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Systems engineering as a holistic approach to life cycle designs

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ABSTRACT

The environmental effect from shipping is an area of focus for the maritime industry and for external stakeholders. Even though there are many tools, methods and initiatives, there is still a lack of a holistic approach. This paper presents existing environmental assessment tools and introduces systems engineering as a holistic approach to life cycle designs.

1. Introduction

Industrial companies are to an increasing extent faced with requirements for better sustainability performance. Addressing life cycle sustainability in early design phases is necessary to effectively and efficiently handle environmental, social and economic concerns. The concept of life cycle design, both as a design methodology and a design strategy, has proven useful in common goods industries by providing a holistic and systematic framework for complying with regulation and meeting stakeholder requirements. Even though there are many tools, methods and initiatives to manage sustainability (Sikdar and Diwekar, 1998; Wrisberg and Udo De Haes, 2002; UNEP/SETAC, 2009), there are no equivalent holistic approaches widely employed in the maritime sector (Johansen and Fet, 2010). Due to a large, complex and fragmented structure of the maritime industry, the life cycle perspective in terms of environmental aspects is often lost (Fet et al., 2000). Managing sustainability in ship design requires a methodology targeted towards physically large and complex systems with long life spans and multiple stakeholders. For the purpose of this paper, only the environmental aspects of sustainability are considered. This paper gives an overview of the existing environmental management tools and how they in general can be used to improve a system's environmental performance. Further it proposes the Systems Engineering (SE) methodology as a superstructure for integrating environmental concerns, and provides a basis for combining life cycle management tools and integrating environmental concerns in design principles in the maritime sector.

2. The life cycle perspective

Designing for the life cycle implies making use of the life cycle management (LCM) toolbox to estimate, monitor and control the sustainability performance throughout the ship's lifecycle. LCM can be described as the total sustainability management of products and services in a life cycle perspective (Remmen et al., 2007). This is done through the application of tools for collecting, structuring, disseminating and managing information on the economic, environmental and social performances of product and service life cycles. LCM may be viewed as an umbrella framework for the use of management practices and analytical tools in a life cycle perspective (Balkau and Sonnemann, 2010). The main goal of LCM is to improve the sustainability performance of production and consumption activities in a life cycle perspective by new product design, new business processes and practices or new business models (Remmen and Münster, 2003; UNEP/SETAC, 2009).

Companies that choose to implement environmental LCM practices may select from a wide array of management models based on data, methods, management systems and strategies as listed in Table 1. These can be organized hierarchically according to what level they target, and in this paper, the main focus is on the second and third level in Table 1. Methods and techniques will be combined in a systematic way reflecting their application in the evaluation of the sustainability performance of a ship and will be further connected to sustainability design principles through SE and LCM.

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3. Classification of environmental performance levels

Traditionally environmental management has focused on the management of an organization or a production-site. However, the environmental concerns are currently changing from the site specific focus towards the life cycle perspective. A company's environmental performance is not only a measure of the impacts caused by the production processes; it is also a total measure of the environmental impacts caused by the products and the activities, ideally in a life cycle perspective. To reach the goal of reduced environmental impact in every phase of a product's or an organization's life cycle, appropriate methods for evaluating and improving the environmental performance should be used. This paper introduces and classifies some of the methods from the LCM-toolbox in accordance with the levels of environmental performance presented in Fig. 1. The time axis includes the product's lifetime (with its phases: planning, manufacturing, use and disposal), the human lifetime and the civilization span. The second axis indicates the scope of the environmental concern, ranging from a single product life cycle to several products from one manufacturer and towards a number of manufacturers. The numbers of areas in Fig. 1 represent environmental performance efforts at different levels; (1) Environmental Engineering; (2) Pollution Prevention; (3) Environmental Conscious Design and Manufacturing; (4) Industrial Ecology; and (5) Sustainable Development.

