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Integrating Ship Recycling Facility into Existing Shipyard: A Study of Malaysian Shipyard

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ABSTRACT

Ship recycling in Malaysia is an unknown business as no dedicated ship recycling yard is currently operated in this country. Most Malaysian shipowners send their end-of-life (EOL) ships to prominent ship recycling yards in Pakistan, India, and China, which are key players in the global ship recycling industry. Due to various factors, establishing a proper ship recycling facility for Malaysia is challenging. One issue that arises is the ability of Malaysian yards to offer competitive EOL ship prices, which can be achieved by increasing the revenue or lowering the ship recycling process costs. It will allow Malaysian recycling players to offer a high price to ship owners and attract them to recycle their ships locally. This paper studies the potential of an integrated ship recycling facility for a Malaysian shipyard. A medium size shipyard situated at Chukai, Terengganu, was selected as a case study. The facility analysis was performed to determine share resources, and a revised layout was proposed. The prospect of ship recycling facility integration in Malaysian shipyards was discussed and summarised. The result analysis signifies that the shipyard facility can be adequately shared for ship recycling activity, and no major change is required in the overall shipyard layout. Lastly, the findings suggest that an integrated ship recycling facility is feasible for a Malaysian shipyard.

1. Introduction

The data from [1] shows that for the past ten years, about 89 Malaysia flagship vessels were sent to foreign yards for recycling, mainly from a sizeable number of ships, including containerships and tankers. Few, if any, Malaysian yards are involved in breaking large, ocean-going vessels and mainly involve medium to small size vessels. Most yards in Malaysia undertake the design, building,

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repairing, refurbishing, retrofitting, conversion, and modification of ships and marine engineering structures. The existence of ship recycling activity in Malaysia is still considered as a ship breaking rather than ship recycling or a place for cutting parts of a ship by using the beaching method without concerning the environment and safety workers aspect. Most ship-breaking operators in Malaysia didn't have a proper yard facility and usually performed their dismantling activity on a case basis to cater operations from ship salvage or shipwreck. Generally, it will be carried out by a third-party operator without a proper ship recycling facility and usually performs their project using a rented yard area.

Many previous works were done to improve the safety, health, and environmental aspect of ship recycling yards to comply with international rules and regulations [2-8], for example, a design of green ship recycling by Sunaryo [9] has proposed a yard design including a list of facilities required by ship recycling yard to be operated as a green ship recycling yard. Similar works were also done by Fachry [7] and Fariya [5] who work on environmentally friendly ship recycling yards specifically for recycling general cargo ships, tug boats and barge and design sustainable ship recycling yard maximum capacity of 25,000 DWT respectively. Further review on ship recycling yard design including material flow process and facility layout can be referred from Samsudin [10]. However, their works focus on dedicated ship recycling yards, which may incur high costs for Malaysia to implement, considering Malaysia's nature in ship recycling activity.

No effort was seen to establish a ship recycling yard in Malaysia can be understood from the economic constraint due to the fact that Malaysia cannot compete with the low labour cost of the leading nations in ship recycling and the lack of incentives for local yards to take part in this unattractive business [11]. Due to the recycling cost restrictions, some of these EOL ships will be turned into artificial reefs or left as abandoned ships, which might harm the environment. Conventional green ship recycling yards are known to be less competitive, whereas substandard ship recycling yards are hindered by health and environmental issues. As a result, the green ship recycling operation is cost-ineffective compared to substandard ship recycling yards. Integrating ship recycling activity into an existing conventional shipyard has been recently discussed, and significant benefits are highlighted [2,8,12]. Zainol [8] investigates the interaction between a conventional shipyard and a ship recycling yard in terms of operation, facility, and layout and finds that several significant similarities can provide a ship recycling with some ready use resources from a conventional shipyard. The shipbuilding industry of Malaysia is getting larger, and shipbuilders are adapting to the latest technology [13].

