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An Assessment of Sustainability Indicators for a Shipyard, Utilizing the Analytic Hierarchy Process (AHP)

Mehmet Tantan
Department of Naval Architecture and Marine Engineering
Istanbul Technical University (ITU), Istanbul
Türkiye
tantan18@itu.edu.tr

Hatice Camgöz Akdağ
Department of Business Engineering
Istanbul Technical University (ITU),Istanbul
Türkiye
camgozakdag@itu.edu.tr

Abstract

Sustainability and sustainable development are becoming more popular in the literature and are applied in many sectors since environmental concerns have increased globally. Consequently, sustainability concerns have started to focus on shipyards, where all ships are constructed, repaired, maintained, and dismantled. Since 90% of world trade merchandise is transported by ships, the shipbuilding sector has been concerned with energy efficiency and focused on either environment or emission-oriented research. However, sustainability has three dimensions: environmental, social, and economic. Each innovation and transformation have a positive or negative impact on each of those dimensions. In addition, the shipyards should implement a simple approach or initiative to reach the necessary sustainability targets. Therefore, the authors proposed modeling of identified indicators determined by the experts and used an analytical hierarchical process (AHP) method to prioritize the dimensions and indicators. The model is applied in a shipyard, and the economic dimension with profitability and revenue indicators was found to be significant. The shipyard evaluates environmental issues from an economic and social point of view, as shipyards face fierce global competition and the challenge of ensuring the availability of skilled labor with a minimum of accidents. Surprisingly, environmental dimensions are not at the forefront because shipyards are not obliged to respect international standards like ports and ships sailing on the overseas.

Keywords
Shipyard, Sustainability, AHP, and Performance Indicator.

1. Introduction
The sustainability concept emerged in 1987 regarding Brundtland reports. After that report, governmental and non-governmental organizations, academicians, and private sector executives started to examine the subject in detail, and many studies, approaches, and reports were published as an outcome of these efforts. In 1995, the intention of United Nations meetings evolved into seventeen sustainable development goals. Conference of Parties (COP) meetings were held every 4 years, so the awareness about sustainability increased globally and the governments, international institutions, local and national corporations, entities, and academicians have started to act to decrease unexpected effects of environmental pollution, economic constraints, and social unrest.

Shipbuilding, being one of the oldest sectors in the world, is inextricably linked to the aforementioned concerns. Indeed, it is estimated that 90% of global trade is still transported by sea. Ships are constructed, repaired, maintained, and decommissioned in shipyards during their life cycle. Consequently, the relationship between the ship and shipyard persists throughout the entire operational life of a vessel. Consequently, shipyards are obliged to adapt to the regulations and standards applied to ships by national and international entities to contend with global competition and survive in a highly diversified market.

Nevertheless, the shipbuilding sector has not received sufficient attention since the start of the sustainability era, with only a limited number of studies published on the subject. Tantan, et al. (2020). Additionally, energy efficiency and CO_2 emission targets have indirectly guided the sector to the energy efficient and substitutable solutions. The impact of each solution, whether it is innovative or transformative, is multifaceted, exerting a positive or negative influence on the various sustainability dimensions.

1.1 Objectives

Consequently, the absence of a holistic approach to the three dimensions of sustainability may generate further challenges that remain unaddressed and unsettled. In addition, a lack of awareness by senior-level managers and academicians may lead the literature to focus on partial and temporary solutions. Therefore, the authors aimed to contribute to the literature by addressing this gap to offer a revised perspective and expanding the existing literature on the environmental, social, and economic dimensions of sustainability with performance indicators. A similar study was performed by Fitriadi, et al. (2024) that examined sustainability indicators to optimize the traditional shipbuilding process for continuous improvement by integrating value stream mapping.

In this study, the authors proposed modeling of identified indicators determined by the experts and used an analytical hierarchical process (AHP) method to prioritize the dimensions and indicators. The AHP is a well-established methodology for multi-criteria decision-making (MCDM) processes, and it has been demonstrated to be more efficient and straightforward for pair-wise comparisons in a study of the Indian ports, Sengar, et al. (2018). The following section of the study will address the remaining aspects. Section 2 provides a comprehensive literature review of shipyards and the three dimensions of sustainability, with a detailed discussion of the research gaps. The research methodology is presented in Section 3, followed by the findings in Section 4. Finally, the study concludes with a discussion of its findings in Section 5.

