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Safety on the Horizon: Mapping Human Factors in Offshore Wind

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Abstract

Global wind energy is experiencing an unprecedented period of expansion. Such requirements present challenges concerning maintaining safety standards and training at scale with industry data indicating a range of hazards during operations and maintenance activities. Wind technicians work in small teams to conduct critical operations and maintenance tasks on wind turbines often in remote, hazardous environments. Industry evidence suggests behavioral issues significantly contribute to these incidents, yet the limited human factors (HF) research in offshore wind typically focuses on design and physiology. Three online stakeholder workshops identified the principal HF impacting offshore wind technicians during operations and maintenance activities. It resulted in a preliminary framework of 16 HF, and 16 sub-factors, for offshore wind technicians encompassing individual, crew/team, organizational factors, and task and environmental factors. This can be used to direct effective interventions that support worker safety, health and performance in the expanding wind industry and wider renewable energy sector.

Keywords

human factors, psychological factors, wind technicians, wind energy, worker safety

Introduction

The global wind energy industry is experiencing an unprecedented period of expansion in response to net zero targets, emerging markets and international energy demands, estimated to be worth $89.60 billion globally in 2023 (Precedence, 2024). To meet these renewable energy demands there is a significant need to recruit and train a competent workforce. Wind technicians, responsible for maintaining the operation of both onshore and offshore wind turbines, are a key growth group with global estimates suggesting half a million wind technicians will be needed by 2026 (GWEC, 2024). Such rapid progress presents challenges for maintaining safety standards and training at scale, with industry incident data revealing safety issues during operations and maintenance (G+, 2024). For example, the total recordable injury rate is estimated to be three times higher and lost time injury rate four times higher in offshore wind, than in oil and gas (Rowell et al., 2024). Human Factors (HF) and ergonomics approaches have been introduced in similar sectors as a means of enhancing safety and accelerating training (e.g., Teperi et al., 2023). Yet, there is a limited understanding of HF in the emergent wind industry, typically focusing on ergonomic and physiological factors. To address this gap, three stakeholder workshops were conducted to map the principal HF that shape offshore wind technicians' safety and performance during O&M, with a particular focus on psychological and organizational factors.

Background

Wind technicians conduct varied and complex operational and maintenance activities (O&M) on wind turbines often in hazardous, remote environments. Crews typically consist of two-four people, working with minimal supervision and often limited communication (e.g., with the beach or service vessel) for up to 12 to 14-hr shifts. They face a range of health and safety hazards including environmental conditions (e.g., hot/cold, high winds), mast sway, noise, vibration, work pressure, isolation, poor communication, and contract uncertainty (Karanikas et al., 2021; Rowell et al., 2024; Scheu et al., 2018). The tasks are physically demanding, requiring working at height and suspension in confined spaces, manual handling, and adoption of awkward body positions (Cunha et al., 2024). Diagnosing faults and conducting corrective maintenance requires high-level risk

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awareness, problem-solving, and decision-making skills. Although some of the hazards are not unique to offshore wind installations, turbine maintenance activities may be more demanding when located in a remote maritime environment (Tveiten et al., 2011).

Human factors approaches are particularly pertinent to the wind industry because of the combination of contextual characteristics such as the remote, hazardous environment, awkward working conditions and small multi-skilled teams with limited communication and supervision (Hanson & Thatcher, 2019). HF in the wind industry is typically viewed from an ergonomic perspective with research examining the physiological factors and occupational hazards that impact on worker performance (e.g., job task analysis, Milligan et al., 2019; seasickness, Earle et al., 2022). Whilst data indicate that behavioural failures contributed to 60% of the working at height incidents on wind turbines (G+, 2018), research does not appear to examine the psychological and organisational factors affecting wind technicians. A recent scoping review, based on only 13 research articles, identified a preliminary list of potential HF impacting on onshore and offshore wind workers safety, health and productivity (authors, accepted). Yet given the emergent and rapidly expanding wind industry, as well as differences in onshore and offshore contexts, this does not provide a comprehensive understanding of the principal HF for offshore wind technicians, particularly of the less well understood psychological and organizational factors.

Approach

Three online stakeholder workshops were run to examine the key HF impacting on the safety, health and productivity of offshore wind technicians (June–October 2024). The workshops were advertised through social media platforms with several industry bodies promoting them via their membership (e.g., G+, GWO). Informed consent for audio recording of the break-out sessions was obtained via online ticket booking. Once completed, the audio recordings were transcribed for analysis.

Sample

In total, 53 participants took part in three stakeholder workshops from the UK, Europe and USA. Roles included operations managers, wind technicians, training specialists, health and safety managers and consultants, and researchers.

Workshop Structure

The workshops consisted of (1) rapid research presentations (between 2 and 4 per workshop) and (2) recorded focus-group sessions with facilitation (3–5 participants per group). The discussions were framed around the individual, crew, task and environmental, and organizational factors that may influence technicians with prompts on a virtual wall.

Data Analysis

The preliminary list of HF in Wind identified from a prior scoping review was used as an initial coding framework and refined iteratively. The transcribed focus groups were analyzed using Braun and Clarke's (2022) thematic analysis via the software program Nvivo 14 (Lumivero, 2024). Inter-rater reliability was undertaken using Cohen's (1960) kappa coefficient (Fleiss, 1981) and found to be acceptable.

Outcomes

Four categories, comprising of a preliminary list of 16 factors (underlined) were identified with 16 sub-factors (italicized). These factors are likely to interact with each other.

Individual factors relate to wind technicians' cognitive (*situation awareness, decision-making skills, competence level*), social (*frontline management*), and personal resource skills (*seasickness*, *fatigue*, *stressors*, and *mental health*). Two additional sub-factors of *attitudes* (e.g., toward safety) and *risk perception* (e.g., impacting on wearing PPE) were identified.

Team factors relate to how the maintenance crew work together consisting of teamwork (e.g., trust in team members), team situation awareness (e.g., shared understanding of a work plan), team dynamics (e.g., group dynamics), and communication (e.g., talking about fatigue or mental health issues).

Task and environmental factors were found to relate to physical stressors (*ladder climbing, casualty evacuation, confined spaces*), workload, and environmental conditions (*weather*, *motion and noise*, *technician welfare*). An additional design factor, relating to the turbine and equipment was identified.

Organizational factors consist of managers' safety leadership (e.g., mindset/values), organizational culture (e.g., company and safety culture), policies, procedures and health and safety management (e.g., incident reporting), organizational resources (e.g., expertise and equipment), and training (e.g., variation in certification).

Conclusions

A safe and competent workforce is essential to ensure the long-term success of the wind industry. Given the early stage of study for HF in the offshore wind industry, our workshop focus groups contribute to the literature by identifying a set of 16 psychological, task and environmental, and organizational aspects of HF that impact offshore wind technician safety, wellbeing and performance during O&M activities. It suggests that HF is beginning to be recognized by practitioners working in industry (e.g., trainers, safety managers). By

taking a psychological approach, it provides a more comprehensive understanding of the impact of HF on wind technicians. Whilst it will require refinement, it can be used to direct future research (e.g., comparison with other HF tools such as HFACS, Shappell & Wiegmann, 1997) and effective interventions that support worker safety, health and performance in the expanding wind industry and wider renewable energy sector.

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