The ship recycling industry consistently faces serious internal and external financial constraints to keep it competitive and environmentally friendly. The decision by the ship owner on which recycling facilities to use will centre around price and location. Malaysian ship recycling needs to stay competitive to attract shipowners and prevent them from being sent their ships to a third-world country. These, however, depend on Malaysia's ability to keep costs low and face its competitive position in the international ship recycling market. Similarly to the shipyard industry, providing a proper and green compliance ship recycling facility is capital-intensive with large investments [14]. Developing a new ship recycling yard is costly and will face several constraints, for example, topography characteristics and availability of location to the sea, accessibility to supporting industries, acceptance of international law regulations over domestic, etc. Therefore, utilisation of existing shipyard facilities could be a good step and achieved through integration of ship recycling facility into existing shipyard. The integration of ship recycling in existing shipyards could enrich the ship recycling economy through resource sharing and circular economy, as reviewed in the following.

1.1 Resources Sharing

According to Gunbeyaz [15] problems that affect ship recycling performance are manpower, lifting equipment and yard layout. Ship recycling is popular in third-world countries due to cheap labour, making it more competitive than others. Previously, it was profitable to carry out operations manually rather than using high-cost machinery due to cheap and abundant labour. However, this brings the issue of a high rate of worker fatalities resulting from poor labour management where labourers are exposed to a harsh work environment, the predominance of manual processes and lack of protective clothing [16]. The complexity of ships with various safety and environmental issues has made the ship breaking process challenging [17]. Compared to the conventional shipyard, the major challenge in ship recycling activity is it possessed high environmental and health risks to workers. On the other hand, in a labour-intensive industry like ship recycling, labour costs become a crucial and sensitive issue [18]. Ship owners and shipyards are always very keen on reducing labour costs. Any effort to reduce labour costs will positively impact the economy of the yard for both segments, which can soon be transformed into better cost savings for the owner and higher productivity for a shipyard, later enhancing shipyard competitiveness.

Chanabe [19] underlines the possibility of combining the two activities within a single shipyard and addressing its performance. The visibility only can be realised through a balanced share of some facilities and resources. According to Hossain [16] drydock facility provides better environment compliance in which dismantling activities are performed therefore the risk of environmental pollution can be minimised. Dry dock facility is the safest and cleanest method of ship recycling [20]. Nevertheless, the drydock construction and maintenance costs are relatively higher than other docking facilities and are rarely used in ship recycling yards. Integrating a ship recycling yard would provide ship recycling a ready use of some of the main facilities from the existing shipyard as mentioned previously. Additionally, the existence of technology in the shipyard will be beneficial in facilitating the ship recycling process especially for overcoming the issue of the unsafe beaching method.

1.2 Circular Economy

The accessibility of a ship recycling facility in the existing shipyard could improve the circular economy within the shipyard. Like the shipbuilding and ship repair industry, the ship recycling industry is also driven by industry cycles, as illustrated in Figure 1.

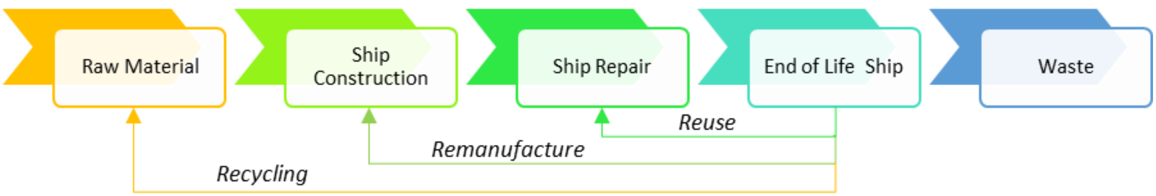

Fig. 1. Context of circular economy in the shipping industry

The opposed economic cycle between shipbuilding and ship repair to ship recycling will ensure the balance utilisation of shipyard resources and reduce waste. In case of low activity in the shipbuilding activity due to the slow economy and high freight rate, the number of ships to be recycled will increase. The continued imbalance between the demand and supply of ships brings the freight rates down to such low levels that ship owners cannot operate their ships profitably. Furthermore, increased scrap metal prices will encourage ship owners to scrap their ships as it will be more financially viable than operating the ship [21] , which later increases demand for the ship recycling segment and offers jobs to shipyards. As a result, it helps the shipyard to reduce the tension between activities like low demand for shipbuilding and repair by focusing on ship recycling activity to stay competitive. Similar situations happen when the scrap metal prices are down, and scrapping activities will decrease. As a result, ship owners will avoid scrapping their ships and continue to operate their old ones, which is expected to increase ship repair segment demand.

