ABSTRACT

A MULTI-CRITERIA METHOD FOR THE SELECTION OF SERVICE PORTS LOCATION FOR OFFSHORE WIND FARMS IN POLAND, ACCOUNTING FOR ECONOMIC EFFICIENCY

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The development of offshore wind energy (OWE) in Poland necessitates the provision of adequate port infrastructure to ensure the efficient servicing of offshore wind farms (OWFs) throughout their entire operational lifespan. Service ports are of particular importance; their location influences vessel transit times to the wind farms, the organization of operations and maintenance (O&M) activities, resource availability, the functioning of the logistics chain, and operational costs. The objective of this dissertation was to identify and evaluate the factors that determine the selection of service port locations for offshore wind farms in Poland, to develop an original multi-criteria assessment method for potential sites, and to quantify specific economic consequences resulting from alternative location decisions. The study focused on the ports of Ustka, Łeba, Władysławowo, and Darłowo, as well as selected offshore wind farm projects being developed in the Polish sector of the Baltic Sea. This study includes a literature review and employs three complementary research approaches: spatial modeling using GIS, multi-criteria analysis, and optimization methods. Additionally, a quantitative model was developed to assess the incremental economic consequences of selecting specific service port locations; this model accounts for crew transfer vessel (CTV) transport costs, scenario-based production losses, adaptation expenditures, and discounted cost differentials between alternative options. The research is supplemented by a SWOT analysis and an evaluation of criteria based on a seven-point ordinal scale. Drawing on the results, the study identifies the criteria of greatest significance to the decision-making process and proposes an original, simplified method for evaluating service port locations. The empirical scope covers the ports of Ustka, Łeba, Władysławowo, and Darłowo, as

well as the Baltica 2, BC Wind, PGE 7, and PGE 9 projects. A further component of the research involved expert validation, conducted through eleven interviews with representatives from entities operating across various segments of the offshore wind value chain. These interviews were primarily aimed at assessing the validity of the selected criteria, the logic behind the method's simplification, and its potential practical utility as a tool to support the pre-selection of service port locations. The analyses conducted demonstrate that the selection of a service port is a multi-criteria process and should not be based solely on the distance from the wind farm. Key factors include the spatial relationship between the port and the farm, transit distance and travel time, logistics and transport accessibility, port infrastructure parameters, as well as environmental and geotechnical conditions. The results also confirm that no single port among those analyzed is optimal for every project; the final choice depends on the specific location of the wind farm, the nature of the investment, and the technical, operational, and logistical parameters adopted.

The proposed method showed a high degree of alignment with the results of the comprehensive (full-scale) method. For three of the four projects analyzed, it identified the same optimal port, while for the Baltica 2 project, it narrowed the selection down to the same two leading locations. The stability of the method was further verified through three types of sensitivity analysis: One-at-a-Time (OAT), analysis of criteria groups, and decision-maker preference scenarios. In none of the scenarios did the top-ranked port change; observed variations were limited to the rankings of ports in lower positions. These findings indicate that the method is highly robust regarding the primary decision, while remaining sensitive to changes in underlying assumptions and preferences.

Additional validation was performed using an "out-of-sample" approach for the F.E.W. Baltic II project, which was not included in the development of the proposed method. First, the proprietary method was applied in its original form, and the resulting outcome was then compared with the results obtained from comprehensive methods, as well as with publicly available information regarding the actual selection of the service port. The method identified the port of Ustka — a result that aligned both with the findings of broader analyses and with the decision ultimately made for the project in question. This serves as further evidence confirming the method's applicability to scenarios beyond those considered during its development. The results indicate that reducing the number of criteria makes it possible to simplify the process of assessing service port locations

without losing the basic accuracy of the decision outcome. The developed method may therefore serve as a tool supporting the preliminary assessment and comparison of potential service ports for offshore wind projects. The study further demonstrates that multi-criteria locational attractiveness does not necessarily correspond to the lowest modeled operating costs. In the PGE 7 case, the multi-criteria assessment favored Ustka, whereas the scenario-based economic model indicated a cost advantage for Darłowo. The estimated difference was approximately PLN 2,380 million in present-value terms over a 25-year period at a 7% discount rate. Deterministic sensitivity analysis showed that this advantage was conditional upon assumed sailing distances and operational parameters. The findings therefore support integrating multi-criteria port assessments with incremental economic analysis rather than treating either approach as a sufficient basis for the final investment decision.

Keywords: offshore wind energy, offshore wind farm, service ports, determinants of investment efficiency, multi-criteria decision analysis, location optimization.