Hybrid shipyard concept for improving green ship recycling competitiveness

I Zainol[1,2], C L Siow[2], A F Ahmad[3], M R Zoolfakar[1] and N Ismail[4]

[1] Malaysian Institute of Marine Engineering Technology, Universiti Kuala Lumpur, Lumut
[2] Faculty of Engineering, Universiti Teknologi Malaysia, Skudai
[3] Faculty of Maritime Studies, Universiti Malaysia Terengganu, Kuala Nerus
[4] Razak Faculty of Technology and Informatics, Universiti Teknologi Malaysia, Kuala Lumpur

Corresponding author: ismailz@unikl.edu.my

Abstract. This article presents the concept of a hybrid shipyard, a new idea in shipyard design that integrated ship recycling activity into a conventional shipyard. The essence of this hybrid concept is resource sharing and maximising facility utilisation. This article describes the issues arise in ship recycling yards and related works taken to overcome the problems. It also describes the basic process of each segment and includes the relevant aspects of yard facilities and layout based on the previous literature. Furthermore, the shipyard capacity was analysed to explore the available resources in conventional shipyards to adapt ship recycling. Lastly, this article provides insight into the prospect of the hybrid concept to improve ship recycling yard competitiveness.

1. Introduction

A shipyard can be defined as a place to build or repair a ship. [1] described shipyards into two main types: Shipbuilding and ship repairing. [2] classified shipyards not limited to shipbuilding and repair only but other functions including ship conversion and ship scrapping. [3] added that a shipyard is an industrial production facility where specific input is used to design, build, repair, or dismantle a ship. Current shipyards are known to operate either on dedicated shipbuilding yards, dedicated ship repair yards or multifunctional yards, covering both building new ships and repairing ships [4]. Ship recycling yard, however, currently operates as an individual yard.

The issue arises when the competitiveness level is reduced along the process of turning the substandard yard into a green ship recycling yard due to the extra cost of maintaining the standard as a green yard. It is clear from the examples on ship recycling issues in [5,6] that the current green ship recycling operation is cost-ineffective compared to the conventional ship recycling yard. There is still a gap in defining an approach to overcome the issue of green ship recycling competitiveness. Recent work has shown that a green yard, in general, can be made more competitive by either increasing the revenue or reducing the costs of the ship recycling process. This allows for a green recycling yard to offer a high price to ship owners.

The need for continuous technological improvement of ship recycling yards to achieve a concurrent shipyard requires a complex decision-making process. Therefore, improving ship recycling often means improving existing infrastructure boundaries which would be cost tolerant. One proven approach to reducing the process cost is through resources sharing, which has gained a lot of attention in recent years

[7,8]. A possible solution is by cooperating with similar industries in terms of resources to reduce investments costs and environmental impact [9]. It can be further improved by focusing on re-use of dismantled metal and turn a single business pattern of ship recycling to the multi-dimensional business of ship repairing and shipbuilding [8]. Despite the importance of sharing resources, there is a lack of study on integrating ship recycling segments into a current shipyard operation. This paper is primarily centred on opportunities and prospects of combining ship recycling activity into the existing marine shipyard to improve the competitiveness of ship recycling.

2. Theoretical Definition of Hybrid Shipyard

A sharing concept in shipyard operation is not new, and the existing shipyard has been put into practice. [10] investigated the possibility of shipbuilding yard supplementing this activity with a substantial repair workload without disrupting work organisation. His work was further analysed when [11] examined the interaction between shipbuilding and repair yards in three aspects: location, operation, and sharing of facilities. He concluded that all these activities could be carried out within the same yard. The similar idea was adopted for ship recycling activity to be placed in the same area of existing shipyard to facilitate the sharing of resource. Figure 1 illustrates the idea of integrating the recycling segment into a conventional shipyard.

