Grid-Ready Shore Power Planning from Port-Call Data: Load Characterisation at the Port of Valencia

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Motivation/Background

- European ports are increasingly deploying Onshore Power Supply (OPS) systems to comply with Alternative Fuels Infrastructure Regulation (AFIR 2030) [1]. This introduces challenges for electrical grid planning and operational demand assessment [2].

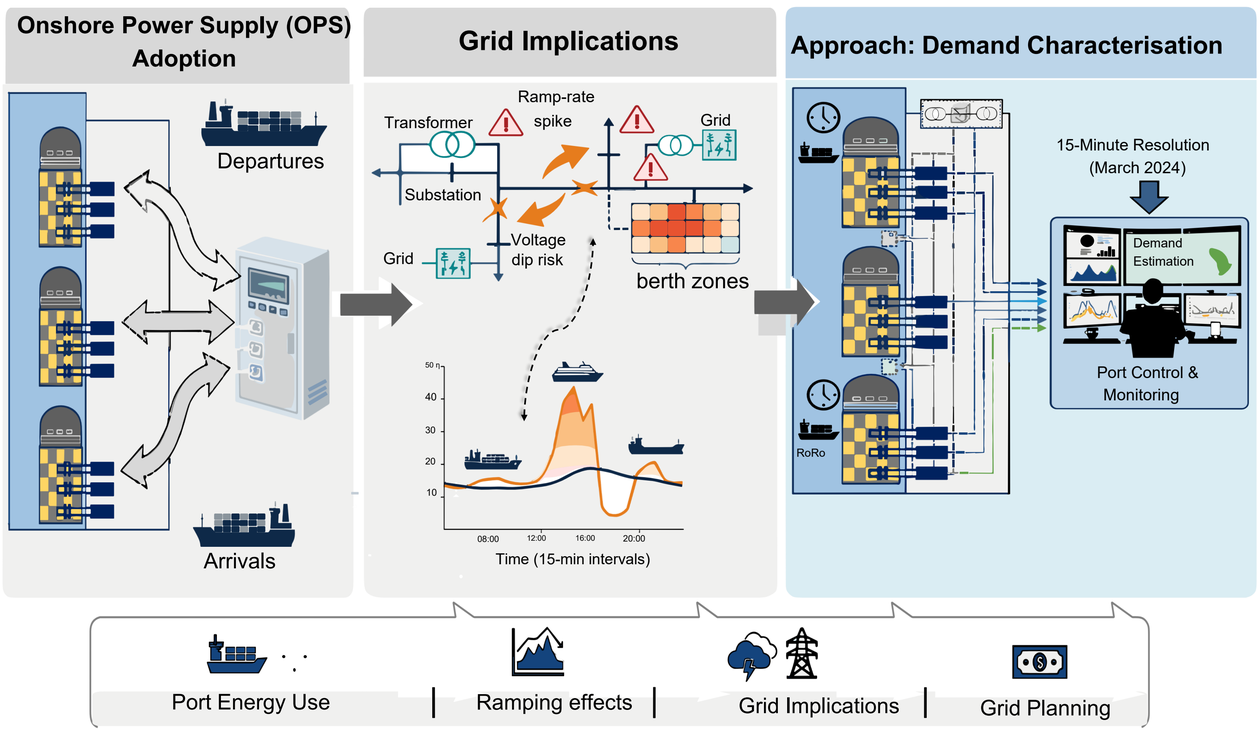

Figure 1. OPS adoption and associated grid implications, such as ramping effects

- This work develops a 15-minute OPS load model for the Port of Valencia using real vessel port-call data to quantify temporal demand, ramp events, and berth-level infrastructure requirements.

Research Objective

- Develop a high-resolution operational OPS demand model and evaluate energy demand, simultaneous peak load, ramp-rate dynamics, and zonal level grid classification.

