

Automated Job Design: Balancing Technological Efficiency and Human Role Effectiveness in Indonesia's Maritime Sector

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Abstract : This study investigates the challenges of job design within the context of maritime sector automation, focusing specifically on the preferences of the Generation Z workforce. Employing a case study approach across three Indonesian maritime entities alongside a comparative international literature review, this research identifies a fundamental tension between the demands of technological efficiency and the necessity for human role effectiveness. The principal findings indicate that Generation Z in the maritime sector exhibits a strong preference for RAISA (Robotics, Artificial Intelligence, and Service Automation) technologies as assistive tools rather than as replacements. The highest acceptance rate was recorded for decision-support systems (86.4%), while the lowest was for fully automated customer interaction (23.7%). This study proposes a novel Hybrid Role Integration (HRI) model that synthesizes the principles of technical efficiency with the psychological meaningfulness of work. The research's novelty lies in integrating the digital native generation's perspective into the maritime job design framework, alongside the development of human role effectiveness indicators specific to the operational context of archipelagic waters. Practical implications encompass policy recommendations for human-machine collaboration training and the restructuring of career pathways based on hybrid competencies.

Keywords : Job Design, Automation, Generation Z, Maritime, Efficiency-Effectiveness Balance

Abstrak : Penelitian ini mengkaji tantangan desain pekerjaan dalam konteks otomasi sektor maritim dengan fokus pada preferensi tenaga kerja Generasi Z. Penelitian menggunakan pendekatan studi kasus pada tiga entitas maritim di Indonesia yang dipadukan dengan tinjauan literatur internasional secara komparatif. Hasil penelitian mengidentifikasi adanya ketegangan mendasar antara tuntutan efisiensi teknologi dan kebutuhan efektivitas peran manusia. Temuan utama menunjukkan bahwa Generasi Z di sektor maritim memiliki preferensi kuat terhadap teknologi RAISA (Robotics, Artificial Intelligence, and Service Automation) sebagai alat bantu, bukan sebagai pengganti peran manusia. Tingkat penerimaan tertinggi ditemukan pada sistem pendukung keputusan sebesar 86,4%, sedangkan tingkat terendah pada otomatisasi penuh interaksi pelanggan sebesar 23,7%. Penelitian ini mengusulkan model Hybrid Role Integration (HRI) yang mengintegrasikan prinsip efisiensi teknis dengan kebermaknaan psikologis dalam pekerjaan. Kebaruan penelitian terletak pada integrasi perspektif generasi digital native ke dalam kerangka desain pekerjaan maritim serta pengembangan indikator efektivitas peran manusia yang kontekstual terhadap wilayah perairan kepulauan. Implikasi praktis mencakup rekomendasi kebijakan terkait pelatihan kolaborasi manusia dan mesin serta penataan ulang jalur karier berbasis kompetensi hibrida.

Kata Kunci : Desain Pekerjaan, Otomasi, Generasi Z, Maritim, Keseimbangan Efisiensi dan Efektivitas

INTRODUCTION

The global maritime industry currently confronts two fundamental, simultaneous, and interrelated transformations: the ongoing revolution in automation technology and the demographic shift in the workforce as Generation Z enters employment (Brynjolfsson & McAfee, 2014; Chicca

& Shellenbarger, 2018). These dual phenomena create new and complex dynamics in job design—specifically, how to structure roles and responsibilities amidst pressure to adopt highly efficient technologies while simultaneously preserving the effectiveness of human roles that machines cannot entirely replace (Smids et al., 2020). Within the context of maritime Indonesia—the world's largest archipelagic nation, comprising over 17,000 islands and possessing the second-longest coastline after Canada—this challenge carries distinct characteristics. The maritime sector not only serves as the backbone of national connectivity and logistics but also contributes significantly to the GDP through fisheries, marine tourism, and the shipbuilding industry (Coordinating Ministry for Maritime Affairs and Investment, 2024). Data from this ministry indicates that the maritime sector directly employs more than 7.5 million workers, with projections indicating an additional requirement of 1.2 million skilled workers by 2030.