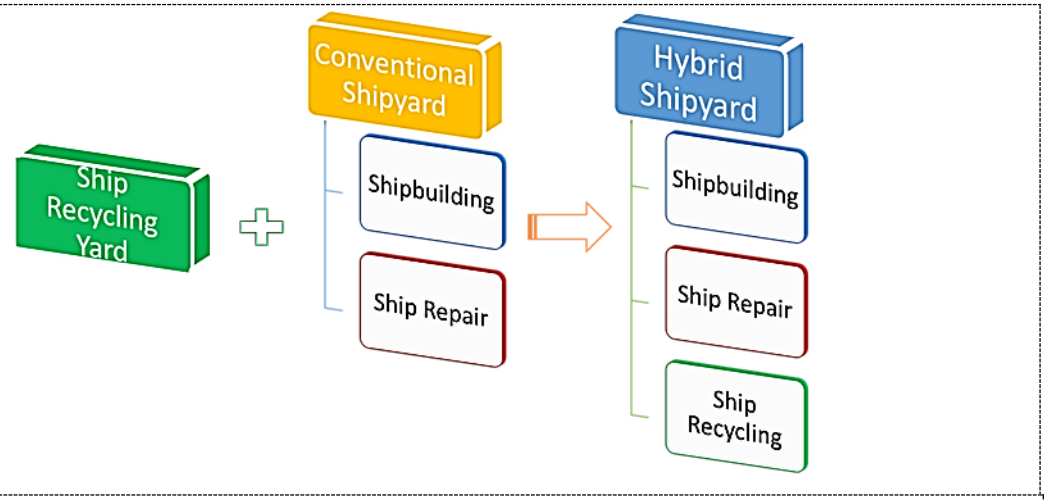

Figure 1. Hybrid Shipyard Concept.

The concept analysis is carried out to identify and discuss the common characteristic and available resources in conventional shipyard for adaptation of ship recycling yard to testify the feasibility of integrating a ship recycling activity into a conventional shipyard. The concept analysis that investigates important aspects of operation, facility, and layout is essential to ensure that resources are available to enable facilities to comply with critical delivery schedules at minimum costs. The following section discusses the shared resources available within the existing conventional shipyard and ship recycling yard.

3. Shipyard Operation

A conventional shipyard operation involves a complex activity [12] concerned with the design and fabrication process. However, these types of shipyards differ in operations for each segment performed on the yard, as shown in Figure 2 [13–18]. A shipbuilding and ship repairing have many industrial processes such as cutting, surface treatment, blasting, painting and coating, solvent cleaning, degreasing, welding, and fiberglass manufacturing [19]. The shipbuilding process covers most of the usually carried out works at shipyard and posts the highest return in investment [20]. Shipbuilding also involves the most advanced process and requires competency to conduct several projects simultaneously compared to ship repair and ship recycling [21]. Meanwhile, ship repair is generally a slightly moderate process

and focuses on the maintenance and repairing of a damaged ship. The specific characteristic of ship repair lies in its operational challenges, which are more complex due to the variation of tasks [11]. Moreover, a standard procedure applied by ship repair yards is difficult to define in a typical flowchart due to their unstructured working and considerable process variety [22].

On the other side, the ship recycling yards focus on dismantling vessels to reuse materials. [14] described the processes of ship recycling activities in a ship recycling yard involves a large scale of activities. From extracting all equipment and items such as fittings and engine parts left on the ship, cutting down and recycling the entire ship's infrastructure before handling them to temporarily storage the hazardous materials before being transported to the recycle center. The process of shipbreaking is a challenging task because of the structural complexity of ships and various environmental and safety issues [23]. Therefore, the critical concern in ship recycling operations is to ensure the good handling of hazardous waste. A proper handling must be established according to international guidelines. In this aspect, a shipyard with ship repair activity 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 the experience if compared to dedicated shipbuilding yard.

