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Circular Business Innovation and Circular Economy Development in the Shipbuilding Industry: A Design Strategy Perspective

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Abstract: *This paper evaluated the prospects of circular business model approach to maximizing the potentials of Circular Economy (CE) objectives encompassing reduce, reuse, repair and recycle or remanufacture in the shipbuilding industry of the maritime economy. The study also explored the implications of circular design strategies as a key value strategy embedded in sustainable circular business model that translates circular objectives into practices by situating economic incentives to the price and gains of circular design strategies. Within the domain of CE, business models that integrate circular design strategies have been evolving in different sectors such as food, paper, energy, plastics, electronics industries, etc. especially in developed economies. However, circular design strategies in the shipping or shipbuilding industry and the maritime industry as a whole have been poorly studied. This is further compounded by lack of enabling frameworks or policy guidelines for CE implementation in most developing contexts. We isolated, synthesized and analysed secondary materials using qualitative design. Evidences from a broad body of literatures enabled theoretical insights into the study, allowing sets of themes to emerge. Our findings suggest that integrating circular design strategies into business models for CE implementation in the shipbuilding industry can inform and strengthen policy and regulatory frameworks that can promote circular growth in the global maritime sector. This paper contributes to the emerging and growing body of knowledge on the opportunities in circular business model innovations that prioritise circular design strategies and the requisite business, technological, social innovations, as well as circular enhancers to accelerate circularity in the global maritime sector and transition from circular objectives into practices.*

Keywords: Circular economy, Business models, Circular Business model innovations, Shipbuilding, circular design strategies

1.0 Introduction

Global industrial systems are expected to use around 140 billion tons of minerals, ores, fossil fuels, and biomass per year, three times the current consumption, towards meeting humanity's need by 2050 [1]. Amidst these projected global production and consumption needs one of the key challenges to sustainability has been the inadequate management of commodities throughout the post-production stage. Addressing post-production challenges has become expedient in view of the consequences of diverse production and consumption practices [2, 3] and the ever growing human demands [4, 5], as well as the impacts of discarding used products (resources) at their end-of-life (EOL) [6]. Effectively, throwing away used products increase the waste load in the environment, and this has triggered a rethink in resource management resulting in transition from the traditional Linear Economy (LE) of take, make, use and dispose (throwaway) to Circular Economy (CE) take, make, use, reuse, recycle, reproduce or remanufacture [6, 7]. Ellen Mac Arthur [8] described CE as "an economy that is based on the principles of designing out waste and pollution, keeping products and materials in use, and regenerating natural systems. As a result, the economy is restorative and regenerative by design". Also, CE refers to a production system that necessitates the designing and redesigning of production processes and consumption patterns [9], as well as business model innovation [10]. Essentially, reuse and remanufacture are the key drivers of CE. Reuse refers to the practice of repurposing leftovers and wastes from one stage of production to another, as well as maximizing the capacity of products. Remanufacturing, on the other hand, is the process of replacing useless materials with used ones [11, 12]. Although circular practices in the maritime industry can appropriate high potentials similar or related to CE breakthroughs in other industries, it has remained underrepresented in maritime policies and programmes globally [13]. The rationale behind circularity in the maritime industry stems from high regulatory demands on the entire divisions of the industry and the need to meet the sustainability standards relating to environmental friendliness of end users or beneficiaries of the industry services. In the maritime industry, transition to CE is generally considered on the basis of lifecycle process, encompassing beginning of life (such as material or product design), middle of life (such as manufacturing, use and maintenance) and end of life (such as waste or non-usable state). At the beginning of life, the designing process of products/equipments or services or operations has been commonly conceived as 'built to last', but circularity offers an alternative referred to as 'designed to last'. The idea behind 'designed to last' is to develop products/equipments or services or operations that can be utilized for a long time and later looped into another use in the manufacturing process [14]. Conversely, the high reuse possibilities in various aspects of the maritime industry services is taken advantage of by the informal sector through repurposing and resale of components of ship for other uses, in relation to reprocessing activities in developing countries [15]. Even the issue of creating frameworks or operational guidelines that can assist in optimizing the opportunities generated by the informal sector in reuse possibilities has yet to receive much attention.