A combination of a suitable product mix made of high-value ships and appropriate repair activities signifies the assurance of several shipyards toward preserving survivability [13,19]. This could be one of the prospective strategies to ensure that the shipyard is economically viable and maintain survivability. For example, to recapture the losing market share in the ship recycling sector, the industry must upgrade its work process and provide recycled products with high-value addition. High-value-added recycled steel, equipment and other products would command a premium in the market, which would offset the additional cost of undertaking the environment [22]. This can be further applied to an integrated yard where reused items from recycling can be directly sent to ship repair as refurbished spare part items. In fact, recovering components and materials for reusing would give advantages to the ship repair segment [5]. This study aims to incorporate ship recycling facilities into existing shipyards and carry out facility analysis to determine the potential of a Malaysia shipyard to run a ship recycling activity.

2. Methodology

Figure 2 illustrates a research methodology process. It starts with determining the design requirements for ship recycling facilities, followed by collecting data through published data and field visits from selected shipyards. The published data is quoted from different sources are mainly refers to standard practice. The field survey was carried out to collect relevant data and identify an existing condition, including related information. Analysis of the existing condition of the shipyard facility was performed to determine the number of facilities available, including its capacity and size. Facility analysis was carried out to identify the similarity level between the existing shipyard and ship recycling facilities suitable for sharing purposes. Redesign of the layout with new facilities was proposed to be added to ensure the shipyard can support ship recycling activity according to green standards such a rule provided by IMO on Basel Convention (BC) and Hong Kong Convention [9,21]. Constraints and suggestions for future works are also discussed at the end of this paper.

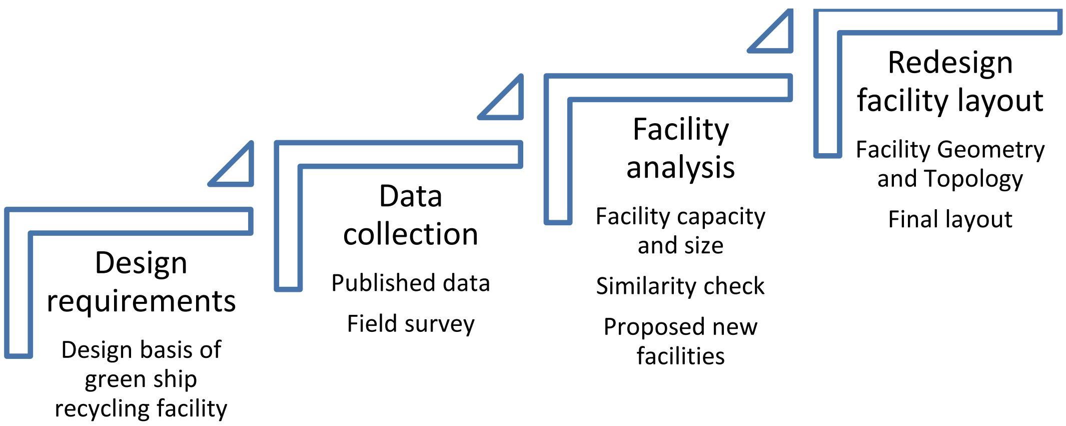

Fig. 2. Methodology flowchart

3. Design Requirement of Ship Recycling Facility

The ship recycling facility shall be able to support the ship recycling process by removing hazardous and liquid materials, machinery, electrical and electronic materials, and items such as fittings and interior parts, followed by cutting down the entire ship's structure before recycling useable or disposal items take place. In the matter of green ships, recycling yards are restricted by international regulations and requirements, for example, the Basel Convention (BC) and Hong Kong Convention (HKC) [23], to ensure it is safe for the workers and environmentally friendly. For this study, a green ship recycling facility model [9] was taken as a design basis. The common facilities that need to be considered and some of the essential facilities are described in Table 1. The capacity for ship recycling operation is planned according to standard shipyard capacity.

