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CURRENT PRACTICES AND INFLUENTIAL FACTORS OF GREEN SHIPBUILDING AND SHIP REPAIR: AN EXPLORATION ON RESOURCE PLANNING IN MALAYSIAN SHIPPING INDUSTRY

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ABSTRACT

Environmental pollution in the maritime sector has become an urgent concern, driving towards the emergence of Green Shipbuilding and Ship Repair (Green SBSR) as a strategic strategy to minimise the impact. This study offers one of the first stakeholder informed qualitative investigations into the status of Green SBSR in Malaysia, with a particular focus on resource planning in current Malaysian shipping sector. Despite the rising awareness, the practice of Green SBSR in Malaysia remains low, indicating a major research gap. By conducting Focus Group Discussions (FGD) with 17 key stakeholders, including shipyard operators, suppliers, regulators, and classification societies, this research identifies core themes representing current practices, influential factors, challenges as well as strategies related to effective resource planning for sustainable operations. The findings of this research show Malaysia current Green SBSR practices, shedding light on the factors that drive or hinder the adoption of Green SBSR and highlighting the significance of strategic resource planning in this context. This study contributes to the global initiatives on sustainable maritime practices and provides practical recommendations for policymakers and promote Green SBSR initiatives in Malaysia by integrating robust resource planning into future strategies.

Introduction

Shipbuilding and Ship Repair (SBSR) industry is one of the oldest industries in the world that contribute to the rise of the global economy. As the majority of global trade is being transported by sea due its cheaper costs, the SBSR sector is crucial to support the shipping industry in supplying and repairing vessels (Salleh *et al.*, 2021). However, as Du *et al.* (2018) expressed, this industry produces high pollution and consumes high amounts of energy, especially in the shipyard workshop, as it involves dust pollution, noise pollution, and gas contamination, all of which are harmful to the environment and to workers' health. Vakili *et al.* (2022) mentioned that the future of the shipbuilding industry is moving towards Green Shipbuilding and Ship Repair (Green SBSR) environment due to the International Maritime Organization (IMO) strategy on reducing Greenhouse Gas (GHG) emissions from ships and its goal of eliminating GHG emissions as soon as is practicable. It is noteworthy to mention that the effective resource allocation especially on the planning and managing the development of green shipyards in Malaysia is still in the early stages, but there are initiatives underway to promote green practices in Malaysia's SBSR industry.

According to the Malaysian Industry-Government Group for High Technology (MIGHT) (2019), approximately 100 shipyards and 200 SBSR-related businesses were operating in Malaysia in 2018. Malaysia has prioritised resources or formal channel to utilise the green technology and adoption since 2009 with programs like the National Green Technology Policy. Industrial centric resource incentives were extended by the Malaysian Investment Development Authorities (MIDA) in 2016 until 2027, benefiting both existing and new partners (Ministry of Investment Trade and Industry, 2023). Through industrial centric resource incentive, new businesses can apply for pioneer status for the first five years of operation and enjoy 70% tax break on their statutory revenue. These incentives may contribute to the growth of the SBSR industry by promoting the use of sustainable capital planning which is related to technology in energy, construction, transportation, and waste management. It depicts that the concept of resource planning has become a prerequisite for the implementation of sustainable SBSR.

Resource planning involves the allocation and utilisation of resources to meet the demand and streamline operations (Mohamad, 2013). It focuses on the development of detailed schedules, determining resources needed as well as anticipating the future demand. In general, the concept of resource planning captivates 3R domain which focuses on several subsidiary concepts including resource usage (Clark, 2008), resource recycling and planning (Li *et al.*, 2013) as well as reusing the resources (Solomon, 2019). Hence in this research, the concept of 3R will be utilised to examine Green SBSR's influencing factors and practices in Malaysian shipyards.

The outline of this research has been arranged as follows: Section 2 reviews 3R principles in Green SBSR procedures worldwide. Section 3 describes the components and steps that were used to build the study framework and collect and analyse the data. Section 4 delves into the interpretation and discussion of the FGD findings. The investigation is ultimately concluded in Section 5, which also provides suggestions for additional investigation.

Literature Review

Current Status of 3R Principles in Green SBSR

Literature sources stated in this study were identified through a structured search using Scopus, Web of Science, and Google Scholar databases. The selection was guided by keywords such as "Green Shipbuilding", "Green Shipyard", "Sustainable SBSR Malaysia", and "Green Maritime Practices", with a focus on peer reviewed publications between 2015 and 2024. The concept of Green SBSR involves the creation of environmentally friendly ships and shipyards (Noordin & Salleh, 2022). The facilities and structure should be designed to have the least environmental effect possible during their lives which will be aligned with the concept of resource planning. Green SBSR promotes resource planning by focusing on the 3R principle; minimising energy and resource usage, encouraging recycling and reuse, and protecting the environment. Table 1 provides a summary of previous research on status of Green SBSR. These studies highlighted the challenges and opportunities for Green SBSR implementation and offered recommendations for improving sustainability of the resources in the industry. Buruiana (2015) stressed on the global issues that shipyards faced in integrating operations with sustainable development goals, where the study demonstrated that appropriate waste management helped reduce environmental impacts. Samsudin *et al.* (2022) provided details on the geographical and legislative dynamics of ship recycling, highlighting the need for sustainable practices especially on resource planning in nations that are struggling with poor environmental legislation.

With the world moving towards the advancement of technology, Zacharaki *et al.* (2022) addressed issues in human-robot collaborative assembly in the shipbuilding

Table 1: Summary of previous research on the current status of Green SBSR

Article's Title	Author	Research Scope	Principles and Practices of Resource Planning
Development of waste management systems in an integrated shipyard	Buruiana (2015)	Waste management	Shipyards globally are facing the challenge of restructuring their operations to align with sustainable development goals.
Challenges in human-robot collaborative (HRC) assembly in shipbuilding and ship maintenance, repair and conversion (SMRC) industry	Zacharaki *et al.* (2022)	Industry technology	There are still limited industrial applications of high technological readiness levels that incorporate human-robot collaboration.
Design of green ship recycling yards: A review	Samsudin *et al.* (2022)	Green ship recycling yard	Ship recycling mainly occurs in developing nations where labor and land costs are cheaper and environmental regulations are less strict.
The role of emerging technologies in implementing green practices to achieve sustainable operations	Umar *et al.* (2022)	Effect of industry 4.0 on green practices	Environmental impact of non-renewable resources and harmful practices, highlighting challenges in adopting eco-friendly alternatives due to cost and skill constraints.
A systematic review of the current trends and potential practices of green shipbuilding	Daud *et al.* (2024)	Current trend and potential practices of green shipbuilding	Green shipbuilding trends, emphasizing on Industry 4.0 technologies and international attention, aiding Malaysian stakeholders in adopting eco-friendly practices.
Empty pallet allocation optimisation in shipbuilding using a pallet pool system	Yu *et al.* (2022)	Green shipbuilding with pallet pool system	In case there is a shortage of pallets, industry could obtain them from a center located outside the shipyard to ensure seamless transportation.
Identifying the shipyard waste: An application of the lean manufacturing approach	Fitriadi and Ayob (2022)	Shipyard waste optimisation in lean manufacturing	Traditional shipbuilding methods hinder modern lean manufacturing concepts, lacking standards for efficient production.
Strategy for shipyard industrial waste management in controlling water and air pollution in ship repair	Ashari *et al.* (2021)	Environmental management strategies	Shipyard activities that triggered environmental pollution and human health.
Identification of sustainable practices applied to ship recycling	Fernandes *et al.* (2023)	Sustainable practices of supply chain (ship recycling)	19 sustainable ship recycling activities that can be applied within the supply chain for ship recycling activities.

