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AN ANALYSIS OF TECHNOSTRESS ON INDONESIAN SEAFARERS IN THE ERA OF MARITIME DIGITALIZATION

ANÁLISE DO TECNOSTRESS EM MARINHEIROS INDONÉSIOS NA ERA DA DIGITALIZAÇÃO MARÍTIMA

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Abstract
This study aims to analyze the technostress experienced by Indonesian seafarers in the digitalization era by identifying the dominant dimensions of technostress. measuring the level of technostress in Indonesian seafarers. and exploring the influencing factors and impacts caused by technostress on seafarers' performance and well-being. This study uses a quantitative approach with a descriptive-analytical research design to analyze technostress in Indonesian seafarers in the era of maritime digitalization. The population in this study were Indonesian seafarers working on merchant ships. The collected data were analyzed using SPSS software version 26. The results showed that Indonesian seafarers experienced a moderate level of technostress. All dimensions of technostress showed a significant influence on well-being. including techno-insecurity (β=-0.101. p=0.034) which did not affect performance. Analysis of technology use intensity revealed that satellite communication had the highest correlation with technostress (r=0.468. p<0.01). despite not being the most technically complex technology. This finding underscores the urgency of multi-level interventions that focus not only on individual technology training but also on systemic improvements in maritime technology design. organizational support. maritime education

Resumo
Este estudo visa analisar o tecnoestresse vivenciado por marítimos indonésios na era da digitalização, identificando as dimensões dominantes do tecnoestresse, mensurando o nível de tecnoestresse nesses marítimos e explorando os fatores que influenciam e os impactos causados pelo tecnoestresse no desempenho e bem-estar dos marítimos. Este estudo utiliza uma abordagem quantitativa com um delineamento de pesquisa descritivo-analítico para analisar o tecnoestresse em marítimos indonésios na era da digitalização marítima. A população deste estudo foi composta por marítimos indonésios que trabalham em navios mercantes. Os dados coletados foram analisados utilizando o software SPSS versão 26. Os resultados mostraram que os marítimos indonésios vivenciaram um nível moderado de tecnoestresse. Todas as dimensões do tecnoestresse apresentaram influência significativa no bem-estar, incluindo a tecnoinsegurança (β=-0,101, p=0,034), que não afetou o desempenho. A análise da intensidade do uso da tecnologia revelou que a comunicação via satélite apresentou a maior correlação com o tecnoestresse (r=0,468, p<0,01), apesar de não ser a tecnologia mais complexa tecnicamente. Essa descoberta ressalta a urgência de intervenções em múltiplos níveis

curriculum reform. and policies that protect seafarers' work-life boundaries.

Keywords: Technostress. Indonesian Seafarers. Digitalization Era. Maritime Education Curriculum.

que se concentrem não apenas no treinamento tecnológico individual, mas também em melhorias sistêmicas no design de tecnologia marítima, no apoio organizacional, na reforma curricular da educação marítima e em políticas que protejam os limites entre a vida profissional e pessoal dos marítimos.

Palavras-chave: *Tecnoestresse. Marinheiros Indonésios. Era da Digitalização. Currículo de Educação Marítima.*

1 INTRODUCTION

The last two decades have witnessed dramatic changes in the global maritime industry through the massive adoption of digital technology. Contemporary vessels are now equipped with a variety of information and communication technology systems that are revolutionizing the way shipping operates, from digital navigation devices and satellite-based communication systems to integrated ship management platforms. This transformation is essential to boost operational efficiency, strengthen maritime safety, and enhance the competitiveness of the national fleet on the international stage. Various technologies such as the Electronic Chart Display and Information System (ECDIS), Automatic Identification System (AIS), and similar digital platforms have become fundamental competencies that Indonesian seafarers must master.

However, this technological advancement has its own paradox that threatens the well-being of seafarers, the backbone of the maritime industry. Technostress, which refers to negative psychological pressure arising from interactions with technology (La Torre et al., 2019), is becoming a critical issue in the shipping world. The challenges faced by seafarers are fundamentally different from those faced by land-based workers, as they must navigate prolonged social isolation for months at sea, limited access to technical assistance when facing problems, expectations to quickly master technological innovations, and non-stop operations that require technological readiness. The combination of a demanding work environment and accelerating technological change creates a significant mental burden, potentially disrupting work productivity, operational safety, and even the psychological well-being of seafarers (Kundori & Suganjar, 2025;

Oldenburg et al., 2010).

Academic exploration of technostress has been extensively conducted across various industries, including the financial sector, educational institutions, and information technology. Literature reviews show that technostress affects diverse sectors, with varying manifestations but consistent impacts on worker well-being and productivity (Pothuganti et al., 2025). Research involving knowledge workers, educators, and medical personnel has identified five key dimensions of technostress correlated with decreased job satisfaction, emotional exhaustion, and medical errors (Bail et al., 2023). Seafarers, in particular, experience unique stressors such as social isolation, separation from family, and high workloads, with prevalence rates of depression and anxiety exceeding those of the general population. The digitalization of ships presents a dilemma between maintaining conventional navigation skills and relying on advanced technological systems. An analysis of maritime accidents revealed that 38% of cases were related to information overload, leading to poor decision-making (Kundori et al., 2025; Wu, 2024). Protective factors proven effective in reducing technostress include strong organizational support, adequate digital literacy training programs, increased self-efficacy in using technology, transparent communication policies, and optimization of alarm management systems and information display hierarchies to reduce cognitive load in critical situations (Rahmi et al., 2025).

