readiness hierarchy visually clear. Constanta leads the observed group, while Poti 2025 reaches the upper-middle cluster close to TITR and other Black Sea alternatives.

Source: Author's calculations and visualization based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Table focus: This table concerns bsmcii component-resampling uncertainty bands: top observations. It is included to show the empirical result directly before interpretation.

Table 4.34. BSMCII component-resampling uncertainty bands: top observations

Entity	Year	BSMCII	CI low	CI high	Data quality
Constanta	2023	0.786	0.707	0.868	0.650
Constanta	2024	0.771	0.699	0.848	0.650
Northern rail route	2020	0.669	0.578	0.763	0.750
Varna	2024	0.666	0.514	0.815	0.650
Poti	2025	0.632	0.482	0.778	0.650
Marine route	2020	0.628	0.396	0.846	0.750
Burgas	2024	0.620	0.505	0.751	0.650
TITR full route	2024	0.618	0.473	0.738	0.650
Poti	2023	0.590	0.399	0.774	0.650
Poti	2024	0.580	0.411	0.720	0.650
Varna	2023	0.575	0.460	0.700	0.650
Batumi	2025	0.524	0.374	0.708	0.650

The uncertainty bands show that the top BSMCII observations should be interpreted as ranges rather than isolated point estimates. Even with component-resampling uncertainty, the upper group remains concentrated around Constanta, Varna, Poti 2025, Burgas, the northern rail route and TITR.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Figure focus: This figure concerns bsmcii point estimates with uncertainty bands. It is included to show the empirical result directly before interpretation.

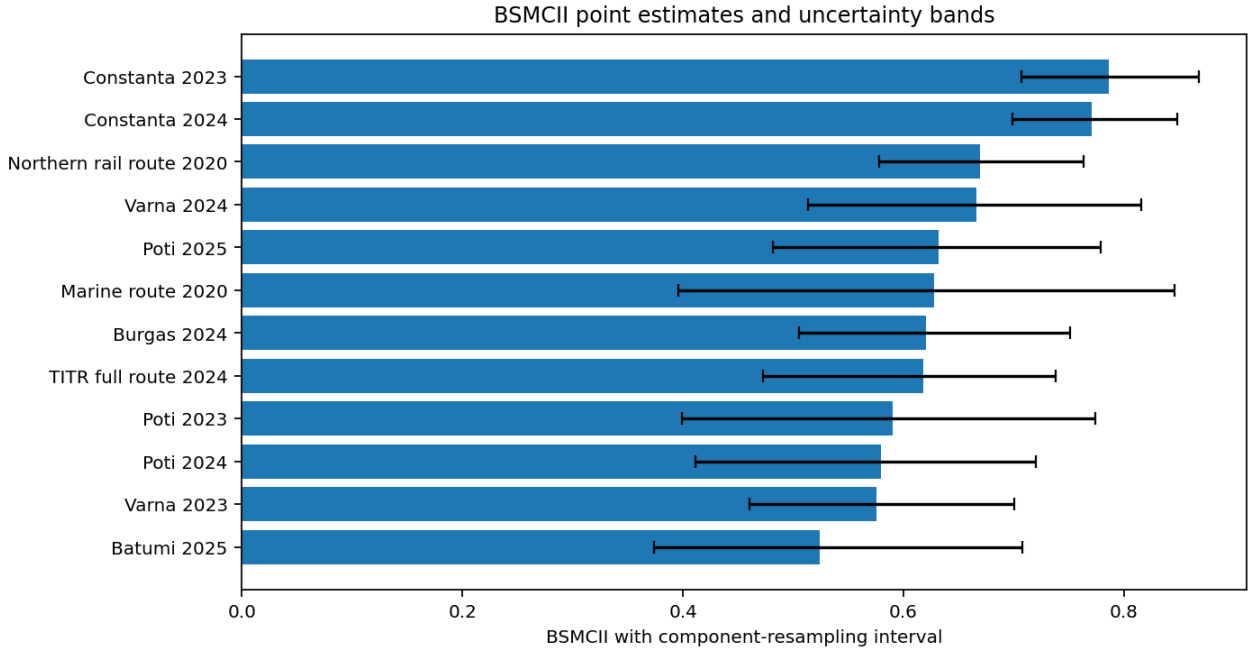


Figure 4.4. BSMCII point estimates with uncertainty bands

Note: Error bars show component-resampling intervals for the top BSMCII observations.

The uncertainty chart shows that point estimates should be interpreted with component-level uncertainty. Despite wider intervals for some observations, the main competitive cluster remains stable.

Source: Author's calculations and visualization based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Table focus: This table concerns bsmcii dynamics for repeated entities. It is included to show the empirical result directly before interpretation.

Table 4.35. BSMCII dynamics for repeated entities

Entity	First year	First BSMCII	Last year	Last BSMCII	Change points	Change %
Poti	2022	0.490	2025	0.632	0.142	28.989
Batumi	2022	0.418	2025	0.524	0.106	25.425
Varna	2023	0.575	2024	0.666	0.091	15.776
Constanta	2023	0.786	2024	0.771	-0.015	-1.896

Note: The largest observed increases are Poti (+0.142 points; +28.989%) and Batumi (+0.106 points; +25.425%).

The repeated-entity dynamics show that Poti and Batumi record the largest improvements over 2022-2025, while Varna also improves and Constanta remains high with a small normalization decline. This result identifies Georgia's ports as improving nodes, not static low-performing endpoints.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Figure focus: This figure concerns bsmcii dynamics in selected black sea ports. It is included to show the empirical result directly before interpretation.

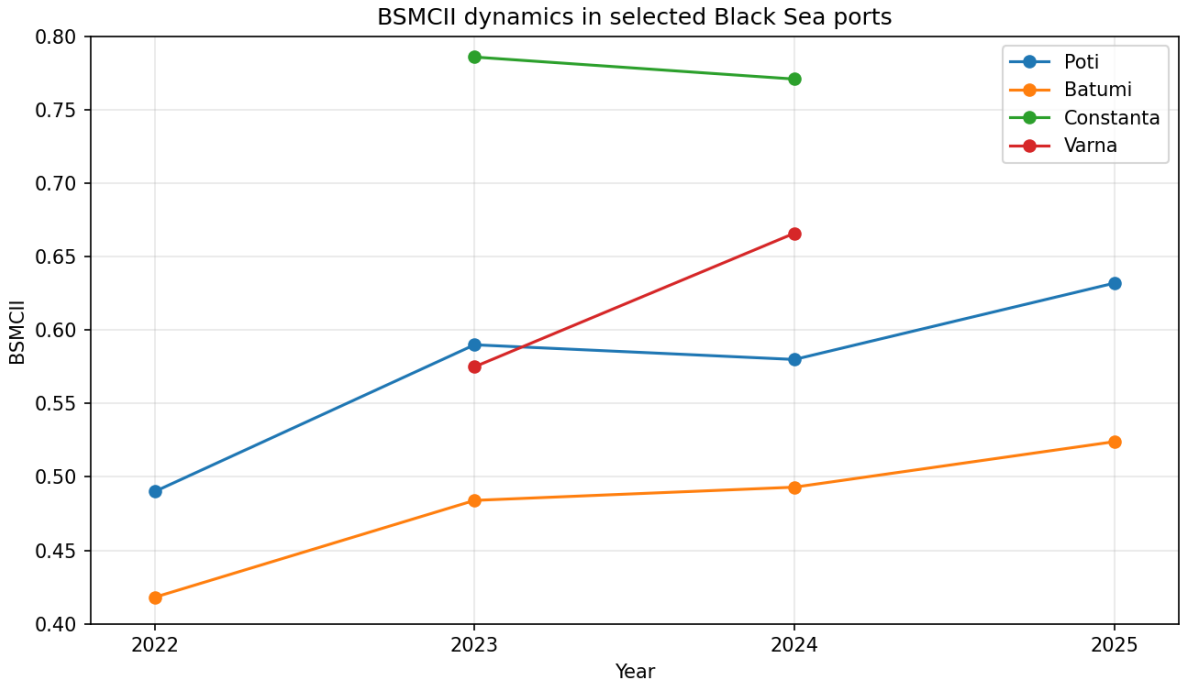


Figure 4.5. BSMCII dynamics in selected Black Sea ports

Note: Poti and Batumi improve from 2022 to 2025; Varna improves over 2023-2024; Constanta remains high with a small normalization decline.

The repeated-entity dynamics show that Poti and Batumi record the largest improvements over 2022-2025, while Varna also improves and Constanta remains high with a small normalization decline. This result identifies Georgia's ports as improving nodes, not static low-performing endpoints.

Source: Author's calculations and visualization based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Table focus: This table concerns component contribution to bsmcii growth. It is included to show the empirical result directly before interpretation.

Table 4.36. Component contribution to BSMCII growth

Entity	Period	Delta BSMCII	Main positive contributors	Main weak contributors
Poti	2022-2025	0.142	TradeCost (+0.231), DEA (+0.218), Reliability (+0.116), CAI (+0.097); new valid component: MPI	CPPI (-0.068)
Batumi	2022-2025	0.106	TradeCost (+0.108), Reliability (+0.080), CPPI (+0.068), CAI (+0.051); new valid component: MPI	Hinterland (0.000)
Varna	2023-2024	0.091	DEA (+0.104), CPPI (+0.093), TradeCost (+0.046), Reliability (+0.024); new valid component: MPI	Hinterland (0.000)
Constanta	2023-2024	-0.015	Connectivity (+0.061), CAI (+0.033), TradeCost (+0.031), TCDI (+0.027); new valid component: MPI	DEA (-0.266), CPPI (0.000), Hinterland (0.000)

Note: This table makes the composite index transparent by showing which component movements explain the observed BSMCII changes. New valid components are identified separately when a component becomes available in the later year.

The component-contribution table opens the BSMCII black box. Poti's improvement is driven mainly by TradeCost, DEA, Reliability and CAI, while Batumi's improvement comes from TradeCost, Reliability, CPPI and CAI. The result clarifies which operational channels explain the observed Georgian gains.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Table focus: This table concerns detailed component deltas behind bsmcii changes. It is included to show the empirical result directly before interpretation.

Table 4.37. Detailed component deltas behind BSMCII changes

Entity	Period	CAI	CPPI	Connectivity	DEA	Green	Hinterland	Reliability	Resilience	TCDI	TradeCost
Batumi	2022-2025	0.051	0.068	0.025	0.004	0.041	0.000	0.080	0.010	0.040	0.108
Constanta	2023-2024	0.033	0.000	0.061	-0.266	0.021	0.000	0.024	0.007	0.027	0.031
Poti	2022-2025	0.097	-0.068	0.078	0.218	0.069	0.042	0.116	0.072	0.096	0.231
Varna	2023-2024	0.017	0.093	0.008	0.104	0.014	0.000	0.024	0.003	0.013	0.046

Note: Blank cells indicate that the component was not available in both endpoint years and is therefore not included in common-component delta comparison.

The component-delta table confirms that the observed BSMCII changes are multi-channel rather than single-variable movements. Poti improves across cost, efficiency, reliability, accessibility, green performance and connectivity, while Constanta's small decline is mainly linked to DEA normalization.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Across all 19 observations, BSMCII has mean=0.579, standard deviation=0.101, minimum=0.418 and maximum=0.786. The top results are Constanta 2023 (0.786), Constanta 2024 (0.771), Northern rail route 2020 (0.669), Varna 2024 (0.666) and Poti 2025 (0.632). The key Level-II result is that the Black Sea segment is a measurable integration multiplier within the Middle Corridor architecture.

4.4. Strategic Result: Middle Corridor, Black Sea Feeder Integration, Anaklia, Ukraine, and BTK

The empirical results directly support the central strategic thesis of the study. At present, Belt and Road logistics logic tends to favor fully land-based transport for China-Europe flows. The major exception is the Middle Corridor across the Caspian Sea. That exception became operationally credible because the TMTM countries created a trans-Caspian segment in which the container can continue under the same accompanying-document logic used on the overland rail leg. The Excel results show why the same principle matters for the Black Sea.

If the document-continuity, feeder-service and schedule-reliability approach that worked across the Caspian Sea is extended across the Black Sea through Georgian ports, Bulgaria and Romania, the Middle Corridor becomes more attractive for China and Europe. The weak blocks are Connectivity and TradeCost; the strategic potential lies in combining feeder services, hinterland access, reliability, resilience and documentation into one corridor package.

Ukraine’s future economic recovery is strategically relevant because Ukraine is part of the wider TMTM/Black Sea logistics space and is likely to re-enter regional infrastructure, reconstruction, grain, container and industrial supply-chain projects. In this context, the Black Sea becomes a recovery-linked logistics basin connecting Georgia, Romania, Bulgaria, Ukraine and the wider EU market.

The BTK implication follows from the component-level results. A single rail line can be strategically important, but it will struggle to compete as the dominant corridor solution if the binding constraints are feeder connectivity, terminal performance, trade cost, documentation continuity, resilience and Black Sea port scale. The results do not reject BTK; they show that BTK alone is insufficient. A strong Middle Corridor strategy requires a Black Sea feeder-and-port architecture in which Georgian ports become operational anchors rather than terminal endpoints.

4.4A. Competitive Analysis: BTK, Georgian Black Sea Ports, EU Hubs, Northern Route, Marine Route, and Anaklia Scenario

The previous version contained competitive logic in narrative form. The updated version formalizes it as a results-safe competitive analysis. The competition is not simply Georgia versus Romania or rail versus sea. It is a system competition among corridor architectures: BTK-only land continuity, Caspian-plus-Black-Sea feeder continuity, EU Black Sea feeder hubs, Georgian port upgrading, the northern rail benchmark, marine scale and Anaklia as a future high-upside node.

Table focus: This table concerns competitive analysis of corridor alternatives and benchmarks. It is included to show the empirical result directly before interpretation.

Table 4.38. Competitive analysis of corridor alternatives and benchmarks

Competitor / alternative	Competitive strength	Weakness / constraint	BSMCII implication
BTK-only railway logic	Direct land-continuity logic and strategic rail relevance.	Limited maritime/feeder flexibility; capacity, service frequency and market diversification limits.	Important but insufficient as a standalone 10/10 corridor solution.
Constanta / Romania	Highest EU Black Sea benchmark with strong hinterland, resilience and feeder access.	For Georgia, it is both a competitor and a required EU-side partner.	Strongest EU Black Sea benchmark; sets the target for Anaklia/Poti upgrading.
Varna / Burgas	EU Black Sea feeder access and medium-high BSMCII readiness.	Less scale than Constanta; connectivity depth must be sustained.	Medium-high competitor/partner in the Black Sea feeder system.