Hazardous materials analysis and disposal procedures during ship recycling	Du *et al.* (2018)	Hazardous material and disposal method	Ship recycling processes at Chinese shipyards and suggests improved methods for handling hazardous materials. Green shipbreaking procedures to enhance environmental and safety standard.
Application of the transdisciplinary shipyard energy management framework by employing a fuzzy multiple attribute group decision making technique toward a sustainable shipyard: Case study of a Bangladeshi shipyard	Vakili *et al.* (2022a)	Shipyard energy management	Energy management framework - five interrelated areas; human factors, technology and innovation, operations, policy and regulations, and economics.
Effect of ecological, economic, and social factors on the implementation of ISO 14001 (Environmental Management System) in heavy industries in Indonesia	Mahzun *et al.* (2020)	Environmental, heavy industry	ISO 14001 as a standard that aligns business goals with environmental concerns, globally recognised standard for environmental management system requirements.
Green shipbuilding and recycling: Issues and challenges	Rahman and Karim (2015)	Green recycling, green shipbuilding	Conventional production techniques, including welding, painting, blasting, and fiberglass production, pose a threat to the health and safety of workers and have harmful impacts on the environment.

sector, recommending proactive safety analysis approaches that would allow more widespread use of modern technology. Furthermore, Daud *et al.* (2024) mentioned about the interest in building Green SBSR through the adoption of Industry 4.0 technology for smoother production and design of ships in the yard. The infusion of humans and robotics in the shipbuilding sector goes beyond simply boosting productivity. This collaborative approach can also significantly reduce resource wastage and enhance operational efficiency, leading to more sustainable and cost-effective practices.

Fernandes *et al.* (2023) outlined option on sustainable practice within ship recycling supply chains and urged their adoption to enhance environmentally friendly ship recycling. A comprehensive framework for shipyard energy management that considers human factors, technology, operations, policy, and economics are important to enable long-term operations (Vakili *et al.*, 2022b). Meanwhile, research by Mahzun *et al.* (2020) on ISO 14001 (Environment Management System) concluded that sustainable growth in heavy industries such as shipbuilding and ship repair requires a holistic approach. Their findings showed the importance of balancing ecological, economic, and social considerations, with a particular emphasis on responsible resource use, recycling, and reusing materials. In addition, this economic growth may produce spill over benefits to the entire region by infrastructure development, enhancement in new job market, and urban development (Jeevan *et al.*, 2020, 2021).

Furthermore, it is widely known that the main barriers to adopting new technology in the SBSR are due to the higher cost of implementation and the availability of highly skilled workers in the sector (Umar *et al.*, 2022). Fitriadi and Ayob (2022) encouraged the use of lean manufacturing methodologies for identifying and minimising shipyard waste and cost to improve the quality in a shorter lead time. Du *et al.* (2018) emphasised the need for ecologically appropriate shipbreaking processes while handling hazardous materials during ship recycling. To reduce environmental and health risks, the industry should shift from traditional methods. Green SBSR seeks to reduce waste and emissions throughout the manufacturing process, supporting resource conservation while providing economic and social advantages (Rahman & Karim, 2015). Research emphasises the need to integrate principles of sustainability into all parts of SBSR operations such as waste reduction, energy efficiency, technology adoption, and environmental management. By addressing concerns like hazardous material disposal and resource allocation, these studies offered practical strategies for improving sustainability in the SBSR business industry.

Global Green SBSR Practices

Table 2 illustrates current global Green SBSR practices, which were obtained from a thorough examination of published papers, official websites, and organisations' reports. The study uncovered leading practices that have been classified into their respective groups. The United Nations (UN) specialised agency for the maritime sector, the International Maritime Organization (IMO) is now working to promote environmentally friendly practices in the maritime industry, utilise resources that reduce pollution on land, sea, and air, which is in line with the Sustainable Development Goals (SDGs) 2030 agenda (Sciberras & Silva, 2019). The IMO's long commitment to this goal can be seen in the Pollution Prevention, Ballast Water Discharge, and Hong Kong Conventions (Kao *et al.*, 2020).

The Hong Kong Convention, a global agreement on hazardous waste disposal was crafted through collaboration with IMO member states, NGOs, and international partners (IMO, 2019). The convention established criteria for ship design, construction, operation, and maintenance to optimise the resources, reducing the presence of waste and use of dangerous substances (Jain *et al.*, 2013). The European Union (EU) is also encouraging environmentally favourable practices by limiting the use of hazardous substances in ships and mandating recycling at shipbreaking yards that are designated within EU guidelines and recommend shipowners to open an escrow account (Lin *et al.*, 2022). These escrow accounts encourage ship owners to be able to recycle their ships at certified green facilities by requiring regular deposit. Fund and interest from the escrow account will be released to coupon proof of environmentally ship-recycling to maintain the resources. In the long run, these international policies and regulations aid the growth of the SBSR industry, prioritising sustainability, safety, pollution prevention, and ecologically friendly technologies (Mishra, 2018).

New developments in equipment and infrastructure technologies used by the SBSR industries demonstrate significant investment aimed at improving facilities and innovating solutions. Damen Shipyards Group has launched a Virtual Reality (VR) painting training facility that effectively decreases air pollution emissions, acquired maritime-approved battery containers for shipyard green energy usage to reduce diesel in generator use, and adopted Hydro-Treated Vegetable Oil (HVO) diesel as an alternative source to powered yard forklifts and cranes, resulting in a significant 90% decrease in CO_2 emissions compared to conventional diesel (Damen Shipyards Group, 2022). Similarly, COSCO Shipping Heavy Industry Co. Ltd. (COSCO) has installed rooftop solar power plants, producing roughly 18 million kWh of energy per year and contributing to a decrease in carbon emissions to maintain capital investment. In addition to this, COSCO has also invested in sludge filtration system, high pressure water derusting equipment and installation of LED light to gain both operational efficiency, resource utilization, and environment protection (COSCO, 2020).

Furthermore, research on smart shipyards shows that a Chinese shipyard has made significant investment in robot production lines for strip material handling, section steel assembly, pipelining, and spraying large ship surfaces (Yi *et al.*, 2023). This has reduced the need for six workers per task, increased overall

Table 2: Global Green SBSR practices

Category	Practice	Source
Policy and regulation	• International Maritime Organization • European Union • Sustainable Development Goal	Sciberras and Silva (2019), Kao *et al.* (2020), IMO (2019), Jain *et al.* (2013), Lin *et al.* (2022), Mishra (2018)
Equipment and infrastructure investment	Virtual reality (VR) Hydro-treated vegetable oil (HVO) diesel Battery containers Solar power stations Multi-robotic system Computerised numerical control machine (CNC) Internet of things (IoT) Blasting painting chamber 3d technology Oil barrier Sludge filtration system Ultra-high-pressure water de-rusting equipment Light-emitting diode (LED)	Damen Shipyards Group (2022), DSME Integrated Report 2022 (2022), COSCO (2020), Yi *et al.* (2023)
Sustainable planning	Employee training and engagement programs Green procurement policies Regular monitor report performance Environment impact assessment	Hyundai Heavy Industries (2022)
Recycling and waste reduction	Practice of reducing, reuse, and recycling Rainwater harvesting Environment monitoring system	Ana *et al.* (2023), Damen Shipyards Group (2022), DSME Integrated Report 2022 (2022)
Accreditation	Offshore renewables awards Green award Green marine ISO standards (ISO 14001, ISO 45001, ISO 5001, ISO 9001, ISO 26000)	Vakili *et al.* (2021), Vakili *et al.* (2022), Bazari (2016)

production efficiency by 70%, and improved the quality of products. Some yards also utilise advanced automation techniques such as CNC plasma cutting and laser cutting to enhance efficiency (Oliveira & Gordo, 2018). Currently, IoT is integrated into advanced 3D technology function within ship design software, such as Computer-Aided Design (CAD), Computer-

Aided Manufacturing (CAM), and Computer Aided Engineering (CAE) specifically designed for complicated structures, pipelines, and machinery (Perez-Martinez & Perez Fernandez, 2023; Zhang & Wang, 2021).