2. Literature Review

The authors applied a systematic literature review, a method that is well-established within academic research. This approach provides a comprehensive summary of the literature related to the research subject by synthesizing preceding studies. This methodological approach serves to reinforce the necessity of the research topic, whilst concurrently outlining with precision the existing gap in the extant literature. The review is structured in four phases. Initially, search assumptions, limits, and coverage are established. Google Scholar is selected for the literature research. The search time set for manuscripts written in English between 2015 and 2024. The keywords "sustainability assessment, shipyard, sustainable development" were identified in the title, abstract, and keyword search areas of the articles. The search was conducted individually for each keyword and subsequently combined using EndNote software. Following the elimination of duplicates, each article was examined methodically within its title and abstract to ascertain its relevance to the research subject. Following this process, a total of 16 articles were selected for further analysis. The result is highlighted in Table 1.

Ali, et al. (2015)investigated the applicability of the concept of remanufacturing in the shipbuilding industry. The authors focused on the environmental and economic dimension of sustainability and developed a five-stage framework that would aid the shipyard in integrating the remanufacturing concept into its strategic decision-making process to construct a vessel with similar operation capability but at a lower cost and lesser environmental footprint. Papamanolis, et al. (2018) examined several sources of waste generated from shipbuilding activities and investigated a Greek shipyard's emission and whether the wastes can be managed in a sustained manner. They stated the pollution occurred under specific weather conditions near the island where the shipyard is located caused mainly by that shipyard's operation. This incident should need special interest and amelioration. This article focused on the environmental dimension. For the shipbuilding sector, sustainability carries a very important weight, Ramirez-Peña et al. (2020).

Companies can implement sustainable policies at all levels, taking advantage of the transversally offered by the supply chain. This research is oriented in the supply chain management enabling industrial 4.0 technologies.
In another article, nine sustainability challenges were identified to improve sustainability in shipbuilding regarding Industry 4.0 technologies, Strandhagen, et al. (2020). These challenges are "Optimization of ship design for increased energy-efficiency, Efficient sharing of knowledge and information, Closer collaboration with suppliers, Increased information visibility and data availability, Improved work conditions and productivity, Efficient manufacturing logistics, Continuous design optimization, On-demand spare parts production, Improved end of life handling of the ship". However, the focus is more on the supply chain than on shipbuilding operations.

A real strategy to improve the sustainability of all shipyards is missing. The literature often quickly jumps from sustainability towards the use of renewable energy resources or improving energy efficiency. The development of a more sustainable shipyard means not only implementing environmentally sustainable improvements but also ensuring economic feasibility, Janson (2016). He developed a Green Shipyard concept focusing only on the environmental dimension of sustainability. However, the developed GPF is applicable as a method to compare the environmental performance of specific categories of an operational shipyard or can be applied as a self-assessment method to determine the environmental performance of a shipyard.

Yugowati Praharsi (2020) discussed the activities of a sustainable supply chain to support the industrial ecosystem and recommended supporting the regulations on environmental, social, and economic sectors to achieve the sustainability of the material supply chain. For example, shipyards should use sophisticated tools to reduce the risk of product failure and achieve production process efficiency regarding environmental dimension. The shipbuilding workers ask for the assistance of the government not only in providing perishable tools such as drills, grinders, etc. but also in training and socialization on the benefits of technological development in the trade regarding economic dimension. Socially, an association of workers is needed to convey the regulations, experience sharing, and assistance provided.

While shipbuilding, as an energy-intensive sector, produces significant amounts of air emissions, including greenhouse gases, Vakili, et al. (2021) identified priorities for a Turkish shipyard to become energy efficient. Technology and innovation are the highest priority, followed by policy and regulation, economic and human factors. Operation is the lowest priority. In another research, to overcome energy efficiency barriers, a transdisciplinary framework developed by Vakili, et al. (2021) revealed that economic barriers have the greatest impact, while human barriers have the least impact on the shipyard's energy performance of an Iranian shipyard. Both types of research focused on energy efficiency used fuzzy methods, and applied in a unique shipyard to validate. In another article, Vakili, et al. (2022) implemented the transdisciplinary shipyard energy management framework on a Bangladeshi shipyard that the political and legal discipline, the social criteria, and the implementation of ISO 14001 and cyber security were the most important criteria and options for the yard's decision makers. Vakili (2023) undertook an investigation of five shipyards, each possessing distinct characteristics to evaluate sustainability through Corporate Social Responsibility, Stakeholder Theory, Corporate Sustainability, and Green economics theories.