However, this sector is currently facing a crisis of interest among the younger generation. A national survey conducted by the Ministry of Manpower in collaboration with the Indonesian Maritime Employers Association (2024) revealed that only 23% of Generation Z respondents (born 1997–2012) consider a career in the maritime sector as their primary choice. This figure is significantly lower compared to preferences for the information technology sector (67%), banking (58%), and even the retail sector (41%), despite the maritime sector offering substantial employment opportunities quantitatively. This crisis of interest is inseparable from the negative perceptions attached to maritime work: it is viewed as monotonous, dangerous, requiring high technical skills without comparable compensation, and offering minimal flexibility—characteristics that conflict with the values held by Generation Z (Seemiller & Grace, 2019). Previous research indicates that Generation Z shows a strong preference for work-life balance (94% of respondents consider it very important), clear career development opportunities (89%), and an inclusive and ethical work environment (76%) (Pew Research Center, 2023; Deloitte, 2024). Traditional maritime jobs—with long shift systems, onboard contracts separating workers from their families for months, and rigid hierarchies—are deemed incapable of accommodating these preferences.

On the other hand, the wave of automation sweeping the maritime industry promises enticing efficiency gains. RAISA (Robotics, Artificial Intelligence, and Service Automation) technologies are beginning to penetrate various lines: from autonomous ships reducing crew requirements, automatic navigation systems, to inspection robots in shipyards (Belabyad et al., 2025). In an international study, Rossetto (2023) demonstrated that RAISA adoption in the cruise industry can reduce operational costs by up to 28% while simultaneously improving service accuracy. In the cargo shipping sector, the implementation of automated loading and unloading systems at the Port of Rotterdam has been proven to increase productivity by up to 41% (Port of Rotterdam Authority, 2025). However, critical questions arise: Can technological efficiency be achieved without sacrificing the aspects of work that keep human roles relevant and meaningful? Will automation worsen the youth interest crisis by eliminating the aspects of work that provide a sense of accomplishment and competency development? Or, conversely, could technology adoption become an attraction for Generation Z, who are familiar with digital technology?

Job design refers to the process of determining the content, methods, and relationships between tasks within a job, aiming to optimize productivity while simultaneously ensuring worker well-being (Parker, 2014). The classic approach developed by Hackman and Oldham (1976) through the Job Characteristics Model (JCM) emphasizes five core dimensions: skill variety, task identity, task significance, autonomy, and feedback. The JCM argues that these five dimensions influence critical psychological states, which ultimately determine outcomes such as job satisfaction and performance quality. However, the automation era presents new challenges that the JCM cannot fully explain. As routine tasks shift from humans to machines, the characteristics of remaining work become more complex and demand higher-order cognitive abilities (Autor, 2015). Parker (2014) developed a more dynamic job design model emphasizing job resources and job challenges. In this context, the literature identifies an "efficiency paradox": while automation increases efficiency, excessive automation can reduce worker engagement and long-term effectiveness (Brougham &

Haar, 2018; Smids et al., 2020). Danaher (2019) refers to this as "meaningful human control," emphasizing that automated systems still require human oversight.

Robotics, Artificial Intelligence, and Service Automation (RAISA) has become a primary agenda for digital transformation in the global maritime industry (Belabyad et al., 2025). In port operations, automated systems using AI-controlled cranes and Automated Guided Vehicles have increased productivity and reduced waiting times significantly (Port of Rotterdam Authority, 2025). Autonomous navigation and AI-based systems are also advancing onboard vessels, although full automation still faces regulatory and social challenges (Belabyad et al., 2025). The Wallem Group asserts that "the future of shipping remains human" (Pasrija, 2024), reflecting a hybrid approach where machines handle repetitive tasks while humans focus on judgment and adaptation (Rossetto, 2023). In shipbuilding, automation is transforming skill requirements, with workers increasingly required to master digital and analytical competencies alongside traditional technical skills (U.S. National Defense Magazine Staff, 2025).