This technology significantly decreases the time it takes for on-site staff to comprehend drawings, allows real-time monitoring, reduces the need for manufacturing personnel, and enhances production efficiency (Cil *et al.*, 2021; Yi *et al.*, 2023). Integration of this advanced software and equipment helps improve networking and monitoring capabilities by matching department groups efficiently to perform tasks such as material sorting, cutting, and transportation, ensuring precise product quality and maintaining a stable production schedule for ships (Dolz *et al.*, 2023). Other than that, the potential of 3D printing technology in maritime applications is widely being tested. Some of these applications have already been successfully deployed on-board ships (Zhang & Wang, 2021), for example, in ship design, manufacture of boats, and offshore construction (Vujović *et al.*, 2021). Incorporating 3D printing technology in ships requires owners, users, and maintainers to adapt their supply chain (Jasiński *et al.*, 2023). This adaptation should include sufficient assistance in terms of awareness, training, and expertise for users and operators (Agarwala, 2024).

Sustainability strategy planning for green shipbuilding is very important for capital development. The element includes employee participation and training, with updated programs being established to increase workers' commitment to green practices and understanding of energy efficiency, waste reduction, and sustainable sourcing (Hyundai Heavy Industries, 2022; Fitriadi & Mohamad Ayob, 2025). The green procurement strategy of Daewoo Shipbuilding and Marine Engineering (DSME) is an example of sustainable supply chain management that seeks to reduce the environmental effects of shipyard operations by including social and environmental factors in supplier selection (DSME Integrated Report 2022, 2022). By incorporating its marine engineering solutions that prioritise sustainability into its shipyard operations, Mitsubishi Shipbuilding hopes to positively impact the maritime sector's growth in Japan and globally in partnership with several Japanese shipping and energy firms, both local and international (Isobe *et al.*, 2022).

Research indicates a growing emphasis on waste reduction, reuse, and recycling across shipyards globally, with variations in practice quality (Ana *et al.*, 2023). As for example, Monaco Marine has developed a system for repurposing contaminants water and rainwater by treating the water before discharge into the sea (Super Yacht Times, 2024). The treated water is then preserved in storage and filtration systems enabling it to be utilised again for daily operation. Damen Shipyards Group has implemented a comprehensive waste management program that includes waste segregation, recycling, and the use of reusable packaging materials, while also developing environmental monitoring systems that provide a robust framework for regulatory compliance, such as environmental impact assessments (Damen Shipyards Group, 2022). Other than that, DSME developed a ballast water treatment solution that effectively eliminates harmful species from being released to local surroundings (DSME Integrated Report 2022, 2022).

Following that, it is essential for shipyards to adopt international standards such as ISO 14001, ISO 9001, and ISO 50001, to improve their monitoring of the environment, quality of work, energy management, and operational efficiency. Attaining ISO 14001 should be the primary goal for any shipyard since it is a crucial measure in tackling environmental issues and preserving the capacity (Vakili *et al.*, 2021, 2022). The focus on obtaining such certifications reflects a broader trend towards adopting rigorous environmental standards to ensure sustainability in shipbuilding and repair activities (Vakili *et al.*, 2021).

By implementing numerous Green SBSR practices, these initiatives demonstrate a global commitment to environmental responsibility and advance sustainable practices in the SBSR industry, though the attention to Malaysian current practices remains inadequate.

Methodology

The research investigated the current practices and influential factors related to green initiatives among Malaysian shipyards. Figure 1 shows the methodological approach of this research. Although there has been broad research published on the global current practices of Green SBSR, there is still a lack of studies on the influential factors and the current practices of Malaysian shipyards related to the Green SBSR initiative. This highlights the need for qualitative research to be carried out through a Focus Group Discussion (FGD). The FGD will help to understand the context of Green SBSR development in Malaysia and identify the significant factors driving current Green SBSR practices among Malaysian shipyards. Compared to other conventional methods such as individual interviews and surveys, FGD is a versatile and adaptable method that is widely used by researchers (Nyumba *et al.*, 2018). According to Stokes and Bergin (2006), plenty of research on the maritime sector has been conducted using FGD as a methodological approach to gather data. Thus, it offers researchers the chance to investigate more deeply the Green SBSR development in the Malaysian shipyard industry.

Focus Group Discussion (FGD)

Convenience sampling was used to acquire detailed information on Malaysia's Green SBSR activities. Experts who fulfilled relevant criteria were selected on a first-come, first-served basis until the required sample size was reached (Robinson, 2013). According to Duboz *et al.* (2022), participants with specific expertise and more working experience in a specific industry are more likely to elaborate on a clear understanding of challenges and present more arguments. Invited experts were selected by their knowledge of environmental sustainability, shipbuilding, and industry consulting. These experts should be knowledgeable about shipyard operations, eco-friendly procedures, governmental guidelines, and market trends in their fields (Table 3). Seventeen experts from several key stakeholder groups, including shipyard operators, ship owners, industry associations, government agencies, suppliers, classification societies, and academic experts were involved in the discussion.

There were two discussion sessions conducted, each taking about two hours to enable experts' participation. Each FGD session should be limited to two hours to keep participants engaged and attentive (Nyumba *et al.*, 2018). The FGDs were physically held in the central part of Peninsular Malaysia to make it easier for all participants to attend. With the participants' consent, every conversation was audiotaped for subsequent transcription and analysis. It was emphasised that there were no right or wrong responses and that we were interested in all thoughts and perspectives. The focus group discussions were structured based on the aim of exploring Malaysia's current Green SBSR practices and influential factors (Table 4).

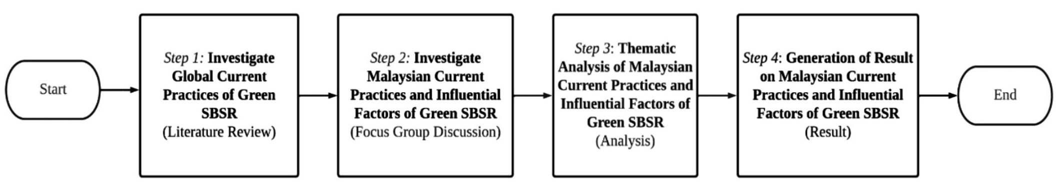

Figure 1: Research methodological approach
Source: Authors

Table 3: Details of the experts engaged in the focus group discussion

No. of Experts	Type of Organisation	Organisation	Years of Experience	Position in the Organisation	Educational Background
1.	Supplier	Ship Paint Maker	15–20	Assistant General Manager	Bachelor's degree
2.		Ship Paint Maker	15–20	General Sales Manager	Bachelor's degree
3.		Ship Paint Maker	10–15	Head of Marketing	Bachelor's degree
4.		Ship Designer	> 20	Vice President, Engineering	Bachelor's degree
5.	Association	Association of Marine Industries of Malaysia (AMIM)	10–15	Secretary General	Bachelor's degree
6.		Malaysia Shipowners' Association	> 35	Honorary Secretary	Bachelor's degree
7.	Shipyard operator	Company A	15–20	Head of Shipbuilding Product Department	Bachelor's degree
8.		Company A	15–20	Senior Technical Executive	Bachelor's degree
9.		Company A	> 20	Head, Group Corporate Communications	Master's degree
10.		Company B	15–20	Head, New Business, Corporate Planning	Bachelor's degree
11.		Company B	15–20	Senior Manager, Production and Operation	Bachelor's degree
12.		Company C	> 20	General Manager	Bachelor's degree
13.	Ship owner	Company D	> 20	Managing Director	Bachelor's degree
14.	Classification society	Company E	10–15	Lead, Sustainability	Bachelor's degree
15.		Company E	15–20	Regional Manager, Business Development, South-East Asia	Bachelor's degree
16.		Company E	15–20	Power and Utilities Business Development Manager	Master's degree
17.		Company E	15–20	Head of Rail Building and Infrastructure	Master's degree