The study results showed that the definition and meaning of sustainability differ from case to case and from individual yard to individual yard. The larger shipyards were committed to reducing GHG emissions from shipyard operations, while the smaller shipyards in less developed countries were more interested in economic performance than environmental issues. Vakili, et al. (2023) applied an interdisciplinary approach to provide trends, recommendations, and policies for the decarbonization of the shipping industry from a life cycle perspective and highlighted that the implementation of the energy management framework can accelerate the transition to a zero-emission shipbuilding industry.

Woo, et al. (2021) developed a new diagnostic framework for smart shipyard maturity level assessment and performed a data envelopment analysis (DEA) to confirm the usefulness of the diagnosis results. Some shipbuilding materials are environmentally hazardous during production, construction, operation, and recycling. The shipbuilding industry must adopt a life-cycle perspective to implement a more integrated environmental focus. As the percentage of aluminum materials used increases, the material-based impact increases, while the environmental impact of the process decreases Önal (2022). Baihaqi, et al. (2023) developed a framework for shipyard performance measurement under five criteria groups; Technical, Business, External, Personnel Safety, and Environment. This framework may help the shipyard to determine the lowest performance score within the prioritized criteria and sub-criteria to evaluate the cause-effect link and prioritize steps to improve performance.

Fitriadi, et al. (2023) developed a concept that enables the assessment of measurable environmental, economic, and social systems in the shipbuilding process in traditional shipyards, allowing for continuous monitoring of changes in the shipbuilding system. Fitriadi, et al. (2024) enhanced the sustainability of the Traditional Shipyard Industry necessitates continuous improvements in the production process to optimize efficiency and minimize waste. They proposed ongoing enhancements within the Traditional Shipyard Industry, integrating a Value Stream Mapping tool with Sustainability Indicators in three dimensions. These indicators were raw material consumption and energy consumption under the environmental dimension; cycle time (CT), Takt time, non-value-added activities (NVA), value-added activities (VA), process cycle efficiency (PCE), labor cost, material cost under economic dimension; work environment risk, attendance and absence days, salary level, diversity ratio.

Jebbor, et al. (2023) stated that examining the role of sustainability practices, such as eco-friendly materials, energy-efficient processes, and waste reduction strategies, is crucial for the industry's long-term viability and environmental responsibility. Kocak, et al. (2023) developed a novel method to calculate a dimensionless "Productivity Number" system to overview the productivity status of a shipyard. The authors identified 185 factors as having a clear impact on ship delivery schedule from the start of contracting activities until the end of sea trials.

Shipyards around the world are predominantly second and third-generation. The fourth and fifth-generation shipyards do not fully meet the 2070 criteria. Therefore, it is necessary to build green shipyards or convert the existing shipyards to produce green ships, Koray (2023). Economic feasibility, energy efficiency, biodiversity, and government incentives were determined as prioritized criteria for the conversion of existing shipyards to green. In addition, the issues of energy efficiency and sustainability and automation and digitalization will play a vital role in the medium term. Ali Azhar (2024) aimed to develop a concept for the development of a multi-oriented shipyard industry that is environmentally friendly and sustainable. They underlined that the development begins with identifying problems, collecting secondary data, and reviewing related articles (shipyard industry, ship recycling yard industry, environment, sustainability, and supporting methods). Shipyards are heavy industry facilities and each process in the shipyards may pose great environmental risks. Among shipyard processes, especially painting has the potential to cause serious damage not only in the shipyard but also around the shipyard, Şahin, et al. (2024). Ait Allal, et al. (2020) proposed operational measures to attenuate the harmful and hazardous character to the environment and health and safety of the workers in an African shipyard to progress for the environmental, social, and economic impact.

3. Research Methodology

The Analytic Hierarchy Process (AHP) is a decision-making method that allows individuals and organizations to evaluate and compare alternatives based on a systematic and objective approach. This methodology involves establishing a hierarchy, whereby alternatives are placed into a structured framework, allowing for the assessment of their attributes and relative merits. The resulting rankings facilitate informed decision-making by providing a clear and coherent structure for evaluating and selecting the most suitable options. Saaty (1997). The research model is presented in Figure 1.