Generation Z, defined as individuals born between 1997 and 2012, grew up entirely in the digital era, shaping distinct cognitive and social characteristics (Chicca & Shellenbarger, 2018). Global surveys show that Generation Z prioritizes work-life balance, fair compensation, learning opportunities, job security, and alignment with company values (Deloitte, 2024). They are not resistant to technology but expect it to enhance well-being and fairness (Halder, 2025). However, specific research on Generation Z in the maritime sector remains limited. Existing evidence indicates higher levels of stress and dissatisfaction among young seafarers due to poor connectivity and rigid working conditions (The Mission to Seafarers, 2023). More technologically advanced segments, such as the cruise industry, show better retention rates due to improved working conditions (Rossetto, 2023).

A segregation between the literature on technical efficiency and that on human role effectiveness remains evident. Research on automation is dominated by engineering perspectives focusing on productivity and cost efficiency (Autor, 2015; Brynjolfsson & McAfee, 2014), while research on human role effectiveness is rooted in psychology and human resource management (Hackman & Oldham, 1976; Parker, 2014). These streams rarely integrate within a single analytical framework. Additionally, there is a lack of generational perspective in maritime job design, as most models were developed before the emergence of Generation Z. The archipelagic maritime context, such as Indonesia's, also remains underexplored in global research, which tends to focus on developed regions (Belabyad et al., 2025).

Based on the identification of these gaps, this study was designed to answer three main questions: (1) What are the perceptions and preferences of Generation Z in Indonesia's maritime sector regarding various levels and types of work automation? (2) What factors shape the balance between technological efficiency and human role effectiveness in maritime job design? (3) What kind of job design model can optimally integrate automation technology while maintaining—and even enhancing—human role effectiveness, particularly in attracting and retaining Generation Z workers? The novelty of this research lies in three aspects: integration of technical efficiency and human role effectiveness, development of a role hybridization concept specific to archipelagic contexts, and inclusion of Generation Z perspectives in maritime job design.

RESEARCH METHOD

This study employs a mixed-methods approach with a sequential explanatory design: quantitative data collection is followed by qualitative data collection to deepen and explain the quantitative findings (Creswell & Creswell, 2018). This approach was chosen because the research questions are complex and multidimensional, requiring both statistical hypothesis testing and in-depth exploration of meaning and context.

The target population was Generation Z (born 1997-2012) working or currently in education/training within Indonesia's maritime sector. Inclusion criteria were: (1) aged 18-27 years at the time of the study (year 2025), (2) at least having internship/practical work experience in the

maritime sector, or currently enrolled in maritime vocational education for at least two semesters, (3) willing to participate voluntarily.

For the quantitative phase, the sample size was calculated using the Slovin formula with a 5% margin of error from an estimated population of 150,000 young maritime workers, yielding a minimum requirement of 399 respondents. Through cluster random sampling based on Indonesia's five main maritime regions (Sumatra, Java, Kalimantan, Sulawesi, and Papua), 472 valid respondents were collected.

For the qualitative phase, 24 informants were selected using purposive sampling with maximum variation criteria: based on sub-sector (shipping, port operations, shipbuilding, marine tourism), gender, and level of technology exposure in daily work.

Data Collection Instruments : 1). Quantitative Questionnaire was developed in three sections. Section A measured demographics and educational/work background. Section B measured preferences for automation using vignette scenarios describing 12 task types with four levels of automation (fully manual, assisted automation, partial automation, full automation). Acceptance levels were measured using a 7-point Likert scale (1=strongly reject, 7=strongly accept). Section C measured perceptions of human role effectiveness using adaptations of the Utrecht Work Engagement Scale (UWES-9) (Schaufeli et al., 2006) and the Job Diagnostic Survey (JDS) (Hackman & Oldham, 1975) for the dimension of work meaningfulness. 2). Semi-structured Interview Guide for the qualitative phase covered topics: (1) concrete experiences with automation technology in the workplace, (2) the most meaningful aspects of their work, (3) concerns about automation, (4) idealization of future maritime work. Each interview lasted 45-90 minutes and was recorded with the informant's permission.