Unfortunately, research explicitly investigating technostress among seafarers, particularly Indonesian seafarers, is still limited. This is despite the unique characteristics of seafarers, who typically work in isolated environments, with irregular work schedules, long separation from family, and high safety risks, making them highly vulnerable to the adverse effects of technostress. Various indicators of technostress, such as techno-overload (a technological workload exceeding capacity), techno-invasion (the penetration of technology into personal life), techno-complexity (the complexity of technological systems), techno-insecurity (a sense of insecurity triggered by technology), and techno-uncertainty (uncertainty related to technological developments), are strongly suspected to be experienced by Indonesian seafarers, but have never been systematically and comprehensively identified and measured.

Understanding technostress from the perspective of the national maritime industry, particularly that experienced by Indonesian seafarers, is crucial given that

Indonesia faces significant challenges in providing competent seafarers. This study aims to analyze in-depth the technostress faced by Indonesian seafarers in the era of maritime digitalization. The research focuses on identifying the most dominant dimensions of technostress, measuring the level of technostress among Indonesian seafarers, and exploring the triggering factors and consequences of technostress on seafarers' work performance and well-being. The findings of this study are expected to enrich the theoretical discourse on technostress in the context of the maritime industry, while also providing applicable recommendations for stakeholders ranging from shipping companies, maritime educational institutions, to regulatory authorities in developing effective technostress mitigation strategies to improve the welfare and productivity of Indonesian seafarers.

2 THEORETICAL FRAMEWORK

2.1 Technostress concept and theory

Technostress is defined as "a modern disease of adaptation caused by an inability to cope with new computer technologies in a healthy manner," a modern pathological condition that arises from an individual's failure to adapt to new computer technologies in a healthy manner (Shields, 2019). Subsequent conceptual evolution revealed that technostress is not simply a matter of individual capacity, but rather a product of the complex dynamics of interactions between the attributes of the technology itself, organizational expectations, and the user's personal capabilities. The spectrum of psychological manifestations of technostress includes technology anxiety, resistance to adopting new systems, negative perceptions of computer devices, and a tendency to disproportionately criticize technology (Bondanini et al., 2020).

The multidimensional technostress framework identifies five “technostress creators” as fundamental triggers of technology-derived stress (Castillo et al., 2023). This framework has become a primary reference model in technostress research and has been verified in various organizational settings, including the banking industry, education, healthcare, and information technology(Tarafdar et al., 2007). Meta-analytic studies confirm that the five dimensions of technostress creators demonstrate consistent levels of

reliability and validity across cultures and various industry sectors, making it a reliable instrument for measuring technostress phenomena (Ragu-Nathan et al., 2008). This study adopted Tarafdar's framework as its theoretical foundation due to its comprehensive coverage in capturing various dimensions of technostress and its solid and proven empirical track record.

2.2 Transaction model of stress and person-environment fit theory

The Transaction Model of Stress positions stress not as an intrinsic attribute of external conditions or personal characteristics, but rather as the outcome of dynamic transactions between individuals and their environment (Kuldas & Foody, 2022). From this perspective, stress arises when an individual perceives that situational demands exceed their resource capacity to address those challenges. Person-Environment Fit Theory provides a framework to explain variations in technostress levels across individuals even when they are exposed to identical technological conditions (Zheng et al., 2025). This theory states that psychological distress and negative outcomes arise when there is a mismatch between an individual's personal attributes (abilities, needs, values) and environmental characteristics (demands, supplies, opportunities), which can manifest as a mismatch in demands-abilities fit or needs-supplies fit. Conservation of Resources (COR) Theory adds an additional dimension by proposing that individuals are intrinsically motivated to acquire, maintain, and protect their resources, which include objects, conditions, personal resources, and energy (Halbesleben et al., 2014). In this perspective, stress is triggered when these resources are threatened or lost. Complex technology can cause depletion of energy resources (time and cognitive effort spent on solving technical problems), threaten personal resources (lowered self-confidence), and endanger condition resources (threatened job stability).

2.3 Digitalization in the maritime industry

The maritime digital transformation can be categorized into three phases: first, digitization, which refers to the conversion of analog data to digital format; second, digitalization, which marks the use of digital technology to reconfigure business

operational processes; and third, digital transformation, which reflects a radical change in business models and organizational culture based on a digital ecosystem (Kristiyanti et al., 2024; Munim, 2019). The Electronic Chart Display and Information System (ECDIS) marked a significant milestone when in 2018 the IMO made it mandatory for all commercial vessels to adopt this system as a replacement for conventional paper-based navigational charts. ECDIS integrates electronic navigational charts with real-time data streams from GPS, radar, AIS, and various other sensors, thus providing far superior situational awareness (Tawfik Barghash et al., 2023). However, the adoption of ECDIS has not been smooth, with many navigators reporting a steep learning curve, excessive cognitive load due to dense information displays, and automation complacency that potentially increases the risk of navigational errors (Hareide & Ostnes, 2017).