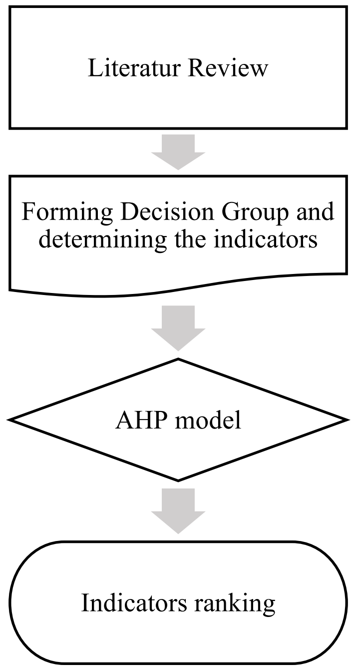

Figure 1. Research Model

Table 1. Literature Review Summary

Id	Author	Scope	Methodology	Objective
1	Ali, et al. (2015)	The environmental and economic dimensions of a shipyard	Case study	Applicability of the concept of remanufacturing in the shipbuilding
2	Janson (2016)	The environmental dimension of a shipyard	Case study	Development of a green performance framework for the shipyard
3	Papamanolis, et al. (2018)	The environmental dimension of a shipyard	Case study	Adoption of the appropriate waste management techniques
4	Ramirez-Peña, et al. (2020)	Shipbuilding supply chain	Systematic review	Overview of the state of the art in the shipbuilding adaptation of Industry 4.0
5	Yugowati Praharsi (2020)	Shipbuilding material supply chain	Survey	Modelling of industrial ecosystem on wooden boat building
6	Ait Allal, et al. (2020)	Environmental dimension	Case study	To assess shipyards in order to ensure a sustainable ship maintenance and repair activity and to reduce their environmental impact
7	Vakili, et al. (2021)	Shipbuilding process	Transdisciplinary approach	To develop a conceptual transdisciplinary framework to overcome energy efficiency barriers during the shipbuilding phase
8	Vakili, et al. (2021)	Greenhouse gas emissions of a shipyard	Fuzzy Multi-Criteria Decision-Making method	Identification of priorities to become energy efficient for a shipyard
9	Vakili, et al. (2022)	Energy management framework of a shipyard	Fuzzy Analytical Hierarchy Process and Fuzzy Order of Preference by Similarity to Ideal Solution methods	To support shipyard decision-makers in making rational and optimized decisions to make shipyards sustainable
10	Baihaqi, et al. (2023)	Shipyard performance measurement	Integrated Fuzzy Decision-Making Trial and Evaluation Laboratory (DEMATEL) and Weighted Evaluation Technique (WET) method	Conceptual and transdisciplinary framework for shipyard performance measurement through integrated Value Engineering and Risk Assessment (VENRA)
11	Fitriadi, et al. (2023)	Sustainability Indicators	Value stream mapping	to achieve sustainability through continuous improvement in traditional shipbuilding
12	Jebbor, et al. (2023)	Traditional shipbuilding process	Manufacturing Cycle Efficiency	to provide innovative perspectives on optimizing the traditional shipyard industry through production cycle efficiencies
13	Koray (2023)	The environmental dimension of a shipyard	Literature review	to determine the shipyards' conversion requirements and to prioritize the conversion needs so that a 32,000 DWT dry bulk carrier can be built and classified as a green ship
14	Vakili, et al. (2023)	Economic and environmental dimension of a shipyard	Case study	To presents the socio-economic and environmental benefits of the implementation of the proposed energy management framework
15	Vakili (2023)	Environmental dimension	Interdisciplinary approach	Implementation of an energy-efficient management framework
16	Ali Azhar (2024)	Environmental dimension	Literature review	to develop a concept for developing a multi-oriented shipyard industry that is environmentally friendly and sustainable

The method was selected on account of its capability to identify, evaluate, and prioritize the sustainability dimensions and indicators for a shipyard. The decision group comprised academics and industrial experts. During the course of the discussions, and face-to-face interviews with the experts and academics, the group concluded to identify general indicators as much as possible. The number of indicators may vary depending on the shipyard, the ship type, and the process. Therefore, the group was limited to four indicators for each dimension, based on literature and industrial experience, with a view to simplifying the study and easy to follow for the management. The identified indicators with references are listed in Table 2