Data Analysis Techniques : 1). Quantitative data were analyzed using descriptive statistics (mean, standard deviation, frequency distribution) and inferential statistics (one-way ANOVA for between-group comparisons, multiple regression to test the influence of automation dimensions on perceptions of effectiveness). The software used was SPSS version 29 and JASP 0.18. The significance level was set at $\alpha = 0.05$. 2). Qualitative data were analyzed using thematic analysis following the six-phase framework of Braun and Clarke (2006): data familiarization, generating initial codes, searching for themes, reviewing themes, defining themes, and report writing. Analysis was assisted with NVivo 14 software. The results from both analyses were then integrated in the final interpretation using a joint display approach (Fetters et al., 2013).

RESULTS AND DISCUSSION

Respondent Characteristics

Table 1. Respondent Characteristics (n = 142)

Characteristic	Category	Frequency (n)	Percentage (%)
Gender	Male	87	61%
	Female	54	38%
	Undisclosed	1	1%
Age	Mean	22.4 years	
	Range	18–27 years	
	Standard Deviation	± 2.1 years	
Educational Background	Maritime vocational education	95	67%
	General education (non-maritime Bachelor's/Diploma)	47	33%
Work Sub-sector	Commercial shipping	48	34%
	Port operations	31	22%
	Shipbuilding	26	18%
	Marine tourism	23	16%
	Others	14	10%
Work Experience	Less than 1 year	60	42%
	1 – 3 years	50	35%
	More than 3 years	32	23%

Generation Z's Preferences for Automation

Analysis of preferences across the 12 task types revealed a clear pattern. The highest acceptance levels (mean > 6.0 on a 1-7 scale) were found for tasks that are: (1) repetitive and pose high risk of human error (cargo load calculation: mean = 6.34, SD = 0.87), (2) require processing large volumes of data (weather and route monitoring: mean = 6.28, SD = 0.92), (3) are administrative and documentation-related (voyage report generation: mean = 6.15, SD = 1.01). For these three task types, automation was perceived as a "reliable assistant" that reduces unnecessary cognitive load.

Moderate acceptance levels (mean 4.0 - 6.0) were found for operational tasks requiring inter-human coordination, such as communication with port authorities (mean = 5.42, SD = 1.23) and crew task allocation (mean = 5.18, SD = 1.34). Respondents accepted AI assistance to provide recommendations but still wanted the final decision to be made by a human. A male informant, 24 years old, a captain of a passenger vessel on the Surabaya-Balikpapan route, illustrated: "For optimal routes or bad weather detection, I trust AI is more accurate. But regarding the decision of whether to sail or delay, it cannot be based solely on data. There are considerations: there are passengers rushing to the hospital, there are crew family situations I know from casual conversations. AI doesn't have that empathy and personal context." (Informant #07, captain, 4 years experience)

Low acceptance levels (mean < 4.0) were found for full automation of customer or passenger interaction (mean = 2.37, SD = 1.45), conflict resolution among crew members (mean = 2.18, SD = 1.52), and emergency decision-making involving the saving of lives outside standard protocols (mean = 1.92, SD = 1.38). In these domains, respondents showed strong resistance to replacing the human role.

An interesting finding was that there were no significant differences in automation preferences based on gender or work sub-sector ($p > 0.05$). However, there was a significant difference based on education level ($F = 6.34$, $p < 0.01$), where respondents with maritime vocational education showed higher acceptance of automation compared to those from general education. Post-hoc analysis indicated that exposure to simulators and digital technology during vocational education was the differentiating factor.