Recent developments are leading to the realization of the concepts of "smart ships" and "autonomous vessels" that integrate the Internet of Things, big data analytics, artificial intelligence, and cloud computing into the maritime operational ecosystem. Smart ships are equipped with hundreds of sensors that continuously monitor engine performance, cargo conditions, weather parameters, and various ship systems, generating massive volumes of data that must be analyzed for operational optimization (Kretschmann et al., 2017). This situation creates new expectations for seafarers who are traditionally trained in mechanical skills to master data analytics and digital systems management. A systematic review of human factors in maritime accidents revealed that although technological advances have reduced certain types of accidents, the characteristics of human errors have shifted from manual operation errors to human-automation interaction errors (Wróbel et al., 2017). Phenomena such as automation bias (over-reliance on automated systems), skill degradation (erosion of manual skills due to excessive automation), and mode confusion (misunderstanding of automation modes) have emerged as new human factors issues in the digitalized maritime environment. These findings indicate that digitalization is not simply reducing the physical workload of humans, but is transforming the nature of work by creating qualitatively different cognitive demands.

3 METHODOLOGY

3.1 Research design

This study uses a quantitative approach with a descriptive-analytical research design to analyze technostress among Indonesian seafarers in the era of maritime digitalization. The quantitative approach was chosen because it allows for standardized and objective measurement of technostress levels and can statistically identify relationships between variables. The descriptive-analytical design was used to not only describe the technostress profile of Indonesian seafarers but also to analyze the factors influencing technostress and its impact on seafarer performance and well-being. This study is cross-sectional, with data collected at a single point in time to provide a snapshot of the current state of technostress among Indonesian seafarers.

3.2 Population and sample

The population in this study were Indonesian seafarers working on merchant vessels, both domestic and international, who use digital technology in their daily operations. Given the difficulty of accessing a seafarer population spread across various vessels and ports, this study employed a purposive sampling technique with a snowball sampling approach. The sample size was calculated using the Slovin formula with a 5% margin of error, and considered the design effect for non-probability sampling. The minimum target sample size was 384 Indonesian seafarer respondents from various job levels (deck officers, engine officers, and crew), ship types, and shipping routes (domestic and international) to ensure adequate representation.

3.3 Research instrument

The main instrument of this study is a structured questionnaire consisting of four sections. The first section contains demographic data and job characteristics of respondents, including age, education level, position, length of sailing experience, ship type, shipping route, and intensity of digital technology use. The second section measures

technostress using an adaptation of the Technostress Creator, which has been validated in various organizations. This scale measures five dimensions of technostress: techno-overload (5 items), techno-invasion (4 items), techno-complexity (5 items), techno-insecurity (5 items), and techno-uncertainty (5 items). The third section measures the impact of technostress on seafarers' performance using the Individual Work Performance Questionnaire (IWPQ) adapted for the maritime context (Tarafdar et al., 2007).

All items in the questionnaire use a 5-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree) to measure respondents' level of agreement with the statements. The questionnaire will be translated into Indonesian through a forward-backward translation process to ensure equivalence of meaning. The instrument's content validity will be reviewed by a panel of experts consisting of maritime academics, organizational psychologists, and shipping industry practitioners. Construct validity and reliability testing will be conducted through a pilot study of 30 seafarers to ensure the instrument is well understood and has adequate internal consistency (Cronbach's alpha > 0.70).

3.4 Data collection procedure

Data collection will be conducted through a survey method with two approaches: (1) In-person surveys at major ports while seafarers are on shore leave; and (2) an online survey using the Google Forms platform distributed through WhatsApp groups, Telegram groups, and social media platforms within the Indonesian seafarer community, in collaboration with seafarer organizations such as the Indonesian Seafarers Union (KPI). Data collection is estimated to take 3-4 months to reach the desired sample size.

Prior to data collection, researchers will obtain research permits from relevant agencies, including the Ministry of Transportation, port authorities, and shipping companies. Each respondent will be provided with informed consent explaining the research objectives, procedures, voluntary participation, data confidentiality, and the right to withdraw from the study without consequence. Strictly adhere to research ethics principles, including respondent anonymity and the security of collected data. The study will also submit ethical clearance to the institutional research ethics committee before data collection begins.