Source: Authors

Table 4: Structure for focus group discussion

Phase	Agenda
Introduction and icebreaker (ten minutes)	The discussion commenced with a warm welcome and icebreaker questions to engage the attendees. An overview of the research concern was presented, including existing global practices and influencing factors.
Discussion 1: Current practices	The session started by delving into current green initiatives implemented in Malaysian shipyards. Participants were prompted to discuss the motivations to drive these initiatives with the following questions: i. What green initiatives are currently being implemented in Malaysian shipyards? ii. In your opinion, what are the motivations for implementing green shipyard initiatives in Malaysian shipyards? iii. How effective have these initiatives been? iv. In terms of energy efficiency, other than the use of LED and electric power tools, what other improvements can be made? v. What are the obstacles to the implementation of green practices in shipyards?
Break	A short break was provided to allow participants to refresh themselves before continuing with the discussion.
Discussion 2: Factors influencing green initiatives	The second discussion focused on factors influencing the decision to adopt green initiatives in shipyard and the following questions were used as prompts: i. What factors influence the decision to adopt green initiatives in shipyards? ii. How important are regulatory requirements in driving green practices? iii. How significant are collaboration and partnerships in encouraging green initiatives? iv. How can policy regulation and stakeholder pressure influence the shipyard to adopt green initiatives? v. In your opinion, how can Malaysian shipyards encourage and incentivise their suppliers and contractors to adopt green practices?
Wrap-up	To conclude, participants were thanked for their valuable contributions to the discussion.

Source: Authors

Step 2 Analysis: Thematic Analysis Procedures

A voice-recorder device was used to accurately record the discussions, making it possible to gather and evaluate the variety of insights given throughout the FGD. Following the FGD sessions, these recordings were transcribed, converting spoken words into written text for simpler study (Then *et al.*, 2014). Next, the acquired written text was analysed through the thematic analysis method. According to Ibrahim (2012), thematic analysis may be suitable where the purpose of the research is to explain any person's existing activities. The process of analysis consists of multiple phases such as familiarisation to become thoroughly acquainted with the data, data coding to systematically classify information, and the development and modification of themes to extract relevant patterns and insights (Braun & Clarke, 2006). The NVivo software package was used as a strong tool to help browse, organise, and manage the huge amount of interview material gathered into themes and codes (De Vass *et al.*, 2021).

Step 1: Data Familiarisation

As each expert had different viewpoints and areas of interest regarding the state of green practices in the Malaysian shipbuilding sector, there was a range of answers to this question. The FGD and interview transcripts were reviewed multiple times to become familiar with and understand the script. Table 5 shows some of the quotes from the FGD session that the author has to be familiarised with.

Step 2: Generation of Codes

Initial codes were created manually. This approach gathers data unique to each code and systematically codes unique data structures during the data harvest process. Table 6 shows a sample of coding for this research.

Table 5: Sample transcripts from FGD

Quotes from the Experts
• *"We installed solar facilities in our yard three years ago."*
• *"The installation of this 8.3-megawatt peak (MWp) solar rooftop makes it as Malaysia's largest rooftop solar installation in a single compound."*
• *"We have invested in blasting painting chamber facilities. This change allows for better control of paint particles and reduces the dispersion of harmful substances into the environment."*
• *"Our yard also has invested in gas-particle equipment, specifically to minimise small particles of garnet."*
• *"We have adopted to use 3D technology in the ship design phase."*
• *"We do 3D printing in the creation of some ship parts."*
• *"Is using a CNC machine considered as part of green efforts? Because, for your information, most shipyards have started to use the CNC machine for quite some time now."*
• *"I see that some few shipyards in Miri and Sibu have implemented energy-efficient building technologies. They used transparent walls and roofs to reduce electricity consumption in warehouse and workshop areas."*

Source: Authors

Table 6: Sample coding from FGD

Initial Codes
1. Installed solar facilities
2. Focused on clean energy
3. Blasting painting chamber facilities
4. Control of paint particles
5. Reduced the dispersion of harmful substances
6. Use of portable batteries and charging facilities
7. Designed a floating charging dock
8. Virtual Reality in repairing part of machinery or structure in offshore structures
9. Implemented energy-efficient building technologies
10. Transparent walls and roofs
11. Reduced electricity consumption in warehouse and workshop areas
12. Advancements in painting formulations
13. Enhancing ship fuel efficiency
14. Declare all oil waste/schedule waste/CO_2 emissions produced
15. Survey during design and construction
16. Scheduled waste disposal
17. Encouraged to control and manage waste production
18. Previous proactive measures as commendable green initiative
19. REC certificate
20. Green energy

Source: Authors

Step 3: Creation of Themes

After all the data were compiled and coded, Step 3 started. At this stage, researchers switched the focus back to themes, rather than codes, as the primary level of analysis. The process included categorising the codes into possible themes and then compiling all the pertinent coded data extracts inside those themes.

Step 4: Reviewing Themes

After a set of themes and sub-themes has been developed, Step 4 involved polishing those subjects. Some of the identified codes and sub-themes in this study may overlap. It is essential to refine or categorise these codes into more suitable themes to ensure that they are better aligned with the overall analysis. The outcome of this improvement process is presented in Figure 3. Step 4 consisted of two stages in which the themes were carefully reviewed and improved.

Step 5: Defining and Naming Themes

After the data produced a satisfying thematic output, Step 5 began. Theme and sub-theme summaries for Malaysian shipyards' current green practices are shown in Table 6. During this stage, the researchers defined and further refined the themes that emerged at this point. "Define and refine" refers to finding the "essence" of the summary and the overarching themes and then figuring out what part of the data each theme represents (Braun & Clarke, 2006).

Step 6: Publish the Report

Step 6, which comprises conducting the final analysis and writing the report, commenced when fully developed themes had been gathered. Table 7 displays the topic and sub-themes derived from the thematic analysis of Malaysian shipyards' current green practices.