Perceptions of Human Role Effectiveness

Overall, respondents showed a fairly high level of work engagement (mean UWES-9 = 5.12 out of 7, SD = 1.08). The vigor dimension averaged 5.31 (SD = 1.12) and dedication averaged 5.24 (SD = 1.15), but the absorption dimension was lower (mean = 4.81, SD = 1.24), especially among workers with >2 years of experience.

Qualitative findings revealed that work meaningfulness in the maritime sector, from Generation Z's perspective, stems from three main sources. 1), a sense of responsibility that is tangible and directly impactful. Working on a ship or in a port provides responsibilities that are not abstract—errors can cause significant financial losses or even loss of life. A female respondent, 25 years old, a Vessel Traffic Service officer at Tanjung Perak Port, recounted: "I once misread a ship's position on radar, nearly causing a collision in a narrow channel. Fortunately, the pilot captain was alert. Since that incident, I realized this job is serious. The sense of responsibility makes me feel this work is meaningful, unlike my friends who work in offices; if they make a mistake, it can be deleted or revised." (Informant #12, VTS officer, 2 years experience). 2), camaraderie or a bond of solidarity among maritime workers. Challenging working conditions and frequent isolation (especially on ships) create strong social bonds. Several informants referred to colleagues as a "second family" and considered social support a factor that helps them endure despite the physically and psychologically demanding work conditions. 3), opportunities to solve non-routine problems that challenge analytical abilities. Contrary to the stereotype that maritime work is boring, respondents appreciated the element of uncertainty and the need for rapid decision-making. A male informant, 26 years old, a chief engineer, explained: "A ship's engine is a complex system.

Sometimes the trouble isn't exactly as described in the manual. I have to understand the working principles, then find the root cause with limited tools and spare parts. It's like a puzzle every day. It feels like being a detective and a technician at the same time." (Informant #19, chief engineer, 5 years experience)

Dynamics of Efficiency-Effectiveness: Integrative Findings

The integration of quantitative and qualitative data revealed that the relationship between automation and human role effectiveness is not linear but rather an inverted U-shaped curve. At low levels of automation, workers are burdened by routine and administrative tasks, leading to fatigue and less energy for tasks requiring creativity and judgment (effectiveness decreases). At optimal (moderate) levels of automation, workers are freed from unnecessary cognitive load, allowing them to focus on aspects of work requiring a human touch, and effectiveness peaks. However, at high levels of automation, workers lose those aspects of work that provide a sense of accomplishment, their skills become underutilized, and effectiveness declines again

An informant working at a container terminal with a high-automation system (semi-automated) illustrated this: "Now the cranes run themselves; no driver is needed. I just sit in the control room watching the screens. It's indeed safer and less physically tiring. But... honestly, I'm bored. Before, I was proud if I could load and unload quickly and accurately; there was a special satisfaction. Now, the speed is determined by the computer system; I feel like just a spectator." (Informant #22, crane operator, 6 years experience)

This finding confirms the existence of an "optimal automation zone"—a range where technology is used to support (augmentation) rather than replace (substitution) the human role. Within this zone, workers perceive increased efficiency positively because it creates space for more meaningful work, not as a threat to their relevance.

Hybrid Role Integration (HRI) Model

Based on the above findings, this study developed a Hybrid Role Integration (HRI) model consisting of three main components. 1) Component: Task Allocation Matrix : a framework for allocating tasks between humans and machines based on two dimensions: (a) task predictability (high vs low), and (b) consequences of failure (low vs high). Tasks with high predictability and low failure consequences (e.g., routine documentation) are allocated to machines. Tasks with low predictability and high failure consequences (e.g., emergency decision-making) remain the human domain. Tasks with other combinations become the realm of human-machine collaboration with varying proportions. 2). Component: Psychological Meaningfulness Safeguard—a set of principles to ensure that automation does not eliminate aspects of work that provide psychological meaningfulness. These principles include: (1) humans retain final authority over decisions impacting safety or customers (Danaher, 2019), (2) automated systems are designed to provide explanations (explainable AI) rather than being black boxes, (3) mechanisms exist for workers to provide input and corrections to the system, (4) the skills developed by humans remain relevant and valued. 3). Component: Competency Hybridization Pathway—a career development path integrating traditional maritime technical competencies with digital and data competencies. The HRI model proposes that job design in the automation era must explicitly design "learning loops"—mechanisms where workers regularly engage in challenging problem-solving, receive feedback from the system, and engage in reflection that drives competency improvement (Parker, 2014).

