



Onshore Power Supply (OPS) in Adriatic-Ionian Ports: A Multi-Criteria Prioritisation of Readiness from Structured Port-Authority Judgements

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ABSTRACT

Onshore power supply (OPS) is increasingly mandated to eliminate ship emissions at berth, yet its feasibility varies sharply from port to port and weighing the competing factors is inherently a multi-criteria task. This article ranks the OPS readiness of six dissimilar Adriatic-Ionian ports – Ancona, Ploče, Durrës, Volos, Belgrade on the Danube and lakeside Ohrid – whose operations run from ferry, cruise and cargo traffic to lake tourism and which sit on both sides of the European Union regulatory boundary. A twenty-factor SWOT consolidated from a common multiple-case protocol is taken through hybrid SWOT-AHP elicitation completed by the six port authorities and a best-worst cross-check, then a TOPSIS ranking over seven readiness criteria. Every returned comparison set passes the consistency screen. The elicited weights put the funding opportunity and the capital-cost weakness first among the factors, and grid readiness and capital intensity first among the criteria; the resulting order – Ancona, Ploče, Belgrade, Volos, Durrës, Ohrid – holds at its head and tail under perturbation of the weights. The article delivers elicited regional priorities, a transparent and transferable prioritisation pipeline for heterogeneous ports and a ranked baseline for tracking the region's progress towards the 2030 obligations.

1. Introduction.

Maritime transport carries the bulk of world trade, and although shipping contributes only around 3 per cent of global carbon dioxide (CO₂) emissions, its air-pollution burden is concentrated in coastal regions and ports. A berthed ship runs its auxiliary engines to cover hotelling loads, so Marine Gas Oil (MGO) continues to burn at the quay and nitrogen oxides (NO_x), sulphur oxides (SO_x), particulate matter (PM) and CO₂

– with engine noise and vibration besides – are released metres from the shore. In the Adriatic-Ionian (ADRION) region, where ports typically sit against dense and frequently historic urban cores, that burden lands directly on city populations. Onshore power supply (OPS) – the measure also termed cold ironing or shore-side electricity – removes the source itself: auxiliary engines are shut down for the duration of the call and the ship's hotelling demand is met from the shore grid instead.

Regulation has converted what began as a voluntary green-port measure into an obligation. Globally, MARPOL Annex VI – the International Maritime Organization's instrument on air emissions from ships – limits SO_x and NO_x output and provides for Emission Control Areas, and a control area for SO_x covering the Mediterranean has applied since 1 May 2025; within the European Union, the Alternative Fuels Infrastructure Regulation (AFIR; Regulation (EU) 2023/1804) and the FuelEU Maritime Regulation (Regulation (EU) 2023/1805) jointly im-

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pose, with effect from 2030, a duty on core and comprehensive trans-European-network ports to supply OPS and a matching duty on the relevant ships to plug in at berth. For ports inside that scope the decision is no longer whether but how and at what scale – and the answer turns on grid capacity, on the level and allocation of capital cost, on electricity prices and on how demand is distributed across the day and the season, all of which differ markedly between ports.

Nowhere do those conditions vary more than across the – ADRION basin, where European Union members bound by the 2030 rules sit beside Western Balkans states following the Green Agenda instead, and where ports differ by orders of magnitude in berth demand and span the whole range of implementation maturity. The literature on OPS, reviewed below, is mature on technology, environmental performance, techno-economics and regulation, but its empirical centre of gravity lies with big cruise and container hubs in Northern Europe and Asia. Methodologically, the multi-criteria techniques suited to weighing competing technical, economic, regulatory and environmental considerations are long established, yet they have rarely been brought to bear on OPS: existing applications typically examine one port in depth or optimise a narrow technical sub-problem, and a transparent prioritisation across several dissimilar candidate ports is largely absent.

This article takes up that methodological gap. Its purpose is to rank the OPS readiness of six structurally dissimilar ADRION ports – Ancona (Italy) and Ploče (Croatia), Durrës (Albania) and Volos (Greece), Belgrade (Serbia), a Danube river port, and Ohrid (North Macedonia), a lake port – and to attach differentiated implementation strategies to that ranking, using structured judgements supplied by the six port authorities themselves. The evidential base is a multiple-case assessment carried out to a common protocol; its consolidated SWOT furnishes the factor set, while the full case narratives and thematic synthesis appear in a companion study, leaving the present article to carry the prioritisation. Three contributions follow: regional factor and criteria weights elicited from the authorities that would implement OPS; a transparent, reproducible pipeline – SWOT-AHP and best-worst elicitation coupled to TOPSIS – that transfers to comparable port sets; and a ranked readiness baseline for the region's 2030 transition. The article proceeds from a review of OPS and the decision methods used to appraise it, through the research design and elicitation pipeline, to the elicited priorities and the resulting ranking, closing with differentiated strategies, recommendations and limitations.