Methodology

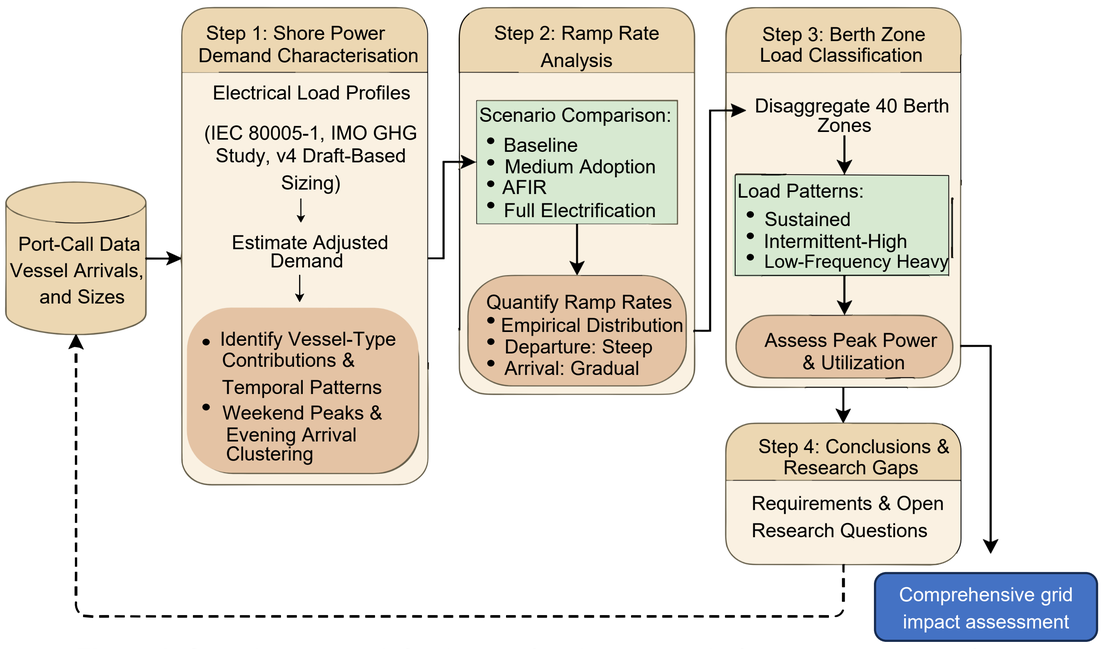

Figure 2. Stepwise approach for data exploration, categorical ramp rate, and zonal load classification

- A multi-stage OPS modeling approach was developed using progressively refined vessel power-mapping, scenario-based ramp analysis, and berth-level spatial load classification derived from operational port-call patterns.

Results

- Container ships serve as a baseload, showing minimum feeder capacity requirements.
- Weekend demand exceeds by 21% due to occupancy accumulation.
- Ferry arrivals cluster on evenings, coinciding with the Spanish grid evening demand peak.