The importance of business models in translating circular principles/goals to practices has been widely acknowledged, e.g. in the European Environmental Agency (EAA) CE publications [16-19], while the place of sustainable or circular business models in particular sectors or systems have been illustrated in other reports [20-22]. However, among these sectors, the place of circular business models in translating circular goals to practices in the maritime industry and particularly, shipbuilding or shipping sector has been poorly understood. A business model is a conceptual description regarding a company's operations [23] and how an organization generates, distributes, and captures value [24] based on three primary characteristics that connect to value [25-27]. They include, i) value proposition: the product or service offering and the target customer (what value is provided to whom); ii) value creation and delivery: the product or service's specific features and distribution channels (how is value delivered?); and iii) value capture: cost structure and revenue streams (how does the company generate value?). For instance, in the shipbuilding industry, the value proposed includes designing and constructing ship/vessel according to the owner's or operator's specifications, while value creation is achieved through full construction of ship or vessel. Value delivery is by means of shipyards or dockyard and value capture is realized when the price or demand for ship or vessel exceeding the cost of construction. Essentially, sustainable business model combines these three value plans, which constitutes a departure from long-established business model that focused only on economic value by means of turnover and profits [24, 28]. In the light of the foregoing, it can be deduced that business model is a goal-based approach centered on value blueprint of any business and it can be structured or tailored to achieve defined goal(s) such as circular objectives giving rise to circular business model. [29] argue that circular business models can reduce resource overconsumption and waste generation, making CE principles or objectives a viable option for achieving sustainable development. Circular business model has been variedly defined. [30], [31] and [32] gave a broader definition of circular business model as the one that balances the establishment of economic value with the narrowing, retarding and completing resource loops. Circular business models attempt to retain the embedded value and functioning of products, as well as the materials that make them up, to the greatest extent possible [33], which necessitates the incorporation of one or more circular aims, namely, reuse, repair, recycling, and so on, into the business model from the standpoint of the three dimensions of value. This implies strong interrelationship and complementary roles between the objectives of circular business model and the modeled value package. Where this is incompatible with a company's present business model, the company or its competitor must come up with a new business plan referred to as 'business model innovation'. The dynamic process of redirecting business models toward more sustainable or circular ways of shipbuilding is the emphasis of this perspective [34-36].

Product design is a critical lifecycle strategy for achieving all circular aims by contributing to product's ability to meet circular principles/processes, including reduce, reuse, repair, remanufacture, or recycle. Hansen [37] refers to design in a circular economy, as corresponding to cradle-to-cradle concept, which considers product design for continual reclamation and new or different use, making it a never-ending value chain that extends throughout the product's whole supply chain. The goal is to design for usefulness by designing goods that have more positive than negative effects. For example, wastes can have biological values such as providing nutrients to the soil through composting, which can be regenerative and lead to more productive activities. Essentially, the goal is to achieve ongoing use of the same resources through design, and if that isn't possible, to ensure that the waste is reused through natural processes such as composting (biological process) or recycling (technical process). As a result, adoption of circular design is reliant on technological solutions to put the principles into practice, business model innovation to align business incentives with the outlays and advantages of circular design practices, as well as social innovation to align the intentions behind a product's design with how it is actually used. The products lifecycle phases assist in identifying the circular objectives required in each product phase and assessment of the values plans that inform the realization of the target circular objectives. Among the various product lifecycle phases, including materials, product design, manufacturing and delivery, use and end-of-life, the product design phase is considered separately because the designation and arrangement of the various materials that go into a product are key determinants of the ability to retain materials and goods in the economy for as long as possible. For this reason probably, product design for circularity has emerged as a topical priority in circular economy discourse, which the World Business Council for Sustainable Development

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considers as the phase having a greater degree of opportunities in a circular economy [7] than product acquisition, production, use, discard, etc. Furthermore, the importance of each circular objective has been observed to be different in each product lifecycle phase. For example, the circular objective of repair can be actively addressed during the design phase by choosing repairable designs (design-for-repair), or during the use phase by selling spare parts or providing repair services. However, product repair is not a direct goal throughout the raw materials, manufacture, or end-of-life stages but after the use phase. In the same way, while recycling is an important goal in the raw materials and end-of-life phases, it is not relevant in the use phase. As a result, the product design phase can be regarded as the most crucial for the effective creation of circular lifecycles [17].