Table 7: Summary of the themes and sub-themes for Malaysian shipyards' current green practices

Theme	Sub-theme	Summary
Malaysian shipyards' current green practices	Green technology and facilities investment	This encompasses investments in energy-efficient machinery, renewable energy sources, and environmentally friendly materials that improve the capital sustainability of shipyard operations.
	Standard policy and regulation enforcement	The creation and strict enforcement of official rules and regulations that control the shipyard's environmental procedures. This makes sure that national and foreign environmental standards are followed, encouraging consistent and legally required ways to reduce pollution, handle waste, and protect resources.
	Strategic sustainable planning awareness	This includes setting long-term goals and strategies for sustainability within the shipyard and practice to increase awareness and educate the importance of sustainable practices. This entails incorporating sustainability into the main business plan and encouraging suppliers, staff, and the general public to have an environmentally conscious mindset.
	Recycling and waste reduction initiatives	Waste-reduction strategies include activities and programs that attempt to reduce material consumption and increase material reuse and recycling. This includes encouraging trash reduction at the source, waste segregation, and recycling.
	International standard on environment and green energy accreditation	Sets global benchmarks and certifications aimed at promoting sustainable practices in the SBSR industries. These standards ensure compliance with environmental regulations and endorse the use of renewable energy sources, reducing carbon footprints, and encouraging green innovation.