2. Literature Review.

2.1. OPS: Technology, Benefits and Economics.

An OPS installation pairs shore-side supply equipment with on-board receiving gear across a standardised interface, and its central engineering challenge is compatibility: ships call at 50 Hz or 60 Hz and connect anywhere from low voltage for small craft up to 6.6 and 11 kV for large ships, so the shore plant must convert frequency and synchronise precisely (Kumar et al., 2019; Abu Bakar et al., 2023; Mendes, 2025). The

governing standards are settled – the ISO/IEC/IEEE 80005 series for ship-shore connection, IEC 61851 at small-craft scale and EN 15869 on inland waterways (European Maritime Safety Agency, 2025; ISO/IEC/IEEE, 2019) – so the technology itself is mature, and the literature locates the decisive questions elsewhere. Local effects are well documented: cutting the auxiliary engines while alongside removes their exhaust and noise and delivers large reductions in the principal air pollutants (Winkel et al., 2016). The climate effect, by contrast, is contingent: OPS exchanges on-board MGO combustion for grid electricity, so where generation is fossil-heavy the emissions move from the quay to the power station rather than disappearing (Stolz et al., 2021) – the reason much current work pairs OPS with on-site renewables, storage and port microgrids (Abu Bakar et al., 2022; Colarossi and Principi, 2023). Economics remains the hardest constraint: capital outlays fall on shore and ship alike, operating viability hinges on electricity-versus-MGO prices, tariffs, taxation and above all utilisation, and the benefits scatter so widely across port authority, terminal operator, shipowner and grid operator that no party alone has a business case for the full investment (Coppola et al., 2016; Dai et al., 2019; Tan et al., 2023); studies repeatedly find that a well-designed mix of incentives and public funding is what unlocks alignment (Tan et al., 2023; Fostiropoulos et al., 2026). Two mutually reinforcing barriers complete the picture: shore-side and ship-side investment each wait on the other, and the economics bite hardest at small and medium ports (Innes and Monios, 2018; Zis, 2019; Abu Bakar et al., 2023).

2.2. The Regulatory Framework.

OPS regulation now operates at several levels. Internationally, MARPOL Annex VI sets the SO_x and NO_x regime and designates Emission Control Areas, and the SO_x control area covering the Mediterranean – the basin holding the ports studied here – has been in force since 1 May 2025 (International Maritime Organization, 2022). At European level the rules are prescriptive on both sides of the quay: AFIR obliges core and comprehensive trans-European-network ports to make OPS available by 2030 for a stipulated proportion of their container and passenger calls (Regulation (EU) 2023/1804), while FuelEU Maritime obliges the ships concerned to take the connection while berthed (Regulation (EU) 2023/1805). Outside the European Union, comparable pressure reaches the region's ports indirectly – via the Green Agenda for the Western Balkans, via the Regional Transport Community and via the extension of the trans-European network – rather than through any binding national rule. Feasibility work on Mediterranean and Adriatic ports has begun extending the empirical base towards the region considered here (Glavinović et al., 2023; Karapidakis et al., 2022; Nikolaidis and Maniati, 2024; Piccoli et al., 2021).

2.3. Multi-Criteria Decision Methods in Port Sustainability.

Appraising OPS is intrinsically a multi-criteria exercise: technical, economic, regulatory and environmental considerations pull against one another and their balance shifts from port to port. SWOT (strengths, weaknesses, opportunities and threats)

analysis gives port and maritime strategists a standard frame for organising such considerations, yet on its own it neither weights nor ranks them. The hybrid SWOT-AHP method supplies the missing quantification, applying Saaty's analytic hierarchy process (AHP) to pairwise comparisons of the SWOT factors so that relative importance becomes measurable and consistency testable (Kurttila et al., 2000; Saaty, 1980; Helms and Nixon, 2010); the best-worst method reaches comparable weights from far fewer judgements by anchoring every factor to the most and least important of the set (Rezaei, 2015); and TOPSIS (technique for order of preference by similarity to ideal solution) ranks alternatives by their relative closeness to an ideal point (Hwang and Yoon, 1981). All three are routine in transport, energy and environmental planning, but OPS applications remain scarce and narrow – typically one port assessed in depth, or a technical sub-problem optimised – and a structured, transparent appraisal of the competing factors across several candidate ports is rarer still. That is the gap this article fills with what is, to the authors' knowledge, the first multi-port OPS prioritisation elicited end to end from the implementing port authorities themselves.