Circular design has received a lot of attention recently [38], with the purpose of giving guidance for the design of items that accomplish one or more circular aims. Several design solutions have been presented by [31] with the goal of either retarding or completing resource loops, e.g. 'Design for ease of maintenance and repair,' 'design for upgradability and adaptability,' or 'design for attachment and trust'. Furthermore, phase-out of hazardous compounds is a critical circular design aspect. Whichever way the circular design principles are described, they all require proper innovation and enablement to be implemented. The phrase, "design for..." emphasizes the circular design techniques' intended purpose. However, if these concepts are to be put into reality, they must be linked to practical or technical solutions. For example, design for disassembly in shipbuilding industry necessitates technical solutions/innovations for integrating different component parts in a way that allows them to be separated again before reassembly to achieve other or enhance same circular objectives. Another necessity for successful implementation of circular design strategies is that their costs and consequences align with the product's business model. For example, designing for durability may necessitate the use of superior materials that improve the product's quality and lifespan. This sounds excellent for a company whose target is to reach superior quality and expensive part of a market, but it must be balanced against the fact that greater material costs normally result from it. In addition, it is critical to recognize that design choices are influenced by purchasing needs and user demands. A product will not succeed in the market if it does not suit the needs of the user. For example, recent report shows that LNG has broken new records in new fleet order since 2021 and more new vessel demand contracted out in 2022, triggered by high gas demands in Europe as a result of Russia's offensive against Ukraine. In 2021, LNG ordered a total of 85 carriers, out of which 77 were more than 40,000m^3 [39]. The year 2022 records additional 43 vessels, with 37 vessels recorded in first quarter. Clarksons Research Services has predicted more rising number of LNG carrier contracting in the remaining part of 2022, mainly propagated by Qatar's main gas expansion project. Another factor propelling rising number of vessel/carrier demand is projected to hit 17% in 2030 as against 12% in 2020, with a corresponding growth in trade projected at 5.5% yearly from a previous estimate of 4.8%, to approximately 615metric tons around 2030 [39]. Furthermore, Clarksons posited that though the expected growth can potentially attract major LNG carrier obligations based on new environmental regulations, such as compliance to eco-friendly energy practices, which may promote fleet renewal. This is also against the background of steam turbine vessels still contributing to 33% of fleet capacity [39]. Further findings by Banchero Costa research shows lifespan related issues in the global LNG gas carrier fleet, indicating that 12% of the fleet is above 20 years, 17% between 15 and 19 years, 20% from 10-14 years, 21% from 5-9 years and 29% below five years old [39]. The boom in LNG gas carrier, especially as it relates to projected increase in new vessel demand, rising global trade, the need to meet the requirements for emission reduction in the context of recycling and the fleet lifespan concerns can present opportunity for shipbuilding circular business innovation using circular design approach to optimize the realization of circular objectives throughout the lifespan of the vessels for sustainability of the sector. In another development, a new design initiative has been conceived by C-Job Naval Architects, in collaboration with LH2 Europe, to develop new category of vessels with liquid hydrogen tanker to optimize the green energy market globally with a view to expanding the supply chain to different parts of the world as demand increases [40]. As a result, the CEO of LH2 Europe, Dr. Peter Wells foresees a smart energy future in liquid hydrogen production and supply. He also considers the tanker design as a major milestone in achieving infrastructural development that can make clean energy future possible by 2027 [40]. On the other hand, Job Volwater, Customer Care Officer at C-Job has illustrated the challenge in designing hydrogen tanker ships due to light weight of liquid hydrogen compared to LNG tankers, which use ballast water to offset weight loss after product delivery to ensure adequate draft [40]. To address this challenge, the hull of the ship has been designed in trapezium-like form to ensure adequate space that will accommodate the tank on the deck, to eliminate the use of ballast water. However, this design approach is restricted to enhancing global hydrogen supply chain to mitigate atmospheric emissions, which is service-oriented and fit-for-purpose ship design (more deck space to accommodate the hydrogen tank). Although this design initiative has the potential to transform the green energy sector, there is no certainty on the circular business model innovation conceived here and circular goals or objectives intended in this innovation.

This study explored the potentials of reimagining circular business model towards realizing circularity through integration of product design strategies into business model innovations for the global shipping or shipbuilding sector. Within the context of reimagining circular business model for achieving circularity in the global shipping sector, this paper envisioned the requisite business, technological, social innovations, that can support the incorporation of circular design principles into the mainstream circular business model innovation for the sector such as the possibility of creating incentives within the CE value chain to compensate for the opportunities lost in linear economy. These are also considered alongside the guidelines and consumer or user-influenced drivers that can promote the realization of circular design principles in the shipping or shipbuilding sector, which can contribute to expanding knowledge and technological transformation towards exploring and maximizing the prospects of circularity on the maritime industry.

2.0 Methods and Materials

The dearth of research and evolving state of CE development and implementation in the maritime industry globally, particularly as it relates to design, manufacturing and maintenance services in the shipping or shipbuilding sector, informed the application of narrative review [41,42] and qualitative design to isolate and analyse evidences from a broad body of literatures. This approach contributes to analytical review which enabled theoretical insights into the study, allowing sets of themes to emerge [43-45]. The narrative review provides a complete overview of current knowledge and highlights essential areas for future research. Other resources used include IMO and EU publications, as well as case studies incorporating country-wide policy documents, to systematically evaluate opportunities in circular business model innovations that prioritise circular design strategies and the requisite business, technological, social innovations, as well as circular enhancers to accelerate circularity in the global maritime sector and transition from circular objectives into practices. Essentially, the paper adopted mixed method, involving narrative review and qualitative design.