Table 1
Green ship recycling facilities [9]

Facility Unit	Description
Primary cutting area	It is an area where the ship is being cut into a module or block. All hazardous materials and chemicals are removed during this process. All machinery, outfitting, and electrical systems can be decommissioned and transported to the storage facility. This process may vary slightly depending on the location of the cutting area, either at a berth, slipway, or docking area.
Secondary cutting area	A place where ship parts are cut into a suitable size and later relocated to structural part storage area using forklifts. This cutting area should be a fully protected area with an proper drainage system so that liquid wastes will not flow into the sea.
Structural part storage open area	A place where all recycled ship parts are stored after being cut into small plates classified according to their types
Machinery and outfits storage	In this area, all machinery, such as main engines, pumps, generators, and outfits material from the ship are sort and store.
Electric and electronics storage	A place where all recycled electrical and electronic equipment and cables will be stored before further recycling process
Hazardous and chemical storage	A place to temporarily store solid hazardous wastes, including asbestos-containing materials, and three different liquid storage tanks dedicated for fuel oil, lubrication oil, and dirty water, respectively
Scrapping work facilities warehouse	A place to store scrapping work equipment and tools, flame cutting and equipment, scaffoldings, hoists and tackles, etc.
Facility Garage	A place to store safety appliances and facilities, fire safety appliances, oil spill prevention, and recovering equipment, etc.

4. Facility Analysis

An investigation has been conducted on the selected shipyard as a case study situated at Chukai, Terengganu, as shown in Figure 3. This shipyard involves in ship repair and maintenance and shipbuilding operations. The size of a yard is normally determined by the size and complexity of the ships being built and repaired. This case study shipyard has approximately 48000 m^2 in size and lifting capacity in yards is capable of catering to various ship sizes up to 2000 tonnes.

Fig. 3. Case study shipyard

According to Kyaw [24], typical shipyards should have specialised workshops and spaces such as mechanical, electrical, steel sandblasting, docking, painting, and others that can be categorised as the main facilities.

Table 2 shows a list of available facilities in the case study shipyard. The main infrastructure mainly laid on its docking facilities consists of a dry dock and three slipways with a maximum upslip capacity of 1000 tonnes. There are four hangars available which have layout sizes of 1464 m^2 each. There are only two workshops available namely engineering workshop and carpenter work. Engineering workshop is a centralised workshop where all essential machinery is placed. The main store of this shipyard is used to store various equipment and ship parts with a size of about 30m x 18m.

Table 2
Existing shipyard facility

No	Facility	Legend	Size (m)	Area (m^2)	Reference
1	Slipway 1	A	73 x 14	1022	Field survey
2	Slipway 2	B	75 x 15	1125	Field survey
3	Dry dock	C	90 x 18	1620	Field survey
4	Slipway 3	D	80 x 24	1920	Field survey
5	Hardstand	E	72 x 52	3744	Field survey
6	Oil and gas hangar	F	61 x 24	1464	Field survey
7	Shipbuilding hangar	G	61 x 24	1464	Field survey
8	Ship repair hangar	H	61 x 24	1464	Field survey
9	Store	I	30 x 18	540	Field survey
10	Carpentry workshop	J	28 x 28	784	Field survey
11	Shipbuilding hangar	K	61 x 24	1464	Field survey
12	Engineering workshop	L	37 x 18	666	Field survey
13	Administration building	M	50 x 15	750	Field survey

Facility similarities checklist were carried out and presented in Table 3. Facility similarities checklist is used to determine which shipyard facility among having similar function to ship recycling facility. From the checklist, it was observed that several prominent ship recycling facilities are available and can be shared with common facilities in a current shipyard. As an example, the primary cutting area can be shared with a slipway or drydock facility. Meanwhile, secondary cutting can be done using three available hangars. Primary cutting and secondary cutting processes can be performed within the same facility area for medium to small-range vessels, such as in a shipyard hangar. All recycled ship parts that have been cut into small plates will utilise a free space of a hardstand area. Scraping work facilities and facilities garages generally used to store essential equipment and tools are not required as the engineering workshop provided all common facilities.