3. Research Methodology.

3.1. Research Design and Case Base.

The prioritisation stands on a comparative, multiple-case evidence base (Eisenhardt, 1989; Yin, 2018). Selection was purposive: the six ports were chosen to stretch across the region's main axes of variation – in function, from river cruise through sea ferry, Ro-Pax and ocean cruise to multipurpose cargo and lake tourism; in regulatory exposure, with three European Union members under the binding 2030 obligations against three Western Balkans states proceeding via the Green Agenda; and in maturity, from construction under way to no plan at all, the lake port of Ohrid deliberately anchoring the lower bound. Theoretical sampling implies analytical generalisation: the findings are meant to carry over to structurally similar ports of the ADRION basin and the wider Mediterranean, not to a statistical population.

Evidence was gathered to a single predefined protocol: one reporting template, identical for every port, covering operations and cargo profile, ship types with traffic and forecasts, hotelling durations and auxiliary power, the state of every OPS prerequisite – from grid connection and cabling through substation and berth works to space and renewable-energy potential – and the scope of planned development. The protocol draws on three evidence classes – documentary sources, the port authority's own structured input as key informant and benchmarking against comparable reference installations – whose triangulation strengthens construct validity. SWOT coding then separated each port's internal attributes from its external conditions, and cross-case synthesis merged the six analyses into one regional SWOT in which every consolidated factor carries the list of ports supporting it, the count of supporters serving as a first measure of salience (Helms and Nixon, 2010). The underlying case narratives, thematic classification and benchmark reviews

appear separately; what this article takes forward is their product – a consolidated set of twenty factors, balanced five to each SWOT group.

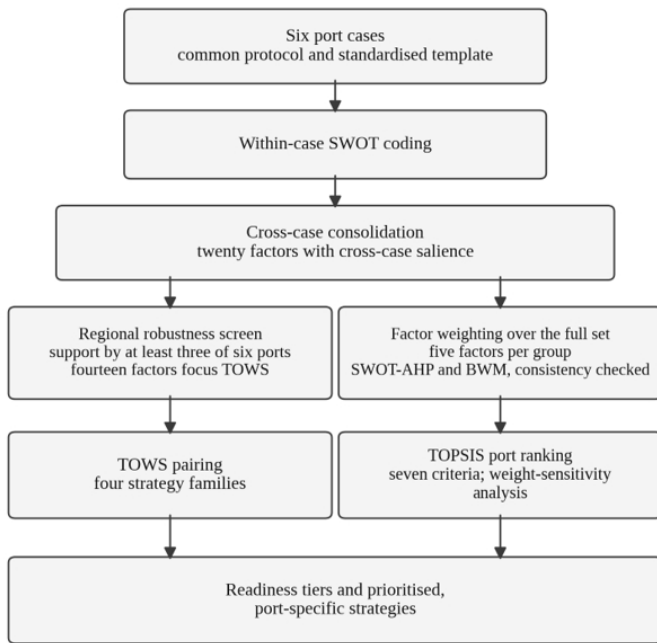
3.2. From SWOT to Ranked Strategies: Elicitation and Ranking.