3.0 Literature review

Many studies have documented the implementation of CE in the management of wastes from diverse sources such as telecommunications industry, water packaging industry, paper and pulp industries, food industry, electronics industry, etc [46-53], but little is known about CE practices in shipping or shipbuilding industry. Notably, at the global level, the maritime industry was omitted from the 2015 Paris Agreement, while only compulsory regulation on ship emission standards came into force in 2005, with specific amendment of the 'International Convention for the Prevention of Pollution from Ships' (MARPOL). Even in developed economies such as the European Union (EU) where new and innovative resource efficiency policy initiatives exist and action plans have been developed within the CE concept, maritime sector has yet to be adequately considered and incorporated [54,55]. More so, studies that considered the place of circular business innovations in achieving circularity in the shipping or shipbuilding industry through circular design strategies remains embryonic and underreported. Circular design strategies have been considered as the most essential phase in industry lifecycle approach to circularity, with greater degree of opportunities in a circular economy.

Milios et al. [56] investigated the limitations to material resource efficiency in the Scandinavian Maritime industry and the prospects of mainstreaming policies towards achieving refurbishing and reproducing ship parts. Repeated use and reproducing operations can be employed to extend the life of marine equipment and delay the inevitable stage of recovery or reclamation, resulting in significant material resource savings as well as labor and energy savings. However, when compared to other industries such as aviation and automotive, the maritime sector, including the shipping sector, has a low percentage of repeated use and reproduction. Through focused stakeholder interviews, [56] identified some of the limitations to material resource efficiency, namely, (i) high prices that prevent the use of reused and remanufactured components; (ii) a haphazard and unpredictable policy framework; and (iii) lack of organizational skills to enable repeated use. A set of policies is addressed, and their acceptance within the industry is analyzed, in order to help overcome these barriers. They include i) lowering labor taxes, ii) improving waste infrastructure that distinguishes collection for repeated use, and iii) regulating information and standardization procedures are all possible governmental actions. Essentially, [56], like other authors showed that repeated use and remanufacture practices (key drivers of CE) in the maritime industry remains underreported. Conversely, the paper did not consider the place of circular business innovations in achieving circularity in the shipping or shipbuilding industry through circular product design strategies, which is regarded as the most essential phase in industry lifecycle approach to circularity, with greater degree of opportunities in a circular economy.

Ma´nkowska, Kotowska and Pluci´nski [57] carried out a case study of the seaport of Szczecin, Poland to identify the challenges, opportunities and key actions required of ports whose tidal tables are determined by predictions from a standard port (secondary ports). In the context of structural changes in the global economy, trade, and marine transport, this article focuses on the development of secondary ports in the circular economy model (as a node of circular supply chains) to implement sustainable seaports. They found out that secondary port without technical infrastructure to accommodate large boats, but have enough room to expand their transfer from one conveyance to another, cargo space, business, delivery and different stages of operations might become key players in circular supply chains. Essentially, this study is limited to challenges and opportunities of secondary ports and circular supply chain involving cargo-based services such as loading, transfer from one conveyance to another, etc. However, the paper did not consider the place of circular business innovations in achieving circularity in the shipping or shipbuilding industry through circular product design strategies, which is regarded as the most essential phase in industry lifecycle approach to circularity, with greater degree of opportunities in a circular economy.

Jansson [58], in a study on “Circular Economy in Shipbuilding and Marine Networks-A Focus on Remanufacturing in Ship Repair”, reported many sorts of ship repair activities such as small-scale ship refurbishing, planned dry-dock and ship refurbishing, large-scale ship refurbishing and upgrading, as well as the frequency (duration or timescale) with which they occur and the collaborative networks (stakeholder involvement) that are involved. The article also discusses the possibilities of remanufacturing approaches for each type of repair activity, as well as the companies engaged and their involvement in the remanufacturing process. Also, within the shipping sector, [58] reported that ships have always been recycled longtime ago. The material used to construct ships, whether it was wood in the past or steel today, has always been precious. The shipping business is a predecessor of other industries in terms of recycling, such as the automobile and aviation industries. By weight, 95–98 percent of ship materials are recycled [59]. However, in Asia, the majority of ships rendered useless take place in what can only be described as horrible conditions, with ships being towed up on muddy beaches (beaching) [60]. The process of rendering ships useless has been known to be hazardous, results in the loss of many lives, and is extremely polluting. Although Jansson’s study highlighted the importance of remanufacture and repair in shipbuilding, the study did not consider the place of circular business innovations in achieving circularity in the shipping sector through circular product design strategies, which is regarded as the most essential phase in industry lifecycle approach to circularity, with greater degree of opportunities in a circular economy.