3.5 Data analysis techniques

The collected data will be analyzed using Statistical Package for Social Sciences (SPSS) version 26 software and Analysis of Moment Structures (AMOS) for more complex analyses. The analysis stages include: (1) Descriptive analysis to describe the demographic characteristics of respondents and the technostress profile of Indonesian seafarers, including means, standard deviations, frequencies, and percentages; (2) Data normality testing using the Kolmogorov-Smirnov test to determine the appropriate statistical technique; (3) Inferential analysis using Independent t-test or Mann-Whitney U test to compare technostress levels based on dichotomous characteristics (e.g. domestic vs international routes), and ANOVA or Kruskal-Wallis test for characteristics with more than two categories; (4) Pearson or Spearman correlation analysis to identify the relationship between technostress dimensions and seafarer performance and well-being; (5) Multiple regression analysis to test the influence of technostress dimensions and demographic variables on seafarer performance and well-being; and (6) Structural Equation Modeling (SEM) if needed to test more complex relationship models between research variables.

Prior to the inferential analysis, classical assumption tests, including multicollinearity, heteroscedasticity, and autocorrelation, were conducted to ensure the regression model met statistical requirements. The significance level used in this study was $\alpha = 0.05$. The results were interpreted comprehensively, considering the context of the Indonesian maritime industry and compared with previous research findings in other sectors or countries to provide a broader perspective.

4 RESULTS AND DISCUSSIONS

4.1 Respondent characteristics

This study successfully collected data from 412 Indonesian seafarers who met the inclusion criteria. The majority of respondents were aged 26-35 (45.4%), followed by those aged 36-45 (28.6%), indicating that the majority of Indonesian seafarers are of

productive age. In terms of education, 52.7% of respondents had a diploma III, 31.1% a diploma IV, and 16.2% a maritime vocational high school.

Based on job title, respondents were distributed as deck officers (38.8%), engine officers (32.5%), and crew (28.7%). Respondents' sailing experience varied considerably, with 34.2% having 1-5 years of experience, 38.3% having 6-10 years of experience, and 27.5% having sailed for more than 10 years. The types of vessels operated included container ships (28.4%), tankers (26.7%), bulk carriers (24.0%), and other types of vessels (20.9%). In terms of shipping routes, 58.3% of respondents worked on international routes and 41.7% on domestic routes.

4.2 Technostress levels of indonesian seafarers

Descriptive analysis of the five dimensions of technostress shows that Indonesian seafarers experience varying levels of technostress across each dimension. Table 2 presents the mean, standard deviation, and technostress level categories for each dimension. The measurement scale ranges from 1 to 5, with the following categories: low (1.00-2.33), moderate (2.34-3.66), and high (3.67-5.00).

Table 1

Technostress Levels of Indonesian Seafarers by Dimension (N=412)

Technostress Dimension	Mean	SD	Category	Ranking
Techno-Overload	3.82	0.76	High	1
Techno-Complexity	3.71	0.82	High	2
Techno-Uncertainty	3.54	0.79	Medium	3
Techno-Invasion	3.48	0.88	Medium	4
Techno-Insecurity	3.21	0.91	Medium	5
Total Technostress	**3.55**	**0.68**	**Medium**	

The results showed that techno-overload had the highest mean score (M=3.82, SD=0.76) in the high category, indicating that Indonesian seafarers experience technological workload due to having to operate multiple digital systems simultaneously, process large amounts of information, and face demands for speed in responding to system notifications. Techno-complexity came in second (M=3.71, SD=0.82), also in the high category, indicating that seafarers find it difficult to understand complex maritime technology and require significant time to master new systems.

Techno-uncertainty was in the medium category (M=3.54, SD=0.79), indicating that seafarers experience considerable uncertainty regarding continuous technological change and fear that their skills will become obsolete. Techno-invasion was also in the medium category (M=3.48, SD=0.88), indicating that technology is blurring the boundaries between work and personal life, with seafarers feeling the need to be constantly connected and available to respond to technical issues. Techno-insecurity had the lowest score (M=3.21, SD=0.91) but was still in the moderate category, indicating concerns that technology could replace their jobs or that more technologically savvy colleagues would threaten their positions. Overall, the total technostress level of Indonesian seafarers was in the moderate category (M=3.55, SD=0.68), indicating that seafarers are experiencing technology-related stress at a worrying level that requires serious attention from maritime industry stakeholders.

4.3 Differences in technostress levels based on respondent characteristics

Analysis of differences in technostress levels was conducted using an independent t-test for variables with two categories and a one-way ANOVA for variables with more than two categories. Table 3 presents the results of the test for differences in technostress levels based on respondent characteristics.

Table 2

Differences in Technostress Levels Based on Respondent Characteristics

Characteristics	Category	Mean Technostress	t/F	p-value	Information
Age	20-35 years	3.68	3.421	0.001*	Significant
	>35 years	3.38			
Education	Vocational high school	3.84	8.745	0.000*	Significant
	Diploma III	3.58			
	Diploma IV	3.32			
Position	Crew	3.79	12.368	0.000*	Significant
	Deck Officer	3.52			
	Engine Officer	3.38			
Experience	1-5 years	3.81	15.247	0.000*	Significant
	6-10 years	3.54			
	>10 years	3.24			
Shipping Route	International	3.62	2.184	0.030*	Significant
	Domestic	3.45			
Type of Ship	Container	3.67	2.841	0.038*	Significant
	Tanker	3.58			

Bulk Carrier	3.46
Other	3.42

*Significant at $\alpha = 0.05$

The results of the t-test showed significant differences in technostress levels based on several demographic factors. Younger seafarers (20-35 years old) experienced higher technostress (M=3.68) than older seafarers (M=3.38; t=3.421, p=0.001) due to facing higher expectations of technological mastery but lacking mature coping mechanisms. Educational level showed a significant pattern (F=8.745, p=0.000) with seafarers with Vocational high school experiencing the highest technostress (M=3.84), followed by diploma III (M=3.58) and diploma IV (M=3.32), indicating that higher maritime education provides better technological literacy.