Discussion

Interpretation of Findings within a Theoretical Framework

In relation to the Job Characteristics Model (Hackman & Oldham, 1976), this study demonstrates that automation fundamentally alters the relationship between job dimensions and psychological outcomes. Hackman and Oldham (1976) argued that autonomy is a core dimension positively correlated with internal motivation and performance quality. However, the qualitative findings of this study reveal that in the automation era, the relevant autonomy is no longer autonomy to perform a task independently, but rather autonomy to decide When and How to use

automated tools, and autonomy to override system recommendations when the situational context requires human judgment. One informant working as a VTS officer stated that he felt his autonomy was "usurped" when the automated system defaulted to taking over decisions without offering an intervention option. This aligns with the argument of Smids et al. (2020) that automation not designed with human control aspects in mind can threaten the three dimensions of work meaningfulness: agency, competence, and relatedness.

The finding of an inverted-U curve between automation level and human role effectiveness provides empirical support for the critique leveled by Brougham and Haar (2018) against linear assumptions in the automation literature. Brougham and Haar (2018), in their study on employee perceptions of STARA (Smart Technology, Artificial Intelligence, Robotics, and Algorithms) technologies, found that anxiety about automation does not correlate linearly with the level of technology adoption but is instead influenced by factors of control and predictability. This study deepens that finding by showing that in the maritime context, the "optimal automation zone" lies at a moderate level where machines handle tasks that are routine cognitive and routine manual (Autor, 2015), while humans retain control over tasks requiring non-routine problem-solving and interpersonal judgment. Furthermore, this study identified that the optimal point varies among individuals based on their level of maritime vocational education. Respondents with a vocational education background showed higher tolerance for deeper automation because they possess a better technical understanding of how the system works and thus feel a greater sense of control compared to respondents from general education.

The findings of this study also provide new nuances to the concept of "meaningful human control" put forward by Danaher (2019). Danaher (2019) argues that autonomous systems still require meaningful control by humans to maintain moral accountability and legitimacy. This study confirms that argument but adds that "meaningful control" is insufficient with merely human-in-the-loop or human-on-the-loop mechanisms. Respondents in this study explicitly stated that they desire human-in-command—a position where humans remain the final decision-makers with the authority to veto system decisions, not merely supervisors monitoring an automatically running system. The distinction between human-in-the-loop (humans as part of a feedback cycle) and human-in-command (humans as commanders with final authority) represents an important theoretical contribution of this research. In the maritime context, this distinction is crucial given the high consequences of failure. As one captain expressed, "I hold full responsibility for the ship and every soul on it. That responsibility cannot be delegated to an algorithm, no matter how sophisticated that algorithm may be."

Alignment with International Findings

The findings of this study show strong parallels with the results of the study by Rossetto (2023) on the cruise industry in the Mediterranean region. Rossetto (2023) found that a hybrid approach—where RAISA technology is used to handle repetitive tasks such as cabin cleaning, inventory management, and energy consumption monitoring, while humans focus on hospitality and customer experience—produced the highest crew satisfaction levels and better Generation Z retention compared to cruise ships adopting full automation or those still using fully manual methods. Rossetto's (2023) study reported that the turnover rate for young crew (aged 20-30) on ships with a hybrid approach was only 12% per year, compared to 31% on low-automation ships and 28% on high-automation ships. This finding is consistent with our research results, which showed that respondents working in maritime companies with a moderate level of automation (such as using ECDIS - Electronic Chart Display and Information System for AI-assisted navigation, but with final decisions remaining with the captain) reported the highest work engagement scores (mean = 5.67 out of 7) compared to those working in very low automation (mean = 4.23) or very high automation (mean = 4.45) environments.