Madu [7], in a paper presentation, suggested prioritization of design stage to ensure that resources and materials can be employed indefinitely to extend the product's life, e.g., the World Business Council for Sustainable Development highlighted "design" as the stage with the highest potential. It offers more options than just acquisition, manufacturing, usage, and disposal. Effective design is critical in a circular economy as it can assist in keeping track of and removing every waste at its source. This can be accomplished through ‘designing for ease of disassembly’, where components can be reused in future manufacture, ‘design for maintainability’, ‘design for reprocessing’, ‘design for remanufacturing’, and ‘design for alternative uses’. In order to comprehend how new values may be created, understanding the different applications for the product, and how the product may appeal to diverse target groups, designers in a circular economy must expand their worldviews to explore both the disruptive and positive elements of products or services. Necessarily, innovative designs must not be brand new, but can be borrowed or benchmarked as long as they match the requirements for CE. The cradle-to-cradle view, which was conceived by Michael Braungart, a German scientist, and Bill McDonough, an American architect [61], is synonymous with designing for a circular economy [37]. In the light of cradle-to-cradle view, materials employed in industrial operations are viewed as having both technical and biological components. The goal of cradle-to-cradle is to design for effectiveness by designing goods that have more positive than negative effects. Unlike the cradle-to-grave strategy, which considers a product's useful life to terminate at some point, the cradle-to-cradle approach considers how items might be designed for continual recovery and reutilization. As a result, it's a never-ending value chain, which extends throughout the product's whole supply chain. For example, wastes can have biological values such as providing nutrients to the soil through composting, which can be regenerative and lead to more productive activities. Accordingly, while designing for a circular economy, a systemic or holistic approach, equally innovative by investigating both the biological and technological aspects of the product can be used. To accomplish the circularity envisioned here, the design stage of the product should foresee and incorporate the biological and technological components. The design strategies emphasized by [7] under the cradle-to-cradle practices include inverse manufacturing, recycling, remanufacturing, reverse logistics, life cycle assessment, design for the environment, eco-design, extended producer responsibility, and eco-labeling. However, [7] did not evaluate the effectiveness of these design strategies in the maritime industry or any other sector. More so, the paper did not consider the place of circular business innovations in achieving circularity in the shipping or shipbuilding industry or any other sector, through circular product design strategies, which is regarded as the most essential phase in industry lifecycle approach to circularity, with greater degree of opportunities in a circular economy.

3.1 Conceptual and Theoretical Frameworks

The current age of industrialization has created an economy that engages the mixture of components such as raw materials, knowledge, technology and capabilities, to manufacture products. Recently, resource management experts have realized that exploitation, utilization and sustenance of nature’s limited materials are at the threshold of complete run out [62] due to inability of the resources to cope with rising human demands. Towards the reduction of environmental impact of waste materials in the maritime industry, the International Maritime Organization (IMO) pioneered the enactment of MARPOL73/78 Convention to promote initiatives for optimization of resources and managing the disposal of potential polluting agents, which concentrates more on contamination of the marine environment by fuels or pollutant emanating from their consumption, e.g. by ships [63]. Also, the European Union (EU) has recently amended some legislations to align with the CE priorities such as Directive (EU) 2018/851 amending Directive 1999/31/EC on the waste landfill, and Directive (EU) 2018/850 amending Directive 2008/98/EC on waste to achieve improved incentives for resource efficiency and transition from LE to CE. Additionally, the United Nations, the Organization for Economic Cooperation and Development (OECD) and the World Economic Forum (WEF) have collectively raised a concern for the development of new business model that will promote resource optimization and reduced pressure on the environment, while prioritizing poverty reduction and improved living standard [3].

For circular business model innovation, an analytical framework is built that allows for the identification of relevant actions that different players should take in order to implement the circular business model effectively. This has been accomplished by: i) redirecting the business model as a means of achieving circular goals; ii) placing business model innovation within the conditions of two other critical innovation spectra, namely, technical and social; and iii) recognizing the importance of appropriate policy, education, and behavioral action in enabling innovation. This analytical approach is depicted graphically in Figure 1. It is organized around the many lifespan phases (shown in green outside the circles), with circular goals that could be implemented throughout those phases displayed in the figure's center. The three categories of innovation are depicted as a layer (blue) surrounding the circular goals, illustrating the fact that specific types of business models, as well as technical and social innovation, may be necessary to achieve a given circular goal throughout a lifecycle phase. As a second layer, enablers that support the execution and adoption of the desired innovation are added (orange). The responsibility of realizing circularity rests on the understanding that as an emerging sustainable business and industry strategy, CE requires collective mobilization, promotion and attitudinal transformation, where all players are acquainted with the relevance of incorporating sustainable consumption and production into their respective spheres of operation and supervision. For instance, in developing nations, well-timed records and information on roles and responsibilities have been generally acknowledged as the lost relationship among stakeholders in the waste value chain [64]. In the case of a recycling operator, for example, such records and information bordering on the quantity of recyclable materials or components from a manufacturing firm periodically for the purpose of research and policy development can contribute to sustainable resource consumption and production. Remarkably, studies that consider the opportunities in industry lifecycle approach to CE development and implementation in the shipping or shipbuilding industry are still at infancy and developing [65].