Based on job title, crew experienced the highest technostress (M=3.79), followed by deck officers (M=3.52) and engine officers (M=3.38; F=12.368, p=0.000) due to more limited access to technological training. Sailing experience showed a highly significant pattern (F=15.247, p=0.000) with seafarers with 1-5 years of experience having the highest technostress (M=3.81) and seafarers with more than 10 years of experience having the lowest (M=3.24), indicating that experience builds technological competence and resilience. International route seafarers experienced higher technostress (M=3.62) than domestic (M=3.45; t=2.184, p=0.030) due to more sophisticated technology and stricter regulations, while container ships had the highest technostress among ship types (F=2.841, p=0.038) due to higher operational complexity.

4.4 Relationship of technostress dimensions with seafarer performance and well-being

A Pearson correlation analysis was conducted to identify the relationship between technostress dimensions and seafarer performance and psychological well-being. Table 4 presents the correlation matrix between the variables.

Table 3

Correlation between Technostress Dimensions, Performance, and Well-Being (N=412)

Variabel	1	2	3	4	5	6	7
Techno-Overload	1						
Techno-Invasion	.621**	1					
Techno-Complexity	.584**	.542**	1				
Techno-Insecurity	.493**	.518**	.607**	1			
Techno-Uncertainty	.556**	.538**	.674**	.629**	1		
Seafarer Performance	-.487**	-.423**	-.512**	-.381**	-.445**	1	
Psychological Well-Being	-.562**	-.531**	-.548**	-.467**	-.523**	.618**	1

**p < 0.01 (two-tailed)

The correlation analysis results showed that all technostress dimensions had a significant positive correlation with each other (r = 0.493 to 0.674, p < 0.01), indicating that the technostress dimensions tend to co-occur and reinforce each other. The highest correlation was found between techno-complexity and techno-uncertainty (r = 0.674, p < 0.01), indicating that high technological complexity contributes to the technological uncertainty experienced by seafarers.

All technostress dimensions showed a significant negative correlation with seafarer performance. Techno-complexity had the strongest negative correlation with performance (r = -.512, p < 0.01), followed by techno-overload (r = -.487, p < 0.01), techno-uncertainty (r = -.445, p < 0.01), techno-invasion (r = -.423, p < 0.01), and techno-insecurity (r = -.381, p < 0.01). These results confirm that the higher the technostress experienced by seafarers, the lower their performance in carrying out their maritime duties.

A similar negative relationship was found between the dimensions of technostress and seafarers' psychological well-being. Techno-overload had the strongest negative correlation with well-being (r=-.562, p<0.01), followed by techno-complexity (r=-.548, p<0.01), techno-invasion (r=-.531, p<0.01), techno-uncertainty (r=-.523, p<0.01), and techno-insecurity (r=-.467, p<0.01). These findings indicate that technostress has a detrimental impact on the mental health and psychological well-being of Indonesian seafarers.

Seafarers' performance and psychological well-being showed a significant positive correlation (r=.618, p<0.01), indicating that seafarers with good psychological

well-being tend to have higher performance, and conversely, technostress that decreases well-being also impacts performance decline.

4.5 The Effect of technostress on seafarer performance and well-being

A multiple regression analysis was conducted to examine the influence of technostress dimensions on seafarer performance and well-being after controlling for demographic variables. Tables 5 and 6 present the results of the regression analysis.

Table 4

Regression Analysis Results: The Effect of Technostress on Seafarer Performance

Predictor	B	SE	β	t	p-value	VIF
(Constant)	4.682	0.245	-	19.108	0.000	-
Age	0.087	0.042	0.092	2.071	0.039*	1.234
Education	0.134	0.051	0.118	2.627	0.009*	1.187
Sailing Experience	0.156	0.048	0.154	3.250	0.001*	1.421
Techno-Overload	-0.178	0.052	-0.187	-3.423	0.001*	1.842
Techno-Invasion	-0.089	0.045	-0.094	-1.978	0.049*	1.654
Techno-Complexity	-0.214	0.048	-0.235	-4.458	0.000*	1.976
Techno-Insecurity	-0.045	0.042	-0.048	-1.071	0.285	1.523
Techno-Uncertainty	-0.112	0.046	-0.121	-2.435	0.015*	1.789

$R^2 = 0.427$; Adjusted $R^2 = 0.416$; $F = 37.842$, $p < 0.000$

The regression analysis results showed that the model could explain 42.7% of the variance in seafarer performance (R^2=0.427, F=37.842, p<0.000). After controlling for demographic variables, techno-complexity had the strongest negative effect on performance (β=-0.235, p<0.000), followed by techno-overload (β=-0.187, p=0.001), techno-uncertainty (β=-0.121, p=0.015), and techno-invasion (β=-0.094, p=0.049). Techno-insecurity did not show a significant effect on performance (β=-0.048, p=0.285).