SWOT identifies factors but neither weighs them nor indicates what should be done about them. Two established steps address this. First, a TOWS matrix pairs internal with external factors to generate four strategy families – strength-opportunity, weakness - opportunity, strength-threat and weakness-threat – converting the descriptive SWOT into explicit strategy sets that can be tailored to each port type and maturity tier. Second, the factors are quantified through a hybrid SWOT-AHP analysis (Kurttila et al., 2000): the four SWOT groups form the upper level of a decision hierarchy and the individual factors the lower level; pairwise judgements elicited from the port-authority informants yield the relative weights of the groups and the local weights of the factors within each group, and multiplying the two gives global priority scores on a common scale. The consistency of every comparison matrix is checked through the consistency ratio. As a more economical alternative, the best-worst method (Rezaei, 2015) is offered alongside the AHP in the elicitation instrument, with block weights recovered by its linear formulation (Rezaei, 2016); although presented as an alternative, the partners were asked to complete both methods so the two weighting schemes could be cross-validated on the same respondents. Returned judgements are aggregated across respondents by the geometric mean of the individual priority vectors; any comparison set failing the consistency screen would be returned for revision – a step the returns made unnecessary. The cross-port appraisal is completed with TOPSIS: the ports form the alternatives, the consolidated factor structure is condensed into seven decision criteria – grid and prerequisite readiness (C1), implementation maturity (C2), on-site renewable feasibility (C3), regulatory driver strength (C4), at-berth demand and emission-reduction potential (C5), capital intensity and financing risk (C6, the cost criterion) and utilisation potential (C7) – each port is scored against every criterion in a weighted decision matrix, initially encoded from the case evidence and returned to each authority for revision of its own row, and the ports are ranked by their relative closeness to the ideal solution. The pipeline from case evidence to ranked strategies is depicted in Figure 1.

3.3. Validity, Reliability and Limitations.

Validity rests on three supports: triangulated evidence under a uniform protocol; a documented chain from every consolidated factor back to the ports reporting it, with the template, case database and elicitation instrument allowing full repetition of the procedure; and replication across six deliberately varied cases, which warrants analytical rather than statistical generalisation. The limitations are stated plainly. Much of the evidence is secondary, and part of it is the port authorities' own reporting, so optimistic or uneven assessment cannot be excluded. The quantitative prioritisation draws on one structured return

Figure 1: Analytical pipeline from the six case studies to prioritised strategies.



Source: Authors.

per authority, meaning the weights express institutional judgement that no second respondent triangulates, and the decision-matrix scores are in part self-assessed. The assessment is also a snapshot: one region, one point in time, before the 2030 milestone falls due. Together these bounds confine the claims to a transparent, transferable assessment and mark where additional data collection would firm them up.

4. Results.

4.1. Case Base and Readiness Typology.

Table 1 sets the six ports side by side, and the contrasts are stark on every dimension the sampling targeted. Functionally the set runs from the multipurpose Adriatic ports of Ancona, Durrës and Volos – each mixing ferry, Ro-Pax, cruise and cargo work – through the dedicated cargo port of Ploče to Belgrade’s Danube river-cruise terminal and the lake-tourism port of Ohrid. Demand at berth stretches across more than three orders of magnitude: a few kilowatts for Ohrid’s smallest craft, one to three megawatts where river cruisers and ferries berth, around eight megawatts for a cruise call at Volos and sixteen megawatts planned for Ancona’s cruise connection. Maturity runs the full distance from construction in progress (Ancona) to neither plan nor material direct benefit (Ohrid), and regulatory exposure splits the set in two – Ancona, Ploče and Volos under the binding European Union obligations for 2030, Durrës, Belgrade and Ohrid outside any equivalent national mandate.

Table 1: Comparative overview of the six participating ports.

Port, country / waters	Port type and main ships	Current OPS status and maturity	Grid / prerequisites	On-site renewables	Planned OPS-related investment
Ancona, Italy - Central Adriatic, city-adjacent	Multipurpose: ferry/Ro-Pax, cruise, container, bulk, OSV, tug	Under construction (ferry quays); OSV quay and tugs already operational	Dedicated system being built: 6.6/11 kV, 50/60 Hz, 2.5 MW/connection, 9 MW total	Limited on-site	≈ €7 M (ferry, 2025-26); €12 M cruise terminal (16 MW)
Ploče, Croatia - Adriatic, Corridor Vc	Cargo: container, bulk (to 180,000 DWT), liquid, general	Nonexistent/planned - prerequisites reported favourable	Reported adequate across components	Yes - 175 kW PV operational (2024)	Modest; PV in place
Durrës, Albania - Adriatic	Multipurpose: ferry, container, bulk, general, Ro-Ro (roll-on/roll-off)	Planned - to be built into relocated port	20 kV network; grid/berth inadequate, civil works needed	Solar feasible (none yet)	Within ≈ €400 M relocation (2025-29)
Volos, Greece - Pagasetic Gulf	Mixed: ferry/Ro-Pax, cruise (≈ 8 MW aux), bulk, container	Planned - CEF-funded studies; 5 OPS positions designed	Inadequate grid/cabling/substation; spatial adequate	Yes - PV for ≈ 99% of port power planned	€17.19 M OPS (2025-32); €1.35 M PV
Belgrade, Serbia - Sava Danube (inland)	River-cruise passenger terminal (≈ 1-2 MW/ship)	Nonexistent, planned - OPS designed into new terminal	Inadequate grid, cabling, substation; limited space	≈ 34% national hydro	€5-7 M new terminal (2025-27)
Ohrid, North Macedonia - Lake Ohrid (UNESCO)	Small passenger/tourist craft (aux ≈ 3-368 kW)	Nonexistent, not planned - marginal direct benefit	None; spatial inadequate at city port	Excellent solar potential (unbuilt)	None defined; canal-side PV/marina concept