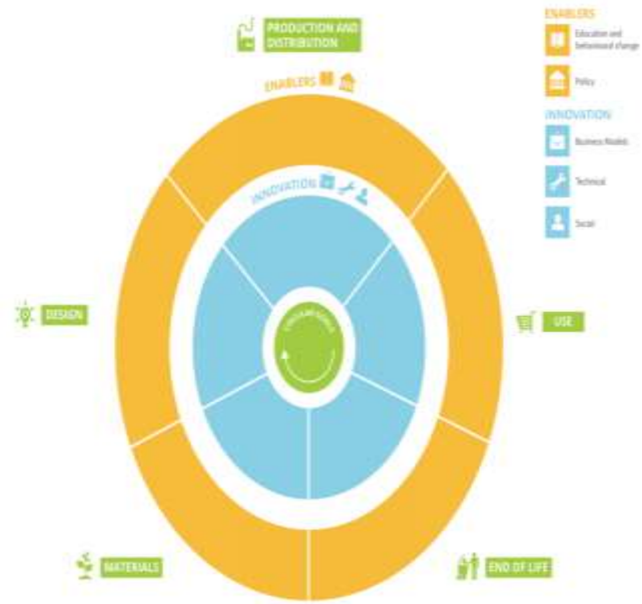

Figure 1: Analytical framework for business models in a circular economy
Source: EEA and ETC/WMGE, 2021 [66]

4.0 **Findings and Discussions**

Circular business sustainability drivers, such as declining demand, increased competition, increased consumer requirements for extended producer accountability and increasing need for transparency about product and asset lifecycles etc. or the potential to capitalize on new opportunities, including changing customer preferences, new technology, new social practices, policy changes, make it relevant to investigate how circular economy ideas may be applied to shipping or shipbuilding industry. In other words, how can we make sections or all of the shipping industry's lifecycle more environmentally and socially sustainable while maintaining economic viability? Circular design strategies can contribute in addressing this question by delivering diverse innovations that can stimulate the holistic adoption of circularity in the shipping or shipbuilding industry. In the light of the foregoing, the following circular innovations/solutions and their enablers are discussed.

4.1 **Technological Innovations/solutions enabling Circular Design strategies for shipbuilding industry**

For the benefit of the entire maritime industry, the energy shift in shipping gives an opportunity to adopt new circular business models for asset management and dramatically transform ownership structures. Until now, the majority of efforts to reach the International Maritime Organization's (IMO) aim of lowering emissions by 50% by 2050 have been focused on the creation of sustainable fuels [67]. There are significant synergies between circular business models and the transition to new fuel types. Green fuels, on the other hand, will not be sufficient to make shipping or shipbuilding viable or circularity-compliant; instead it will almost certainly result in either significant remanufacturing or expedited scrapping of older vessels to accept new and upcoming fuel types. More so, in the coming years, operating costs (fuel and maintenance) will become increasingly essential, while raw material prices are expected to rise [67]. Vessels must be able to adapt and accommodate changes in order to reduce compliance costs and remain competitive in the face of these [67]. This provides an opportunity to analyze the business case for adopting circular thinking by reviewing current industry practices. Other technologically-driven solutions or enablers that can drive circular design strategies in shipping or shipbuilding industry include 'Design for disassembly' or 'Inverse Manufacturing', which enables or facilitates extended lifespan of a ship/vessel in such a way that at end of its initial life, the constituent parts could be reused, recycled, maintained or up-graded. Similar circular design strategy also enables constituent materials combined in the shipbuilding process such as steel or worn-out engine parts, to be isolated or segregated from each other and reused or remanufactured into new ship with possibly, similar specifications or improved version of the same ship or vessel category. Essentially, identifying and analyzing available technical options for increasing circularity in the shipping or shipbuilding industry can contribute to determining the necessary technological innovation or solution and the enablers that will be integrated into the circular business model for sustainability. It can also be understood that technologically-driven solutions/innovations and the enablers can change from time to time, depending on the prevailing consumer or user demands and market circumstances. For instance, with the prevailing global economic downturn occasioned by the Covid-19 pandemic, heightened threats to global peace and international trade, as well as high cost of delivering the appropriate circular solutions or innovation, 'Design for upgradability or adaptability', might be preferred in place of 'Design for disassembly' or 'Inverse Manufacturing' [21, 7]. 'Design for upgradability or adaptability' can be implemented through technical and operational improvements of existing ship/vessel or incorporating elements of flexibility in available consumers or users choices. Flexible and multiuse ship design and standardization of vessel parts, for example, could improve the remanufacture, repair, upgrade, and recovery of components and resources at end-of-life. It is also necessary that in considering the appropriate circular design strategies driven by technological solution/innovation in the shipping or shipbuilding industry, priority should be given to standard and quality of product, as this will enhance consumers or users preference for the outcome/product of such circular innovation or solution.