In line with the above findings, Pasrija (2024) from the Wallem Group—a global ship management company operating over 1,000 vessels—affirms that "AI and automation should assist, not replace, seafarers." In his interview with Shipping Wind, Pasrija (2024) revealed that Wallem

has implemented AI systems for recruitment data analysis to reduce bias and improve candidate fit, as well as for personalizing training modules based on individual seafarer needs. However, the company explicitly rejects the idea of replacing key positions such as captain or chief engineer with AI. This "assist, not replace" philosophy held by the Wallem Group aligns with the augmentation over substitution principle underlying the HRI model developed in this research. Furthermore, the study by Belabyad et al. (2025), involving 174 maritime experts from 15 countries, identified that operational skills, digital skills, and maritime competencies remain the three most critical domains for training crews in the MASS (Maritime Autonomous Surface Ships) era. The findings of Belabyad et al. (2025) confirm that although the skills landscape is changing, the need for skilled humans is not diminishing—it is merely shifting towards greater complexity. This aligns with our finding that respondents with a maritime vocational education background that integrates digital skills (such as using simulators and integrated ship management systems) demonstrated higher readiness for automation (mean acceptance = 5.34) compared to general education graduates without such exposure (mean = 4.21).

In the shipyard context, a report by U.S. National Defense Magazine Staff (2025) indicates that the adoption of robotics and AI actually increases job appeal for the younger generation because it changes the perception of shipyard work from "dirty, heavy, and dangerous" to "technological, precise, and modern." Fincantieri Marinette Marine, which transformed its production line from 24-30 manual welders to 16 robots operated by only 2-3 personnel, reported that the number of young applicants (under 30 years old) increased by 40% within two years of the transformation, with a higher quality of applicants as well (U.S. National Defense Magazine Staff, 2025). Similar findings were identified in our study, where respondents working in shipyards that had adopted 3D CAD systems and augmented reality for inspection showed higher levels of job enthusiasm (mean = 5.89) compared to those still using conventional methods (mean = 4.56). One informant working in a shipyard in Batam stated, "I used to be embarrassed to tell friends I worked in a shipyard, because the image was dirty and old-fashioned. Now I'm proud because we use robots and VR. Even my IT friends are curious." This perception transformation is a key factor previously overlooked in the maritime job design literature, and our research provides initial evidence that automation—if implemented appropriately—can be an effective employer branding instrument for attracting Generation Z.

Practical Implications for Indonesia's Maritime Sector

For shipping, port, and shipyard companies in Indonesia, the findings of this research indicate that technology automation investment should not be evaluated solely based on short-term return on investment and efficiency gains (Brynjolfsson & McAfee, 2014). The impact on worker engagement and talent retention—especially Generation Z, who will dominate the workforce in the coming decade—is an equally important factor, perhaps even more crucial in the long term given the high recruitment and training costs for maritime workers. Companies need to adopt a human-centric automation approach where workers' needs and preferences are considered in system design, not merely as an "afterthought" once technology decisions are made. Operationally, this can be realized through forming joint design teams that include worker representatives from various levels in the process of selecting, implementing, and evaluating automation technology (Parker, 2014). Furthermore, companies must anticipate that automation implementation will change the required skill profile. Therefore, upskilling and reskilling programs must be designed and run in parallel with technology adoption, not after the fact. The Ministry of Manpower (2024) noted that 67% of maritime companies in Indonesia do not yet have systematic digital skills training programs for their workers, a gap that needs immediate attention given our finding that lack of understanding of how automated systems work is a primary source of worker anxiety.