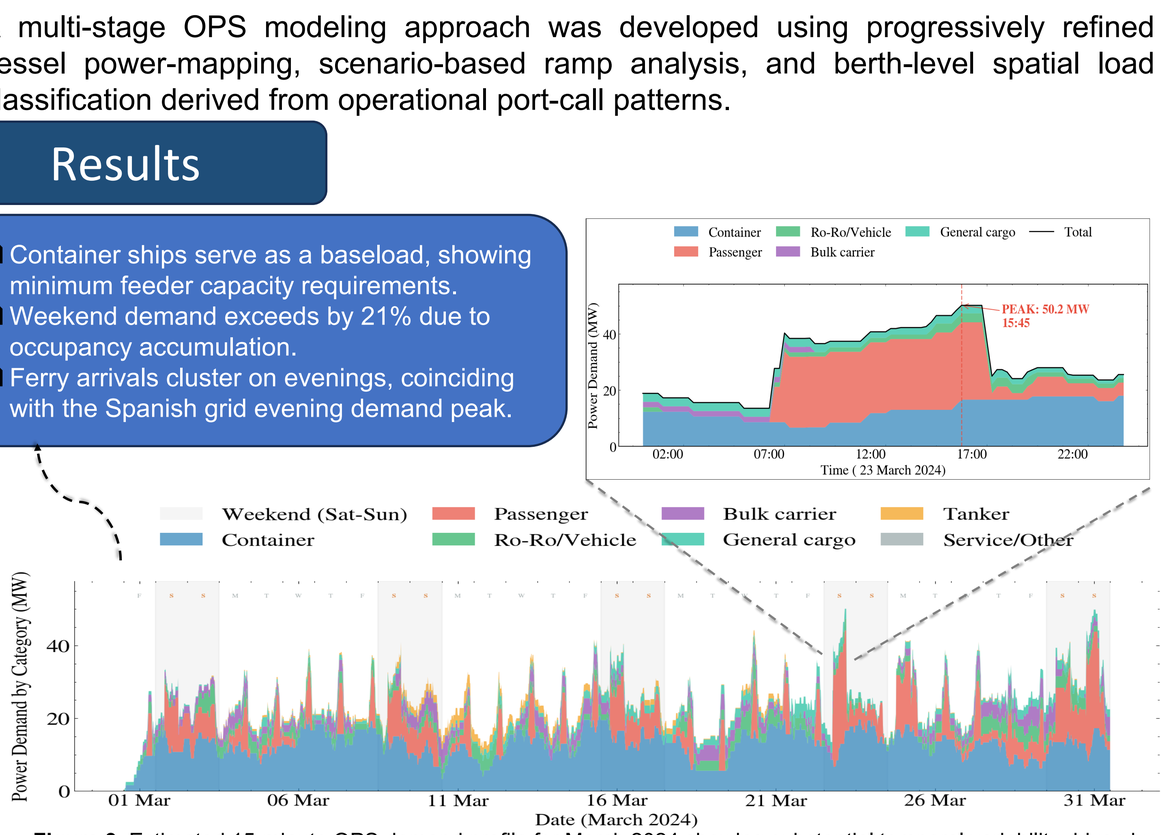

Figure 3. Estimated 15-minute OPS demand profile for March 2024 showing substantial temporal variability driven by vessel concurrence and cruise operations.

- The estimated demand profile shows vessel-category contributions, peak simultaneity, and operational variability. Container vessels establish a baseload, while passenger and cruise operations generate transient peak events.

Ramp-Rate Dynamics

- It quantifies the rate at which the OPS demand changes rather than individual peaks. 15-minute intervals for observing the grid implications.

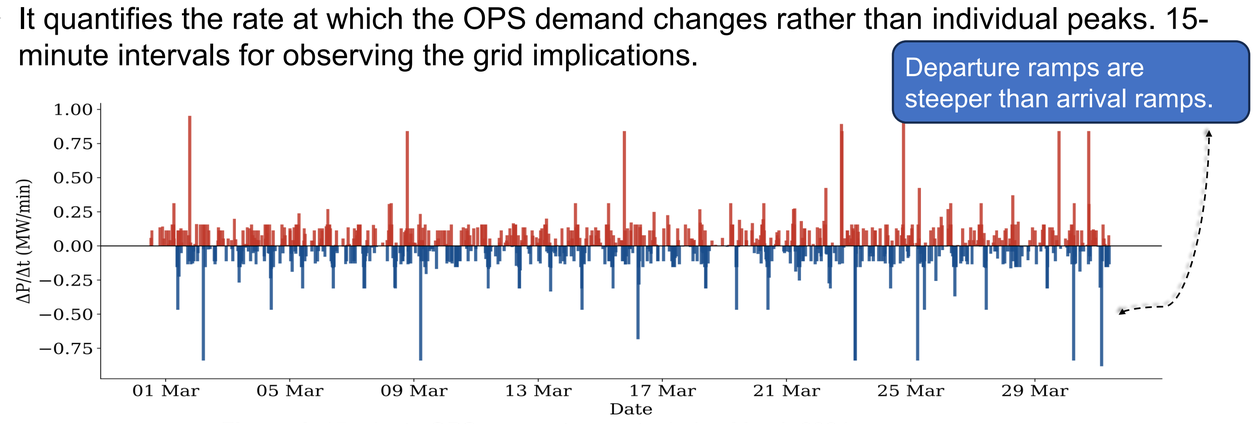

Figure 4. 15-minute OPS ramp-rate events during March 2024.

- Empirical distributions of OPS ramp rate scenarios show that higher OPS adoption produces more frequent extreme ramp events with P99 ramp-up of 0.227 MW/min and ramp-down of −0.312 MW/min.