Table 3
Facility similarity checklist

No	Ship Recycling Facility Unit	Shipyard Facility Unit
1	Primary cutting area	A, B, C, D
2	Secondary cutting area	F, G, H
3	Structural part storage open area	E
4	Machinery and outfits storage	×
5	Electric and electronics storage	×
6	Hazardous and chemical storage	×
7	Scrapping work facilities warehouse	L
8	Facility Garage	L

Despite potential facility sharing, some compulsory facilities, such as storage for dismantled materials and wastes, are unavailable. A facility for storing useful materials such as machinery, outfits and electrical equipment, and other equipment that can be reused and recycled needs to be provided. Most importantly, the shipyard must provide a storage tank to temporarily store any chemicals, materials, and liquids before further processing in separate facilities to prevent any environmental issues [25]. The additional required facility size is determined based on a comparative analysis with similar facilities used in ship recycling yards from published literature [9,26,27] as shown in Table 4. Hazardous and chemical waste storage is crucial and must have a facility in a ship recycling operation. This temporary storage shall possibly be located near to primary cutting to reduce the risk of handling hazardous materials. The structural part can be safely placed in an open area in any free space at the steel stockyard or hardstand area. The case study shipyard has no dedicated stockyard as plates and sections stocks usually store in the hangar. Alternatively, a new place can be allocated if sufficient space is available.

Table 4
Proposed new additional facilities

No	Facility	Legend	Size (m)	Area (m^2)	Availability	Reference
1	Hazardous and chemical waste storage	N	20 x 20	400	New	[26]
2	Structural part storage open area	O	50 x 30	1500	New	[9]
3	Machinery and outfits storage	P	30 x 30	900	New	[9]
4	Electric and electronics storage	Q	20 x 10	200	New	[9]

5. Redesign of Facility Layout

Integrating ship recycling facilities into the existing shipyard required a redesign of the facility layout as the facility arrangement resulting from the integrating process would significantly change the existing workflow. Redesign of layout relies on several factors: the size of the ship, work process, available space, number of machineries, material handling, and construction method employed. All the factors mentioned above must be considered when modifying the existing layout to achieve an efficient work process. The information on facility geometry and topology is presented in Table 5. Choi [28] asserted a 'Free' in geometry and topology column indicates its relative location and size is not constrained while 'Fixed' indicates its geometry and topology is constrained or pre-determined.

In this case, the entire shared basis facilities are considered fixed positions whereby all additional facilities are free to be allocated or resize.

Table 5
Facility geometry and topology

No	Description	Shared Facilities	Geometry	Topology
1	Primary cutting area	Dry dock/Hangar	Fixed	Fixed
2	Secondary cutting area	Hangar	Fixed	Fixed
3	Structural part storage open area	N/A	Fixed	Fixed
4	Machinery and outfits storage	N/A	Free	Free
5	Electric and electronics storage	N/A	Free	Free
7	Hazardous and chemical waste storage	N/A	Free	Free
8	Scrapping work facilities warehouse	Engineering workshop	Fixed	Fixed
9	Facility garage	Engineering workshop	Fixed	Fixed

An example of the revised layout is shown in Figure 4. Layout design is not subject to major changes due to several main facilities already established in the shipyard. Only four additional facilities with a total space taking up about 3000 m^2 were added and merged into the existing yard to enable a shipyard adequately supported to run the ship recycling process. The percentage of space utilisation for new facilities is calculated at approximately 7% of total shipyard space.