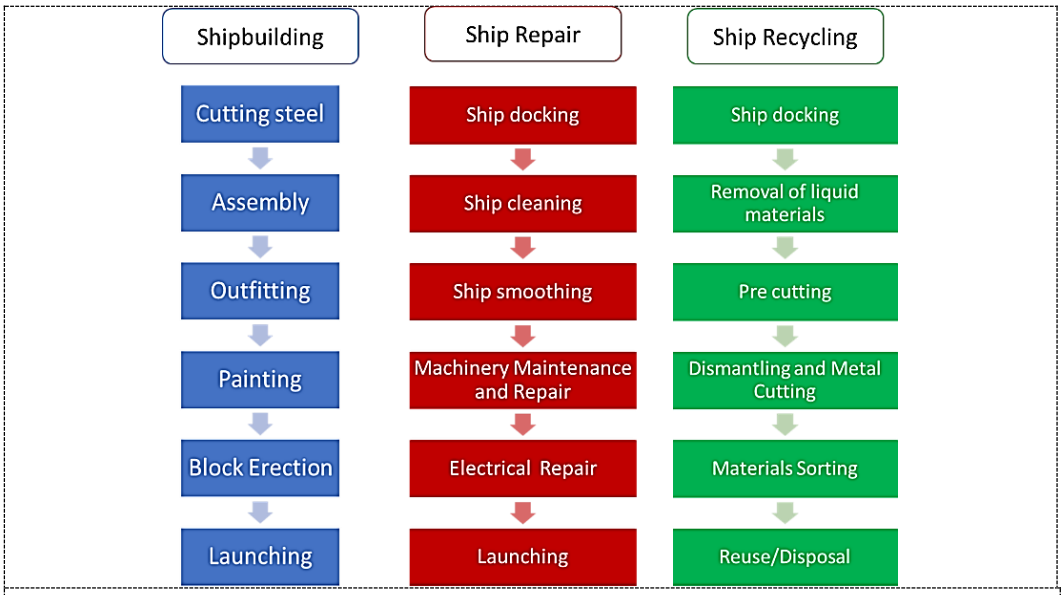

Figure 2. Process flow for each segment.

Labour is a primary contributor to shipyard operation and one of the critical parts of ship recycling operation [24,25], where labour cost is the crucial determinant of the competitiveness shipyards [20]. Both shipbuilding and ship repair are known for their labour-intensive industry and labour-oriented and the work performed with shipbuilding are more prone to automation [20]. Ship repair is naturally labour-intensive due to unique job for every repair task [11]. While shipbuilding is more concentrated, labour is, however, interchangeable in these areas on an inter-firm basis according to supply and demand.

Similarly, current ship recycling practice involves labour-intensive work and hazardous as most ship recycling industries employ manual labour to break ships [26]. Compared to shipbuilding and ship repair, ship recycling requires relatively low skills labour. Ship recycling majorly involves a manual cutting process and material handling skills. Such activity is typically carried out at substandard yards with low regulatory standards and regulations due to improper facilities which create residue from hazardous materials and waste [27]. This raises the issue of poor labour management due to the harsh working environment for the manual labourers, the lack of protective clothing and equipment, predominance of manual processes and a high rate of accidents [26]. On the other hand, integration of ship recycling into conventional shipyard will benefit ship recycling in the way of manpower sharing.

Furthermore, workforce utilisation can be reduced with advanced material handling equipment that is already accessible in the conventional shipyard.

4. Shipyard Facility

A shipyard facility is the activity area where the process is carried out. In general, typical shipyards have specialised workshops and space such as mechanical, electrical, steel sandblasting, docking, painting, and others that can be categorised as the main facilities [28]. Figure 3 shows a list of common facilities that are used in different yards [10,14,29]. It can be observed from the equivalent comparison, as illustrated in Table 1, ship recycling yards share several equivalent facilities with a typical shipyard such as berthing facility, docking equipment, and essential services facility. Some of the essential facilities are discussed in the following paragraph.

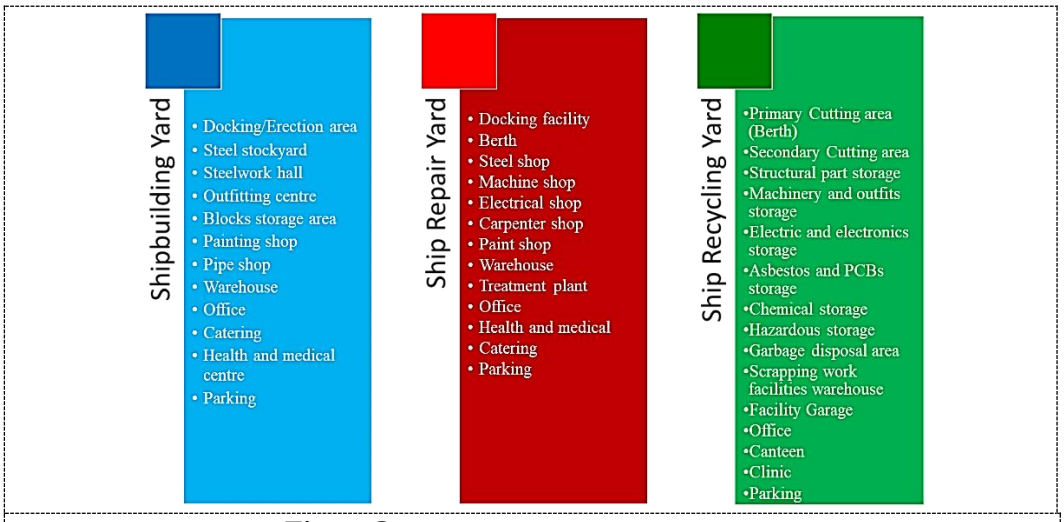

Figure 3. List of facilities for all yard functions.