Table 2. Sustainability Performance Indicators

Dimension	Indicator	ID	Description	Reference
Environmental	Energy consumption	Env1	Energy is used or consumed during a certain production cycle or period.	Fitriadi, et al. (2023)
	Scrap recycled	Env2	The amount of scrap recycled per quarter	Decision Group
	Hazardous waste	Env3	The amount of hazardous waste per quarter	Decision Group
	Greenhouse gas emissions	Env4	direct greenhouse gas (GHG) emissions per unit of net value-added	UNCTAD (2020)
Economic	Revenue	Eco1	value generated from the sale of goods or services, or any other use of capital or assets, recognized by an entity in a given reporting period	Decision Group
	Green investment	Eco2	the expenditures for those investments whose primary purpose is the prevention, reduction and elimination of pollution and other forms of degradation to the environment	UNCTAD (2020)
	Profitability	Eco3	Total profit earned by the year	Decision Group
	Material cost	Eco4	All costs incurred during the production of the ship include the cost of material prices, transportation costs, and storage.	Fitriadi, et al. (2023)
Social	Average hours of training per employee	Soc1	scale of an entity's investment in employee training (i.e., in human capital) per year	UNCTAD (2020)
	Employee wages and benefits	Soc2	total costs of the employee workforce for the entity in the reporting period as a proportion of the total revenue	UNCTAD (2020)
	Attendance and absence days	Soc3	The presence and absence of workers during the production process in traditional shipyards take place.	Fitriadi, et al. (2023)
	Work accidents	Soc4	the number of work days lost due to occupational accidents, injuries per quarter	Decision Group

The study problem is determined to assess the sustainability dimensions and performance indicators of a shipyard. Hence, a hierarchy prioritization model is formed. The authors constructed the questionnaire to collect data and asked industrial experts to make pair-wise comparisons between the environmental, social, and economic dimensions and their indicators. The questionnaire included the nine-point scale given by Saaty (1999). After determining weights for the dimensions and indicators, normalized weights and ranking have been performed. The consistency is the last step, and the ratio (CR) ensures the consistency of pair-wise comparison. CR value is used to assess the consistency and reliability of the decision group. The formula consists of CR = CI/RI, whereas CI is the consistency index and RI is the random index according to the criteria. (In the study 3 and 4). As a thumb rule, the value of the CR ≤ 0.10, is acceptable, otherwise, values need to be revised to get a consistent matrix. All CR values are less than 0.10 and hence the model is consistent and validated as presented in Table 3.

Table 3. Consistency Check

Model	**RI**	**CR value**	**CR ≤ 0.10**
Dimensions	0,58	0,010	Consistent
Environmental indicators	0,89	0,065	Consistent
Economic indicators	0,89	0,059	Consistent
Social indicators	0,89	0,055	Consistent

4. Findings

The result of the pairwise comparison matrix of the sustainability dimension is presented below in Table 4. The dimensions are ranked economic, social, and environmental respectively, thereby demonstrating the shipyards' primary focus is economic in the face of fierce global competition. The social dimension is the second most significant, depending on the importance of the qualified labor force necessary for modern ship construction processes. In contrast to the study of Sengar, et al. (2018) about Indian ports, in which the environmental dimension was ranked the first due to the strict regulation in the ports, the environmental dimension ranked the lowest in the shipyard because the focus is mainly economic and then social. This finding is similar in the study of Tantan, et al. (2023), where environmental performance was found insignificant. Although many academicians and industrial experts are concerned about environmental issues, actions about amelioration and improvement are decided and implemented regarding economic and social issues.

Table 4. Sustainability Dimensions Pairwise Comparison Matrix

Criteria	ENV	ECO	SOC	Weight	Ranking
ENV	1	1/7	1/3	0,088	3
ECO	7	1	3	0,669	1
SOC	3	1/3	1	0,243	2

Table 5 represents the pairwise comparison of economic dimensions. The profitability (Eco3) ranked first, then the revenue (Eco1) the second. This is aligned with the market condition because a company needs profit and revenue for continuous growth and future investments. Material cost (Eco4) is the third significant indicator that has a direct effect on the profit. As seen in the table green investment (Eco2) has the lowest weight stating that if there is no profit orientation, the shipyard has no interest in any green investment.