Source: Authors

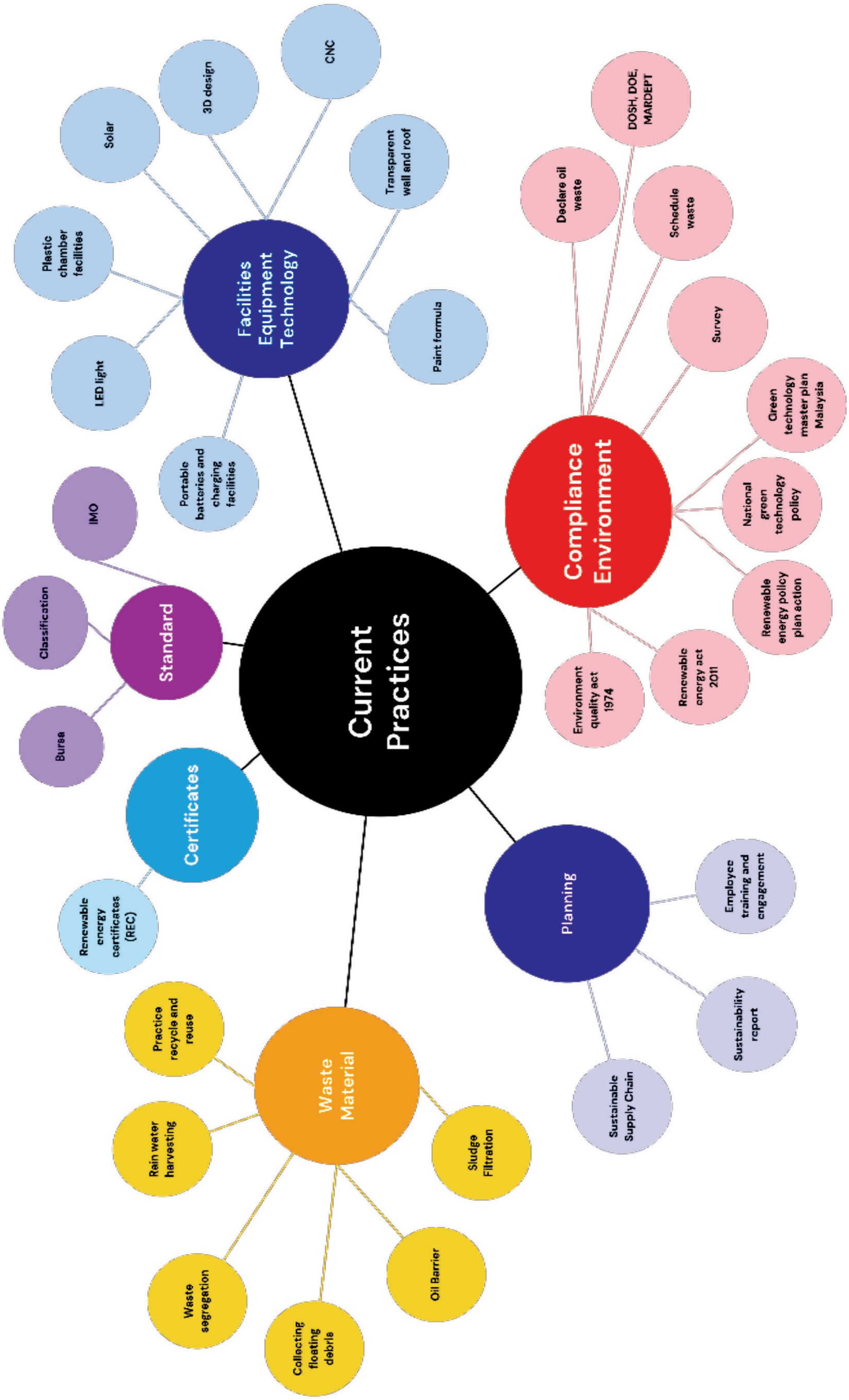

Figure 2: Categorising codes into possible themes
Source: Compiled by authors

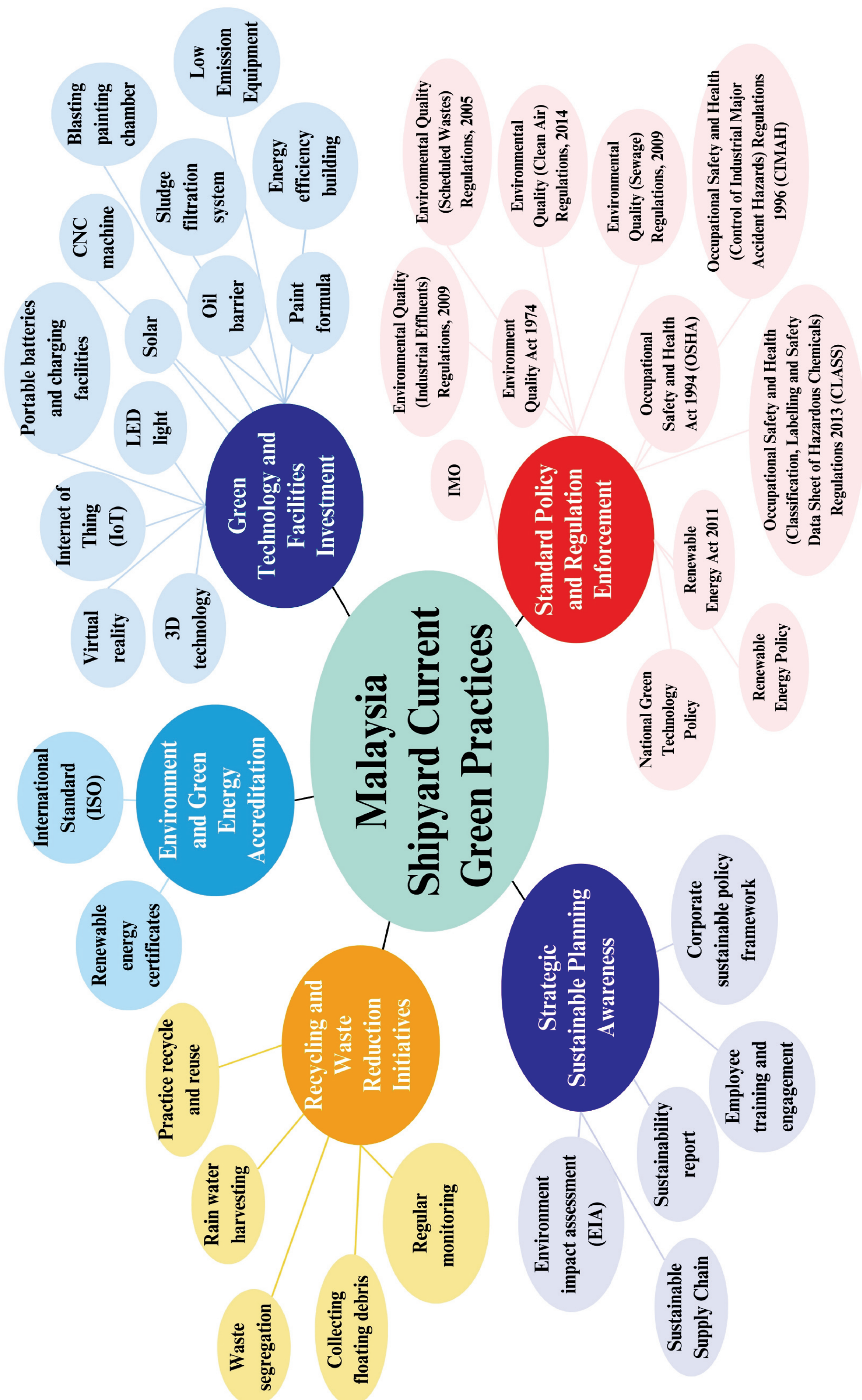

Figure 3: Thematic map of Malaysian shipyards' current green practices
Source: Compiled by authors

Results

A comprehensive exploration of the transcript data collected from experts participating in the FGDs generated findings of nine main themes and 15 linked codes. These themes and codes correspond to stakeholder input on current Green SBSR practices, factors influencing Green SBSR, and challenges of implementation Green SBSR in Malaysia. The perspectives shared in the thematic quotes are drawn from participants during the FGD session as shown in Table 3.

Current Green SBSR Practices in Malaysian Shipyards

Based on thematic analysis from interview transcripts of 17 experts during the FGD, five main themes were identified that relate to the current Green SBSR practices in the Malaysian shipyard industry: Green technology and facility investment, standard policy and regulation enforcement, strategic sustainable planning awareness, recycling and waste management, and international standard on environment and green energy accreditation.

Based on the theme of green technology and facility investment for the current shipyard practices, shipyard operators claimed that a few of them were already using renewable energy in their yards as shown in this excerpt:

> *"Some of our yards have already installed solar facilities… three years ago. The solar installation was carried out by a third-party company, which is owned by a global Malaysian energy group, with zero CAPEX cost borne by the shipyard. This project is known as Malaysia's largest rooftop solar installation in a single compound."*

Apart from that, shipyard operators mentioned that some of the major shipyards have already installed blasting painting chamber facilities in their shipyards as expressed in this excerpt:

> *"Installing blasting painting chamber facilities has allowed us a better control of paint particles and reduces the dispersion of harmful substances into the environment while protecting our staff. Most major shipyards have started to use CNC machines in the phase of build and repair, 3D printing in the creation of small ship parts, and use of Artificial Intelligence (AI) for information transfer by digitalising all data sharing in the cloud base."*

Collective voice from shipyard association mentioned that few shipyards have worked on the minor implementation of energy-efficient building technologies based on this excerpt:

> *"Some shipyards in Miri and Sibu have implemented installing transparent walls and roofs which contributes to reducing electricity consumption in yard areas."*

Furthermore, collective voice from supplier experts mentioned that they have adapted to the updated technology their daily operation and able to supply current advance technology to the industry as evidenced from this excerpt:

> *"There is a local shipyard which works on building offshore structures that uses Virtual Reality VR in repairing part of machinery or structure in offshore structures from its shore base. We have designed a floating charging dock capable of installing the batteries. While batteries can last an average ship hour of operation, their suitability depends on the ship's operation profile. We have also been using 3D technology in the ship design phase and advanced software in designing maritime structures. We have advancements in painting formulations. This formula plays a role in enhancing ship fuel efficiency while using environmentally friendly materials."*

Based on the theme of standard policy and regulation enforcement, ship owner mentioned that currently, major companies that are listed on Bursa Malaysia need to declare all waste produced and the schedule of waste being disposed. The participant mentioned that:

> *"Ship owners whose companies have been listed on Bursa Malaysia need to declare all oil, water, and carbon dioxide waste and the schedule of waste being disposed of. We also need to declare waste generated by ships to the Malaysia Marine Department."*

Additionally, on the side of the shipyard operator, the local environmental authority will annually audit each shipyard, as mentioned by the participant:

> *"Shipyards undergo annual checks by entities like DOSH and DOE, which assess their compliance with regulations. Usually, shipyards will appoint dedicated companies to handle scheduled waste disposal."*

A participant commented when asked about strategic sustainable planning awareness, that major companies listed on Bursa Malaysia need to produce their sustainability policy and framework as part of their commitment to environmental sustainability:

> *"Annually, we would produce a sustainability report which includes the company's sustainable policy and framework. We adopted a policy on carefully disposing of discharged water from ballast tanks. Special tanks are designated for this purpose to ensure responsible and environmentally conscious water disposal."*

Based on the theme of recycling and waste management, most major companies in the Malaysian SBSR industry have implemented waste management planning and recycling of waste material in their facilities. Shipyard operators expressed hope that their previous efforts in the protection of environmental sustainability are recognised, as shown in this excerpt:

> *"We practice recycling, for example, the copper grit, by sending it for reuse in road construction materials and have actively encouraged all yards to control and manage waste production. We also consider that previous proactive measures taken to safeguard the environment within the shipyard premises can indeed be categorised as a commendable green initiative."*

There is already recognition of the Green Certificate in Malaysia other than ISO certificates. According to the Shipyard Operator and Classification Society:

> *"A company needs to have a REC certificate to claim the company is using green energy. By acquiring RECs, businesses can demonstrate their commitment to using green energy and can be recognised as being powered by renewable energy sources."*

Thus, Figure 4 provides summary of Malaysian shipyards' current Green SBSR practices which is linked to 3R principle**.** Data that have been generated during the FGD session reveal that industries are in transition, aiming for a more sustainable and greener future. The Malaysian shipbuilding industry is moving to promote environmental sustainability and contribute to a greener industry through investments in green technology, being in compliance with regulatory standards, strategic planning for sustainability, and commitment to recycling and renewable energy.

The current landscape of Green SBSR practices in Malaysia unfolds across five key themes to shed light on the industry's concerted efforts. Green technology and facilities investment form a cornerstone, with shipyard operators actively integrating renewable energy, illustrated by Malaysia's largest rooftop solar installation. Some major shipyards delve into