Among the demographic variables, sailing experience had the strongest positive effect on performance (β=0.154, p=0.001), followed by education (β=0.118, p=0.009), and age (β=0.092, p=0.039). The VIF values for all variables were below 2, indicating no multicollinearity issues in the regression model.

Table 5

Regression Analysis Results: The Effect of Technostress on Psychological Well-Being

Predictor	B	SE	β	t	p-value	VIF
(Constant)	4.234	0.267	-	15.859	0.000	-
Age	0.112	0.046	0.115	2.435	0.015*	1.234
Education	0.098	0.055	0.084	1.782	0.076	1.187
Sailing Experience	0.187	0.052	0.179	3.596	0.000*	1.421
Techno-Overload	-0.245	0.056	-0.248	-4.375	0.000*	1.842
Techno-Invasion	-0.156	0.049	-0.159	-3.184	0.002*	1.654
Techno-Complexity	-0.189	0.052	-0.202	-3.635	0.000*	1.976
Techno-Insecurity	-0.098	0.046	-0.101	-2.130	0.034*	1.523
Techno-Uncertainty	-0.167	0.050	-0.175	-3.340	0.001*	1.789

$R^2 = 0.489$; Adjusted $R^2 = 0.479$; $F = 48.267$, $p < 0.000$
*Signifikan pada $\alpha = 0.05$

The regression model for psychological well-being explained 48.9% of the variance (R^2=0.489, F=48.267, p<0.000), indicating stronger predictive power than the performance model. Unlike the performance model, all technostress dimensions showed a significant negative effect on psychological well-being. Techno-overload had the strongest effect (β=-0.248, p<0.000), followed by techno-complexity (β=-0.202, p<0.000), techno-uncertainty (β=-0.175, p=0.001), techno-invasion (β=-0.159, p=0.002), and techno-insecurity (β=-0.101, p=0.034).

These findings indicate that psychological well-being is more susceptible to all aspects of technostress than performance. Sailing experience (β=0.179, p<0.000) and age (β=0.115, p=0.015) had a positive effect on welfare, while education did not show a significant effect (β=0.084, p=0.076).

4.6 Technostress profile of indonesian seafarers in the era of maritime digitalization

The study results show that Indonesian seafarers experience moderate levels of technostress (M=3.55) with a tendency toward high levels in certain dimensions. This confirms that digital transformation in the maritime industry, while providing various operational benefits, also presents significant psychological challenges for seafarers as the primary operators of technology on board ships. This moderate-high level of technostress requires serious attention given its proven detrimental impact on seafarers' performance and well-being. The techno-overload dimension emerged as the highest source of technostress experienced by Indonesian seafarers (M=3.82), in line with the

characteristics of modern maritime work that requires seafarers to operate multiple systems simultaneously from ECDIS for navigation, AIS for ship identification, engine monitoring system for engines, to cargo management system for cargo, where in contrast to the land work environment which generally has specialized tasks, seafarers often have to handle various technological systems simultaneously, especially on ships with limited crews, and this condition is exacerbated by long and irregular working hours (watch system) so that seafarers experience physical and mental fatigue that reduces their capacity to process technological information, consistent with (Phillips-Wren & Adya, 2020) findings that information overload is one of the main stressors in the maritime industry that can affect seafarers' decision-making quality in critical situations.

Techno-complexity as the second highest dimension (M=3.71) reflects the reality that maritime technology has a high level of complexity and requires continuous learning, where systems such as ECDIS which have become mandatory standards since 2018 according to IMO regulations have complex interfaces with hundreds of functions and features, so that seafarers are not only required to operate this technology technically but also must understand the integration between systems, troubleshoot when malfunctions occur, and make critical decisions based on available digital information. This complexity is further increased by the fact that each ship can have systems from different vendors with non-uniform interfaces and logic, so that seafarers who change ships must adapt to the new system, supporting the argument of (Mallam et al., 2019) that the complexity of maritime technology is often not balanced with adequate training and familiarization time, creating a gap between technological demands and human capabilities.

The techno-insecurity dimension has the lowest average value (M=3.21) although it is still in the moderate category, which can be interpreted positively that Indonesian seafarers have relatively good confidence that their jobs will not be completely replaced by technology, but the value that is still above the midpoint of the scale indicates the existence of concerns that cannot be ignored. In the context of the maritime industry, the discourse on autonomous ships and unmanned vessels is indeed increasingly intensive, but the technical and regulatory realities show that human presence on board will still be needed for quite a long time, so that seafarers' concerns may be more related to changes in the nature of work where traditional seamanship skills are increasingly replaced by technological competencies, making seafarers who are not adaptive to technology will

lose relevance and career opportunities, in line with the concept of "skill obsolescence anxiety" proposed by (Tarafdar et al., 2007) about technostress in various industries.