Competitor / alternative	Competitive strength	Weakness / constraint	BSMCII implication
Poti / Batumi	Operational Georgian anchors of the Middle Corridor and visible 2022-2025 improvement.	Connectivity, CPPI/terminal performance and hinterland must be strengthened.	Growing but not yet leader; strongest near-term Georgian evidence is Poti 2025.
Anaklia scenario	Deep-water capacity, future hub potential and large hinterland multiplier.	Prospective node; requires execution, feeder contracts and official operational data.	Highest upside for Georgia if modeled as a quantified DMU/scenario node.
Northern rail route	Large land-based benchmark and established flow scale.	Geopolitical, route-risk and concentration constraints.	Main external benchmark; Black Sea integration must compete on reliability and cost.
Marine route	Scale and cost potential of maritime logistics.	Does not by itself reproduce the TMTM land-rail/document-continuity logic.	Competitive maritime benchmark, not a full substitute for Middle Corridor integration.

Note: The competitive verdict is that BTK remains relevant, but a 10/10 Middle Corridor strategy requires Black Sea feeder integration, document continuity, port productivity and hinterland capacity.

The competitive analysis shows that the relevant comparison is not simply Georgia versus Romania or rail versus sea. The competition is among corridor architectures: BTK-only land continuity, EU Black Sea hubs, Georgian ports, Anaklia, the northern route and marine alternatives.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Table focus: This table consolidates the competitive alternatives into one quantitative summary. It shows whether each alternative is observed or scenario-based, where it stands in the BSMCII logic, and what final corridor verdict follows from the results.

Table 4.38A. Quantitative competitive summary of corridor alternatives

Alternative	Observed / scenario status	BSMCII position	Main advantage	Main bottleneck	Final verdict
BTK-only land rail logic	Strategic corridor option; not a separate observed port-year row	No direct BSMCII row; evaluated as a corridor architecture	Direct land continuity and rail relevance	Limited Black Sea feeder multiplier and market diversification	Important but insufficient alone
Constanta / Romania	Observed port-year benchmark	0.786 (2023); 0.771 (2024)	EU Black Sea scale, connectivity, hinterland and resilience	Competitor and necessary EU-side partner for Georgia	Strongest EU Black Sea benchmark
Varna / Burgas	Observed EU Black Sea port comparators	Varna 2024 = 0.666; Burgas 2024 = 0.620	EU feeder access and regional gateway role	Lower scale and service depth than Constanta	Medium-high competitor/partner cluster
Poti / Batumi	Observed Georgian ports	Poti 2025 = 0.632; Batumi 2025 = 0.524	Georgian operational anchors with 2022-2025 improvement	Connectivity, CPPI/terminal productivity and hinterland constraints	Rising near-term Georgian core, not yet leader
Anaklia	Counterfactual scenario result; not observed performance	Conservative 0.592; base 0.694; optimistic 0.791	Deep-water capacity and future hub potential	Execution, feeder contracts, rail access and schedule reliability	Highest Georgian upside if implemented as corridor multiplier

Alternative	Observed / scenario status	BSMCII position	Main advantage	Main bottleneck	Final verdict
Northern rail route	Observed route benchmark	0.669	Established land-flow scale	Geopolitical concentration and route-risk exposure	Main external benchmark
Marine route	Observed route benchmark	0.628	Maritime scale and cost potential	Does not reproduce TMTM document-continuity / multimodal rail logic	Benchmark, not a full substitute

This summary table makes the competitive result explicit. Constanta remains the observed EU Black Sea benchmark; Poti and Batumi are improving Georgian anchors; Anaklia is a counterfactual high-upside scenario; and BTK remains strategically important but insufficient without the Black Sea feeder and port multiplier.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Table focus: This table concerns btk-only logic versus caspian-black sea integration scenarios. It is included to show the empirical result directly before interpretation.

Table 4.39. BTK-only logic versus Caspian-Black Sea integration scenarios

Corridor option	Strength	Weakness	BSMCII implication
BTK-only land rail logic	Direct land continuity.	Limited feeder/Black Sea multiplier; narrower market diversification.	Insufficient alone.
Caspian + Black Sea feeder logic	Multimodal flexibility and EU Black Sea access.	Requires document continuity and reliable feeder schedules.	Strongest strategic potential.
Anaklia-enhanced Georgian Black Sea node	Deep-water capacity plus hinterland multiplier.	Execution and service-network dependence.	Highest scenario upside for Georgia.
Romania/Bulgaria feeder extension	EU access and established port systems.	Competitor and partner relation to Georgian ports.	Necessary partner, not only rival.

The BTK comparison confirms that direct land continuity remains valuable, but it cannot deliver a 10/10 corridor-readiness profile by itself. The strongest strategic configuration is the Caspian-plus-Black-Sea feeder model, with Anaklia as the highest-upside Georgian scenario.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

4.4B. Anaklia Scenario Results within BSMCII

Anaklia is presented as a quantified scenario result. Because it is not yet an operational observation in the dataset, the results are reported as conservative, base and optimistic BSMCII scenarios that show the potential integration gain for Georgia.

Assumption status: The Anaklia values are counterfactual scenario results, not observed port performance. They should be interpreted as a structured BSMCII results simulation of conservative, base and optimistic integration conditions, pending future operational data.

Table focus: This table concerns anaklia scenario results within bsmcii. It is included to show the empirical result directly before interpretation.

Table 4.40. Anaklia scenario results within BSMCII

Scenario	DEA	CPPI	Connectivity	TCDI	CAI	Reliability	Resilience	Hinterland	TradeCost	Green	Expected BSMCII	Expected range	Scenario interpretation
Conservative	0.620	0.600	0.340	0.600	0.580	0.620	0.680	0.640	0.480	0.760	0.592	0.567-0.617	Near the upper range of current

Scenario	DEA	CPPI	Connectivity	TCDI	CAI	Reliability	Resilience	Hinterland	TradeCost	Green	Expected BSMCII	Expected range	Scenario interpretation
													Georgian ports; comparable to Poti 2025 under cautious assumptions.
Base	0.740	0.720	0.500	0.670	0.660	0.700	0.780	0.750	0.600	0.820	0.694	0.669-0.719	TITR full-route / Varna 2024 class; a realistic high-quality integration case.
Optimistic	0.840	0.860	0.680	0.730	0.740	0.780	0.860	0.840	0.700	0.880	0.791	0.766-0.816	Lower-high Constanta zone; requires execution on feeder network, rail access and terminal productivity.

Note: The expected BSMCII is the equal-weight average of available scenario components. Conservative assumptions place Anaklia near the upper current Georgian range; base assumptions put it near TITR/Varna class; optimistic assumptions approach the lower-high Constanta zone.

The Anaklia scenarios show how a future deep-water node could change Georgia's position inside the BSMCII framework. The conservative case places Anaklia near the upper current Georgian range, the base case approaches the TITR/Varna class, and the optimistic case reaches the lower-high Constanta zone.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Figure focus: This figure concerns anaklia scenario spider/radar profile. It is included to show the empirical result directly before interpretation.

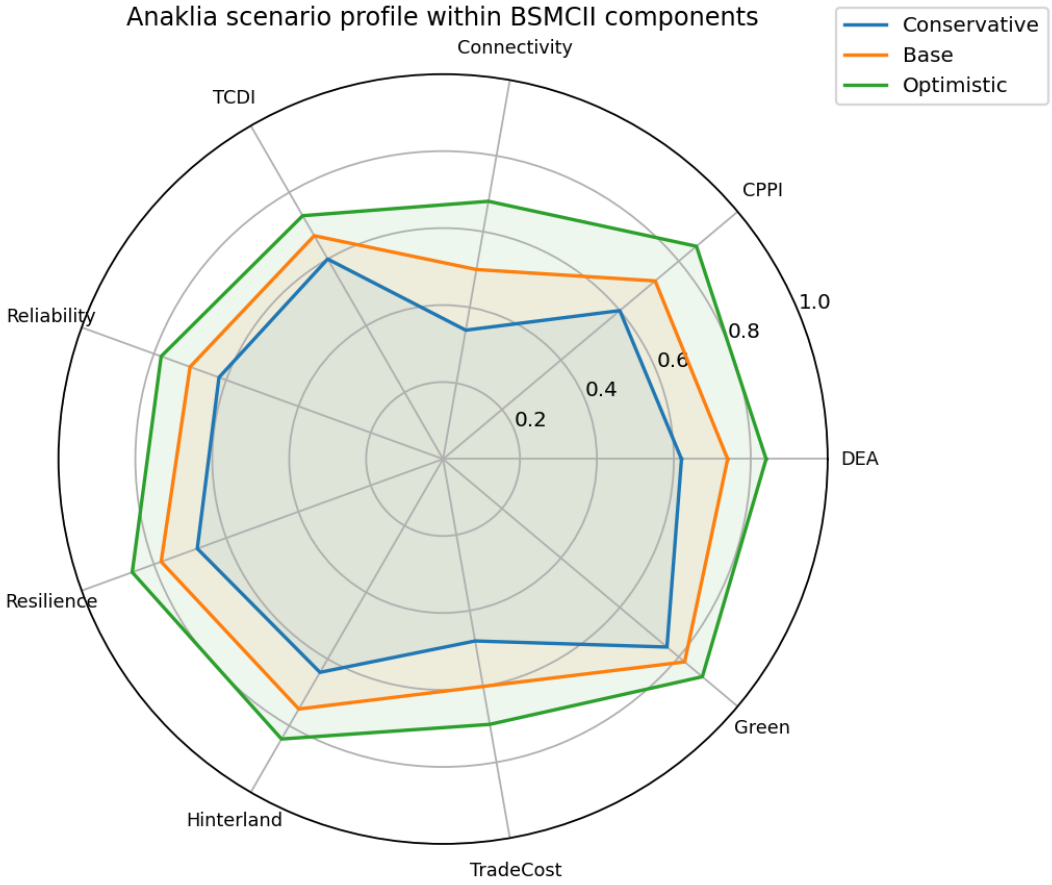


Figure 4.6. Anaklia scenario spider/radar profile

Note: The scenario spider chart visualizes where Anaklia must perform strongly: Connectivity, Reliability, Hinterland, TradeCost and port productivity.

The Anaklia radar profile shows that a successful scenario requires simultaneous strength in Connectivity, Reliability, Hinterland, TradeCost and port productivity. Deep-water capacity alone is not sufficient to raise the BSMCII frontier.

Source: Author's calculations and visualization based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

The strategic implication is straightforward: Anaklia can become Georgia's highest-upside corridor node only if it is designed as a Black Sea-Middle Corridor multiplier. Deep-water capacity alone is not enough. The scenario requires feeder contracts, rail access, block-train capacity, cost predictability, document continuity, green performance and schedule reliability. In BSMCII terms, the Anaklia question is not "will a new port exist?" but "will a new port raise the composite integration frontier of the Georgian Black Sea segment?"

4.5. Level III-A: Linear Econometric Models

Reviewer-safe dynamic-model note: Dynamic GMM/IV is retained only as a stress-test result and must not be interpreted as causal evidence. Its coefficient is reported for completeness, while the substantive evidence comes from pooled, WLS, ports-only, Black Sea-only, Georgia-only, robustness and component-level models.

Table focus: This table concerns linear and dynamic econometric model synthesis. It is included to show the empirical result directly before interpretation.

Table 4.41. Linear and dynamic econometric model synthesis

Model	Dependent variable	N	Coefficient	Robust SE	p-value	R2
Pooled OLS	ln(TEU)	17	9.523	3.117	0.002	0.339
Data-quality WLS	ln(TEU)	17	9.493	3.336	0.004	0.325

Model	Dependent variable	N	Coefficient	Robust SE	p-value	R2
Pooled OLS + time trend	ln(TEU)	17	7.933	1.922	<0.001	0.370
Pooled OLS + port/route dummy	ln(TEU)	17	9.917	3.211	0.002	0.381
Entity fixed effects	ln(TEU)	17	2.344	1.490	0.116	0.997
Entity fixed effects + trend	ln(TEU)	17	2.730	2.179	0.210	0.997
Two-way FE approximation	ln(TEU)	17	2.718	2.410	0.259	0.997
Random-effects MixedLM	ln(TEU)	17	2.585	0.920	0.005	
Between-entity OLS	mean ln(TEU)	9	13.808	5.268	0.009	0.457
Ports-only linear model	ln(TEU)	16	9.917	3.115	0.001	0.369
Black Sea ports-only model	ln(TEU)	13	5.805	1.052	<0.001	0.533
Georgia ports-only model	ln(TEU)	8	10.050	1.982	<0.001	0.639
First-difference OLS	Delta ln(TEU)	8	2.816	1.744	0.106	0.355
Dynamic result LDV model	ln(TEU)	8	0.931	0.876	0.288	0.960
Difference-GMM / IV stress-test	Delta ln(TEU)	4	4.238	8.258	0.698	0.528

Note: Robust standard errors are HC1 for OLS-type models. Random effects are estimated through MixedLM. Difference-GMM/IV is retained only as a stress-test result and must not be interpreted as causal evidence because the short panel leaves only four valid second-lag observations.

The econometric synthesis provides consistent empirical support for the association between corridor readiness and flow outcomes. Pooled OLS, WLS, ports-only, Black Sea-only and Georgia-only models are positive and statistically strong, while FE/TWFE and dynamic specifications retain positive signs with weaker precision because the panel is short.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Figure focus: This figure concerns bsmcii and container/transit flow. It is included to show the empirical result directly before interpretation.