Level 1, Environmental Engineering, includes various types of engineering and production. In Level 2, Pollution Prevention, the planning process is essential. The next level, Environmental Conscious Design and Manufacturing, takes system thinking into account and is related to product design and the improvement of products concerning the manufacturing process, the distribution, the use and final disposal of the products. Both Industrial Ecology and Sustainable Development, levels 4 and 5, are concepts for the macro and meso levels. Companies may find themselves within one of these areas. A shift or movement from one area to the area at a higher level represents a change towards more holistic thinking and improvement of environmental life cycle performance.

4. Classification of tools for environmental performance improvements

There are many ways of classifying the environmental management tools, and one way is presented in Table 2 where they are classified according to their application to processes, to products and to management performance improvements.

4.1. Process oriented tools

Environmental Accounting (EAc), Input–Output (I/O) analyses and Cleaner Production (CP) assessment are often used to calculate and evaluate the environmental aspects of production

Table 1
Levels and instruments for LCM (modified after Jensen and Remmen, 2003).

Levels	Instruments
Policies/strategies	Sustainable development, triple bottom line, integrated product policy (IPP), dematerialization (factor 4–10), cleaner production, industrial ecology, eco-efficiency, sustainable asset management
Systems/ processes	Integrated and environmental management systems, extended producer responsibility, product development process, certification, environmental communication, value chain management
Tools/techniques	Life cycle assessment, material –and substance flow analysis, input output, environmental risk assessment, cost-benefit analysis, life cycle costing, total cost of ownership, audits, checklists, labeling
Data/information/ models	Databases, data warehousing, controlling, best practice benchmarks, references, indicators, fate, dose-response, Monte Carlo

Table 2
Classification of tools for improvement of environmental performance.

Levels	Environmental assessment and improvement tools
Process level	Input–output analysis (I/O) Cleaner production (CP) Environmental accounting (EAc)
Product level	Life cycle assessment (LCA) Life cycle costing (LCC) Environmental product declaration (EPD) Water footprint of products (WFP) Carbon footprint of products (CFP)
Management level	Environmental auditing (EA) Environmental performance evaluation (EPE) Environmental management systems (EMS) Green House Gas management (GHGm) Eco-Efficiency assessment (EEA)

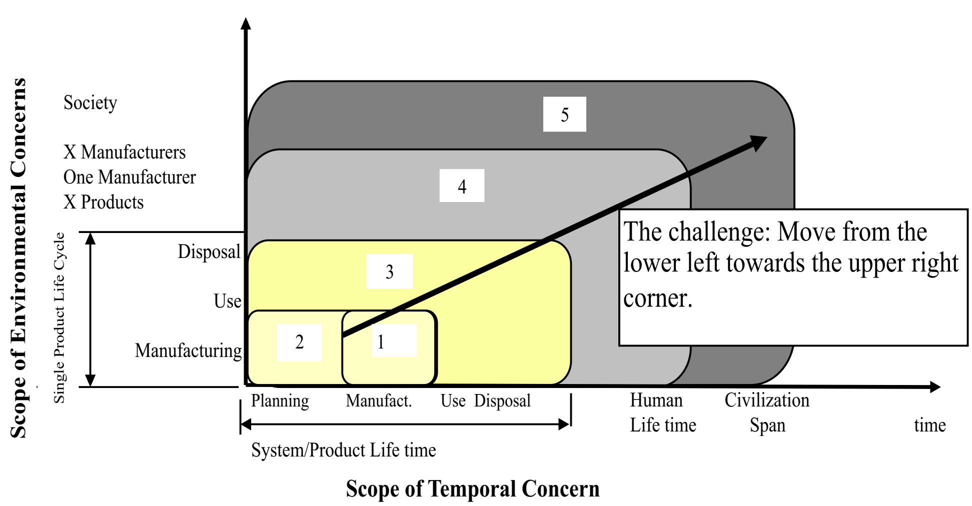

Fig. 1. Classification of environmental performance levels. In Fet (2002), adapted from Bras (1996).