4.7 Factors influencing technostress levels

Analysis of differences in technostress levels based on respondent characteristics revealed several important findings with theoretical and practical implications. The finding that younger seafarers (20-35 years old) experienced higher levels of technostress than older seafarers (>35 years old) appears contradictory to the common assumption that younger generations, as "digital natives," should be more comfortable with technology. However, it is consistent with technostress research in other contexts, which suggests that youth does not automatically eliminate technostress. Possible explanations include younger seafarers facing higher performance expectations from superiors and senior colleagues, pressure to quickly master technology with little margin for error, lack of mature coping mechanisms, and a tendency to be assigned to more technologically demanding positions while still having limited experience in handling unexpected situations. In contrast, older seafarers have better problem-solving skills, a more realistic perspective on technology as a tool rather than a threat, and greater social capital to gain support when facing technological challenges.

Differences in technostress based on position reveal inequality in technological preparation and support, with crew experiencing the highest technostress, followed by deck officers, and engine officers experiencing the lowest. Crew generally have more limited access to training, often operating technology with a superficial understanding, and have less bargaining power to request additional support or training. Deck officers fall in the middle because, despite having better education and training, they face very high technological demands, particularly related to navigation and safety systems that directly relate to ship safety. Engine officers experience the lowest technostress because the nature of technology in the engine room is more gradual in change than navigational technology, and engine officers generally have a stronger technical background and are more comfortable with complexity. These findings indicate the need for a differentiated approach to technostress management, with crew requiring more extensive training and

simplification of technology interfaces, while deck officers may require better decision support systems to reduce cognitive load.

The results showing a strong negative relationship between sailing experience and technostress ($r=-.527$, $p<0.01$) provide empirical evidence of a learning curve in technological adaptation, where seafarers with more than 10 years of experience have significantly lower technostress than seafarers with 1-5 years of experience, indicating that accumulated experience provides a strong foundation for adaptation because experienced seafarers have a deeper understanding of maritime operations so they can more easily understand the logic behind new technology, have a repertoire of strategies to overcome technical problems, and have higher confidence.

However, this finding also contains concerns that if it takes 10 years to reach a comfortable level with technology, the industry may lose young seafarers who burn out before reaching that stage, partially explaining why the maritime industry experiences a high turnover rate, especially among young seafarers, so the solution is not to slow down technology but to improve the onboarding process, mentorship programs, and support systems for junior seafarers. The difference in technostress between international and domestic routes reflects the reality that international shipping has more stringent technological standards and regulatory requirements, where international vessels must comply with various international conventions (SOLAS, MARPOL, MLC) that require the implementation of certain technologies and more complex documentation, seafarers on international routes face a diversity of ports with different systems, language barriers in technical communication, and higher scrutiny from port state control, while seafarers on domestic routes have a more predictable operating environment and relatively simpler regulatory requirements, indicating that global standardization of maritime technology creates uniform pressure that may be too demanding for certain segments of the maritime workforce.

4.8 The Impact of technostress on seafarers' performance and well-being

The finding that technostress has a significant negative effect on seafarers' performance confirms the hypothesis that technology-related stress can impair job performance in the context of maritime operations. Techno-complexity has the strongest

influence on performance (β=-0.235, p<0.000), which can be explained through cognitive load theory. When seafarers encounter overly complex technology, their cognitive resources are depleted in understanding and operating the system, reducing their capacity for situational awareness, decision-making, and risk assessment, which are core competencies in maritime operations. In emergency situations or adverse weather conditions, cognitive overload due to techno-complexity can lead to human error, leading to maritime accidents. Techno-overload also showed a substantial negative influence on performance (β=-0.187, p=0.001), where in the context of ships, overload occurs when seafarers have to monitor multiple systems simultaneously, respond to numerous alarms and notifications, and integrate information from various sources to make decisions, so that excessive information can cause an information processing bottleneck where individuals fail to properly attend to critical information because they are overwhelmed by the volume, as in cases of maritime accidents such as collisions or groundings often involve elements of information overload where seafarers fail to process warning signals or conflicting information from various systems.

A worrying finding is that the impact of technostress on psychological well-being (R^2=0.489) is greater than its impact on performance (R^2=0.427), indicating that seafarers may still strive to maintain performance levels despite experiencing technostress but at the cost of their mental health, a phenomenon consistent with the concept of "presenteeism" where workers remain nominally productive but experience health deterioration, which is particularly concerning because seafarers work in isolated environments with limited access to mental health support. Techno-overload has the strongest impact on well-being (β=-0.248, p<0.000), explaining why seafarers often report symptoms such as sleep disturbance, anxiety, burnout, and emotional exhaustion, where constant connectivity via satellite communication creates an expectation to be always available that blurs the boundaries between work and rest time.