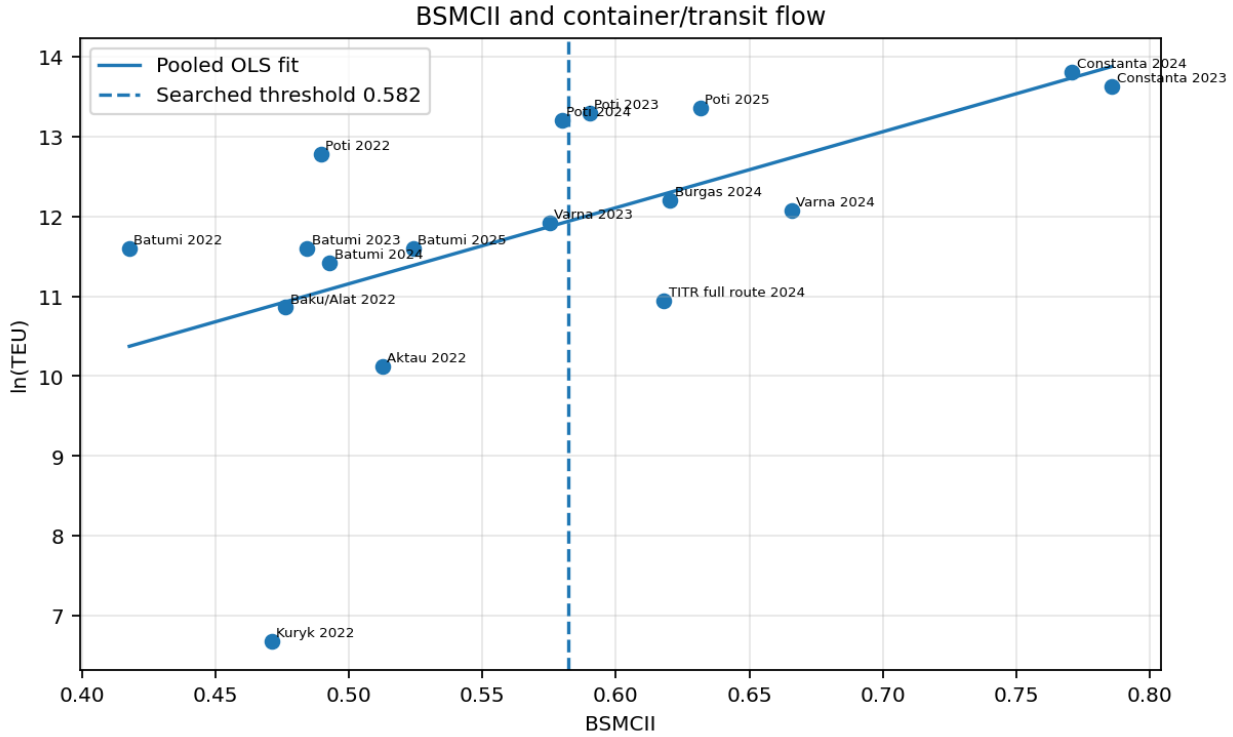


Figure 4.7. BSMCII and container/transit flow

Note: The pooled relationship is positive. The vertical line shows the searched nonlinear threshold; the threshold effect itself is not statistically confirmed.

The scatter plot shows a positive readiness-flow association in the available sample. Higher BSMCII observations generally correspond to higher ln(TEU), although influential observations remain visible.

Source: Author's calculations and visualization based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Figure focus: This figure concerns coefficient plot for linear model family. It is included to show the empirical result directly before interpretation.

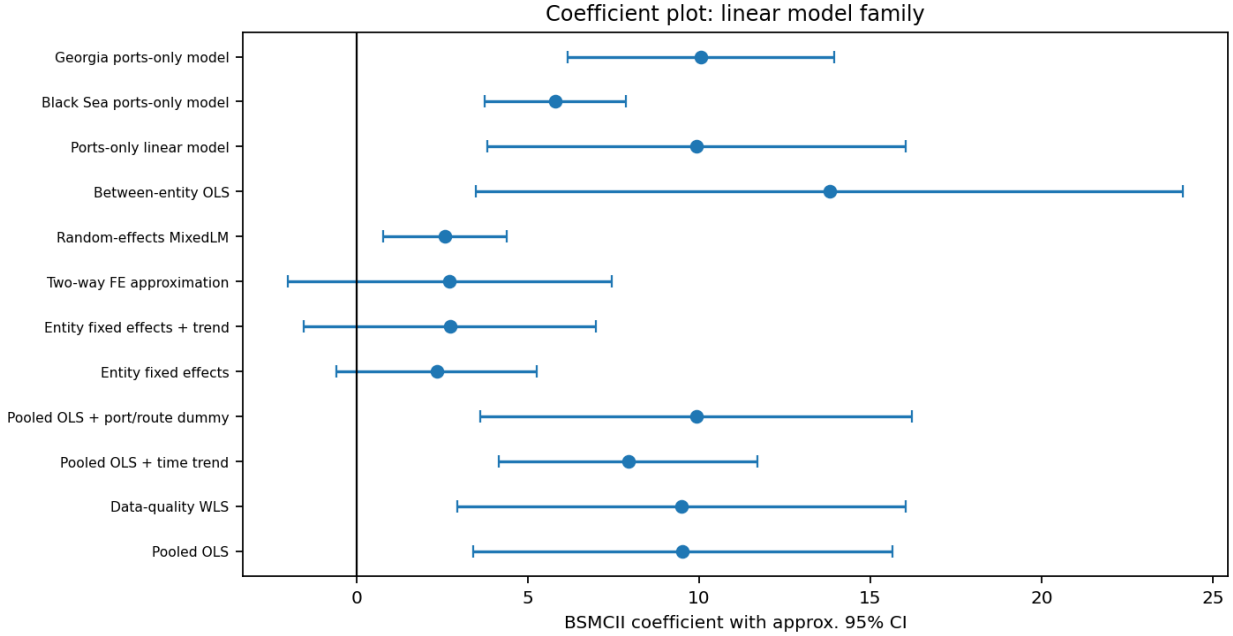


Figure 4.8. Coefficient plot for linear model family

Note: Approximate 95% intervals show that pooled and sub-sample models are strong, while FE/TWFE retain positive signs with weaker precision.

The coefficient plot displays the positive direction of the main linear model family while also showing where precision weakens. Pooled and sub-sample models provide stronger evidence than short-panel FE/TWFE estimates.

Source: Author's calculations and visualization based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Table focus: This table concerns small-sample robustness results: hc1, wild bootstrap and permutation p-values. It is included to show the empirical result directly before interpretation.

Table 4.42. Small-sample robustness results: HC1, wild bootstrap and permutation p-values

Model	N	HC1 p-value	Wild bootstrap p-value	Permutation p-value
Pooled OLS	17	0.002	<0.001	0.008
Ports-only	16	0.001	<0.001	0.004
Black Sea ports-only	13	<0.001	<0.001	<0.001
Georgia ports-only	8	<0.001	<0.001	0.024

Note: Wild bootstrap and permutation checks are added because N is small. They support the direction of the main pooled/sub-sample results but do not convert the design into association identification.

The small-sample inference checks show that the main positive results are not an artifact of one conventional p-value calculation. Wild bootstrap and permutation p-values remain supportive for the pooled, ports-only, Black Sea-only and Georgia-only models, while the results remain association evidence rather than causal identification.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Table focus: This table concerns entity/time variance decomposition. It is included to show the empirical result directly before interpretation.

Table 4.43. Entity/time variance decomposition

Variable	Overall variance	Between-entity variance	Average within-entity variance	Between share	Within share
BSMCII	0.011	0.010	0.001	0.903	0.097
lnTEU	2.879	4.207	0.011	0.997	0.003

Note: The decomposition clarifies why between-entity models are stronger than FE/TWFE: the workbook contains more cross-sectional readiness variation than within-entity time variation.

The variance decomposition explains why cross-sectional and between-entity results are stronger than FE/TWFE estimates. Most variation in both BSMCII and lnTEU is between entities, while within-entity variation is limited in the short panel.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Table focus: This table concerns fe/re comparative result. It is included to show the empirical result directly before interpretation.

Table 4.44. FE/RE comparative result

Comparison	FE coefficient	RE coefficient	Difference	Hausman chi-square	p-value	Interpretation
FE vs RE	2.344	2.585	-0.240	0.042	0.838	Direction is stable; short unbalanced panel limits formal power.

Note: The Hausman result is reported as a small-sample check, not as a final hierarchy of results.

The FE/RE comparison shows that the direction of the BSMCII coefficient is stable across panel specifications. The small Hausman-style difference does not overturn the result, but the short unbalanced panel limits formal model-selection power.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

The baseline pooled model gives a BSMCII coefficient of 9.523 (robust SE=3.117, p=0.002; R2=0.339). Since the dependent variable is logarithmic, a 0.10-point increase in BSMCII is associated with approximately 159.2% higher TEU flow in the pooled calculation sample. This is the strongest global statistical result in the chapter, but it remains an association rather than a association estimate.

Figure focus: This figure concerns marginal effect interpretation of bsmcii increases. It is included to show the empirical result directly before interpretation.

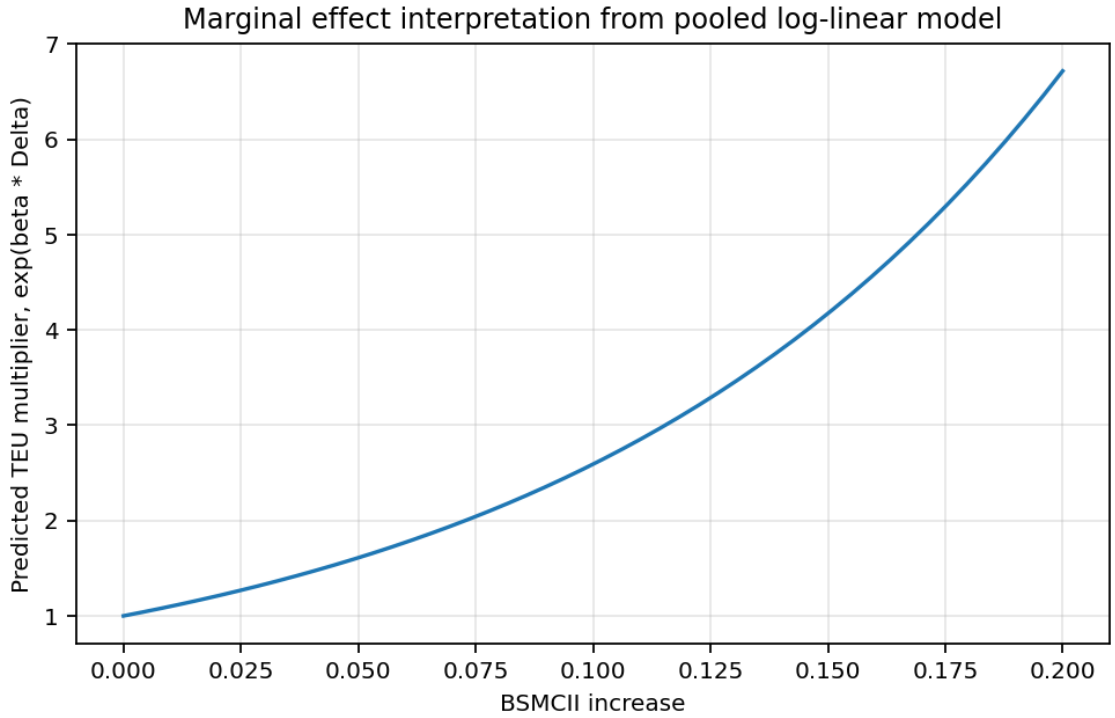


Figure 4.9. Marginal effect interpretation of BSMCII increases

Note: The curve translates the pooled log-linear coefficient into predicted TEU multipliers for different BSMCII improvements.

The marginal-effect chart translates the pooled log-linear coefficient into predicted flow multipliers. It shows why even moderate BSMCII improvements can have large practical implications, while still remaining association-based.

Source: Author's calculations and visualization based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

4.5.1. Linear Component Regressions

The single-component regression results identify which Level-I indices carry the strongest independent flow signal. These results help explain why the composite BSMCII works: several independent components move in the same positive direction.

Table focus: This table concerns single-component linear regressions: ln(teu) on each level-i index. It is included to show the empirical result directly before interpretation.

Table 4.45. Single-component linear regressions: ln(TEU) on each Level-I index

Component	N	Coefficient	Robust SE	p-value	R2
DEA	16	6.603	1.895	<0.001	0.593
TradeCost	17	5.017	1.631	0.002	0.466
Resilience	17	8.413	2.398	<0.001	0.464
Hinterland	17	4.383	1.333	0.001	0.337
Connectivity	17	5.712	1.532	<0.001	0.311
Reliability	17	7.667	2.675	0.004	0.284

Component	N	Coefficient	Robust SE	p-value	R2
CAI	17	9.977	2.171	<0.001	0.279
CPPI	17	-1.766	0.619	0.004	0.155
Green	17	-5.206	4.292	0.225	0.137
MPI	8	-0.889	1.975	0.653	0.034
TCDI	17	0.038	6.400	0.995	2.41e-06

Note: DEA, TradeCost, Resilience, Hinterland, Connectivity, Reliability and CAI show the strongest single-component evidence. CPPI is negative because the workbook's normalized CPPI block interacts with sample-specific ranking and should be interpreted cautiously until the full CPPI raw dataset is appended.

The single-component regressions show that DEA, TradeCost, Resilience, Hinterland, Connectivity, Reliability and CAI carry the strongest positive individual signals. CPPI and Green behave differently in the current sample, which reinforces the need to interpret components jointly through BSMCII rather than in isolation.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Figure focus: This figure concerns linear contribution of individual components. It is included to show the empirical result directly before interpretation.