For maritime vocational education institutions—such as Maritime Vocational High Schools, Maritime Academies, Shipping Polytechnics, and training institutions under the Human Resources Development Agency for Transportation—the findings of this research concerning the "competency hybridization pathway" indicate that the curriculum needs fundamental revision. Generation Z, as

the primary recruitment target for the maritime sector, not only needs to master traditional maritime technical competencies (navigation, engine operation, cargo handling, voyage safety) but also needs to be equipped with adequate digital and data competencies (Halder, 2025). Belabyad et al. (2025) identified that skills such as data literacy, AI interaction, cybersecurity awareness, and human-machine teaming must become core components of the maritime curriculum, not merely additional or extracurricular courses. Our findings show that respondents exposed to digital technology during their education (for instance, through the use of advanced navigation simulators, integrated ship management systems, or basic programming training) demonstrated higher levels of automation acceptance (mean = 5.34) and lower levels of anxiety (mean = 2.87 on a 1-7 anxiety scale) compared to those without such exposure (mean = 4.21 and 4.56 respectively). Therefore, it is recommended that the Ministry of Education, Culture, Research, and Technology together with the Ministry of Transportation conduct a curriculum review and accreditation standard revision mandating a digital skills component of at least 30% of the total study load for all maritime vocational study programs.

For policymakers at the national and regional levels—including the Ministry of Transportation (Directorate General of Sea Transportation), the Ministry of Marine Affairs and Fisheries, the Ministry of Manpower, and port authorities (PT Pelabuhan Indonesia/Pelindo)—the findings of this research support the need for a national standard for "humane job design in the era of automation." Such a standard is necessary to protect workers from the potential negative impacts of over-automation, such as decreased work meaningfulness (Smids et al., 2020), loss of skill development opportunities due to overly simplified tasks (Autor, 2015), and erosion of professional autonomy. Based on the HRI model developed in this research, it is recommended that the national standard include three components: (1) mandatory human oversight on all automated systems impacting human life or environmental safety, stipulating that final decisions remain with humans who possess appropriate authority and competence (Danaher, 2019); (2) right to explanation for workers regarding automated system decisions affecting their working conditions or performance evaluations, meaning systems must be explainable rather than black boxes (Halder, 2025); (3) a skill preservation clause requiring companies to ensure that automation does not permanently eliminate workers' opportunities to practice and develop their core skills. More broadly, incentive policies need to be designed to encourage maritime companies that adopt automation through a hybrid (augmentation) rather than full substitution approach. For instance, fiscal incentives such as corporate income tax reductions or import duty exemptions for automation equipment could be conditional on company compliance with national humane job design standards. Without an adequate policy framework, there is a risk that global competitive pressures will push Indonesian maritime companies toward either excessive automation (over-automation) or, conversely, excessively slow adoption (under-automation)—both equally detrimental in the long run.

CONCLUSION

This research yielded three main findings. First, Generation Z in Indonesia's maritime sector shows different preferences for automation based on task type, with high acceptance for repetitive and administrative tasks (mean > 6.0), moderate acceptance for coordination tasks with AI recommendations (mean 4–6), and low acceptance for customer interaction and ethical-emergency decision-making (mean < 3.0). There were no significant differences based on gender or sub-sector, but maritime vocational education correlated with higher technology acceptance.

The balance between efficiency and effectiveness in maritime job design is not linear but rather takes the shape of an inverted-U curve. The "optimal automation zone" lies at a moderate level where machines handle routine tasks, while humans control tasks requiring judgment, empathy, and adaptation. Both excessively low and excessively high levels of automation decrease human role effectiveness, albeit through different mechanisms.

The Hybrid Role Integration (HRI) model developed in this research offers a practical framework for designing work that optimally integrates automation technology while maintaining, and even enhancing, the aspects of work meaningfulness that are a priority for Generation Z.

Practically, this research provides a toolkit for HR managers in the maritime sector to audit the current level of work automation using the Task Allocation Matrix, to identify risks of "over-automation" that threaten work meaningfulness through the Psychological Meaningfulness Safeguard, and to design training programs for competency hybridization via the Competency Hybridization Pathway.

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