4.2 **Social Innovations/solutions enabling Circular Design strategies for shipbuilding industry**

The place of social innovation/solution in circular business innovation, as an enabler of circular design strategies in shipping or shipbuilding industry can be considered paramount to achieving consumers or users' preference and acceptance of emerging new solutions or innovations being offered through implementation of the appropriate circular design strategies in the industry. Social innovation/solution also presents a new ground for reconstructing the behavior and interests of consumers or users towards gaining new or enhanced capabilities and skills, in order to achieve better competences and efficiencies in the use of the newly designed assets and resources [68]. For instance, before any circular design strategy is implemented within the circular business model innovation, there is a need to accord priority to the consumers, users, policy makers, industry players, etc. in the shipping or shipbuilding industry, to engage them in the process of ownership, uptake and acceptance of the new and emerging design strategy. This can be achieved through enhanced availability of information on the proposed technological changes in form of public awareness, wide-ranging stakeholder integration, use of the social media platforms, etc. This will enable shipbuilding and shipping companies to migrate from being passive consumers to become active players in the process of promoting and sustaining circular design strategies within the circular business innovation model. In a nutshell, appropriate design strategies entails that the perspectives and detailed conception of shipbuilding and shipping companies should be incorporated into the design phase. Once they accept and diffuse the new and emerging social innovation or solution embedded in the desired circular design strategy, the market value and behavioural shift towards the product are enhanced.

4.3 Enabling Policy Environment

Policy measures can provide suitable incentives for change in circumstances where corporate and social behaviors are intrinsically opposed to circular design. By providing the required impulses to unlock their potential for the transition, effective circular economy policies can incentivize the adoption and dissemination of relevant business model, technical, and social innovation. Policies can encourage business model innovation in shipping or shipbuilding industry by, for example, establishing 'Design for upgradability or adaptability' or 'Inverse Manufacturing', technical innovation through influencing product design or manufacturing process standards and social innovation, such as launching new collaboration and social initiatives to improve value chain cooperation [69]. Notwithstanding diverse definitions and classifications of policy, towards accelerating circular design strategies in the shipping or shipbuilding industry, the following policy instruments can be considered; i) Legislative actions, regulations, and disclosure obligations ii) Research and development support iii) Economic incentive mechanisms, and iv) Tools and Guidelines for Volunteers. For example, policy initiatives to encourage the design-out of harmful substances have had a significant influence, not only on consumer health and safety, but also indirectly by removing a significant barrier to recycling materials for reuse in new applications. The EU's Ecodesign Directive has already proven to be effective in increasing the long-term viability of a variety of product categories, particularly in terms of energy efficiency [70]. Regulations limiting the use of hazardous compounds in electrical and electronic equipment could increase compliance with relevant legislation, such as the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) regulation and the Ecodesign Directive [70].

4.4 Incentives to offset the costs and consequences of innovative circular design strategies in the shipping or shipbuilding industry

One of the major necessities for successful implementation of circular design strategies in the shipping or shipbuilding industry is a need to integrate the costs and consequences of innovative circular products design strategies into circular business model innovation. For example, designing for durability of component parts of a ship in shipbuilding may necessitate the use of superior materials that improve the product's quality and lifespan. This sounds excellent for a shipbuilding company whose target is to reach superior quality and expensive part of a market, but it must be balanced against the fact that it involves greater material costs normally. Increased product lifetimes, as well as greater production costs, are not in the best interests of companies who need to replace their product models on a frequent basis with newer versions. In order to surmount the material, production and product model innovation costs of shipbuilding model innovation, as well as the consequences of frequent changes in product model innovation, effective and sustainable measures are necessary to incentivize these circular design innovations among shipbuilding companies and the industry’s market-space [71, 69] as applicable in other sectors. For example, the European Commission has actively supported economic mechanisms such as environmental pricing to assist in extending product lifespan through reuse and repair. The usage of value added tax (VAT) is one of these devices, which is currently governed by the EU Directive on a common system of VAT (Directive/112/EC). For instance, several EU Member States have already taken steps to reduce VAT on second-hand goods and repair services, including Ireland, Luxembourg, Malta, the Netherlands, Poland, Slovenia, and Sweden, by implementing VAT reductions on minor repair services, such as mending and altering bicycles, shoes, and leather goods, among other things [21]. Other countries, such as Austria and Spain, have used tax breaks to encourage people to renovate their homes. In Spain, the Patronage Law, which gives tax breaks to firms and individuals that donate money from their assets to charities, covers the contribution of used products, which are not distinguished from new ones. Furthermore, the EU Member States are required by the Waste Framework Directive to organize frequent stakeholder interactions on policy tools to encourage reuse [21]. Similar incentives can be explored in the shipping or shipbuilding industry to evaluate their effectiveness in offsetting the costs and consequences of ship-based circular design innovations. For instance, creating shipping or shipbuilding cooperative can be an incentive that will support mutual technical assistance for consultancy services to industry players, especially those involved in circular design innovations, as well as create industry standards and regulations for the certification of ships/vessels in terms of compliance to circular design, construction and maintenance [72].