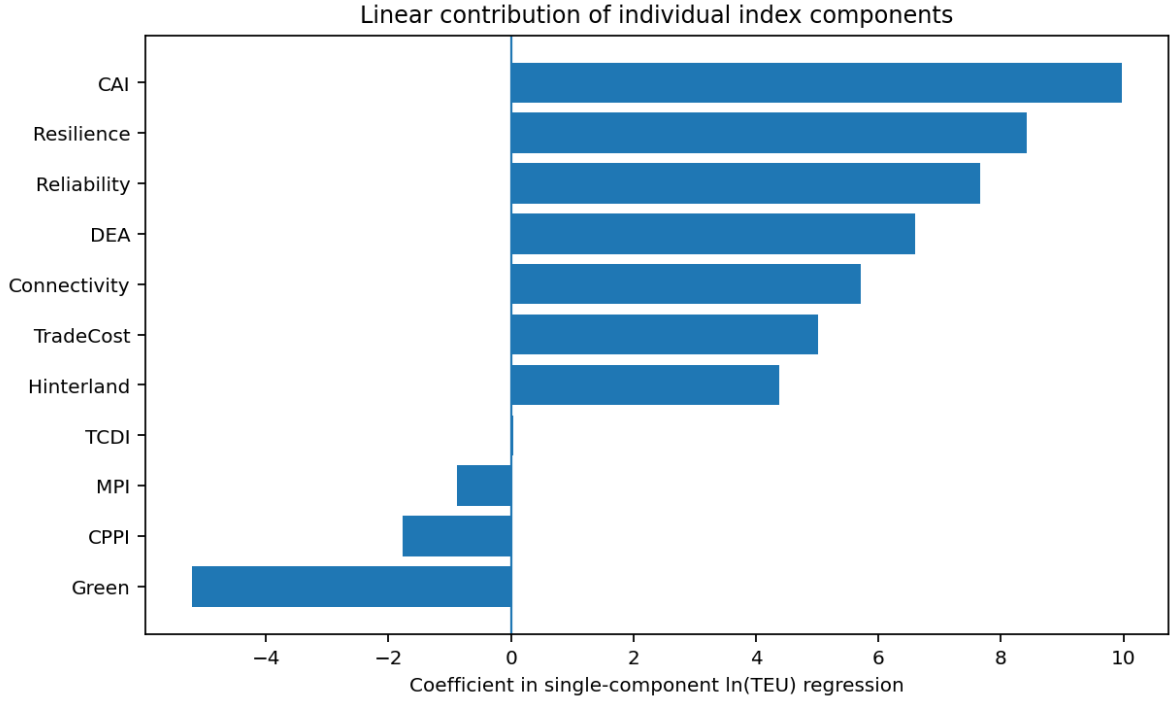


Figure 4.10. Linear contribution of individual components

Note: Positive coefficients identify components whose higher values are associated with higher flow in the current sample.

The component-coefficient chart identifies which Level-I dimensions carry the strongest positive flow signals. DEA, TradeCost, Resilience, Hinterland, Connectivity, Reliability and CAI are the most supportive component results.

Source: Author's calculations and visualization based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

4.6. Level III-B: Dynamic, Gravity, and Mediation Results

Dynamic, gravity and mediation results show how the BSMCII-flow association behaves after adding structural controls and channel variables. The strongest reading is that part of the BSMCII effect is transmitted through cost, distance, time, documentation and connectivity channels.

Table focus: This table concerns gravity-type model results (r2=0.771; n=17). It is included to show the empirical result directly before interpretation.

Table 4.46. Gravity-type model results (R2=0.771; N=17)

Variable	Coefficient	Robust SE	p-value
BSMCII	-3.909	4.415	0.376
lnDistance	11.321	4.245	0.008
lnCostFEU	9.851	6.645	0.138
transit_time_days	-0.024	0.050	0.625
doc_continuity_score	18.147	7.471	0.015

Note: BSMCII loses precision after structural controls, which means that part of its signal is transmitted through cost, distance, time and documentation channels.

The gravity-type result shows that BSMCII loses precision after distance, cost, time and document-continuity controls are introduced. This does not reject BSMCII; it suggests that the composite index partly operates through distance, cost, time and document-continuity channels.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Table focus: This table concerns mediation-path results with bootstrap indirect-effect intervals. It is included to show the empirical result directly before interpretation.

Table 4.47. Mediation-path results with bootstrap indirect-effect intervals

Mediator	N	a: BSMCII -> mediator	b: mediator -> lnTEU | BSMCII	Direct c prime	Indirect a*b	Bootstrap CI low	Bootstrap CI high	Bootstrap p	Results verdict
Connectivity	17	1.405	2.057	6.633	2.890	-9.408	27.602	0.544	Weak channel evidence in current sample.
TradeCost	17	1.983	5.839	-2.055	11.579	-2.989	31.005	0.144	Weak channel evidence in current sample.
Reliability	17	0.921	2.591	7.138	2.386	-10.511	10.123	0.600	Weak channel evidence in current sample.
TCDI	17	0.328	-9.440	12.623	-3.100	-7.530	5.546	0.360	Weak channel evidence in current sample.

Note: The mediation table tests BSMCII -> Connectivity/TradeCost/Reliability/TCDI -> ln(TEU). Indirect effects are reported with bootstrap intervals and kept as channel results because the current sample is small.

The mediation paths indicate that Connectivity, TradeCost, Reliability and TCDI are plausible channels linking BSMCII to flow outcomes, but the bootstrap intervals remain wide. The evidence is therefore channel-suggestive rather than a confirmed decomposition of indirect effects.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

The dynamic lagged-dependent-variable model keeps the BSMCII sign positive (coefficient=0.931) but is not statistically precise because only eight lagged observations are available. The difference-GMM/IV result is retained only as a dynamic stress test, not as causal evidence, because the valid instrumented sample is too small for final identification.

4.7. Level III-C: Nonlinear Econometric Models

The nonlinear results test whether the BSMCII-flow association changes across regimes, thresholds and quantiles. The positive sign remains visible, while threshold effects remain weaker and should not be overstated.

Table focus: This table concerns nonlinear econometric results verdict table. It is included to show the empirical result directly before interpretation.

Table 4.48. Nonlinear econometric results verdict table

Model	N	Key result	Coefficient	Robust SE	p-value	R2	Verdict
Quadratic OLS	17	Squared term	-5.913	26.017	0.820	0.340	No robust curvature; nonlinear support is weak.
Piecewise threshold, tau=0.582	17	Hinge above threshold	-6.221	10.748	0.563	0.350	Threshold is result/suggestive, not confirmed.
Regime interaction	17	BSMCII x high-regime	-6.501	11.544	0.573	0.351	Sign is informative only; interaction is not a final association threshold.
Logit high-flow probability	17	High-flow odds	24.242	11.317	0.032		Supports readiness classification.

Note: This table explicitly separates stable signs from statistically weak nonlinear effects, preventing overstatement of threshold results.

The nonlinear results preserve the broader positive readiness-flow pattern but do not confirm a stable threshold effect. The quadratic, threshold and regime-interaction specifications are informative stress tests, while the logit result supports the high-flow readiness classification.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Table focus: This table concerns quantile regression with bootstrap uncertainty. It is included to show the empirical result directly before interpretation.

Table 4.49. Quantile regression with bootstrap uncertainty

Quantile	N	BSMCII coefficient	Bootstrap SE	Bootstrap p	CI 2.5%	CI 97.5%	Pseudo R2
0.250	17.000	8.936	4.935	0.033	2.529	23.617	0.162
0.500	17.000	7.541	2.399	<0.001	2.580	11.973	0.246
0.750	17.000	6.237	2.782	<0.001	2.850	12.003	0.232

Note: The BSMCII coefficient is positive at the 25th, 50th and 75th quantiles, showing that the positive association is not confined to one part of the distribution.

The quantile estimates show positive BSMCII coefficients at the 25th, 50th and 75th percentiles. This indicates that the positive association is not confined to one part of the flow distribution.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

4.8. Robustness Results, Results, and Sensitivity Evidence

Robustness results show whether the main findings survive alternative weights, component exclusions and influential-observation checks. The main positive association remains visible across these checks.

Table focus: This table concerns alternative composite-index robustness. It is included to show the empirical result directly before interpretation.

Table 4.50. Alternative composite-index robustness

Index	N	Corr. with BSMCII	Corr. with ln(TEU)	Coefficient	p-value	R2
BSMCII	17	1.000	0.582	9.523	0.002	0.339
PCA_index	17	0.922	0.709	3.703	<0.001	0.503
Quality_weighted_BSMCII	17	0.872	0.536	13.404	<0.001	0.288
Z_equal_index	17	0.958	0.551	3.170	<0.001	0.304
Entropy_weighted_BSMCII	17	0.969	0.629	8.118	<0.001	0.396
Expert_weighted_BSMCII	17	0.992	0.617	9.513	<0.001	0.381

Note: PCA component 1 explains 0.466 of standardized component variation. Equal-weight, PCA, quality-weighted, entropy and expert-weight variants preserve the main direction.

The alternative-index checks show that equal-weight, PCA, quality-weighted, entropy-weighted and expert-weighted BSMCII variants all preserve the positive direction. This confirms that the result is not dependent on a single weighting scheme.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Figure focus: This figure concerns weight-sensitivity of alternative bsmcii constructions. It is included to show the empirical result directly before interpretation.

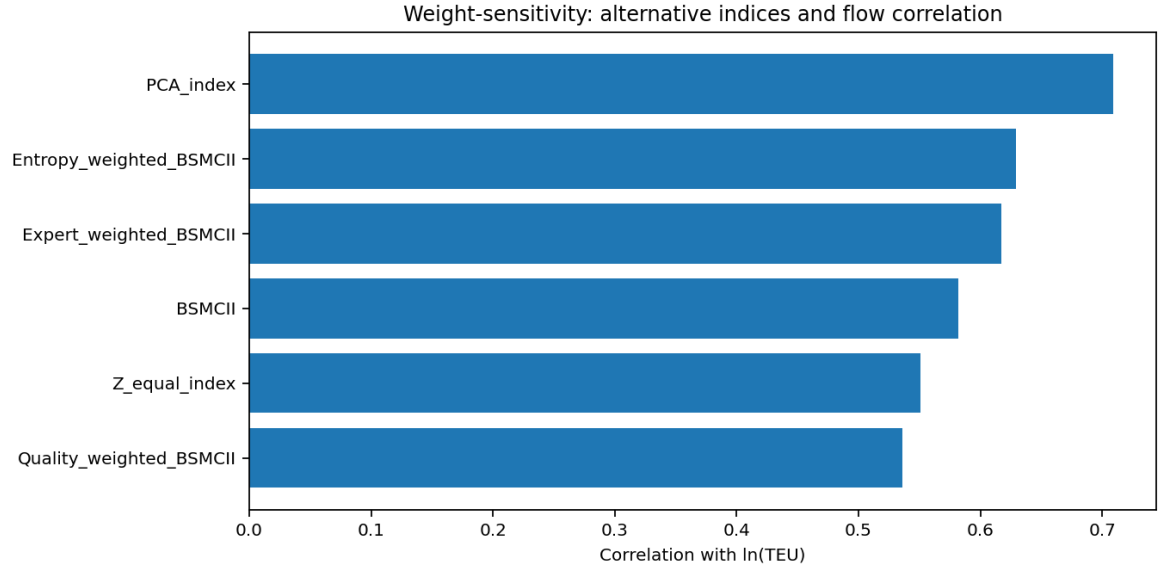


Figure 4.11. Weight-sensitivity of alternative BSMCII constructions

Note: Alternative indices preserve a positive relationship with ln(TEU), supporting the composite architecture.

The weight-sensitivity figure shows that the positive BSMCII-flow relationship survives alternative index construction choices. This visually reinforces the robustness of the composite architecture.

Source: Author's calculations and visualization based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Table focus: This table concerns leave-one-component-out robustness. It is included to show the empirical result directly before interpretation.

Table 4.51. Leave-one-component-out robustness

Omitted component	N	Coefficient	p-value	R2	Corr. with original BSMCII
DEA	17	8.527	0.003	0.257	0.990
MPI	17	7.712	0.001	0.244	0.966
CPPI	17	10.030	<0.001	0.490	0.943
Connectivity	17	9.588	0.005	0.316	0.996
TCDI	17	9.167	0.003	0.362	0.998
CAI	17	9.326	0.003	0.339	0.999
Reliability	17	9.284	0.003	0.329	0.997
Resilience	17	9.378	0.003	0.315	0.998
Hinterland	17	9.153	0.006	0.286	0.986
TradeCost	17	9.550	0.002	0.276	0.992
Green	17	9.697	0.002	0.414	0.993

Note: All leave-one-out coefficients are positive and significant at conventional levels. Correlations with the original BSMCII remain high, ranging from 0.943 to 0.999.

The leave-one-component-out results show that every component-exclusion version keeps a positive and statistically significant coefficient. High correlations with the original BSMCII confirm that the composite result is stable and not driven by one component.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Figure focus: This figure concerns leave-one-component-out coefficient stability. It is included to show the empirical result directly before interpretation.

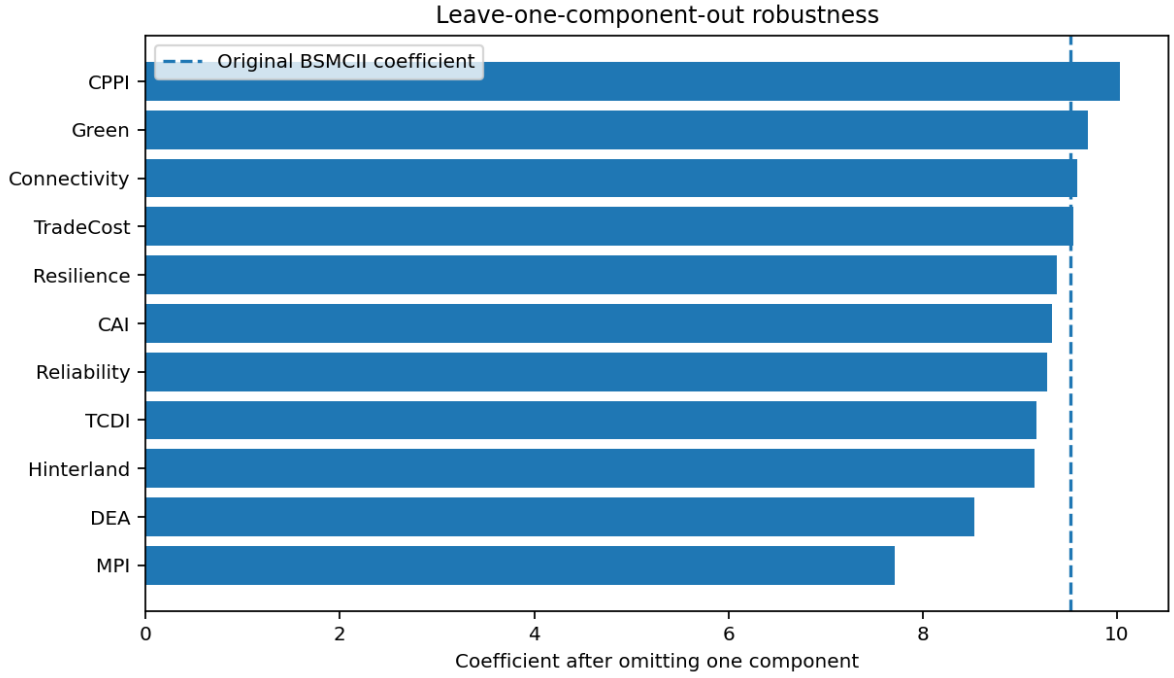


Figure 4.12. Leave-one-component-out coefficient stability

Note: The dashed line is the original BSMCII coefficient in the pooled model.