Table 5. Economic Performance Indicators Pairwise Comparison Matrix

Criteria	Eco1	Eco2	Eco3	Eco4	Weight
Eco1	1	3	1/3	3	0,219
Eco2	1/3	1	1/9	1/3	0,058
Eco3	3	9	1	7	0,613
Eco4	1/3	3	1/7	1	0,109

The weighting of the social criteria is listed in Table 6. The employee wages and benefits (Soc3) is ranked first among the criteria due to the labor force focus being mainly on the salary. Work accidents (Soc4) come after and represent the critical impact on social issues, whereas the shipyard may confront serious implications about work accidents. Average hours of training per employee (Soc1) is ranked in the third position although training is very important for the quality of work and decreasing the risk of work accidents. The last criterion is the attendance and absence days (Soc3) because the shipyard had a good attendance rate and low cumulative absence days.

Table 6. Social Performance Indicators Pairwise Comparison Matrix

Criteria	Soc1	Soc2	Soc3	Soc4	Weight
Soc1	1	1/7	3	1/3	0,101
Soc2	7	1	9	3	0,592
Soc3	1/3	1/9	1	1/7	0,045
Soc4	3	1/3	7	1	0,262

Table 7 depicts the environmental criteria weighting. Energy consumption (Env1) is ranked first due to its direct impact on cost and profitability. Greenhouse gas emissions (Env4) are the second, stating that the shipyard is willing to decrease emissions. Hazardous waste (Env3) and scrap recycled (Env4) are ranked third and fourth. The shipyard focused on emissions rather than hazardous waste and did not have much interest in scrap recycling due to the lack of profitability and modern production techniques and outsourcing that decreased significantly the scrap during the construction phase.

Table 7. Environmental Performance Indicators Pairwise Comparison Matrix

Criteria	Env1	Env2	Env3	Env4	Weight
Env1	1	7	5	3	0,558
Env2	1/7	1	1/3	1/5	0,057
Env3	1/5	3	1	1/3	0,122
Env4	1/3	5	3	1	0,263

5. Conclusion

Sustainability and sustainable development have gained importance globally. The shipyards where the ships are constructed, maintained, repaired, and dismantled are confronting new regulations, standards, or requirements about environment and sustainability due to the IMO emissions targets or international or local regulatory bodies and administrations. The shipyards are aware of these challenges and act to adapt to new situations. Regarding the incident, this study first aimed to evaluate the weighting of sustainability performance and then the performance indicators of each dimension, environmental, social, and economic respectively.

The findings are summarized in Table 8. It is evident that the shipyards continue to emphasize the economic issues and then social issues of sustainability and sustainable dimension although the environmental issues are usually in the front to discuss. The reason is that shipyards engage in environmental issues but act regarding economic (mainly profit indicators) and social (mainly cost of labor force indicator) issues. The profitability indicator (Eco3) is ranked first position among the other performance indicators, enhancing the argument above. Revenue (Eco2) is in the second rank because it is one of the most important financial metrics that measure the company's performance and growth. Employee wages and benefits (Soc2) is the third indicator in the model and emphasizes the labor force's importance for revenue and profitability. The fourth indicator is Material cost (Eco4) which is also an important variable for profitability. Then comes work accidents (Soc4) because the accident rate has a linear and negative effect on a company's economic performance, Estudillo, et al. (2024)Estudillo, et al. (2024). Energy consumption (Env1) is ranked in the 6th position since shipbuilding is an energy-intensive sector, Vakili, et al. (2021). The other indicators ranking are Scrap recycled (Eco2), Average hours of training per employee (Soc1), Greenhouse gas emissions (Env4), attendance and absence days (Soc3), Hazardous waste (Env3), and Scrap recycled (Env4), respectively.

Table 8. Final Ranking Summary Table

Indicator category	Relative preference weights	Relative rank	Specific indicator	Relative preference weights	Relative ranking	Global preference weights	Global ranking
ECO	0,669	1	Eco1	0,219	2	0,146511	2
			Eco2	0,058	4	0,038802	7
			Eco3	0,613	1	0,410097	1
			Eco4	0,109	3	0,072921	4
SOC	0,243	2	Soc1	0,101	3	0,024543	8
			Soc2	0,592	1	0,143856	3
			Soc3	0,045	4	0,010935	10
			Soc4	0,262	2	0,063666	5
ENV	0,088	3	Env1	0,558	1	0,049104	6
			Env2	0,057	4	0,005016	12
			Env3	0,122	3	0,010736	11
			Env4	0,263	2	0,023144	9

In conclusion, the shipyards evaluate environmental issues from economic and social views since shipyards confront a global competition Mickeviciene (2011) and challenge to guarantee of qualified labor force availability with minimum accident, Barlas, et al. (2018). Surprisingly, environmental dimensions are not at the forefront because shipyards are not obliged to respect international standards like ports and ships sailing on the overseas.