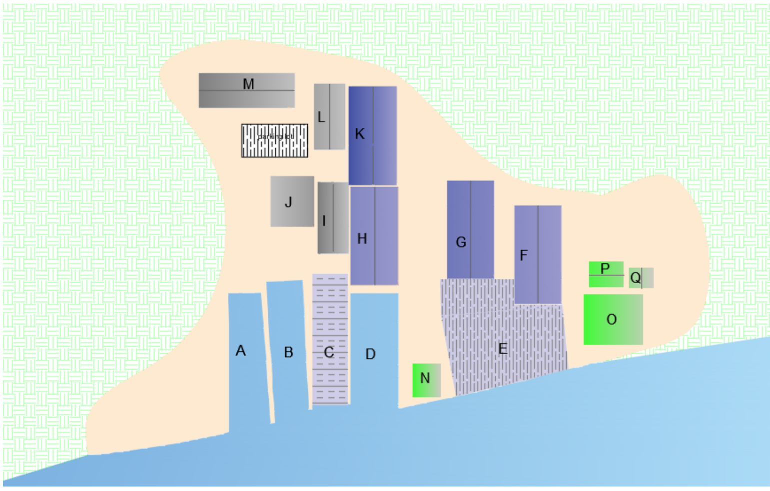

Fig. 4. Revised layout

6. Discussion

One of the issues in adopting new ship recycling segments is the limited capacity constraints in sharing facility environment. While shipyard facilities and resources are shared among multiple segments being run simultaneously, the need for continuous improvement of ship recycling operation within a concurrent shipyard requires a very complex decision-making process. For that subject, many different requirements and constraints must be discussed to be able to find covenant solutions, and tasks related to other operations must also be considered and well planned when establishing a ship recycling operation as many projects concurrently run at a shipyard. Another constraint is cost, even though investing in expanding the existing shipyard infrastructure to accommodate ship recycling facilities outweighs building a new ship recycling yard, it should be emphasised that investing in expanding cost is still a major concern. One way this could be done is to enter into a concessioner agreement with any existing shipyards stakeholder to allow for investment in the ship recycling segments. Furthermore, they should be ready to invest in capacity improvement to keep the current market share of shipyard segments while allowing for new ship recycling segments markets.

Space is considered the most critical resource in a shipyard [29]. Integrating ship recycling facility will utilise existing space, and potential space conflict may occur when different operation segments run concurrently, especially at a peak schedule. This can create workflow tension between segments hence the efficient allocation of space must be appropriately planned to reduce the risk of project delays resulting from space constraints. In addition, each segment has its own characteristic of facility areas that need to be considered. Configuration of such areas can be challenging due to the specific characteristics of different segments, especially when handling sizeable products that require large areas. Investigating such problems starts by giving priority to some significant reasons. Firstly, the existing shipyard limited size and shape to change as its demographic requirement is to be close to the sea. Secondly, the existing shipyard layout is restricted to change due to the fact removing or relocating an established large infrastructure likely to incur high costs and lastly, different operation segments mean deviation in facility area requirements. Due to mentioned reasons, the layout arrangement of the ship recycling facility needs to be carefully planned out to avoid any disturbance to existing facilities.

Another critical concern in ship recycling is ensuring the proper handling of hazardous waste. A proper guideline must be established according to international guidelines. Current practice shows that ship repair yards would have a better experience as they are involved in removing chemical waste from a ship during repair activity however, some yards may not have experience if referring to a dedicated shipbuilding yard. Malaysian shipbuilding and ship repair yard are sufficiently advanced in terms of skilled workers and facilities and integrating ship recycling activity would not have any major problem with the workload. To date, the industry is more involved in improving its ability in financing, marketing, management, and technology however, safety, health and the environment are not given serious concerns. For instance, the issue of inadequately skilled labour could be a resort as existing yard workers will be able to support the activity in the ship recycling segment however demand serious management and engineering attention. Proper training for yard personnel must be provided. Skilled management and engineers with ship recycling experience are therefore essential.

7. Concluding Remarks

This study investigates the potential of running a ship recycling operation using an existing shipyard. Integrating a ship recycling facility into an existing marine shipyard offers several advantages over a dedicated ship recycling yard alone. The main contribution of this study is given from the analysis of ship recycling facility integration in Malaysia shipyard. Facility analysis of the case study shipyard discovered a significant number of prominent facilities could be shared to achieve cost reduction benefits in terms of lower ship recycling facility costs incurred via resource sharing and the potential of generating new income thru the circular economy. The number of new facilities to be established is minimum, with four (4) from the total of nine (9) core ship recycling facilities, and no obstruction to existing infrastructure was observed from the revised layout. Space utilisation within the shipyard is well tolerated, with only 7% of the total shipyard size, and size expansion is not required. The constraint of conventional green ship recycling yards to maintain competitiveness over the substandard ship recycling yard could also be reduced. In fact, it can be a new business model that keeps both segments competitive. This standardisation will only be achieved through improvements in equipment, infrastructure, and the well-being of workers. Health and environmental issues can be significantly improved when used and supported by a well-established facility from the existing yard. However, for this proposed approach to be accepted as an alternative solution and considered for implementation in ship recycling in Malaysia, yard stakeholder must study their capability in terms of facilities and equipment as well as skilled manpower to run on ship recycling segments. Due to the difficulty of finding information related to ship recycling practices in Malaysia, this study is relatively preliminary based on the mix of information collected from field surveys and secondary sources. As such, further work is required to determine Malaysia yards' readiness to apply such an approach.