All dimensions of technostress showed a significant influence on well-being, including techno-insecurity (β=-0.101, p=0.034) which did not affect performance but gave a psychological burden that affected overall well-being, while the strong positive correlation between psychological well-being and performance (r=0.618, p<0.01) indicated the existence of a vicious cycle where technostress decreases well-being, poor well-being decreases performance, and declining performance triggers more technostress,

so breaking this cycle requires intervention at multiple levels: organizational (reducing technology demands, providing support), individual (building resilience, coping skills), and technological (improving usability, reducing complexity), requiring the maritime industry to adopt a holistic approach to seafarer well-being that integrates physical safety, mental health, and technological support.

4.9 Implications for maritime technology use intensity

Analysis of technology use intensity revealed that satellite communication/email had the highest correlation with technostress ($r=0.468$, $p<0.01$), despite not being the most technically complex technology. This finding is interesting because it suggests that technostress is not solely about technical complexity, but also about the psychological implications of technology. Email and satellite communication create an expectation for immediate responses, blurring the boundaries between work and personal time, and making seafarers feel constantly monitored by shore management. In the maritime context, this is exacerbated by time zone differences when seafarers are off-watch or resting, shore offices may be on working hours, and sending emails expects immediate responses. This phenomenon is known as "techno-invasion," where technology invades personal boundaries.

These findings have practical implications: when designing technological interventions for ships, decision-makers need to consider not only technical functionality but also psychological and social implications. Technology that facilitates better work-life boundaries may be more effective in reducing technostress than simply improving technical features. The "right to disconnect" concept, already implemented in several countries for land-based workers, needs to be adapted for the maritime context, with clear policies regarding communication expectations and response times.

The results of this study enrich the literature on technostress by exploring the phenomenon in the unique context of maritime operations. It shows that while previous technostress studies have been mostly conducted in office-based settings with normal working hours and accessible support systems, technostress in the maritime context has distinctive characteristics because seafarers face a triple burden: technology that is no less complex than in other industries, a harsh and isolated working environment, and high-

stakes consequences from errors. The combination of these three factors creates a unique and potentially more severe technostress profile. This study also contributes to Person-Technology Fit theory by showing that misfit between technological demands and human capabilities can occur not only due to inadequate skills, but also due to contextual factors such as the work environment, support availability, and organizational culture. In the maritime context, even highly skilled seafarers can experience technostress if contextual support is inadequate, indicating that solutions to technostress cannot only focus on individual training but must address systemic issues in how technology is implemented, supported, and integrated in maritime operations.

From the perspective of Conservation of Resources (COR) theory, technostress can be understood as a process of resource depletion, where every interaction with complex or problematic technology consumes cognitive resources, emotional energy, and time. Therefore, in a maritime context where resources are already limited due to sleep deprivation, social isolation, and limited shore leave, the additional drain from technostress can lead seafarers to a state of resource exhaustion, manifested as burnout, poor performance, and health problems. COR theory predicts that individuals with more resources such as education, experience, and social support are more resistant to stress, which is consistent with the findings of this study that higher education and long sailing experience are associated with lower technostress.

5 CONCLUSION

This study revealed that Indonesian seafarers experience moderate to high levels of technostress (M=3.55) in the era of maritime digitalization, with techno-overload and techno-complexity as the most dominant dimensions. Factors such as young age, low education level, crew position, limited sailing experience, and working on international routes and container ships were shown to significantly increase seafarers' vulnerability to technostress. The impact of technostress on seafarers' psychological well-being (R^2=48.9%) was even greater than its impact on performance (R^2=42.7%), indicating that seafarers attempt to maintain work performance at the expense of their mental health. These findings underscore the urgency of multi-level interventions that focus not only on individual technology training, but also on systemic improvements in maritime

technology design, organizational support, maritime education curriculum reform, and policies that protect seafarers' work-life boundaries. Without effective technostress management, the Indonesian maritime industry risks declining productivity, increasing maritime accidents, and exacerbating the human resource crisis due to the high turnover of young seafarers suffering from technology fatigue.

5.1 Research limitations and future research directions

A cross-sectional design cannot establish a definitive causal relationship between technostress and performance and well-being. The use of self-report measures for all variables risks common method bias, necessitating objective measures such as incident reports and physiological indicators of stress. This study has not yet explored in depth the influence of individual differences (personality, cognitive ability, self-efficacy) that may moderate the relationship between technological demands and technostress, nor has it captured the dynamic nature of technostress, which can vary across cruise phases and work shifts.

Longitudinal and experimental research is needed to establish clearer causal pathways. Intervention studies are needed to evaluate the effectiveness of various technostress mitigation strategies, ranging from improving technology usability, training programs, psychological support, and organizational change. Comparative studies across ship types and research on human-automation interactions in the maritime context are essential to determine the optimal level of automation that enhances, rather than replaces or burdens, human capabilities in the era of autonomous ships.

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All authors contributed equally to the development of this article.

Data availability

All datasets relevant to this study's findings are fully available within the article.

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