References

Ait Allal, A., Mansouri, K., Youssfi, M., Qbadou, M., and El Had, K. Shipyard Impact Assessment for a Sustainable Ships' Maintenance and Repair Activity in West Africa. In: *Conference*, Location, pp.593-606 , 2020.

Ali Azhar, N. H., Fadillah Putra, Andi Kurniawan, Gde A Prabhawatya Poundra Concept of Multi-Orientation Shipyard Industry Development Environmentally Friendly and Sustainable, *International Journal of Marine Engineering Innovation and Research* 9(1)(pp.171-178, 2024.

Ali, F., Sriram, P. K., Alfnes, E., Brett, P. O., and Fet, A. M. Remanufacturing as a Sustainable Strategy in Shipbuilding Industry. In: *Conference*, Location, pp.232-239, 2015.

Baihaqi, I., Lazakis, I., and Kurt, R. E. Development of a novel integrated value engineering and risk assessment (VENRA) framework for shipyard performance measurement: a case study for an Indonesian shipyard, *Ships and Offshore Structures* 19(8), pp.1118-1133, 2023.

Barlas, B., and Izci, F. B. Individual and workplace factors related to fatal occupational accidents among shipyard workers in Turkey, *Safety Science* 101(pp.173-179 ,2018.

Estudillo, B., Carretero-Gómez, J. M., and Forteza, F. J. The impact of occupational accidents on economic Performance: Evidence from the construction, *Safety Science* 177(2024

Fitriadi, F., and Ahmad Faisal Mohamad, A. Optimizing Traditional Shipyard Industry: Integrating VSM and Sustainability Indicators for Continuous Improvement, *Journal of Advanced Research in Applied Sciences and Engineering Technology* 46(2), pp.155-170 ,2024.

Fitriadi, F., and Ayob, M. Continuous improvement strategy in traditional shipyard industry: A holistic approach towards sustainability, *Journal of Optimization in Industrial Engineering* 16(pp.255-268, 2023.

Janson, D. I. *THE DEVELOPMENT OF A GREEN SHIPYARD CONCEPT*. University of Twente Faculty of Engineering Technology, Construction Management & Engineering. 2016

Jebbor, I., Benmamoun, Z., and Hachimi, H. Optimizing Manufacturing Cycles to Improve Production: Application in the Traditional Shipyard Industry, *Processes* 11(11), pp.3136 ,2023

Kocak, S. T., Helvacioglu, I. H., and Kahyaoglu, N. A Novel Productivity Evaluation Method for Shipyards. In: *SNAME Maritime Convention, Conference*, Location, 2023

Koray, M. Prioritizing Shipyard Conversion Requirements Regarding Green Ship and Green Shipyard Concept, *Transactions on Maritime Science* 12(2), 2023

Mickeviciene, R. Global competition in shipbuilding: trends and challenges for Europe, *The Economic Geography of Globalization* pp.201-222, 2011.

Önal, M. Evaluation of shipyard operation processes with cradle-to-gate life cycle assessment based on material consumption rates for an aluminum and steel yacht, *Ships and Offshore Structures* 18(1), pp.1-7 2022

Papamanolis, G., Giannakopoulos, E., and Kalavrouziotis, I. K. Shipyards waste and sustainable management in Greece: case study, *Desalination and Water Treatment* 127(pp.90-96 ,2018.

Ramirez-Peña, M., Abad Fraga, F. J., Salguero, J., and Batista, M. Assessing Sustainability in the Shipbuilding Supply Chain 4.0: A Systematic Review, *Sustainability* 12(16), pp.6373, 2020.

Saaty, T. L. Basic theory of the analytic hierarchy process: how to make a decision, *Revista de la Real Academia de Ciencias Exactas Fisicas y Naturales* 93(4), pp.395-423 ,1999.

Saaty, T. L. That is not the analytic hierarchy process: What the AHP is and what it is not, *Journal of Multi-Criteria decision analysis* 6(6), 1997

Sengar, V. S., Garg, C. P., and Raju, T. B. Assessment of sustainable initiatives in Indian ports using AHP framework, *International Journal of Business Excellence* 16(1), pp.110-126, 2018.

