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Material flow analysis (MFA) as a tool to improve ship recycling

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ABSTRACT

The ship owner's decision to select a recycling yard for dismantling and recycling an end-of-life ship is primarily influenced by the price offered for purchasing the ship. The recycling yards offering ‘green’ recycling services generally quote lower prices than other yards due to the higher cost of dismantling a ship by following international ship recycling regulations and health, safety and environmental (HSE) management systems. Such ‘green’ recycling yards must either lower their costs or increase their revenues to offer better prices to ship owners compared to the yards which have primitive or non-existent HSE standards. This article analyzes multi-disciplinary scientific tools and techniques that can be used to make ‘green’ ship recycling economically attractive to ship owners without compromising HSE standards. Material flow analysis (MFA) has been found to be a suitable tool to analyze and plan the ship recycling process. This allows ship recycling yards to better manage waste and resources, thereby reducing costs. The material flow diagrams for a bulk carrier (case ship), showing the generic ship recycling process, are also developed and discussed. The analysis approach used in this article shows one way of introducing analytical tools into ship recycling planning and process assessment.

1. Introduction

Ship owners scrap their ships for various reasons, such as ageing, technical obsolescence, low earnings, high scrap prices and bad market expectations (Stopford, 2009). Though the decision on when to scrap a ship depends on the complex dynamics of these factors, the decision on where to scrap a ship is fairly simple. Most ship owners base this decision primarily on the price offered by the ship recycling yard to buy an end-of-life (EOL) ship. The recycling yard offering the best price usually wins the contract. Additionally, the location of the ship recycling yard and its distance from the last port of the ship is also an important factor (Jain et al., 2016b). However, the sustainability related factors such as environmental footprint and the quality of the ship recycling process employed at the yard hardly influence the ship owners' decision in selecting a ship recycling yard.

Most recycling yards are located in India, Bangladesh, Pakistan, China and Turkey. These countries are major ship recycling centers in terms of annual lightweight tonnage recycled. The ship recycling yards compliant with either the international standards for health, safety and environmental (HSE) management or the ship recycling regulations such as Hong Kong convention and EU ship recycling regulation are considered innocuous to environment, health and safety of the workers. Such yards are referred to as ‘green’ recycling yards in this paper. According to an estimate by Abdullah et al. (2012), the annual global capacity of ‘green’ recycling was around 780,000 lightweight tonnes (LDT) in 2012. Such ‘green’ yards generally offer a lower price compared to other yards operating in the same region. This price gap is mainly due to the extra cost of maintaining high HSE standards and investment in recycling facilities and workforce welfare required for ‘green’ ship recycling (Dev, 2010). The cost of the total process must be lower than the income for a recycling yard to be profitable. Therefore, the ‘green’ ship recycling yards are unable to match the price offered by other ‘non-green’ yards employing primitive recycling techniques. In essence, the ‘green’ ship recycling is mainly driven by the regulations and economics.

The ‘green’ ship recycling yards are economically unattractive to most ship owners due to the generally lower offered price for the same ship. These yards must reduce or even close the existing price gap between ‘green’ and ‘non-green’ ship recycling to promote environmentally friendly ‘green’ ship recycling. They must either increase the revenue or lower the cost of recycling a ship. The price gap must be reduced without compromising the HSE standards and considering the forthcoming international regulations on ship recycling such as the Hong Kong convention and EU ship recycling regulation. One way for ‘green’ recycling yards to achieve this objective is to adopt certain scientific tools and techniques used in other similar but matured industries such as automobile recycling and aircraft recycling. However, Jain et al. (2016b) determined that the differences due to large size, various types, large age range, infrequent supply and dynamic composition of ships makes it difficult to use the tools

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implemented in other recycling industries.

Production and manufacturing firms reduce costs and increase profit margins by analyzing and optimizing their processes using the principles of operations management. Alkaner et al. (2006) showed that ship recycling can be considered as a production system that supports the recovery, processing and resale of materials and components at the end of ship's useful life. Therefore, tools and techniques used within the various production systems should be analyzed for their applicability to the ship recycling industry. Although such operations management tools might be capable of reducing the costs of 'green' ship recycling, they must be supplemented with the analytical tools used in environmental engineering to overcome the unique challenges faced by 'green' ship recycling industry in terms of environment related issues. For example, end-of-life ships contain all sorts of hazardous materials which must be treated suitably to avoid harming the environment, health and safety of the workers. The complexity of ships in terms of structural arrangement and use of various types of materials is also a challenging factor.

In recent times, the focus of policy makers, governments and intergovernmental organizations has been shifted to the anthropogenic environmental problems such as increasing global pollution, depleting natural resources, climate change, etc. The need to carry out scientific analysis to develop and implement stricter rules and regulations to tackle such problems has led to the development of innovative scientific tools and techniques in the field of environmental engineering. Material flow analysis (MFA) is one such tool that is widely used by the environmental engineers. Its applicability to the ship recycling industry must be investigated to achieve the objectives of the 'green' ship recycling yards.