Source: Authors, from the project data-collection templates.

Table 2 condenses the cross-case picture into five readiness tiers. At the top, Tier A holds Ancona alone, its dual-voltage, dual-frequency system already in construction; Tier B is Volos, whose Connecting Europe Facility-funded studies have produced five designed OPS positions awaiting execution. Tier C pairs Durrës and Belgrade, each embedding OPS in a wider terminal development that hinges on grid reinforcement – and, for these non-European-Union partners, on a national legal basis still to be created. Tier D is Ploče, whose prerequisites are reported adequate and whose photovoltaic plant already operates, but where the investment decision has not been taken; Tier E is Ohrid, without grid connection or plan and with marginal direct emission benefit, for which a downscaled clean-marina and tourism framing fits better than a high-tonnage installation. Most of the variation collapses onto three axes – readiness, regulatory regime and port type with its demand – and regional action works only when ambition and technical solution are matched to a port’s coordinates on all three.

Table 2: Readiness typology of the participating ports.

Tier	Port(s)	Defining status and immediate priority
A - Implementing	Ancona	Dedicated system under construction; priority is commissioning, the cruise-terminal high-voltage connection (16 MW) and a replicable operating model
B - Designed / funded	Volos	CEF-funded studies complete, five OPS positions designed; priority is securing construction finance and integrating the planned PV plant
C - Planned within larger development	Durrës, Belgrade	OPS designed into new terminals (2027; relocation to 2029); priority is grid reinforcement, distribution-system-operator coordination and a national legal basis
D - Prerequisites favourable, decision pending	Ploče	Prerequisites reported adequate and PV in place; priority is cost-benefit and operating decision and shipowner engagement
E - Not planned / marginal direct benefit	Ohrid	No grid or plan, heritage-constrained; priority is a downscaled clean-marina/PV concept treating OPS as a heritage and tourism enabler

Source: Authors.

4.2. Consolidated Factor Set and Elicited Priorities.

The consolidated regional SWOT holds twenty factors in a balanced structure – five strengths, five weaknesses, five opportunities and five threats – and Table 3 reports each with its

cross-case salience, that is, how many of the six port-level analyses contain it. Salience also drives a screening step: a regional prioritisation should not hinge on circumstances unique to one harbour, so the fourteen factors backed by at least three of the six ports are marked in the table as the regionally robust core, leaving six factors with only one or two supporting cases. The elicitation instrument nonetheless presented the complete set, for two reasons: the balanced five-per-group structure keeps each pairwise comparison block small enough for judgements to stay reliable, and weighting every factor lets the elicited priorities test the salience screen independently.

Table 3: Consolidated regional SWOT: factor set, cross-case salience, regional robustness and elicited global weights.