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References

[1] Platform, NGO Shipbreaking. "Press release: platform publishes list of ships dismantled worldwide in 2018." (2019).
[2] Du, Zunfeng, Haiming Zhu, Qingji Zhou, and Yiik Diew Wong. "Challenges and solutions for ship recycling in China." *Ocean Engineering* 137 (2017): 429-439. https://doi.org/10.1016/j.oceaneng.2017.04.004
[3] Hiremath, Anand M., Sachin Kumar Pandey, and Shyam R. Asolekar. "Development of ship-specific recycling plan to improve health safety and environment in ship recycling yards." *Journal of cleaner production* 116 (2016): 279-298. https://doi.org/10.1016/j.jclepro.2016.01.006
[4] Sunaryo, Sunaryo, Ananda Rizkytama Hanura, and Fariz Hussein. "Feasibility study on the financial aspect of green ship recycling yard business model." In *AIP Conference Proceedings*, vol. 2227, no. 1. AIP Publishing, 2020. https://doi.org/10.1063/5.0001072
[5] FARIYA, Siti, Ketut SUASTIKA, and M. Sholikhan ARIF. "Design of Sustainable Ship Recycling Yard in Madura, Indonesia." In *INTERNATIONAL SEMINAR ON MARINE TECHNOLOGY*, p. 129. 2016.
[6] Fariya, S., S. A. Gunbeyaz, R. E. Kurt, S. Sunaryo, and E. B. Djatmiko. "Developing sustainable green ship recycling facilities in Indonesia: Investigation of current situation." In *Sustainable Development and Innovations in Marine Technologies*, pp. 439-445. CRC Press, 2019. https://doi.org/10.1201/9780367810085-58
[7] Sunaryo, Sunaryo, and Aditya Fachry Indianto. "Environmentally friendly ship recycling yard design for general cargo ship up to 30.000 DWT and ship-sets: Tug and barge." In *AIP Conference Proceedings*, vol. 2227, no. 1. AIP Publishing, 2020. https://doi.org/10.1063/5.0001028
[8] Zainol, I., C. L. Siow, A. F. Ahmad, M. R. Zoolfakar, and N. Ismail. "Hybrid shipyard concept for improving green ship recycling competitiveness." In *IOP Conference Series: Earth and Environmental Science*, vol. 1143, no. 1, p. 012021. IOP Publishing, 2023. https://doi.org/10.1088/1755-1315/1143/1/012021
[9] Sunaryo, Sunaryo, and Dovan Pahalatua. "Green ship recycle yard design." *Journal of Naval Architecture and Marine Engineering* 12, no. 1 (2015): 15-20. https://doi.org/10.3329/jname.v12i1.20450
[10] Samsudin, Mohamad Suhaimi, Ismail Zainol, Zulzamri Salleh, Siow Chee Loon, and Nuraihan Ismail. "Design of Green Ship Recycling Yards: A Review." *Advanced Materials and Engineering Technologies* (2022): 183-192. https://doi.org/10.1007/978-3-030-92964-0_18
[11] Khalid, Nazery. “Green agenda in maritime sector,” *The Star Malaysia*, 2013.
[12] Ocampo, Euler Sánchez, and Newton Narciso Pereira. "Can ship recycling be a sustainable activity practiced in Brazil?." *Journal of Cleaner Production* 224 (2019): 981-993. https://doi.org/10.1016/j.jclepro.2019.03.173
[13] Mokhtar, Ahmad Alliff Anuar, Amir, Mohamad Abu Ubaidah, Hafizah, Ainnur and Abdul Halim, “Technology foresight in modular construction shipbuilding industries: The Case of Malaysia’s Shipyard,” *International Journal of Engineering & Technology* 7, no. 29 (2018): 4.
[14] Rizwan, Thaib, Ayana Rizki, Umiralaska Salsabila, Muhammad Muhammad, Riyan Maulana, Makwiyah A. Chaliluddin, Junaidi M. Affan, Razali Thaib, Suhendrianto Suhendrianto, and Yusrizal Muchlis. "Literature review on shipyard productivity in Indonesia." *Depik* 10, no. 1 (2021): 1-10. https://doi.org/10.13170/depik.10.1.18712
[15] Gunbeyaz, Sefer A., Rafet E. Kurt, and Osman Turan. "Designing efficient contemporary ship recycling yards through discrete event simulation." *Transport Research Arena (TRA) 2018* (2018).
[16] Hossain, K. A. "Ship recycling practice and annual reusable material output from Bangladesh ship recycling industry." *Journal of Fundamentals of Renewable Energy and Applications* 7, no. 5 (2017): 6. https://doi.org/10.26717/BJSTR.2017.01.000428
[17] Rabbi, Hasan Ruhan, and Aevelina Rahman. "Ship breaking and recycling industry of Bangladesh; issues and challenges." *Procedia engineering* 194 (2017): 254-259. https://doi.org/10.1016/j.proeng.2017.08.143