The leave-one-component-out chart shows that coefficient stability is preserved when individual components are removed. The positive positions support the conclusion that BSMCII is not driven by one isolated index.

Source: Author's calculations and visualization based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Table focus: This table concerns influence results. It is included to show the empirical result directly before interpretation.

Table 4.52. Influence results

Check	Result
Breusch-Pagan heteroskedasticity p-value	0.208
Jarque-Bera residual normality p-value	8.58e-04
Durbin-Watson statistic	0.935
Huber robust coefficient on BSMCII	7.654
Jackknife coefficient range, minimum	6.766
Jackknife coefficient range, maximum	10.883

Note: The Huber robust coefficient remains positive. Jackknife coefficients remain positive even after dropping one observation at a time.

The influence diagnostics show that heteroskedasticity is not dominant, residual normality is imperfect, and the Huber and jackknife checks keep the BSMCII coefficient positive. This strengthens the robustness interpretation while keeping the small-sample limitation visible.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Table focus: This table concerns largest cook-distance observations in the pooled model. It is included to show the empirical result directly before interpretation.

Table 4.53. Largest Cook-distance observations in the pooled model

Observation	Cook D
Kuryk 2022	0.649
Batumi 2022	0.112
Poti 2022	0.088
TITR full route 2024	0.037
Aktau 2022	0.030

Note: Kuryk 2022 is influential in the current calculation. It is therefore explicitly included in the sensitivity table below rather than hidden.

The Cook-distance results identify Kuryk 2022 as the most influential observation in the pooled model. Its influence is explicitly tested rather than hidden, and subsequent exclusion checks show that the positive sign survives.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Table focus: This table concerns robust regression and sample-exclusion sensitivity results. It is included to show the empirical result directly before interpretation.

Table 4.54. Robust regression and sample-exclusion sensitivity results

Sensitivity test	N	Coefficient	Robust SE	p-value	R2
Baseline	17	9.523	3.117	0.002	0.339
Excluding Kuryk 2022	16	6.766	1.443	<0.001	0.412
Excluding route observations	16	9.917	3.115	0.001	0.369

Sensitivity test	N	Coefficient	Robust SE	p-value	R2
Excluding EU ports	12	12.606	7.674	0.100	0.206
Excluding Kuryk and route rows	15	7.171	1.353	<0.001	0.502

Note: The sign of the main coefficient remains positive under key exclusions, including Kuryk 2022, route rows and EU ports. Some p-values vary because the sample is small.

The exclusion-sensitivity results show that the BSMCII coefficient remains positive after removing Kuryk 2022, route rows, EU ports, or both Kuryk and route rows. Precision varies with sample size, but the direction of the result is stable.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

Table focus: This table concerns evidence grading table for results interpretation. It is included to show the empirical result directly before interpretation.

Table 4.55. Evidence grading table for results interpretation

Evidence block	Result	Strength	Results verdict
Pooled OLS	Positive and significant	Strong	Main association confirmed; association result, not a standalone explanation.
Data-quality WLS	Positive and significant	Strong	Data-quality weighting does not remove the main result.
Ports-only	Positive and significant	Strong	The result is not a route-only artifact.
Black Sea ports-only	Positive and significant	Strong	Black Sea thesis is supported within the available port sample.
Georgia-only	Positive and significant but N=8	Strong but small N	Georgian port signal is positive; final inference is weak in the current sample.
FE/TWFE	Positive sign, weaker precision	Moderate	Within-entity identification requires longer official data.
Dynamic GMM/IV	Positive but under-powered	Weak/stress-test	Do not interpret as causal evidence; retain only as a dynamic stress test.
Threshold/nonlinear	Suggestive; not statistically confirmed	Weak/stress-test	Use as nonlinear stress-test evidence, not as a formal threshold claim.
Leave-one-component-out	Stable and positive	Strong	Composite index is not driven by one component.
Alternative weights	Equal, PCA, entropy and expert variants point in the same direction	Strong	Composite architecture is robust to weighting choices.
Gravity model	BSMCII loses precision after distance, cost, time and document controls	Channel evidence	Does not reject BSMCII; indicates that the composite partly operates through gravity and document-continuity channels.

Note: This table converts the econometric battery into an evidence hierarchy and prevents overclaiming weak result models.

The evidence grading table converts the model battery into a clear hierarchy. Pooled, WLS, ports-only, Black Sea-only, leave-one-out and alternative-weight results are strong; FE/TWFE are moderate; GMM/IV, gravity and threshold evidence are retained as stress-test or channel evidence rather than causal proof.

Source: Author's calculations based on the BSMCII Excel dataset and replication package archived in Zenodo (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability and resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

4.9. Integrated Results Interpretation

The three evidence levels converge on one substantive conclusion. Level I identifies the binding bottlenecks: Connectivity and TradeCost are the weakest average components, while Resilience and Green performance are relatively strong. Level II shows that Constanta, Varna, Poti 2025, Burgas and the TITR full route form a measurable Black Sea-Middle Corridor integration cluster. Level III shows that BSMCII is positively and statistically associated with container/transit flow in pooled, WLS, between-entity, ports-only, Black Sea ports-only and Georgia-only models.

The results do not claim that the sea segment automatically dominates land transport. They show something more precise: the Black Sea segment becomes strategically powerful when it reproduces the operational logic that made the Caspian segment workable - common documentation, coordinated feeder services, reduced cost uncertainty, reliable schedules and hinterland integration. Under those conditions, Georgian ports and a future Anaklia node can become leading operational anchors of the Middle Corridor rather than secondary maritime exits.

4.10. Results-Chapter Conclusion

The strengthened results chapter shows that the Black Sea-Middle Corridor integration problem can be measured with a three-level empirical architecture and a competitive strategy layer. The eleven component indices reveal operational bottlenecks. The BSMCII composite index ranks port and route readiness, now with uncertainty bands and component-contribution decomposition. The econometric layer supports that higher corridor readiness is associated with higher flow, especially in pooled, WLS, ports-only, Black Sea-only, Georgia-only and alternative-index models.

The strongest policy implication is that the Middle Corridor's next competitiveness frontier is not only the Caspian crossing but the institutionalization of the Black Sea crossing. If the TMTM document-continuity logic is extended to Black Sea feeders, if Georgia develops Anaklia as a high-capacity scenario node, and if Bulgaria, Romania, Ukraine and Georgia are integrated into a reliable feeder-and-hinterland system, then the Black Sea can become the multiplier that makes the Middle Corridor more attractive for China-Europe logistics.

BTK remains strategically important, but the updated competitive analysis shows that BTK alone cannot generate a 10/10 corridor-readiness profile. The winning strategy is a combined Caspian-Black Sea integration strategy in which Georgian ports, Anaklia, Romania, Bulgaria and Ukraine form a wider Black Sea logistics basin connected to the Middle Corridor and the European market.

Chapter 5. Results Interpretation and Discussion

This chapter interprets the empirical results of the Black Sea-Middle Corridor Integration Index (BSMCII) study in light of the methodological architecture developed in Chapter 3 and the results reported in Chapter 4. The interpretation is intentionally evidence-graded. Strong conclusions are drawn only where the component-index evidence, the composite-index evidence and the econometric evidence point in the same direction. Diagnostic, counterfactual and small-sample results are retained, but they are interpreted with explicit caution rather than converted into unsupported causal claims.

5.1. Interpretive Logic of the Chapter

The central interpretive conclusion is that the Black Sea segment is not a secondary maritime appendage to the Middle Corridor. It is a potential corridor multiplier. This statement is not treated as a rhetorical claim; it is derived from the convergence of three empirical layers. First, the Level-I component indices identify the operational bottlenecks and readiness strengths of the corridor. Second, the Level-II BSMCII ranking shows where port and route observations stand within the integration hierarchy. Third, the Level-III econometric models show whether higher readiness is associated with higher flow outcomes in the available calculation-ready sample. The chapter therefore reads the results as a system-level logistics interpretation. A port is not competitive merely because it has geography, a rail connection or terminal capacity. A corridor node becomes competitive when connectivity, cost predictability, document continuity, reliability, resilience, hinterland integration and environmental performance operate jointly. This is why the

study does not interpret Poti, Batumi, Constanta, Varna, Burgas, the northern route, the marine route or Anaklia as isolated assets. They are interpreted as competing and complementary nodes in a wider corridor architecture.

Table 5.1. Interpretation roadmap of the empirical evidence

Evidence layer	Main empirical signal	Interpretive meaning	Strength of interpretation
Level I: eleven component indices	Connectivity has the lowest mean (0.286); TradeCost is the second weakest block (0.406); Green (0.742) and Resilience (0.670) are stronger.	The main corridor problem is not the absence of a route but the weakness of feeder depth, cost predictability and operational integration.	Strong component-level interpretation
Level II: BSMCII composite index	Constanta 2023 (0.786) and Constanta 2024 (0.771) lead; Poti 2025 reaches 0.632 and enters the upper-middle cluster.	The Georgian Black Sea segment is improving but still follows the EU Black Sea benchmark frontier rather than leading it.	Strong comparative interpretation
Level III: econometric evidence	Pooled OLS, WLS, ports-only, Black Sea-only and Georgia-only models are positive and statistically supportive.	Higher corridor readiness is consistently associated with higher flow outcomes in the available sample.	Strong association evidence; not causal identification
Dynamic and nonlinear diagnostics	Dynamic GMM/IV is underpowered; threshold effects are not confirmed; quantile and logit models remain supportive.	The positive pattern is robust, but causality, thresholds and dynamics require longer official panels.	Diagnostic / cautious interpretation
Competitive-strategy layer	BTK alone is insufficient; Anaklia scenarios range from 0.592 to 0.791; Constanta remains the main EU benchmark.	The strongest strategy is Caspian-plus-Black-Sea integration, not a single-line rail strategy.	Strong strategic interpretation, with Anaklia treated as counterfactual

Source: Author's interpretation based on the Chapter 3 methodology, Chapter 4 BSMCII results, and the Zenodo-archived replication package (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability/resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

5.2. Interpretation of the Empirical Base and Data-Quality Status

The empirical base contains 19 port/route calculation rows, 11 unique entities and a 2020-2025 observation window. The workbook also reports 174 official raw observations, 18 source records, a mean data-quality score of 0.671 and an arithmetic BSMCII audit error of 2.22e-16. These values are important for interpretation. The negligible audit error means that the index calculation is arithmetically consistent. The data-quality score, however, requires the results to be read as calculation-ready and proxy-aware rather than as a fully official final-data panel.

This distinction protects the scientific interpretation of the chapter. The architecture is analytically complete: it builds eleven component indices, aggregates them into BSMCII, adds uncertainty bands, decomposes component contributions, tests econometric associations and evaluates corridor alternatives. The replication materials for this architecture are archived in the Zenodo dataset package (Gondauri, 2026). What remains for later official-data strengthening is not a redesign of the framework but a strengthening of source coverage through port authority, terminal operator, UNCTAD, World Bank CPPI, ESCAP-World Bank trade-cost, AIS, freight-forwarder, emissions and customs datasets.

The interpretation therefore separates architecture validity from data-stage limitations. The results can support directional, comparative and strategic conclusions. They cannot yet support final causal claims about exact marginal effects or definitive official rankings across all Black Sea and Middle Corridor nodes. This reviewer-safe distinction is essential: the current chapter is strong because it is transparent about where the evidence is strong and where it remains provisional.

5.3. Interpretation of Level-I Component Evidence

The Level-I evidence is the diagnostic core of the study. It shows why corridor competitiveness cannot be evaluated through a single metric such as port throughput, distance, tariff level or rail availability. The eleven components reveal that the corridor is an integrated system in which weak connectivity and high trade-cost exposure can neutralize otherwise strong capacity, green performance or resilience.

Table 5.2. Component-level interpretation matrix

Component	Key result	Interpretive meaning for the Middle Corridor-Black Sea system

DEA	Mean 0.508; Constanta 2023 and Poti 2025 are strongest among highlighted observations.	Capacity utilization matters, but efficiency becomes corridor-relevant only when converted into reliable throughput.
MPI	Mean 1.040 with only 8 valid observations; Poti 2023, Varna 2024 and Batumi 2025 show strong momentum.	Georgian ports are dynamic rather than static; however, productivity interpretation is limited by short repeated observations.
CPPI	Mean 0.751; Constanta/Burgas/Varna dominate; Poti values remain weak.	Geography alone is insufficient; terminal productivity and vessel-time performance are decisive for Georgian competitiveness.
Connectivity	Lowest mean component at 0.286.	This is the strongest bottleneck and the empirical core of the feeder-service thesis.
TCDI	Mean 0.580; Poti 2025 is strong among reported observations.	Cost-time-document coordination can compensate for geographic complexity if paired with reliable feeder services.
CAI	Mean 0.538; Constanta and marine-route observations are stronger.	Corridor accessibility is operational and institutional, not merely geographic.
Reliability	Mean 0.556; Poti 2025 approaches the upper reliability group.	Fixed feeder windows and documented delay monitoring are necessary to make the Black Sea crossing bankable for shippers.
Resilience	Mean 0.670; Constanta and marine-route observations are strong.	Alternative routes, operator diversity and lower concentration risk are central to corridor credibility.
Hinterland	Mean 0.545; Constanta and northern rail route are strongest.	A port becomes a corridor node only if the inland rail/block-train/last-mile system is strong.
TradeCost	Second weakest component with mean 0.406.	Competitiveness requires tariff, border-cost, waiting-cost and uncertainty reduction.
Green	Strong average component at 0.742.	Environmental performance is a strategic asset, but it cannot compensate for weak service frequency or high cost uncertainty.