Code	Factor	Support (N of 6)	Group	Regionally robust (support ≥ 3)	Elicited weight (rank)
S2	Large local emission and noise reduction at city berths	6	Strength	Yes	0.054 (8)
S3	Existing enabling assets / infrastructure	4	Strength	Yes	0.031 (17)
S4	Strong institutional commitment; OPS embedded in port development plans	4	Strength	Yes	0.061 (6)
S5	Long, predictable cruise/cargo berths (high utilisation)	2	Strength	No	0.047 (11)
S1	Mature, scalable, flexible OPS technology	1	Strength	No	0.045 (13)
W2	High capital cost, cost-allocation, slow/uncertain return	6	Weakness	Yes	0.092 (2)
W1	Inadequate grid, cabling, substations	4	Weakness	Yes	0.063 (5)
W3	Spatial constraints on dense/historic waterfronts	3	Weakness	Yes	0.049 (10)
W4	Ship-side standard variety / low fleet readiness	3	Weakness	Yes	0.064 (4)
W5	Weak operating readiness (skills, standard operating procedures, pricing)	2	Weakness	No	0.039 (14)
O1	European and international funding (CEF, AFIF, ADRIAN, Horizon)	6	Opportunity	Yes	0.092 (1)
O2	Regulatory demand-pull (AFIR/FuelEU; Green Agenda)	6	Opportunity	Yes	0.037 (15)
O4	Green-port competitiveness and branding	6	Opportunity	Yes	0.047 (12)
O5	Design-in at planned new terminals	4	Opportunity	Yes	0.051 (9)
O3	Renewable + storage integration	3	Opportunity	Yes	0.073 (3)
T5	Limited finance; competition from faster adopters	3	Threat	Yes	0.036 (16)
T2	Regulatory uncertainty / funding dependence (non-EU)	3	Threat	Yes	0.054 (7)
T1	High/volatile electricity prices (break-even risk)	2	Threat	No	0.021 (19)
T3	Shipowner resistance / low ship readiness	1	Threat	No	0.024 (18)
T4	Grid stress / seasonal demand peaks	1	Threat	No	0.020 (20)

Source: Authors. Salience counts the ports (of six) whose SWOT supports the factor; the regionally robust subset requires support of three or more; weights are the geometric mean of the six returns, with rank in parentheses.

All six instruments were returned with differentiated judgements, and every submitted comparison set satisfied the consistency screen, with consistency ratios between 0.018 and 0.098 against the 0.10 threshold, so no return required revision. Aggregating the six SWOT-AHP returns by the geometric mean yields the global factor priorities reported alongside the factor set in Table 3. The European and international funding opportunity (O1) and the capital-cost weakness (W2) head the order together, separated by less than a thousandth of a point, followed by renewable and storage integration (O3), the ship-side readiness weakness (W4) and the grid weakness (W1); as a group the weaknesses (0.31) and the opportunities (0.30) carry nearly equal aggregate weight, ahead of the strengths (0.24), with the threats behind (0.16). The elicited order confirms the salience screen at the threat end – the three single- or two-port

threats receive the three smallest weights – but it also separates breadth from judged importance: the universally reported regulatory pull (O2) and the widely supported enabling-assets strength (S3) fall into the lightest third of the order, while the low-salience utilisation factor (S5) sits in the middle of the field, eleventh of twenty.

Four partners additionally completed the best-worst block, enabling the intended cross-method check on a subset of respondents. One of the four returns shows a reversed reading of the comparison direction – in every block the factor declared best receives a best-to-this value greater than the unit value it should take – and is excluded from the comparison. For the three interpretable paired returns the agreement between the SWOT-AHP and best-worst priority vectors is strong in two cases and weak in the third (Spearman rank correlations of 0.87, 0.81 and 0.29), and at the aggregate level both methods place the funding opportunity at the head of the order, although the capital-cost weakness, second under the SWOT-AHP, sits lower in the best-worst aggregate. The cross-validation is accordingly read as supportive at the top of the priority order, where decisions concentrate, and inconclusive towards the lightly weighted tail; with three interpretable paired returns, the SWOT-AHP carries the reported weights.

4.3. Criteria Weights and the TOPSIS Readiness Ranking.

The criteria-weight block was completed by the same six respondents and aggregated identically; Table 4 reports the individual and aggregate weights. The aggregate places grid and prerequisite readiness (C1, 0.20) and capital intensity and financing risk (C6, 0.19) first, followed by the regulatory driver (C4, 0.17), at-berth demand (C5, 0.14), renewable feasibility (C3, 0.11) and implementation maturity (C2, 0.10), with utilisation potential (C7, 0.08) last. The pattern quantifies the qualitative conclusion of the cross-case synthesis – that the binding constraints are the grid and the capital cost rather than the technology – and it is not an artefact of any single respondent: at least one of C1 and C6 stands within each respondent's top three criteria.

Table 4: Elicited TOPSIS criteria weights by respondent and their geometric-mean aggregate (GM).