2. Methods and data

The authors of this article gathered inspiration from both operations management and environmental engineering to implement a well-known technique to improve the ship recycling industry. Therefore, this article reviews analytical tools of both domains. The challenges faced by 'green' ship recycling industry and the inability of various operations management tools to address those challenges are discussed. This article concludes that MFA, an analytical tool used in environmental engineering, is the most practical tool of those reviewed. The methodology and input data for carrying out MFA on a ship recycling yard is explained. The MFA is implemented using a 2006 built, 11044 T lightweight bulk carrier as a case study for assessing its applicability to the ship recycling industry. The application of MFA for various ship recycling planning related tasks such as investigating the flows of economic and non-economic value streams on a yard, assessing and planning the ship recycling process, and anticipating various recycling scenarios are also discussed. The article concludes by explaining the importance and shortcomings of applying MFA to the ship recycling industry. It also summarizes the key takeaways of this research.

2.1. Operations management

Operations management is the systematic planning, execution and control of operations (Slack et al., 2010). Operations is an umbrella term that includes services and manufacturing. Operations management involves scheduling work, assigning resources, managing inventories, assuring quality standards and process-type decisions such as capacity decisions, maintenance policies, equipment selection, worker-training options and the sequence for making individual items in a product-mix set (Gupta and Starr, 2014).

In the last few decades, due to significantly increased levels of competitiveness in modern industry, a range of methodologies and techniques aimed at improving the performance, productivity and profitability of the operational activity have been developed (Grünberg, 2003; Hernandez-Matias et al., 2008, 2006; Shah and Ward, 2003). These techniques can be broadly classified into two main categories: diagnostic tools (process mapping, process flowcharting, value stream mapping, pareto analysis, fishbone diagrams, etc.) and improvement tools (just-in-time(JIT), total quality management (TQM), total preventive maintenance (TPM), theory of constraints (TOC), business process reengineering (BPR), etc.). A wide variety of such management practices, methods, tools and techniques are encompassed under a production approach called lean manufacturing (Womack and Jones, 2010; Womack et al., 1990), based on the Toyota Production System (Ohno, 1988).

All manufacturing and production systems involve the transformation of inputs (labor, machines, and materials) into desired goods and services. The inputs are combined by the process, often including many sub-processes, resulting in the production of units of goods or the creation of types of services. Ship recycling is a one-of-a-kind production system where the inputs are the ship, labor and equipment (such as cranes, gas torches, fork lifts, etc.) which are transformed into outputs (such as ferrous scrap, non-ferrous scrap, re-usable items, waste, etc.) as a result of various processes, such as pre-cutting, cutting and post-cutting.

Lean thinking has been successfully applied to the industries where inputs are transformed into outputs. This includes the manufacturing (Detty and Yingling, 2000; Shah and Ward, 2003; Taj, 2008; Yang et al., 2011), healthcare (Brandao de Souza, 2009; Jones and Mitchell, 2006; Mazzocato et al., 2010; Waring and Bishop, 2010), construction (Ballard and Howell, 1994; Koranda et al., 2012; Salem et al., 2006; Thomas et al., 2003) and process industry (Abdulmalek and Rajgopal, 2007; King, 2009; Melton, 2005). However, it must still be investigated whether lean and other aforementioned tools can be implemented to improve the competitiveness of 'green' ship recycling.

2.1.1. Lean manufacturing tools

The basis of lean manufacturing is to identify, measure and eliminate 'waste' from the system (Pavnaskar et al., 2003) to improve its performance. 'Waste', in the context of lean thinking, means any activity in a process that does not add value to the final product (Melton, 2005). The most sought after areas of improvement using lean tools are inventory and quality management because both these areas significantly drive down the costs in a normal production system. However, their application to the ship recycling industry is not feasible because (1) the high fluctuation in demand and supply on both the input and the output side of the ship recycling process (due to the cyclical nature of the shipping markets) can only be offset by creating buffers (inventory) in the ship recycling system, and (2) the quality of finished product of ship recycling i.e. scrap does not depend much on the ship recycling process. Instead, it depends on the construction, operation and maintenance of the ship.

2.1.2. Diagnostic tools

The diagnostic tools such as process mapping can be helpful in understanding the generic ship recycling process and identifying the problem areas that can be targeted not only to develop and make 'green' ship recycling competitive but also to improve the ship recycling industry on the whole. In any industrial process there are three types of flows i.e. information, product and resources (Veeke et al., 2008). The information flow contains the technical data controlling the operation itself. The product flow is initiated due to the transformation of raw materials into delivered products as a result of the industrial process. The flow of resources includes the people and means required to make the product. Resources must enter the system and leave the system as 'used' resources. From a ship recycling yard's point of view, the product flow (i.e. the flow of materials) is the most critical flow because it influences the revenue generation and the cost factors of a ship recycling project. These cost factors include the amount of resources (labor, cranes, forklifts etc.) required to dismantle a ship, the amount of