The primary area is the place where the ship is cut by a block assemblies or module. This process can be located at berth, slipway, or docking area. A secondary cutting area is where parts of the ship will be cut into the size that can be lifted using forklifts. This area should be a fully protected cutting area with an effective drainage system that ensures the flow of stormwater runoff. It may utilise a block storage area already available in the existing yard. The structural area is where all recycled ship parts are placed after being cut into small plates and classified according to their types. Available steel stockyard area in a shipyard can be a potential area for sharing purposes. Machinery and outfits storage is where all types of machinery such as main engines, pumps, generators, and others from the ship will be placed. The electric and electronics warehouse is where all these electrical appliances will be stored before the disposal process. In the shipyard, the outfitting area is where the installation of machinery equipment and support equipment, such as plumbing and electrical [15]. Machinery and outfits storage of ship recycling can occupy the same area because the materials handled in this facility area are similar to the conventional shipyard.

Despite the number of facilities with great potential for sharing purposes, ship recycling yards require several prominent facilities for storing other types of dismantled materials and hazardous wastes that are not available in the current shipyard. A chemical and liquids storage tank must be provided to ensure that all liquids such as water ballast, oil, and hazardous waste are stored according to green guidelines. Storage facilities containing asbestos must be kept using dry airtight containment and wet containment techniques. Storage containing PCB is where all equipment or appliances such as voltage regulators, switches, electromagnets, and circuit breakers containing PCB are stored. Specific storage for PCBs and asbestos is essential for safe handling and control as it can cause a severe health impact [30,31].

It is clear that the basic infrastructure of the conventional shipyard, irrespective of its dedication to shipbuilding or ship repair operation, is similar and even more advanced if compared to what is required in the ship recycling industry. While the principal facilities vary for each yard, theoretically, it can be expected to be within the standard capability of conventional shipyards. Nevertheless, some considerations need to be observed between the existing sectors, whether it was established as dedicated or sharing yards. Shipyard's specialists in shipbuilding require more capital-intensive activity however possess higher return value over the three industries. Each of these yards can be subdivided into components directly related to ship construction, repair, and conversion [32]. Ship repair is generally equipped with a relatively high spare parts and components inventory [11]. Interestingly, most of main facilities used in the ship recycling yard are available in a shipyard. Furthermore, ship recycling activity does not require high technology facilities. The utilisation of the advanced facilities also reduces the associated costs of building for the dock and cranes.

Table 1. Equivalent facilities.

Green Ship Recycling Facility	Type of Equivalent Facilities in Conventional Shipyard
Primary Cutting area (Berth)	Docking facility/ Berth
Secondary Cutting area	Blocks storage area
Structural part storage open area	Steel stockyard
Machinery and outfits storage	Outfitting centre
Electric and electronics storage	Outfitting centre
Asbestos and PCBs storage	None
Chemical storage	None
Hazardous storage	None
Garbage disposal area	None
Scrapping work facilities warehouse	Warehouse
Facility Garage	Warehouse
Office	Office
Canteen	Canteen
Clinic	Clinic
Parking	Parking

5. Material handling and Yard Layout

Another critical resource in the shipyard is material handling equipment [25]. Material handling equipment in the shipyard is mainly used to transport and deliver material from one place to another. Efficient material flows depend on type of transport employed. Common handling equipment such as heavy lift cranes and forklifts are functioning to handle the lifting activity during ship assembly and installation of large ship components. Besides cutting equipment, material handling equipment can be considered critical due to the high cost of ship recycling. However, handling equipment requires high investment costs, and poor handling equipment can result in slow materials moving, thus taking up space. A sharing strategy of using advanced handling equipment that is accessible in established shipyards will then improve material flows in ship recycling.