Criterion	Ancona	Belgrade	Ploče	Durrës	Volos	Ohrid	GM
C1 - Grid / prerequisite readiness	0.106	0.301	0.117	0.241	0.099	0.304	0.200
C2 - Implementation maturity	0.066	0.117	0.074	0.095	0.085	0.119	0.104
C3 - On-site renewable feasibility	0.106	0.045	0.230	0.044	0.091	0.190	0.112
C4 - Regulatory driver strength	0.271	0.105	0.289	0.330	0.091	0.046	0.173
C5 - At-berth demand / emission-reduction potential	0.271	0.123	0.050	0.095	0.107	0.190	0.140
C6 - Capital intensity / financing risk (cost criterion)	0.090	0.212	0.211	0.152	0.344	0.087	0.188
C7 - Utilisation potential	0.090	0.098	0.029	0.044	0.184	0.063	0.082

Source: Authors, from the returned elicitation instruments. All consistency ratios are below 0.10.

Five ports revised their own rows of the decision matrix when returning the instrument: Ancona lowered its grid and maturity scores while raising the regulatory driver, Belgrade raised its grid, maturity and utilisation scores while lowering renewable feasibility, Ploče raised its demand score one step,

Volos lowered its maturity and demand scores and raised its capital-cost exposure, and Ohrid lowered renewable feasibility and utilisation while raising demand. The ranking therefore rests on the self-assessed matrix as returned, not on the provisional encoding. Under the aggregated elicited weights the TOPSIS closeness coefficients order the ports Ancona (0.72), Ploče (0.62), Belgrade (0.55), Volos (0.54), Durrës (0.40) and Ohrid (0.11), as reported in Table 5 alongside the equal-weight closeness on the same matrix. Two movements distinguish the substantive ranking from that equal-weight baseline: Ploče rises from fourth to second, because the elicited emphasis on prerequisites and low capital exposure rewards exactly the profile the typology labels favourable-but-undecided, and Volos slips from second to fourth – the combined effect of its own candid downward revision and a weight vector that prizes grid readiness over the demand strength on which its case rests – leaving Belgrade ahead of Volos by a hundredth of a point.

Table 5: TOPSIS ranking of the ports under the elicited criteria weights.

Rank	Port	Closeness C* (elicited weights)	Closeness C* (equal weights)	Tier
1	Ancona	0.723	0.639	A
2	Ploče	0.619	0.566	D
3	Belgrade	0.551	0.574	C
4	Volos	0.541	0.611	B
5	Durrës	0.396	0.463	C
6	Ohrid	0.106	0.128	E

Source: Authors. The equal-weight closeness coefficient is computed on the same self-assessed matrix for comparison.

The ranking is robust to the residual weight uncertainty. Under each respondent's individual weight vector Ancona ranks first in five of the six cases and Ohrid ranks last in all six; the single departure places the respondent's own port first, a familiar pattern in self-anchored scoring. Under random perturbation of the aggregated weights by up to ± 50 per cent (renormalised), Ancona ranks first in about 94 per cent of draws and Ohrid last in every draw, while Ploče stays ahead of Belgrade in roughly 80 per cent – the elicited weights resolve the near-tie the equal-weight baseline leaves open at that boundary, and the residual sensitivity moves one place down the order, to Belgrade and Volos, which the perturbed draws separate close to evenly.

5. Discussion.

5.1. Strategic Responses by Readiness Tier.

Read through the TOWS logic, each tier of the typology maps to its own strategy. Ancona and Volos, the implementing and designed-and-funded ports, sit in strength-opportunity territory: their task is converting assets, institutional commitment and completed studies into commissioned capacity, with a replicable operating model and the high-capacity cruise connections their traffic demands. Durrës and Belgrade, planning OPS inside larger developments, face a weakness-opportunity problem: European and international funding has to flow first to the grid reinforcement and distribution-operator coordination

on which all else depends, with renewable and storage integration attached wherever possible. Ploče, the favourable-but-undecided case, needs one strength-opportunity move – an explicit cost-benefit and operating decision, taken with shipowners engaged, that turns latent readiness into commitment; this is precisely the profile the elicited weights reward with second place, prizing as they do prerequisites and low capital exposure. Ohrid calls for weakness-threat discipline: stage the work, scale it down, frame OPS as a heritage-led clean-marina and tourism asset and secure finance ahead of any commitment. One caveat spans every tier: the climate value of OPS depends on the carbon content of the electricity behind it, and that content varies across the six national systems by more than an order of magnitude – Albania's hydro-dominated grid sits at a few tens of grams of CO₂ equivalent per kilowatt-hour while the lignite-heavy Serbian and North Macedonian systems lie well above 500 grams (Ember, 2026) – so grid reinforcement and renewable integration are not parallel agendas but preconditions of the measure's environmental worth, to be planned with OPS rather than after it.