[18] Kr Dev, Arun, and Makaraksha Saha. "Modeling and analysis of ship repairing labor." *Journal of Ship Production and Design* 32, no. 04 (2016): 258-271. https://doi.org/10.5957/jspd.2016.32.4.258

[19] Chabane, Hamid. "Design of a small shipyard facility layout optimised for production and repair." In *Proceedings of Symposium International: Qualite et Maintenance au Service de l'Entreprise*. 2004.

[20] Raju, M. S. P., and A. Prem Anandh. "Sustainability in Ship Recycling Process." In *Proceedings of International Conference on Sustainable Computing in Science, Technology and Management (SUSCOM), Amity University Rajasthan, Jaipur-India*. 2019.

[21] Jain, Kanu Priya. "Improving the competitiveness of green ship recycling." (2017).

[22] Reddy, N., and N. Manoharan. "Ship recycling: an important mile stone for India." *Indian Journal of Science and Technology* 7, no. S6 (2014): 15-21. https://doi.org/10.17485/ijst/2014/v7sp6.10

[23] Jain, Kanu, and Jeroen Pruijn. "An overview of the global ship recycling industry." *Reference Module in Materials Science and Materials Engineering* (2017): 1-22. https://doi.org/10.1016/B978-0-12-803581-8.10396-0

[24] Kyaw, Aung Ye, Djauhar Manfaat, and Buana Ma'ruf. "An Interesting study of capacity improvement of a shipyard in Myanmar." *IPTEK Journal of Proceedings Series* 3, no. 2 (2017): 114-119. https://doi.org/10.12962/j23546026.y2017i2.2307

[25] Mikelis, Nikos. "The Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships." In *UNCTAD Multi-Year Expert Meeting on Transport and trade Facilitation*. 2010.

[26] Jayaram, S. "Development of strategies for efficient recycling of ships, doctoral diss." *Cochin University of Science and Technology, Kochi, India* (2018).

[27] Litehauz, "Feasibility Study For Ship Dismantling," 2013. https://www.informea.org/en/2013-feasibility-study-ship-dismantling

[28] Choi, Minjoo, Sang Hyun Kim, and Hyun Chung. "Optimal shipyard facility layout planning based on a genetic algorithm and stochastic growth algorithm." *Ships and Offshore Structures* 12, no. 4 (2017): 486-494. https://doi.org/10.1080/17445302.2016.1176294

[29] McPherson, Deanne B., Christopher B. Ligetti, Daniel A. Finke, and Drew Anderson. "Integrated Capacity Planning System for Shipyards." In *SNAME Maritime Convention*, p. D021S006R004. SNAME, 2015.