Strandhagen, J. W., Buer, S.-V., Semini, M., Alfnes, E., and Strandhagen, J. O. Sustainability challenges and how Industry 4.0 technologies can address them: a case study of a shipbuilding supply chain, *Production Planning & Control* 33(9-10), pp.995-1010 2020

Şahin, V., and Bilgili, L. A Literature Analysis on Environmental Impacts and Relevant International Legislation of Shipyards, *Naše more* 71(1), pp.38-44 ,2024.

Tantan, M., and Akdağ, H. C. The effect of green supply chain management practices on the sustainability performance of Turkish shipyards, *Sustainability* 15(8), pp.6677, 2023.

Tantan, M., and Camgöz-Akdağ, H. Sustainability concept in Turkish shipyards, *WIT Trans. Ecol. Environ* 241(pp.269-281, 2020.

UNCTAD *Core SDG Indicators for Entity Reporting: Booklet 1 - TUTORIAL SESSIONS on Economic Indicators*. UNCTAD, 2020.

UNCTAD *Core SDG Indicators for Entity Reporting: Booklet 2 - TUTORIAL SESSIONS on Environmental Indicators*. 2020

UNCTAD *Core SDG Indicators for Entity Reporting: Booklet 3 - TUTORIAL SESSIONS on Social Indicators*. 2020

Vakili, S., Schönborn, A., and Ölçer, A. I. Application of the transdisciplinary shipyard energy management framework by employing a fuzzy multiple attribute group decision making technique toward a sustainable shipyard: case study for a Bangladeshi shipyard, *Journal of Shipping and Trade* 7(1), 2022

Vakili, S., Schönborn, A., and Ölçer, A. I. The road to zero emission shipbuilding Industry: A systematic and transdisciplinary approach to modern multi-energy shipyards, *Energy Conversion and Management: X* 18(2023

Vakili, S. V., Ölçer, A. I., and Schönborn, A. The Development of a Transdisciplinary Framework to Overcome Energy Efficiency Barriers in Shipbuilding: A Case Study for an Iranian Shipyard, *Journal of Marine Science and Engineering* 9(10), pp.1113 ,2021.

Vakili, S. V., Ölçer, A. I., and Schönborn, A. Identification of Shipyard Priorities in a Multi-Criteria Decision-Making Environment through a Transdisciplinary Energy Management Framework: A Real Case Study for a Turkish Shipyard, *Journal of Marine Science and Engineering* 9(10), 2021.

Woo, J. H., Zhu, H., Lee, D. K., Chung, H., and Jeong, Y. Assessment Framework of Smart Shipyard Maturity Level via Data Envelopment Analysis, *Sustainability* 13(4), pp.1964, 2021.

Yugowati Praharsi, M. A. J. i., Gaguk Suhardjito, Hui-Ming Wee. Modeling of an Industrial Ecosystem at Traditional Shipyards in Indonesia for the Sustainability of the Material Supply Chain. In: *2020 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM), Conference*, Location, 2020

Biographies

Mehmet Tantan is a part-time lecturer in the Department of Naval Architecture and Marine Engineering at Istanbul Technical University. His academic credentials include a PhD in sustainability from the Business Engineering program at Istanbul Technical University, an MBA from Koc University, and a BA from the Naval Architecture and Marine Engineering Faculty. He conducts projects on sustainable development and shipbuilding, unmanned maritime vehicles and their impact on the labor force market. He is currently employed in the private sector.

Hatice Camgöz Akdağ is a Professor and Chair of the Business Engineering Department at Istanbul Technical University. PhD in the field of quality, from Engineering Faculty, Brunel University, UK; BA from Management Department, Bosphorus University, Turkey. Professor at Istanbul Technical University, Chair of the Department of Management Engineering at ITU. Camgöz Akdağ conducts projects, researches, and provides consultancy on the topics of Sustainability, Sustainability Management, Sustainability reporting and ESG indices, value-added activities, lean systems, lean healthcare applications, healthcare quality, clinic process maps, patient pathways, improving breast cancer departments' patient flow, machine learning for breast cancer diagnosis and patient/survivor follow up. She has a number of publications on the subject of quality, sustainability, Six Sigma, and benchmarking and four best paper awards from international conferences. As well as has also won the Doctor Club Awards 2021: Health Professional of the Year Awards -Innovative Health Professional of the Year". Finally, she is the founder and coordinator of the ITU-continuous education center- "Sustainability Management Specialization Certificate Program".