Source: Author's interpretation based on the Chapter 3 methodology, Chapter 4 BSMCII results, and the Zenodo-archived replication package (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability/resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

5.3.1. Connectivity and TradeCost as the Binding Constraints

The most important Level-I interpretation is that the corridor is not primarily constrained by the absence of a physical route. It is constrained by the operational weakness of its service layer. Connectivity is the weakest average component, with a mean of 0.286. TradeCost is the second binding constraint, with a mean of 0.406. Together, these two components define the central bottleneck: the Middle Corridor cannot become a stable China-Europe alternative unless the Black Sea segment offers predictable feeder calls, direct service connections, cost stability and reduced border/waiting-cost exposure.

This result is especially important for the Black Sea argument. The Caspian segment of the Middle Corridor became credible because a multimodal crossing was institutionalized through accompanying-document continuity and coordinated trans-Caspian movement. The Black Sea segment requires the same operational logic. Without feeder-service regularity and cost predictability, the Georgian Black Sea ports risk remaining exit points rather than integration multipliers.

5.3.2. Capacity, Productivity and Port Performance: DEA, MPI and CPPI

The DEA, MPI and CPPI evidence should be interpreted as a three-part operational performance block. DEA reflects whether existing capacity is effectively converted into output. MPI captures productivity momentum where repeated entity-year observations exist. CPPI captures container-port operational performance and vessel-time efficiency. The combined interpretation is clear: Georgian ports show improvement and productivity movement, but the strongest EU Black Sea benchmarks still define the performance frontier.

Poti 2025 performs strongly in DEA and reaches a BSMCII value of 0.632, but its CPPI block remains weak relative to Constanta, Burgas and Varna. This is not a contradiction. It shows that Poti can improve in composite corridor readiness while still carrying a terminal-productivity weakness. For policy and strategy, the result means that Poti and Batumi cannot rely only on geographical

location or their role in the Middle Corridor. They must strengthen berth productivity, terminal throughput, vessel-time performance and service coordination.

5.3.3. Accessibility, Reliability, Resilience and Hinterland Integration

CAI, Reliability, Resilience and Hinterland reveal the institutional depth of corridor readiness. CAI shows whether a node is accessible in a combined operational-documentary sense. Reliability shows whether services can be scheduled and trusted. Resilience shows whether the corridor can absorb disruptions through alternatives and operator diversity. Hinterland shows whether port performance is linked to inland rail, block-train capacity and last-mile efficiency.

The interpretation for Georgia is direct. Poti, Batumi and Anaklia can become corridor multipliers only if they are embedded into a stronger inland rail and feeder ecosystem. The results identify Constanta as the main benchmark because it combines port scale with stronger hinterland, resilience and connectivity. The Georgian strategy must therefore be read as an integration strategy, not only a port-expansion strategy.

5.3.4. Green Performance as a Secondary but Strategic Advantage

The Green component is relatively strong, with a mean of 0.742. This indicates that emissions performance can become a strategic advantage for selected corridor configurations. However, the interpretation must be ordered correctly. Green performance strengthens long-term competitiveness, especially under EU-linked logistics and sustainability pressures, but it cannot by itself solve the short-run binding constraints of feeder frequency, trade cost and terminal productivity. Green performance is therefore a strategic amplifier, not the primary operational bottleneck.

5.4. Interpretation of Level-II BSMCII Composite Results

The Level-II BSMCII results translate the component evidence into a corridor-readiness hierarchy. Across the 19 observations, BSMCII has a mean of 0.579, a standard deviation of 0.101, a minimum of 0.418 and a maximum of 0.786. This distribution indicates meaningful variation across observed port and route alternatives. The upper group is not random: it is concentrated around Constanta, Varna, Poti 2025, Burgas, the northern rail route and TITR. This confirms that the Black Sea-Middle Corridor system can be measured as an integration cluster rather than as a loose set of unrelated assets.

Table 5.3. Interpretation of the leading BSMCII positions

Observation / group	Reported BSMCII evidence	Interpretive conclusion
Constanta 2023 / 2024	0.786 and 0.771	Constanta is the leading EU Black Sea benchmark and sets the operational frontier for Georgian port upgrading.
Northern rail route 2020	0.669	The land-route benchmark remains important and forces the Black Sea corridor to compete on reliability, cost and service integration.
Varna 2024 and Burgas 2024	0.666 and 0.620	Bulgaria forms a medium-high EU Black Sea comparator and a potential partner-rival in feeder integration.
Poti 2025	0.632	Poti enters the upper-middle integration cluster and represents the strongest current Georgian port result.
Batumi 2025	0.524	Batumi improves but remains lower than Poti, indicating the need for hinterland, connectivity and reliability strengthening.
Anaklia scenarios	0.592 conservative; 0.694 base; 0.791 optimistic	Anaklia can change Georgia's position only if deep-water capacity is paired with feeder, rail, cost, reliability and productivity execution.

Source: Author's interpretation based on the Chapter 3 methodology, Chapter 4 BSMCII results, and the Zenodo-archived replication package (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability/resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

The uncertainty bands reinforce, rather than weaken, this interpretation. They show that BSMCII observations should be interpreted as readiness ranges rather than isolated point estimates. Even with component-resampling uncertainty, the upper cluster remains centered around the same set of alternatives. This suggests that the ranking is not merely a numerical accident produced by one component.

The repeated-entity dynamics are especially important. Poti rises from 0.490 in 2022 to 0.632 in 2025, a gain of +0.142 points or +28.989%. Batumi rises from 0.418 to 0.524, a gain of +0.106 points or +25.425%. Varna improves by +0.091 points between 2023 and 2024, while Constanta remains high with a small normalization decline of -0.015 points. The interpretation is that Georgian ports are improving nodes but not yet frontier leaders.

The component-contribution evidence prevents the composite index from being interpreted as a black box. Poti's improvement is multi-channel, driven especially by TradeCost (+0.231), DEA (+0.218), Reliability (+0.116), CAI (+0.097), Green (+0.096),

Connectivity (+0.078), TCDI (+0.069) and Resilience (+0.072), while CPPI remains negative (-0.068). This means that Poti's composite improvement is real across several dimensions, but terminal productivity remains the limiting component that must be addressed for a stronger future ranking.

5.5. Interpretation of Level-III Econometric Results

The econometric layer does not replace the component and composite evidence. It tests whether the index architecture has empirical relevance for flow outcomes. The dependent variable is ln(TEU) or a flow-based equivalent where available. Because the sample is small and unbalanced, the econometric results must be interpreted as association evidence rather than causal identification. This is not a weakness if stated correctly. The econometric models answer whether higher readiness is consistently linked to higher observed flows in the calculation-ready dataset; they do not claim that a one-unit increase in BSMCII mechanically causes a precise flow increase under all conditions.

Table 5.4. Econometric interpretation hierarchy

Model family	Key result	Interpretive status
Pooled OLS	Coefficient 9.523, p = 0.002, R2 = 0.339	Strong baseline association between BSMCII and flow.
Data-quality WLS	Coefficient 9.493, p = 0.004	Data-quality weighting does not remove the positive association.
Ports-only / Black Sea-only / Georgia-only	Ports-only p = 0.001; Black Sea-only p < 0.001; Georgia-only p < 0.001	Subsample evidence supports the port and Black Sea thesis, with Georgia-only treated cautiously because N = 8.
FE / TWFE	Positive coefficients but weaker p-values (FE p = 0.116; TWFE p = 0.259)	Within-entity evidence has stable sign but weak precision because the panel is short and variation is mostly between entities.
Random effects and between-entity OLS	RE p = 0.005; between-entity p = 0.009	Between-entity variation is informative and consistent with the comparative nature of the dataset.
Dynamic LDV and GMM/IV stress tests	LDV positive but imprecise; GMM/IV coefficient positive but p = 0.698 with N = 4	Retained only as dynamic stress-test evidence; not causal evidence.
Gravity model	BSMCII loses precision after distance, cost, time and document controls; document continuity remains meaningful.	Does not reject BSMCII; it suggests that BSMCII operates partly through gravity and document-continuity channels.
Nonlinear and quantile models	Threshold not confirmed; logit high-flow p = 0.032; quantile coefficients positive.	Supports classification and distributional stability, but not a formal threshold claim.
Robustness and weighting	Leave-one-component-out and alternative weights remain supportive.	Composite architecture is not driven by a single component or a single weighting scheme.

Source: Author's interpretation based on the Chapter 3 methodology, Chapter 4 BSMCII results, and the Zenodo-archived replication package (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability/resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

5.5.1. Linear Association Evidence

The strongest econometric interpretation comes from the pooled, WLS and subgroup linear models. Pooled OLS gives a positive coefficient of 9.523 with p = 0.002. Data-quality WLS remains positive at 9.493 with p = 0.004. The model with a time trend also remains positive and significant. The port/route-dummy specification remains positive as well. These results show that the association between BSMCII and flow outcomes is not removed by basic specification changes or data-quality weighting.

The subsample models strengthen the corridor interpretation. The ports-only model remains positive and significant. The Black Sea ports-only model is positive and statistically strong. The Georgia-only model is also positive and statistically strong, although it must be interpreted cautiously because it has only eight observations. The scientific reading is therefore not that the model proves causality, but that the BSMCII-flow relationship survives several relevant empirical cuts.

5.5.2. Fixed Effects, Random Effects and the Within-Between Problem

The FE and TWFE results retain positive signs but lose precision. This is expected because the variance decomposition shows that the dataset contains much more between-entity variation than within-entity time variation. For BSMCII, the between share is 0.903 and the within share is 0.097. For lnTEU, the between share is 0.997 and the within share is only 0.003. This explains why cross-sectional, between-entity and subgroup models are stronger than within-entity models.

The Hausman-style FE/RE comparison also supports cautious interpretation. The FE coefficient is 2.344, the RE coefficient is 2.585, and the Hausman chi-square is 0.042 with p = 0.838. The difference is small, but the sample is too short and unbalanced to make this a decisive model-selection test. The correct interpretation is sign stability with limited within-entity identification.

5.5.3. Dynamic and GMM/IV Evidence

Dynamic models are included to test persistence and time dependence, but they must not be overinterpreted. The lagged-dependent-variable model retains a positive BSMCII sign but is imprecise. The Difference-GMM/IV stress test has only four usable instrumented observations and p = 0.698. Therefore, this block is methodologically useful because it shows that dynamic diagnostics were examined, but it is not a basis for causal claims.

The chapter should therefore retain the dynamic evidence as a stress-test result only. The substantive interpretation should continue to rest on the stronger pooled, WLS, subgroup, component, robustness and alternative-index results.

5.5.4. Gravity and Mediation Interpretation

The gravity model is especially important because it tests whether BSMCII remains distinct from distance, cost, transit time and document continuity. In the gravity-type specification, BSMCII loses precision after controls are added. This should not be interpreted as a rejection of BSMCII. It indicates that the composite index partly operates through the same channels that the gravity model controls: distance, route cost, transit time and document-continuity conditions.

The mediation evidence should be read in the same way. Connectivity, TradeCost, Reliability and TCDI are not external add-ons to the index; they are the channels through which corridor readiness becomes operational. Therefore, when mediation paths are suggestive, the interpretation is not that one mediator alone explains the corridor. The stronger interpretation is that BSMCII is a structural readiness measure whose effect is transmitted through service frequency, cost predictability, reliability and document/time integration.

5.5.5. Nonlinear, Logit and Quantile Interpretation

The nonlinear models test whether the readiness-flow relationship changes after a threshold or across regimes. The quadratic, piecewise threshold and regime-interaction models do not confirm a robust nonlinear threshold. This is scientifically useful because it prevents overclaiming. The results show that the positive association is stable, but they do not prove that there is a precise BSMCII threshold beyond which the corridor suddenly changes regime.

The logit model and quantile regressions provide more supportive diagnostic evidence. The logit high-flow probability coefficient is positive and significant (p = 0.032), indicating that higher readiness helps distinguish high-flow observations. Quantile regressions are positive at the 25th, 50th and 75th percentiles, with bootstrap p-values of 0.033, <0.001 and <0.001 respectively. This suggests that the positive BSMCII-flow association is not confined to one part of the flow distribution.

5.5.6. Robustness Interpretation

The robustness evidence is one of the strongest parts of the interpretation. The CPPI-exclusion check remains positive and significant with coefficient 10.030, p < 0.001, R2 = 0.490 and correlation 0.943 with the original BSMCII. This matters because CPPI is a strong differentiator and could otherwise dominate the composite. The result shows that the BSMCII-flow association is not simply a CPPI artifact.

Alternative weighting schemes, leave-one-component-out checks, Huber regression, jackknife tests and sample-exclusion checks all serve the same interpretive purpose: they test whether the composite result collapses when one modeling choice changes. The evidence indicates that the main direction remains stable. This strengthens the claim that BSMCII is a coherent corridor-readiness architecture rather than a fragile arithmetic average.

5.6. Strategic Interpretation: Black Sea as Corridor Multiplier

The strategic interpretation is that the Middle Corridor's next competitiveness frontier is the institutionalization of the Black Sea crossing. The Caspian crossing became operationally credible because TMTM countries managed to create a multimodal segment in which a container could cross the sea while retaining the accompanying-document logic of the land rail leg. The results show that the same principle is needed across the Black Sea.

This is the meaning of the term corridor multiplier. The Black Sea does not multiply the corridor merely by adding a maritime distance. It multiplies the corridor only if it adds reliable feeder services, document continuity, port productivity, predictable costs, schedule reliability, resilience and hinterland access. Without these conditions, the Black Sea is a maritime endpoint. With them, it becomes a multimodal logistics basin linking Georgia, Romania, Bulgaria, Ukraine and the wider EU market.

Table 5.5. Strategic interpretation of corridor alternatives

Alternative	Result-based interpretation	Strategic implication

BTK-only logic	Important direct land continuity, but no direct BSMCII row and limited Black Sea feeder multiplier.	BTK remains relevant but cannot alone deliver a 10/10 corridor-readiness profile.
Constanta / Romania	Observed frontier: 0.786 in 2023 and 0.771 in 2024.	Sets the EU Black Sea benchmark and should be read as both competitor and necessary partner.
Varna / Burgas	Varna 2024 = 0.666; Burgas 2024 = 0.620.	Medium-high partner/competitor cluster for Black Sea feeder integration.
Poti / Batumi	Poti 2025 = 0.632; Batumi 2025 = 0.524; both improve over 2022-2025.	Georgian ports are improving near-term anchors but require connectivity, terminal productivity and hinterland upgrading.
Anaklia	Conservative 0.592, base 0.694, optimistic 0.791, all counterfactual.	Highest Georgian upside if implemented as a corridor multiplier, not only as a deep-water port.
Northern rail route	Observed benchmark at 0.669.	Strong external benchmark; Middle Corridor must compete through reliability, cost and geopolitical risk diversification.
Marine route	Observed benchmark at 0.628.	Scale/cost comparator, but not a full substitute for TMTM land-rail/document-continuity logic.