The material flow is also determined by facility arrangement or shipyard layout. Shipyard layout can be defined as the arrangement of yard facilities to achieve the operational objectives at minimum cost and efficiency [2].Change of shipyard workflow process needs to be supported by increased facilities and redesign of shipyard layout [33]. Even though facility unit and material equipment can be identified, facility arrangement or layout is unique and can't be drawn from a specific template [11].

An example of conventional shipyard and ship recycling layouts is shown in Figure 4 and Figure 5. A significant difference can be seen that both layouts are on the main facility, as described in Table 1. Despite most ship recycling facilities being available in the conventional shipyard, several additional facilities need to be added, mainly from the storage facility. It emphasises that integrating the ship

recycling process into the current layout requires a redesign of the shipyard layout. The shipyard layout design relies on several factors: size of 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 in order to achieve an efficient work process.

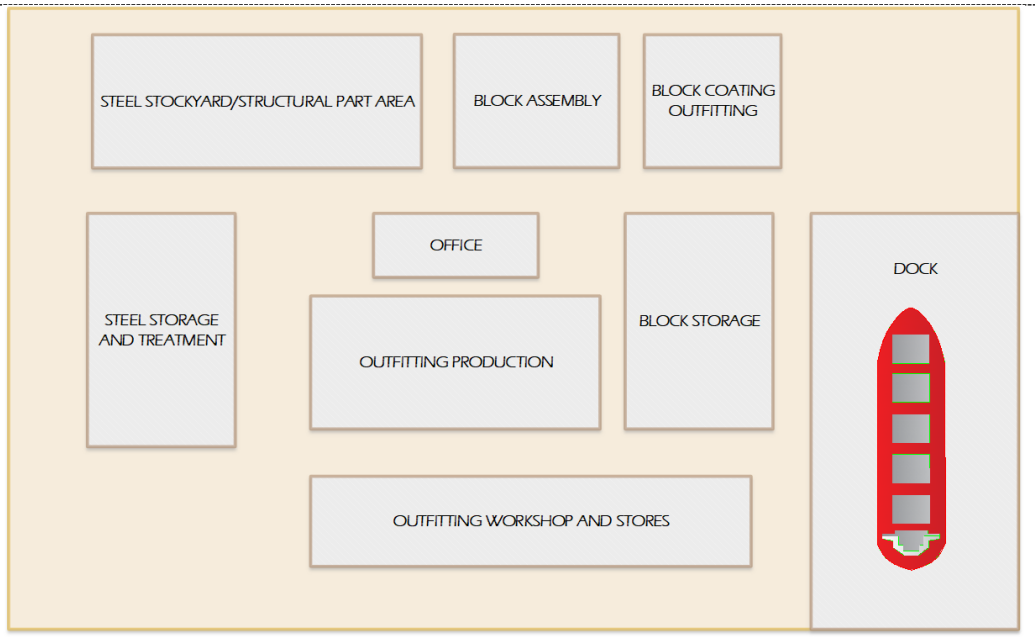

Figure 4. Conventional shipyard layout [34].