4.5 Education and attitudinal change as enablers of innovative circular design strategies in the shipping or shipbuilding industry

Attitudinal insights have been recognized and used as a significant aspect of the development and implementation of a circular economy in all domains and at all levels over the years. Millions of consumer choices can help or hinder the transition to a circular economy [54], allowing for the acceptance and improvement measures for more attraction to business models that implement various circular goals such as reclaim, overhaul, reprocess, and so on, as well as increasing the likelihood of such goals becoming mainstreamed [73]. Understanding why individuals consume and what affects their related behavior is crucial to properly moving towards a circular economy. This context-specific understanding, which may be drawn from three interrelated components, namely motivation, drivers, and determinants, should be considered when addressing education and behavioral change efforts towards mainstreaming innovative circular design strategies in shipping or shipbuilding industry. Motivation refers to the immediate personal and social motives and justifications that push someone to do something or make a decision. Drivers are the conditions that encourage, normalize, or facilitate motivation, e.g., societal norms or media marketing, while Determinants are elements that influence consumer behavior, such as service accessibility and price considerations [75-77]. In essence, consumers will change when they are forced to or have a compelling reason to do so, recognize the importance of the change, develop aptitude and awareness to accept/shift toward new behaviors, and have the opportunity to change socially or physically. A more mindful engagement with shipbuilders, one that recognizes the human and material resources that went into ship construction, could lead to a greater appreciation for the value of circular, sustainable design. Product design that is circular must be combined with targeted information and education campaigns. Shipping or shipbuilding companies need to completely comprehend the circular model that underpins the industry, to discourage the mistaken perception that repaired goods are of poorer quality.

5.0 Conclusion and recommendation

A circular economy model's core assumption regards waste as a resource in other sections of the value chain by focusing on closing material loops at the system level through reduction, reuse, and recycling [78-81]. Similarly, the circular economy model aims to establish self-sufficient industrial systems that recycle materials rather than focusing solely on restricting the use of natural resources as a sink for leftovers or wastes [82, 61, 83]. Circular business model innovation has emerged and is evolving as a novel conception encompassing value strategies that contribute to realization of circular goals/objectives in many sectors. Within the context of circular business model innovation for mainstreaming circularity in any sector, circular design strategies has shown considerable potentials as the most essential phase in industry lifecycle approach to CE, with greater degree of opportunities in a circular economy. Interestingly, CE has recently gained prominence mostly in developed economies, as emerging research and innovations across diverse business segments, which can be leveraged on by stakeholders to achieve efficiency in resource management, social inclusion and sustainable socioeconomic growth [54]. However, the Maritime sector, especially, shipping or shipbuilding industry, remains the least researched industry in evaluating the prospects of circular business innovations [13, 58] despite its importance and significant contributions to global trade, economic integration, growth and development. We show in this paper that circular business model innovations can be conceptualized in shipping or shipbuilding industry to deliver innovative circularity using circular design strategies, which has been shown to demonstrate greater degree of opportunity in circular economy, especially in delivering circular goals or objectives such as reuse, recycle, repair, remanufacture, etc., in many sectors. We also evaluated and suggested key innovative solutions and enhancers that can contribute to activating appropriate circular design strategies, which is expected to make circular business model innovations a reality in the global shipping or shipbuilding industry. In the context of future research, there is a need to investigate the role of strategic education and awareness towards mainstreaming the concept of CE into the global maritime industry. Future study should evaluate the challenges and opportunities of circular business model innovations using industry-based product lifecycle analysis. There is also a need to empirically measure the value strategies driving circular business model innovations towards redefining circular policy initiatives. Governments at all levels need to spearhead the drive towards circularity not only in the maritime industry, but other sectors of the economy such as manufacturing, construction, waste management etc. Therefore, there is a need to begin with creating legislative and legal frameworks for mainstreaming CE in every production sector. This will ultimately generate activities that can contribute largely to the achievement of Sustainable Consumption and Production (SDG 12) in the global maritime industry as a whole, and shipping or shipbuilding industry, in particular. Stakeholders should be willing to share information, knowledge and skills in a manner that supports an inclusive and integrated outcome. It is expected that such collaboration and cooperation will assist in sustaining a standardized system of operations that support efficiency and sustainability of the industry.

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