5.2. The European Union / Non-European Union Divide.

The single most consequential structural feature the prioritisation exposes is the regulatory divide, visible in the criteria as the regulatory driver (C4), where the elicited weights spread widely – from 0.05 to 0.33 across respondents. On the European Union side the demand-pull is firm and dated: container and passenger ships above 5,000 gross tonnes must take shore power for berth stays beyond two hours at trans-European network ports from 1 January 2030 under FuelEU Maritime, and under the Alternative Fuels Infrastructure Regulation the core and comprehensive ports must be able to serve at least 90 per cent of the relevant calls by end-2029. No comparable national obligation binds the Western Balkans ports, whose alignment runs through the Green Agenda, the Regional Transport Community and the trans-European network's extension. Left untreated, the asymmetry points towards a two-speed basin – mandated demand, and with it utilisation and investor confidence, concentrating in the European Union ports while the others depend on funding and political resolve. The remedy is deliberate convergence: harmonised national law, generator-ban zones wherever OPS is in place and the anchoring of OPS in national energy, climate and transport strategy, so that a common-standards Adriatic-Ionian cluster forms across the border rather than splitting along it.

5.3. Methodological Reflection.

Coupling the qualitative cross-case synthesis to a SWOT-AHP and TOPSIS framework adds transparency and reproducibility to what is often an unstructured strategic judgement: factors are made explicit, traceable to the ports that reported them and – with the expert weights elicited – ranked on a common scale, while the consistency check and sensitivity analysis guard the result. The completed elicitation bears this out in practice: every submitted comparison set satisfied the consistency threshold without a revision round, the aggregated weights resolve the

near-ties the equal-weight baseline leaves open and the perturbation analysis shows the resulting ranking to be stable at its head and tail. The exercise also shows the method's honest edges – the best-worst cross-check was completed by four of the six partners and one of those returns inverted the comparison direction – a reminder that structured elicitation disciplines, but does not remove, the dependence on respondent engagement. The principal threats to validity are those already stated – the partly self-reported, secondary evidence and the single-region, single-time-point design ahead of the 2030 milestone – and they bound the present claims to an analytical, transferable assessment rather than a statistical generalisation.

6. Conclusions.

Across the six partner ports OPS is viable and worth pursuing – but never as one proposition, because an identical, mature technology lands on very different grids, demand patterns, regulatory regimes and waterfronts. Six recommendations follow, ordered by what the elicited priorities themselves emphasise – the funding opportunity and the capital cost at the head of the factor order, the grid and the capital cost at the head of the criteria order: (i) build OPS into every new terminal at the design stage, the lowest-cost and least disruptive route; (ii) put grid reinforcement and early engagement with the distribution system operator first wherever the grid is the binding constraint; (iii) couple OPS with on-site renewables so that the conditional climate benefit is captured rather than displaced; (iv) close the regulatory gap for the non-European-Union partners through national legal harmonisation, letting funding instruments stand in for the demand-pull their European Union neighbours receive by mandate; (v) standardise on the established voltage, frequency and connection conventions so interoperability knits the basin into one cluster; and (vi) match the scale of ambition to the port – high-capacity systems where cruise demand justifies them, modular builds for ferry and cargo traffic, and for the smallest, heritage-bound setting a reduced clean-marina formula.

What the article adds is a complete and repeatable prioritisation pipeline – from a consolidated multi-case SWOT through structured elicitation with the six responsible port authorities to weighted priorities and a substantive readiness ranking – together with the elicited regional weights themselves. The bounds on the claims are equally explicit: much of the underlying evidence is secondary and some of it self-reported; each authority contributed a single structured return; the decision-matrix scores are partly the ports' own; and the snapshot precedes the 2030 milestone, covering one region at one moment. The natural continuation is to carry the elicited priorities into implementation – widening the respondent base beyond single institutional returns, repeating the elicitation as projects mature and tracking utilisation as installations come online – so that the ranking offered here serves as the baseline against which the region's 2030 transition is measured.

Data Availability.

The elicitation instrument template and the elicited judgement data – the pairwise-comparison sets, best-worst statements, consistency ratios and computed weights – together with the TOPSIS decision matrix and ranking computations are provided as supplementary material to this article.

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