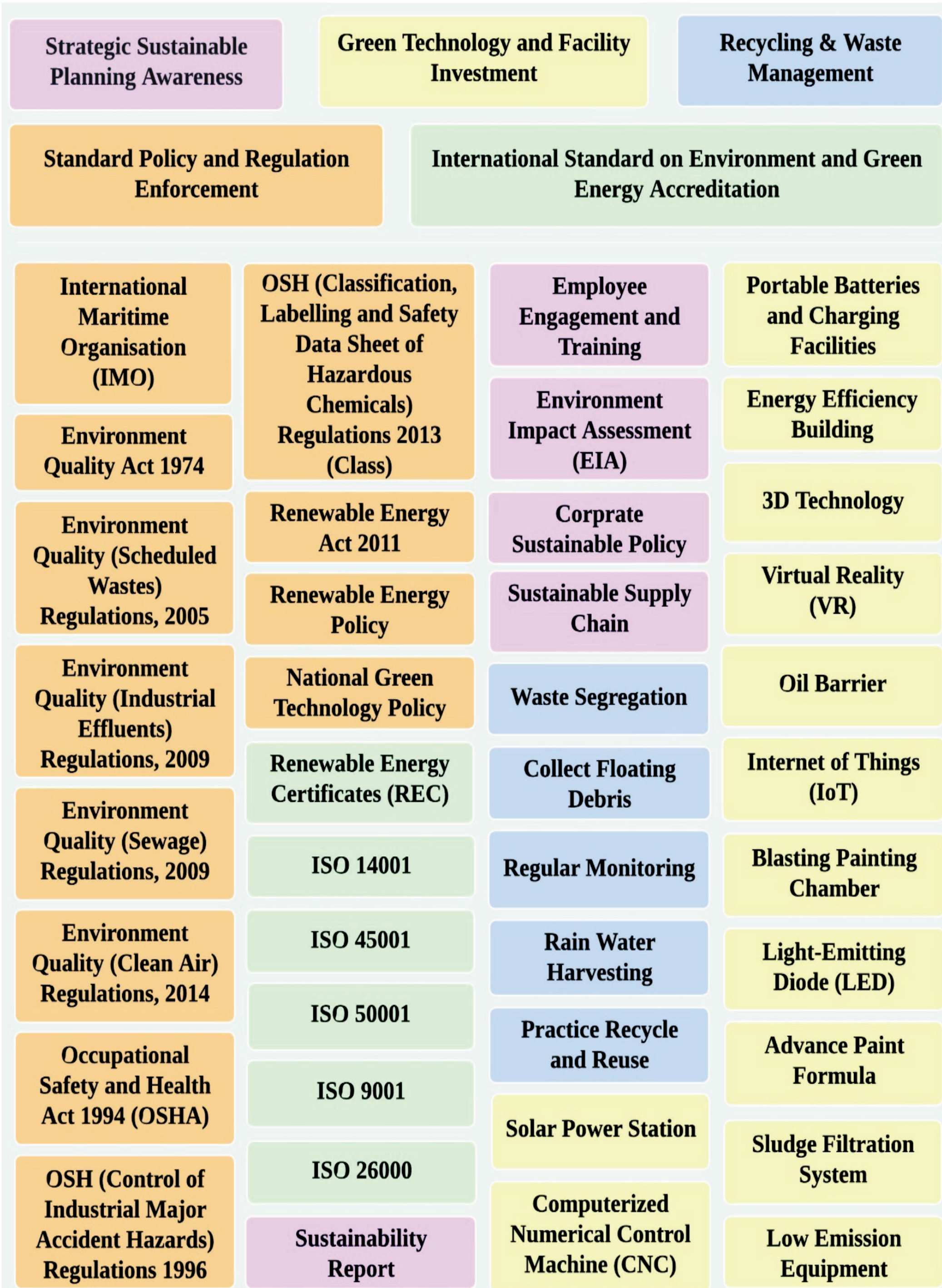

Figure 4: Malaysian shipyards' current Green SBSR practices based on 3R principle
Source: Authors

innovative technologies such as CNC machines, 3D printing, and Artificial Intelligence (AI), driving digitalisation and eco-friendly practices. Standard Regulatory Enforcement Preparedness emerged as a vital dimension, especially for Bursa Malaysia-listed companies. Strict regulations mandate comprehensive declarations of oil, water, and carbon dioxide waste, reinforcing the industry's commitment to regulatory standards. The annual audits by local environmental authorities further highlight the sector's dedication to compliance and proper waste management.

Strategic sustainable planning plays a crucial role where major companies express their commitment through sustainability reports and frameworks. Emphasis is placed on responsible water disposal from ballast tanks, showcasing a proactive action towards marine ecosystem protection. Recycling and waste reduction initiatives amplify these endeavours, with major companies implementing waste management plans and resource utilisation initiatives. The reuse of materials like copper grit in road construction exemplifies the industry's commitment to efficient business practices with an eco-friendly imprint. The Environment and Green Energy Accreditation theme highlights the recognition of the Green Certificate in Malaysia. Notably, companies with sustainability targets can acquire Renewable Energy Certificates (RECs), even in the absence of immediate green energy access. This strategic move allows businesses to signal a commitment to renewable energy sources and participate meaningfully in broader sustainability initiatives. The introduction of RECs has effectively democratised participation in sustainability efforts, enabling areas lacking direct access to green energy to contribute to the broader green energy landscape. Overall, these themes collectively illustrate Malaysia's shipyard industry navigating a transformative journey towards resources and environmentally conscious practices.

Factors Influencing Green SBSR in Malaysian Shipyards

Three themes for the factors influencing Green SBSR in Malaysian shipyards were discovered, which are harmonising financial objectives with environmental accountability, continuous improvement in worker safety, and policy clarity for a green shipyard vision.

Harmonising financial objectives with environmental accountability: The Malaysian SBSR industry has been influenced to maintain business economic sustainability and to try to develop business eco-consciousness among stakeholders. Ship owners and shipyard operators mentioned:

> *"The primary concern lies in ensuring the survival of our businesses before committing to investments in sustainability measures. We need access to better rates that justify the investments."*

According to shipyard operators and ship owners, the intention to purchase green energy only arises when there is demand from international clients, as indicated in this excerpt:

> *"The decision to purchase green energy is driven by the growing demand from international clients and businesses for environmentally friendly practices. This will enhance our brand image and attract clients."*

Thus, all the factors mentioned above should boost the economics of Malaysian shipyards by implementing especially on resource utilisation through green practices, as there is a demand that could be explored.

Continuous improvement in worker safety: SBSR stakeholders agreed that the implementation of green practices has been known to improve work efficiency and worker safety, as pointed out by the participants:

> *"By adopting this approach, shipyards significantly reduce waste generation and ensure the safety of workers involved in the painting process."*

Policy clarity for a green shipyard vision: Stakeholders mentioned that conceptual clarity, development of policy and regulation, and a balanced sustainable approach are needed to direct the Malaysian SBSR industry toward the Green SBSR practices. The creation of specific policies would help industry to be prepared to achieve its vision. The participant highlighted that:

> *"It is important to clarify the concept of green shipbuilding and green shipyard. We wonder whether it pertains to the process design or other aspects."*

Furthermore, collective voice from all experts advised that an inclusive policy and framework need to be developed to attract stakeholders and investors to invest in green practices and mentioned here:

> *"It needs to start with policy. Without these policies, the use of fossil fuels could not be stopped. While larger shipyards may find it easier to comply with enforcement, smaller players also need to adhere to green shipyard policies. Once this legislative framework is in place and becomes the rule, shipyards will eventually implement green practices. Government support, such as incentives, may be offered to ensure shipyards comply effectively."*

Other than that, a balanced sustainable approach needs to be presented to convince both major and SME (Small Medium Enterprise) SBSR stakeholders to apply green practices in their facilities, as asserted in this excerpt:

> *"The framework must be flexible and consider the viability and survival of small shipyard players in its approach to promoting environmentally friendly practices."*

Understanding these three aspects is essential for understanding Green SBSR in Malaysian shipyards. By combining financial growth with preserving the environment, prioritising worker safety, and establishing clear policy regulation, the sector may shift to sustainable practices that improve the environment, operational efficiency, and the industry's long-term viability.