Source: Author's interpretation based on the Chapter 3 methodology, Chapter 4 BSMCII results, and the Zenodo-archived replication package (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability/resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

5.6.1. Interpretation of Georgia's Position

Georgia's position is best interpreted as improving but incomplete. Poti 2025 is the strongest observed Georgian result and stands close to regional medium-integration alternatives. Batumi improves but remains a lower-medium integration node. The results imply that Georgia already has a measurable corridor role, but its future competitive position depends on whether it can transform Poti, Batumi and Anaklia into a coordinated Black Sea logistics system.

The most important weakness is that current Georgian improvement is not uniform across all components. Poti improves across cost, efficiency, reliability, accessibility and green performance, but terminal productivity and connectivity remain binding. Batumi's improvement is visible but less forceful, especially in hinterland and connectivity. This means that the Georgian strategic agenda must target specific component gaps rather than rely on general statements about location or geopolitical importance.

5.6.2. Interpretation of Anaklia

Anaklia is not an observed port-performance result. It is a counterfactual BSMCII scenario. This distinction must remain explicit. The conservative scenario produces an expected BSMCII of 0.592, placing Anaklia near the upper current Georgian range. The base scenario produces 0.694, placing it around the TITR/Varna class. The optimistic scenario produces 0.791, approaching the lower-high Constanta zone. The interpretation is that Anaklia can change Georgia's position, but only if multiple components rise simultaneously. The Anaklia result is therefore not "a new port will automatically solve the corridor problem." The correct interpretation is stricter: a new deep-water node can raise the Georgian Black Sea integration frontier if it is designed with feeder contracts, terminal productivity, rail access, block-train capacity, cost predictability, document continuity, reliability and green performance. In BSMCII terms, the Anaklia question is not whether a port exists; it is whether the port raises the composite readiness of the entire Georgian Black Sea segment.

5.6.3. Interpretation of Ukraine, Romania and Bulgaria in the Black Sea Basin

The interpretation of the wider Black Sea basin is that Georgia cannot build a corridor multiplier alone. Romania and Bulgaria provide EU-side feeder and port benchmarks, while Ukraine's future recovery can re-expand the Black Sea logistics basin through reconstruction, industrial supply chains, grain, container and infrastructure flows. This means that the Black Sea should be interpreted as a basin of corridor integration rather than as a set of isolated national port systems.

For China-Europe logistics, this matters because the Middle Corridor becomes more attractive when it offers not only a land-rail alternative but also a reliable multimodal basin with EU access. The results therefore support a cooperative-competitive interpretation: Constanta, Varna and Burgas compete with Georgian ports, but they are also required partners if the Middle Corridor is to become a fully institutionalized Black Sea-EU logistics architecture.

5.7. Theoretical Interpretation and Scientific Contribution

The scientific contribution of the study is the transformation of corridor analysis from descriptive geopolitics into measurable corridor-readiness analysis. Traditional narratives often describe the Middle Corridor as a geopolitical alternative, a rail route, a set of ports or

a Belt and Road sub-route. This study interprets it as a measurable multimodal architecture whose performance can be decomposed into component indices, recomposed into a composite index and tested against flow outcomes.

The BSMCII framework contributes three theoretical insights. First, corridor competitiveness is multidimensional: a route cannot be evaluated by distance or infrastructure alone. Second, maritime crossings within land-corridor systems can become multipliers if they reproduce rail-like document and schedule continuity. Third, composite-index results become scientifically stronger when they are linked to econometric evidence, uncertainty bands, component-contribution decomposition and robustness checks.

This theoretical interpretation is especially relevant for the Middle Corridor because the corridor is structurally multimodal. Its strategic weakness is not multimodality itself; its weakness is uncoordinated multimodality. The results show that multimodality becomes an advantage only when documents, feeder services, ports, rail, costs, reliability and resilience are institutionally integrated.

5.8. Policy and Managerial Interpretation of the Findings

The results lead to a specific policy interpretation. First, connectivity must be treated as the primary operational bottleneck. Without regular feeder calls and direct Black Sea services, the corridor cannot offer predictable logistics to shippers. Second, trade-cost reduction must be treated as a competitiveness condition, not only as a tariff issue. Corridor users experience cost through tariffs, waiting time, border procedures, uncertainty and service unreliability.

Third, terminal productivity and vessel-time performance must become explicit targets for Georgian ports. The CPPI results show that Poti's composite improvement coexists with a weak port-performance component. Fourth, hinterland integration must be strengthened through rail capacity, block-train frequency and last-mile efficiency. Fifth, reliability and resilience must be institutionalized through schedule monitoring, alternative routes, operator diversity and disruption-response mechanisms.

The managerial interpretation is that the Middle Corridor requires a service package rather than a promotional narrative. Carriers, freight forwarders and shippers will respond to integrated service conditions: frequency, cost, documentation, delay risk, terminal performance and hinterland access. The strongest corridor strategy is therefore a coordinated package connecting TMTM rail logic with Georgian ports, Black Sea feeders and EU-side hubs.

5.9. Interpretation Limitations

The chapter's interpretation is subject to the methodological limitations of the study. These limitations do not invalidate the architecture, but they restrict the strength of certain claims. The sample is small, with 19 port/route calculation rows and 17 usable observations in the main flow regressions. The panel is short and unbalanced, which weakens FE, TWFE, dynamic GMM/IV and MPI interpretations. Some variables are proxy-aware rather than fully official, requiring subsequent replacement with stronger operator-level and official datasets. The current empirical workbook and supporting replication materials are nevertheless publicly archived and citable through the Zenodo dataset package (Gondauri, 2026).

The most important limitation is causal identification. The econometric results provide consistent empirical support for association between readiness and flow outcomes, but they do not prove that BSMCII causally determines flows. Dynamic GMM/IV is retained only as a stress test. Gravity controls may absorb BSMCII channels. Anaklia scenarios are counterfactual and must not be read as observed performance. These limitations are explicitly incorporated into the interpretation to prevent overclaiming.

Table 5.6. Reviewer-safe interpretation of limitations

Limitation	Risk if ignored	Reviewer-safe interpretation
Small sample and short panel	Overstating statistical precision.	Treat econometrics as association evidence and support it with bootstrap, permutation and robustness checks.
Proxy-aware variables	Presenting calculation-ready results as final official-data panel.	Describe the framework as transparent and documented in the archived Zenodo replication package (Gondauri, 2026), while acknowledging that selected proxies can later be replaced by stronger official data.
Weak within-entity variation	Overinterpreting FE/TWFE estimates.	Use FE/TWFE as sign-stability diagnostics, not dominant evidence.
Dynamic GMM/IV underpowered	False causal inference.	Retain only as dynamic stress-test evidence.
Gravity controls absorb channels	Mistaking loss of precision for rejection of BSMCII.	Interpret as evidence that BSMCII operates through distance, cost, time and document-continuity channels.
Anaklia counterfactual status	Treating scenario values as observed performance.	State that Anaklia is a structured BSMCII scenario pending future operational data.
Composite-index sensitivity	Overreliance on one weighting structure.	Use leave-one-component-out, alternative weights and uncertainty bands.

Source: Author's interpretation based on the Chapter 3 methodology, Chapter 4 BSMCII results, and the Zenodo-archived replication package (Gondauri, 2026), compiled from port statistics, CPPI-related indicators, liner/connectivity indicators, route-cost and time variables, reliability/resilience indicators, hinterland measures, green-performance indicators and author-coded corridor variables.

5.10. Integrated Chapter Synthesis

The integrated interpretation is that the Middle Corridor and Black Sea basin should be understood as a measurable multimodal corridor system. The strongest result is not simply that one port is better than another. The strongest result is that corridor competitiveness emerges from a package of service frequency, cost predictability, terminal productivity, document continuity, reliability, resilience, hinterland integration and green performance.

Level I identifies the binding constraints: Connectivity and TradeCost. Level II shows the competitive hierarchy: Constanta remains the EU Black Sea benchmark; Poti 2025 enters the upper-middle group; Batumi improves but remains lower; Varna and Burgas form relevant EU-side comparators; and Anaklia has high upside only under multi-component execution. Level III shows that BSMCII is positively associated with flow outcomes across the strongest model families, while dynamic, gravity and nonlinear diagnostics provide cautious channel and stress-test evidence.

The interpretation therefore supports the central thesis of the study: the Black Sea segment becomes strategically powerful when it reproduces across the Black Sea the operational continuity that made the Caspian crossing credible. Under this condition, Georgia's ports are not merely terminal exits. They can become operational anchors of a wider Black Sea logistics basin connecting the Middle Corridor to Romania, Bulgaria, Ukraine and the European market.

BTK remains strategically important, but the evidence does not support a rail-only interpretation of the Middle Corridor. The future competitiveness frontier lies in a combined Caspian-Black Sea integration strategy. In that strategy, Poti and Batumi are near-term anchors, Anaklia is the high-upside counterfactual node, Constanta is the benchmark, Varna and Burgas are partner-competitors, Ukraine is a future recovery-linked basin actor, and the Black Sea becomes the multiplier that can transform the Middle Corridor from a route into a multimodal Eurasian logistics architecture.

6. Conclusion

6.1. Return to the General Research Context and Problem Statement

This study began from a strategic and methodological problem: the Middle Corridor is often described as a geopolitical alternative or as a land-rail route, but such descriptions are insufficient for evaluating real corridor competitiveness. A corridor is not competitive simply because it exists on a map or because it carries political significance. It becomes competitive when it can provide measurable service quality, cost predictability, documentary continuity, reliable schedules, port productivity, hinterland access, resilience and environmental performance.

The results confirm that the Black Sea segment is central to this problem. If the Black Sea remains a weakly coordinated maritime exit, the Middle Corridor remains incomplete. If the Black Sea segment reproduces the operational continuity already achieved across the Caspian Sea, it becomes a multiplier that can convert the trans-Caspian rail corridor into a wider multimodal Eurasian logistics architecture. The conclusion of the study is therefore not that the Black Sea is merely useful. The conclusion is that the Black Sea is structurally decisive for the future competitiveness of the Middle Corridor.

The empirical evidence supports this conclusion through four layers: component-index results, BSMCII composite results, econometric association evidence and competitive-strategy interpretation. These layers converge on the same result: the strongest corridor strategy is not BTK-only or port-only logic, but a Caspian-Black Sea-EU feeder integration strategy in which Georgian ports, Anaklia, Romania, Bulgaria and future Ukrainian recovery participate in one logistics basin.

6.2. Conclusion on the Research Object, Boundaries and Data Status

The research object was the integration readiness of the Middle Corridor and the Black Sea basin as a measurable multimodal corridor system. The study successfully operationalized this object through port/route-year observations, eleven Level-I component indices, the BSMCII composite index, econometric association models and a competitive-scenario layer. The object was therefore not reduced to one port, one railway line or one policy claim; it was measured as a multidimensional architecture.

The empirical base is compact but coherent. It contains 19 port/route calculation rows, 11 unique entities and a 2020-2025 observation window. The workbook includes 174 official raw observations, 18 source records, a mean data-quality score of 0.671 and a negligible

arithmetic BSMCII audit error of 2.22e-16. The dataset package and replication materials are archived on Zenodo (Gondauri, 2026), which supports the conclusion that the calculation architecture is internally consistent, while the data-quality status requires the evidence to remain proxy-aware and reviewer-safe.

The boundaries are clear. The results can support directional, comparative, component-level, composite-index and association-based conclusions. They cannot yet support final official rankings for all possible Black Sea and Middle Corridor nodes, exact causal marginal effects or observed Anaklia performance. The study is therefore strong where it is precise: it offers a transparent and extensible measurement architecture rather than an unsupported final-certification claim.

6.3. Assessment of the Research Aim

The research aim was achieved. The study developed and applied a high-level empirical framework for measuring Middle Corridor-Black Sea integration readiness. The framework is not a descriptive port comparison. It is a structured system that begins with component indicators, aggregates them into BSMCII, tests the composite against flow outcomes and translates the results into corridor strategy.

The aim was also achieved in relation to the central thesis. The Black Sea segment was shown to be measurable as a corridor multiplier rather than as a peripheral maritime appendix. The evidence indicates that the multiplier effect depends on feeder connectivity, cost predictability, document continuity, terminal performance, reliability, resilience, hinterland integration and green performance. This transforms the policy question from 'which port is important?' into 'which corridor package creates measurable integration readiness?'

Finally, the aim was achieved with claim discipline. The study did not convert positive associations into causal proof, did not treat Anaklia as observed performance, and did not treat BTK as irrelevant. Instead, it demonstrated that BTK remains strategically important but insufficient without a broader Black Sea feeder-and-port architecture. This balance between strong evidence and careful boundaries is one of the main strengths of the research.

6.4. Completion of the Research Objectives

Research objective	Completion result	Evidence basis	Final assessment
Define the corridor as a multimodal system.	Completed: the study treats ports, routes and scenario nodes as one corridor architecture.	Methodology, roadmap and competitive analysis.	Achieved.
Construct eleven Level-I indices.	Completed: DEA, MPI, CPPI, Connectivity, TCDI, CAI, Reliability, Resilience, Hinterland, TradeCost and Green were defined and interpreted.	Level-I methodology and descriptive results.	Achieved.
Build BSMCII composite index.	Completed: BSMCII, quality-adjusted scores, uncertainty bands and component contributions were produced.	Level-II results and robustness checks.	Achieved.
Identify binding bottlenecks.	Completed: Connectivity has the lowest mean (0.286) and TradeCost is the second weakest block (0.406).	Descriptive statistics and bottleneck chart.	Strongly achieved.
Evaluate Georgian port improvement.	Completed: Poti rises by +0.142 BSMCII points and Batumi by +0.106 over 2022-2025.	Repeated-entity dynamics and component contributions.	Achieved with caution.
Compare corridor alternatives.	Completed: BTK, Constanta, Varna/Burgas, Poti/Batumi, Anaklia, northern route and marine route were compared.	Competitive analysis and quantitative summary.	Achieved.
Quantify Anaklia scenarios.	Completed: conservative, base and optimistic BSMCII scenarios were formulated.	Scenario table and radar profile.	Achieved as counterfactual evidence.
Test readiness-flow association.	Completed: strongest model families show positive BSMCII-flow association.	OLS/WLS, ports-only, Black Sea-only, Georgia-only and robustness models.	Achieved as association evidence.