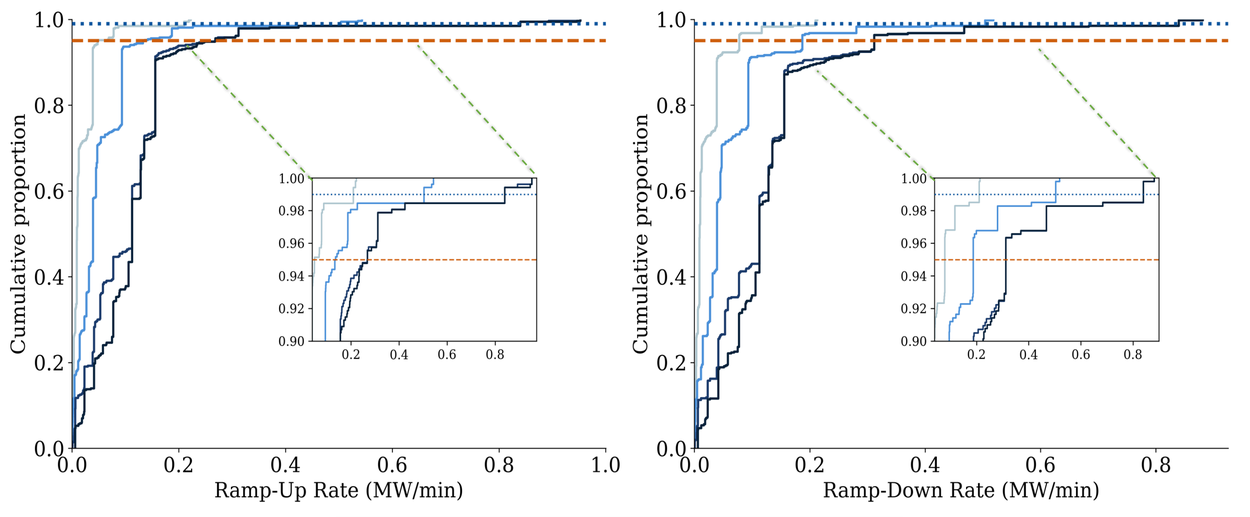

Figure 5. Empirical distributions of OPS ramp rates across scenarios show a heavier tail, increasing extreme events, and tripling the P99 ramp-up threshold relative to existing levels

Zonal Load Classification

- Peak power and utilization index are used to classify berth zones according to operational load characteristics. Sustained-load zones exhibit high utilization and peak demand, while intermittent zones produce high transient peaks.

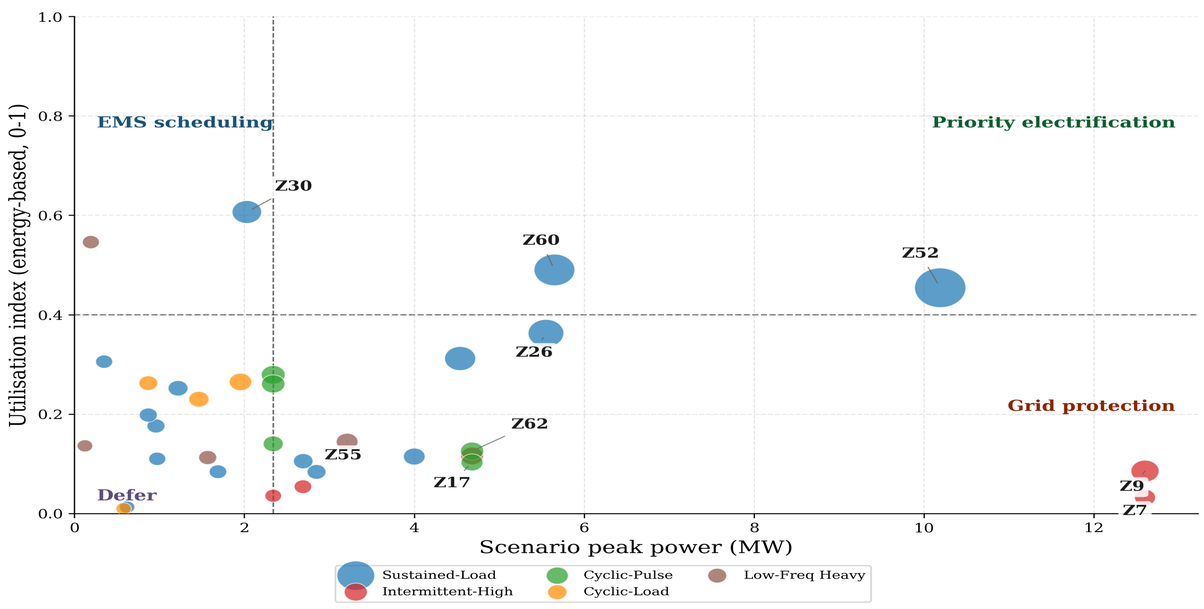

Figure 6. Berth-zone OPS classification based on scenario peak power and utilization index.

Conclusion

- The multi-stage OPS demand modeling with dynamic ramping scenarios and zonal load classification strategy provides critical future grid implications. The case study demonstrates strong potential for operational demand characterization, EMS scheduling, and resilient OPS integration as electrification adoption increases. Though further work is required on diverse port cases, seasonal demand variability, and validated grid-impact simulations.

References

[1] European Parliament and Council of the European Union, *Regulation (EU) 2023/1804 on the deployment of alternative fuels infrastructure*.
[2] Zhang et al., *Collaborative optimization of shore power and berth allocation based on economic, environmental, and operational efficiency*.

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