Following that, the study identified three main factors that influence how Malaysian shipyards can adopt Green SBSR by balancing financial costs with environmental benefits, improving worker safety and operational efficiency, and the need for clear policies and government incentives. Most shipyard stakeholders explained that the high cost of green technologies makes it difficult to invest to achieve a sustainable operation. Many shipyards, especially small and medium-sized ones, operate with limited budgets. A participant from a shipyard operator mentioned:

> *"The main focus is to survive. Sustainability comes second."*

Implementation of technologies like solar power systems, CNC machines, or closed blasting systems requires large capital investments (CAPEX), and they often come with high maintenance costs (OPEX). Without having support from the government such as tax incentives and easier bank loans, or clear customer demand, many yards are hesitant to adopt them. However, some well-established shipyard operators in Malaysia have taken action because their international clients expect sustainability. Foreign companies often request environmental certifications, clean energy use, or green materials before doing business. This shows that global market pressure can encourage local players to act more sustainable (Ramirez-Peña *et al.*, 2020; S. Vakili, Schönborn *et al.*, 2022a).

Challenges in Implementing Green Practices in Malaysia

Three main themes were discovered that related to the challenges of implementing green practices in Malaysia; driving green initiatives without prescribed guidelines, cost efficiency vs. investment necessity, and lack of renewable energy diversity.

Cost Efficiency vs. Investment Necessity

As the SBSR industry is capital-intensive, one of the key challenges is balancing cost efficiency with the need for investment in sustainable technology. Shipyard operators face difficulties in overcoming the high costs associated with implementing these technologies, which can slow sustainability progress. It was expressed by the participant:

> *"The majority of small shipyards strive to obey the fundamental and minimum environmental regulations set by the ISO. However, they often struggle to meet these requirements due to limited financial resources, especially when compared to larger players in the industry who have more funding available for environmental initiatives."*

Other opinions from ship owners mentioned that they are stuck in a dilemma of conflict and demand, as mentioned in this excerpt:

> *"Charterers demand lower rates while expecting compliance with stringent regulations set by the IMO. It is hard to choose between building environmentally friendly vessels or just proceeding to build ships [using] affordable options. Due to the financial burden of adopting green technologies, many ship owners opt for cheaper vessels, prioritising short-term economic gains. With the industry's focus on survival, ship owners face challenges in coping with capital and operational expenses [CAPEX and OPEX] associated with green initiatives. Ship owners need access to better rates that justify the investments required for embracing sustainable practices. There is no bridge created to connect the economic demands, and environmental responsibility requires proactive measures."*

Driving Green Initiatives without Prescribed Guidelines

The shipyard operators and ship owners also mentioned that Malaysian SBSR is moving slowly as there are policy and regulation hurdles. Stakeholders are hoping that the government will provide fair incentives, as expressed in this excerpt:

> *"Currently, MIDA incentives are not promoting enough incentive. There is no incentive given to ship owners who purchase green ships or ship equipment. There are still uncertainties."*

Collective voice from shipyard operators mentioned that the implementation of a carbon tax could work toward developing a sustainable Malaysian SBSR industry,

> *"Policy and regulation need to be established first before funding and incentive can be created. Singapore, our neighboring country, has implemented a carbon tax. Only when we have a carbon tax in place should incentives be introduced"*

Lack of Renewable Energy Diversity

Lastly, lack of renewable energy diversity was mentioned as a theme as there is a limitation on renewable energy in Malaysia. According to the classification society:

> *"The challenge lies in solar power storage, as the high cost of batteries makes it economically impractical to store excess solar energy. Additionally, the policy imposes a cap on solar panel installation, restricted to 75% of the premise's maximum demand."*

The Malaysian SBSR industry's current option to implement renewable energy is only through solar power due to limited access to wind, geothermal, and hydro resources.

Implementing Green SBSR in Malaysia displays significant challenges that must be solved to ensure the sector's long-term viability. A significant issue involves balancing cost efficiency with the required investment in the adoption of sustainable practices. Small shipyards, which have limited financial resources, struggle to invest in green technology such as 3D printing. Owing to this, substantial losses happened especially regarding managing the resources that have been used in the shipyards. For example, mismanagement of technology leads to technological enhancement, complex in supply chain logistics which lead to financial losses (Acciaro *et al.*, 2013). Ship owners are under pressure to satisfy charterer's expectations for cheaper rates while complying with severe regulations established by organisations such as the IMO. Second, the sector has challenges in driving green activities due to lack of specified rules and legislative assistance. Stakeholders urge the development of a comprehensive green policy framework adapted to the shipbuilding sector, emphasising the need for clearer incentives and overcoming difficulties in policy systems.

There is broad agreement that a solid green policy framework specific to the shipbuilding sector is essential for ensuring compliance and successfully promoting green projects. However, obstacles remain, with stakeholders emphasising the need for clearer incentives for ship owners as well as the need to resolve the intricacies of governmental procedures like limits on solar panel installation and the acquisition of Renewable Energy Certificates (RECs). The debate discusses the notion of a carbon tax as a potential catalyst for promoting ecologically friendly industrial practices.

Finally, the industry faces the difficulty of insufficient renewable energy diversification, relying mostly on solar power due to limited access to wind, geothermal, and hydro resources. Despite Malaysia's geographical advantage, constraints in solar power storage and restrictive legislation limit the industry's capacity to fully realise the potential of solar energy. While Malaysia's geographical location near the Earth's equator provides enough sunlight throughout the year, the effective daily duration of solar radiation is just about four hours. Solar power storage challenges, such as high cost of batteries and restrictive rules limiting solar panel installation, limit the industry's capacity to fully realise the promise of solar energy. The restriction on solar panel installation, which is restricted to 75% of a premise's maximum demand, makes it even more difficult for industry to optimise solar power use.

In conclusion, these obstacles highlight the need for strategic regulation and policies, financial incentives, and technical advancements in Malaysia to develop a sustainable and ecologically responsible SBSR business.

Conclusions

In the nutshell, this research aims to explore current resource planning and influential factors shaping the adoption of Green SBSR in Malaysia, drawing comparisons with global trends. The findings reveal that Green SBSR practices in Malaysia is still at an early stage, largely due to the absence of a dedicated national policy framework specific to this sector. Several Malaysian shipyard stakeholders have already begun implementing the five thematic pillars of Green SBSR identified in this study, green technology and facility investment, regulatory readiness and standard compliance, strategic sustainability planning, recycling and waste reduction initiatives, and environmental and green energy certifications. The transition from three pillars or 3R towards five pillar shows a positive transformation in adapting green technology in the shipping industry. However, the extent and interpretation of these themes vary across shipyards and differ from more advanced global practices. In addition, three key factors were found to influence the adoption of green practices; the need to harmonise financial and environmental goals, continuous improvement in workplace safety, and the importance of clear, actionable policies supporting green development.

Furthermore, the study also identified three main challenges, high capital costs, limited access to renewable energy sources, and weak policy enforcement. While this study contributes a thematic framework and provides insight into Malaysia evolving Green SBSR landscape, the research relied solely on qualitative data from a relatively small group of industry stakeholders, which may not fully capture the broader perspectives, especially from international or non-commercial actors. Additionally, the findings are specific to the Malaysian context and may not be directly generalisable to other maritime nations. Future research should aim to validate these themes using quantitative approaches or mixed methods to assess the implementation across different shipyard types. Comparative studies involving other ASEAN countries would also offer valuable benchmarks and broaden the applicability of the findings. Furthermore, a deeper exploration of the economic impact of adopting green technologies in SBSR operations could provide actionable insights for both policymakers and industry leaders. In order to accelerate green adoption, coordinated efforts among government agencies, industry players, and financial institutions are essential. Establishing a clear national roadmap, supported by financial incentives and regulatory enforcement, will be critical in transforming Malaysian SBSR sector into a competitive and sustainable maritime industry.

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Conflict of Interest Statement

The authors declare that they have no conflict of interest.

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