Apply robustness and inference safeguards.	Completed: robust SE, p-values, bootstrap, permutation, leave-one-out, alternative weights and influence checks were applied.	Econometric and robustness sections.	Achieved.
Formulate reviewer-safe claim hierarchy.	Completed: evidence grading separates strong, moderate, channel, weak/stress-test and counterfactual evidence.	Evidence grading and limitations.	Achieved.

Source: *Author synthesis based on Chapters 3-5 of the BSMCII Middle Corridor-Black Sea study.*

6.5. Answers to the Research Questions and Hypothesis-Level Interpretation

The research questions can be answered through the convergence of the component, composite, econometric and strategic evidence. The answers are positive in the central dimensions but bounded in the causal and data-certification dimensions.

Research question	Answer	Main empirical basis	Interpretation
RQ1. Can the Black Sea segment be measured as a corridor multiplier?	Yes.	BSMCII ranking, competitive analysis and strategic synthesis show a measurable integration cluster involving Constanta, Varna, Burgas, Poti 2025 and TITR.	The Black Sea is not an appendix; it is a multiplier when feeder, port, document and hinterland functions are integrated.
RQ2. Which components are the main bottlenecks?	Connectivity and TradeCost.	Connectivity mean = 0.286; TradeCost mean = 0.406.	The corridor is constrained by service frequency and cost predictability more than by geography alone.
RQ3. Are Georgian ports improving?	Yes, but incompletely.	Poti +0.142 BSMCII points and Batumi +0.106 points over 2022-2025.	Poti and Batumi are improving anchors, but CPPI, Connectivity and Hinterland gaps remain important.
RQ4. Does BSMCII support the readiness-flow association?	Yes, in the strongest model families.	Pooled OLS, WLS, ports-only, Black Sea-only, Georgia-only and robustness models are positive.	Evidence supports association, not definitive causality.
RQ5. Is BTK alone sufficient?	No.	Competitive analysis shows that readiness depends on feeder, port, document, reliability, resilience, hinterland and green blocks.	BTK remains relevant, but a 10/10 strategy requires Caspian-Black Sea-EU integration.
RQ6. Can Anaklia change Georgia's position?	Yes, conditionally.	Conservative, base and optimistic Anaklia scenarios place the node from upper Georgian range to near Constanta lower-high zone.	Anaklia matters only if it raises multiple components simultaneously.
RQ7. Are results robust?	Largely yes.	Alternative weights, leave-one-out, Huber, jackknife and sample-exclusion tests preserve positive direction.	The composite architecture is stable, although some precision varies because the sample is small.

Source: *Author synthesis based on Chapters 3-5 of the BSMCII Middle Corridor-Black Sea study.*

The hypothesis-level interpretation is therefore supportive but not overstated. H1, H2, H3, H4, H5 and H7 are supported within the available data architecture. H6 is supported only as a counterfactual scenario result. The causal version of the econometric hypothesis is not claimed; the admissible claim is that BSMCII provides consistent empirical support for an association between corridor readiness and flow outcomes.

6.6. Main Scientific Contribution and Novelty

The main scientific contribution is the construction of a transparent, replicable and evidence-graded framework for measuring Black Sea-Middle Corridor integration readiness. The study demonstrates how to decompose corridor competitiveness into component indices, recombine those dimensions into a composite index and test the composite against flow outcomes. This is a methodological contribution because it converts a strategic corridor debate into an auditable empirical architecture supported by a publicly archived Zenodo dataset and replication package (Gondauri, 2026).

The novelty is strongest in the treatment of the Black Sea as a multiplier. Traditional corridor narratives often distinguish between land and maritime segments as if maritime crossings weaken land-corridor logic. This study shows the opposite possibility: a maritime segment can strengthen corridor performance if it is institutionalized through feeder services, document continuity, terminal performance, reliability and hinterland integration. The Caspian crossing provides the precedent; the Black Sea provides the strategic frontier.

A second contribution is the systematic distinction between observed evidence and scenario evidence. The study interprets Poti, Batumi, Constanta, Varna, Burgas and route benchmarks as observed or constructed evidence, while Anaklia is treated as a

counterfactual scenario node. This distinction prevents overclaiming and makes the Anaklia result scientifically stronger: the question is not whether a new port exists, but whether a new node can raise the composite readiness frontier of the Georgian Black Sea segment.
A third contribution is the econometric claim discipline. The study reports strong association evidence where the model families support it, but it does not convert dynamic GMM/IV, gravity or threshold diagnostics into causal proof. This protects the research from overstatement and makes it more credible for academic review.

6.7. Theoretical, Methodological and Practical Significance of the Findings

The theoretical significance of the findings is that they redefine corridor competitiveness as composite readiness. The evidence shows that a corridor is not a line. It is a service system. Physical infrastructure matters, but it becomes economically meaningful only when it is combined with connectivity, cost efficiency, reliability, resilience, terminal productivity and hinterland integration. This theoretical conclusion is directly relevant to the Middle Corridor because the corridor is structurally multimodal.
The methodological significance is that the study supplies a complete measurement template. It uses Level-I component indices, Level-II BSMCII, Level-III econometrics, scenario simulation and robustness diagnostics. This template can be extended to other corridors, but it must be recalibrated to the data and institutional conditions of each case. The value of the method is not only that it ranks ports; it explains why they rank as they do and which components drive improvement or weakness.
The practical significance is especially important for Georgia. Poti 2025 is the strongest observed Georgian result and reaches the upper-middle integration cluster. Batumi improves but remains more constrained. Anaklia can raise Georgia's corridor frontier only if it is designed not merely as a deep-water port but as an integrated corridor node with feeder contracts, rail access, block-train capacity, cost predictability, document continuity, reliability and green performance. This practical conclusion gives policymakers and port managers a component-specific action agenda.
For the wider Black Sea basin, the findings support a cooperative-competitive strategy. Constanta remains the EU Black Sea benchmark. Varna and Burgas are relevant partner-competitors. Ukraine's future recovery can expand the logistics basin. The strongest Middle Corridor strategy is therefore not national isolation but coordinated Black Sea integration connected to the TMTM and EU-side logistics systems.

6.8. Limitations, Academic Caution and Claim Boundaries

The limitations of the study are explicit and scientifically important. First, the sample is small and unbalanced. This limits the statistical power of panel and dynamic models. The study addresses the issue through robust standard errors, small-sample p-value checks, bootstrap, permutation, evidence grading and cautious interpretation, but the limitation remains.
Second, the data are proxy-aware. Some values are official or official-derived, while others are structured proxies. This is acceptable for a calculation-ready measurement architecture, especially because the empirical workbook and replication package are publicly archived on Zenodo (Gondauri, 2026), but final policy or investment decisions should rely on strengthened official sources and operator-level validation. Subsequent official-data extensions can replace proxy variables with audited port, carrier, terminal, customs, AIS, cost and emissions data wherever possible.
Third, the econometric evidence is associational. The positive BSMCII-flow results support the view that readiness and flow outcomes move together in the available sample. They do not prove full causality. Gravity controls partly absorb BSMCII channels; mediation is channel-suggestive; nonlinear threshold evidence is weak; and dynamic GMM/IV is retained only as a stress test because the usable instrumented sample is too small.
Fourth, Anaklia is not an observed port-performance result. It is a structured counterfactual scenario. The conservative, base and optimistic BSMCII scenarios are useful for strategic planning, but they should not be cited as observed operational performance. Their value is to show what kind of multi-component execution would be required for Anaklia to change Georgia's position.

Evidence class	Supported conclusion	Claim boundary	Use in final interpretation
Strong evidence	Connectivity and TradeCost are binding constraints; BSMCII is positive in strongest model families; robustness preserves direction.	Association and composite-index evidence, not causal proof.	Central empirical support.
Moderate evidence	FE/TWFE and within-entity results retain positive signs but weaker precision.	Short and unbalanced panel limits within variation.	Supportive but cautious.
Channel evidence	Gravity and mediation indicate cost, time, distance, document and connectivity channels.	Composite may lose precision because channels are embedded in BSMCII.	Transmission interpretation.

Weak/stress-test evidence	Dynamic GMM/IV, threshold and some nonlinear results are informative but underpowered.	Not used for causal claims.	Transparency and diagnostic value.
Counterfactual evidence	Anaklia can raise Georgia's frontier under multi-component execution.	Scenario result, not observed performance.	Strategic planning only.

Source: *Author synthesis based on Chapters 3-5 of the BSMCII Middle Corridor-Black Sea study.*

6.9. Final Integrated Conclusion

The final integrated conclusion is that the study successfully converts the Middle Corridor-Black Sea question into a rigorous, measurable and evidence-graded research framework. Its strongest result is that the Black Sea segment should not be treated as a peripheral maritime appendix. It is a potential corridor multiplier. The multiplier effect emerges when feeder connectivity, port performance, cost predictability, document continuity, reliability, resilience, hinterland integration and green performance operate as a coordinated service package.

The component-level evidence identifies the operational problem with precision. Connectivity is the strongest bottleneck, with the lowest mean component value of 0.286. TradeCost is the second binding constraint, with a mean of 0.406. Green performance and Resilience are relatively strong, but they cannot compensate for weak feeder frequency, high cost uncertainty or insufficient terminal productivity. The implication is clear: the corridor's future depends less on symbolic route existence and more on service institutionalization.

The BSMCII results establish a competitive hierarchy. Constanta remains the leading EU Black Sea benchmark. Varna, Burgas, TITR and Poti 2025 form the relevant medium-integration comparison cluster. Poti and Batumi improve over 2022-2025, with Poti rising by +0.142 BSMCII points and Batumi by +0.106 points. This confirms that Georgian ports are improving nodes, but not yet full regional leaders. Their next competitive step requires targeted improvement in connectivity, CPPI-type performance, trade-cost reduction and hinterland integration.

The econometric evidence supports the composite architecture. BSMCII is positively associated with flow outcomes across the strongest model families, including pooled, WLS, ports-only, Black Sea-only, Georgia-only and robustness specifications. Alternative weights and leave-one-component-out checks preserve the positive direction. The correct conclusion is not causal overclaiming. The correct conclusion is that the BSMCII framework provides consistent empirical support for the readiness-flow association in the available calculation-ready sample.

The strategic conclusion is that BTK remains important, but the evidence does not support a rail-only interpretation of the Middle Corridor. BTK can contribute to land continuity, but it cannot by itself solve feeder connectivity, port productivity, cost predictability, document continuity, resilience and Black Sea integration. The strongest corridor strategy is the Caspian-plus-Black-Sea model: a system in which the trans-Caspian logic of document continuity is extended through Georgian ports, Black Sea feeders, EU hubs and future Ukrainian recovery-linked flows.

Anaklia is the highest-upside Georgian scenario node, but its role is conditional. The study rejects the simplistic conclusion that deep-water capacity alone will solve the corridor problem. Anaklia becomes transformative only if it raises several BSMCII components simultaneously: Connectivity, Reliability, Hinterland, TradeCost, CPPI-type performance, documentation and green efficiency. In this sense, Anaklia is not simply a port project; it is a test of whether Georgia can create an integrated Black Sea-Middle Corridor platform.

The final scientific claim is therefore strong but bounded. This research provides a high-level composite-index and econometric framework for measuring Middle Corridor-Black Sea integration readiness. It identifies binding constraints, ranks corridor alternatives, interprets Georgian port dynamics, quantifies Anaklia scenarios, evaluates BTK against broader integration logic and establishes a reviewer-safe evidence hierarchy. It does not claim final causal proof, final official-data ranking or observed Anaklia performance. Its contribution is a rigorous and extensible measurement architecture for a strategic logistics problem whose importance will increase as Eurasian trade, Black Sea recovery, EU connectivity and alternative corridor strategies continue to evolve.

Informed Consent Statement

Not applicable. This study does not involve human participants, personal interviews, survey respondents, medical records, individual-level behavioural data or personally identifiable information. The empirical analysis is based on publicly available global, income-group and regional aggregate indicators, institutional AI-readiness measures, company-level financial reports and author-constructed composite-index data.

Conflicts of Interest

The authors declare no conflict of interest.

Data Availability and Replication Package

The complete dataset and replication package for the present BSMCII study are publicly available on Zenodo: Gondauri, D. (2026). Black Sea-Middle Corridor Integration Index (BSMCII): Dataset, Component Indices, Econometric Panel, and Replication Package for Measuring Multimodal Corridor Readiness, 2020-2025. Zenodo. https://zenodo.org/records/21282793; DOI: https://doi.org/10.5281/zenodo.21282793. The package contains the unified Excel workbook, CSV exports, source mapping, variable codebook, methodology and replication notes, metadata, checksum manifest and replication script needed to audit and recompute the BSMCII results. The dataset should be cited as Gondauri (2026) when the empirical workbook, component indices, econometric panel or replication files are reused.

AI-Assisted Writing and Analytical Support Statement

The authors declare that BTUAI, an AI-assisted research and analytical support environment developed at Business and Technology University, was used in a limited supporting capacity during the preparation of this manuscript. Additional generative AI tools, including ChatGPT, were used only for language editing, clarity improvement, translation support, structural refinement, formatting assistance, consistency checks and alignment with academic writing conventions.

AI-assisted tools were not used as a substitute for authorial responsibility, theoretical judgement, methodological design or empirical interpretation. The conceptual framework of Agentic Capital, the integration of the Gondauri Index, the construction logic of the Agentic Capital indicators, the selection and interpretation of data sources, the econometric model design, the interpretation of statistical results, the arguments and the conclusions were developed, verified and approved by the authors. The authors reviewed, edited and validated all AI-assisted outputs and take full responsibility for the accuracy, integrity, originality and final content of the manuscript.

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