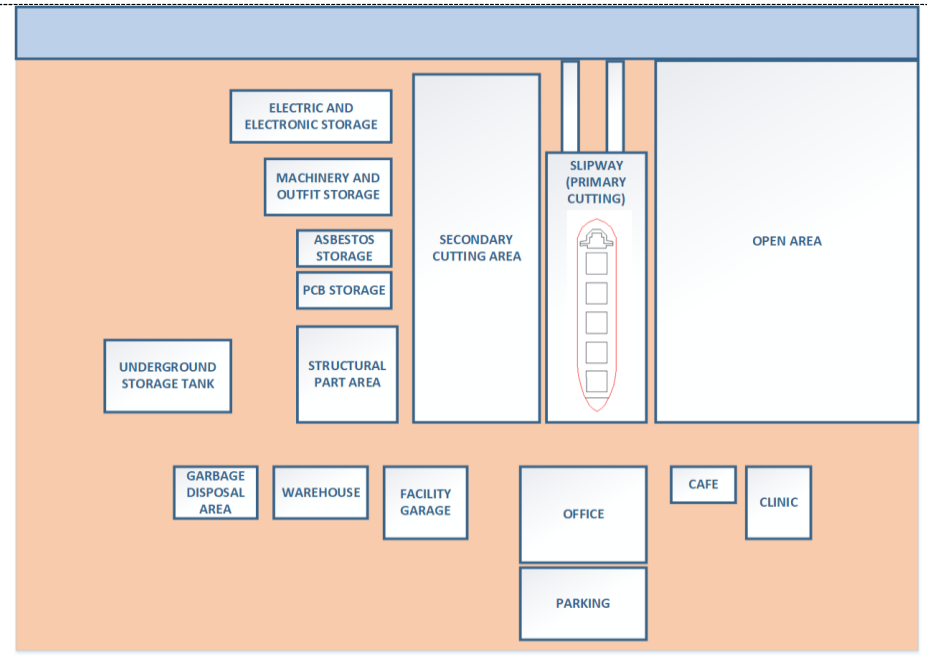

Figure 5. Green ship recycling yard layout [14].

The proposed concept of a hybrid shipyard layout is shown in Figure 6. All the facilities are located within the same area. As discussed earlier, the proposed layout is not usually subject to major changes due to several main facilities already established in the conventional yard and ready for sharing purposes.

Only a few additional facilities will be added and merged into the existing yard to enable a shipyard adequately supported to run on the ship recycling process.

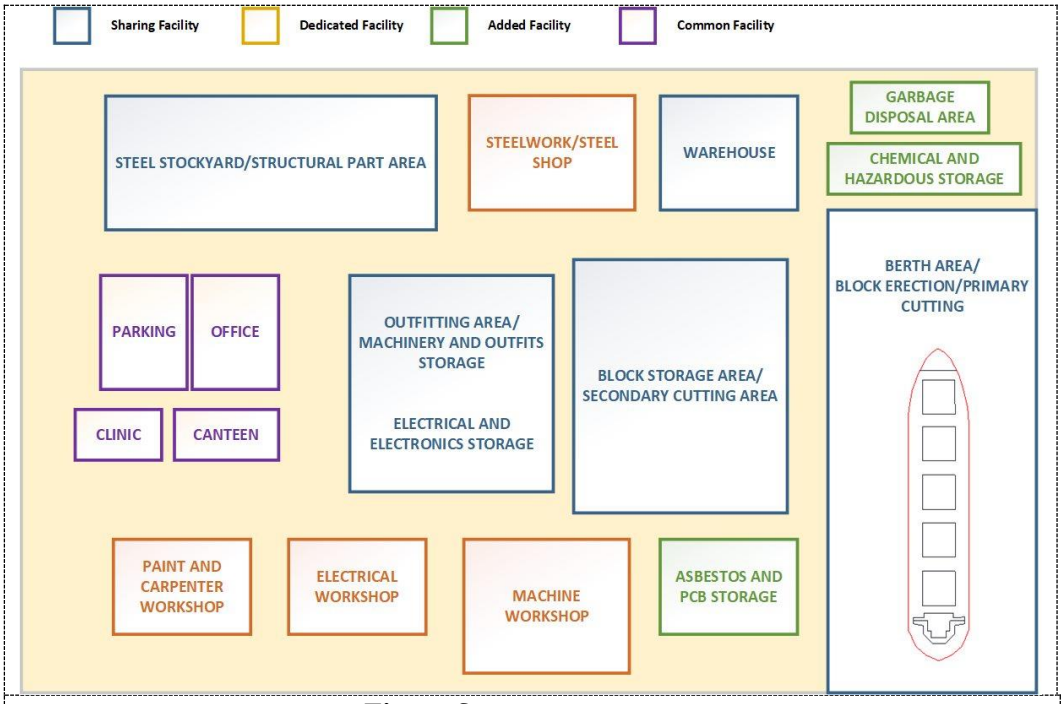

Figure 6. Hybrid shipyard layout

6. Conclusions

Conventional green ship recycling yards are not competitive while substandard ship recycling yards are hampered by various issues on health and environment. This paper presents an idea of a hybrid shipyard for ship recycling by integrating green ship recycling activity into an existing conventional shipyard. The existing shipyard can be a shipyard with shipbuilding activity, ship repair activity or both. Even though there are differences between shipbuilding, ship repair and ship recycling segments, it is found that there are several significant similarities that would provide a ship recycling with some ready use resources from a conventional shipyard. Additionally, the existence of technology in the shipyard will be beneficial in facilitating the ship recycling process, especially in overcoming the environmental, health and competitive issues. By reducing operational costs and increasing yard productivity, significant advantages can be gained from this hybrid concept rather than the individual green ship recycling yard.

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