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ENVIRONMENTAL LIFE-CYCLE COSTING IN MARITIME TRANSPORT

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Abstract. The conventional life-cycle costing (LCC) is based on four categories to be assessed e.g. investment, operation, maintenance and end-of-life disposal expenses, while the environmental LCC method takes into account above mentioned cost also the external environmental costs. Given that maritime operations contribute substantially to global warming and air pollution, the paper analyses the concepts of environmental life-cycle costing and externalities with particular reference to transport sector, reviews the possibilities of environmental LCC application to maritime transport sector, and considers the role of public procurement in environmental issues. Evaluation is made of the sources of law at the European Union level, as well as of the environmentally conscious commitments of the maritime industry. The authors are advocating clean and energy-efficient maritime transport and comprehensive evaluation of environmental LCC aimed at ensuring effective implementation of environmental policy objectives and targets.

Key words: maritime transport, life-cycle costing, environmental engineering, environmental externalities, legal framework

1 INTRODUCTION

Despite an increasing awareness for policy intervention in maritime transport, a comprehensive framework for environmental life cycle costing is still incomplete. Transportation sector exerts significant environmental impact. Although a number of rules and regulations have been imposed with the objective of reducing environmental impacts from ships, no systematic cradle to grave analysis has been performed for the maritime transportation sector to provide a total view on which policy development and research and development priorities can be based [1].

Throughout the paper the authors often refer to public procurement principles as it is obvious that public authorities and entities should pioneer the way for purchases of products, works and services which are least harmful for natural ecosystems, the people and the climate. Namely, because funding is limited, designers and facilities managers are traditionally focused on minimizing the initial cost. Unfortunately, this practice often has produced inefficient, short-lived structures with unnecessarily high operation and maintenance costs [2]. On the other hand, private sector is directly stimulated to reduce whole life-cycle costs, however with the tendency to externalize mainly the environmental and health costs to the society.

2 THE CONCEPT OF ENVIRONMENTAL LIFE-CYCLE COSTING

Environmental life cycle costing (LCC) summarizes all costs associated with the life cycle of a product that are directly covered by one or more of the actors in that life cycle (e.g. supplier, producer, user or consumer), and those involved at the end of life. Externalities that are expected to be internalized in the decision-relevant future comprise real money flows as well, and they must also be included. A complementary life cycle assessment (LCA) with equivalent system boundaries and functional units is also required. LCC cannot be approximated by the market price as the price reflects only costs from the cradle to the point of sale. Also, LCC is an assessment method, not an economic cost-accounting method [3].

The costs in LCC framework will differ from the perspective of the producer, consumer and NGO, see table 1.

Therefore, any product system will be looked upon in a different manner by: a consumer deciding on a new product, e.g. ship, a manufacturer deciding on the next generation design, or a public official deciding on transport policy (infrastructure costs, land use, employment, health impacts of pollution, leakage, noise, accidents, and other externalities).

Environmental impacts that are excluded from the financial transaction can become zones of conflict. Determining the system boundary that defines that is “in” and what is “out” becomes the central question of the analysis, and the answer evolves over time [3].

Therefore, assessing the real costs of purchase means calculating the total cost of an asset, from the point of purchase right through to the use phase and including the end-of-life costs. Unfortunately, at least in public sector, organisations are still faced with budgets which prioritise upfront purchase price over longer-term costs, and which may ignore social or environmental costs altogether. These problems can be exacerbated if one organisation purchases a product, service or work but another is responsible for its operation, maintenance and disposal. Such a scenario presents the so called ‘split incentive’ problem [4]. On the other hand, the development and application of LCC was stimulated by the US Department of Defence which mainly controls the entire life cycle of an aircraft or special vehicle. LCC has moved from defence systems to industrial and consumer product areas, where each user controls only a portion of the actual life cycle of the system [5].

The 2014 EU public procurement directives[1] specify that following costs may be taken into account in environmental LCC, whether they are borne by the contracting authority or other users [4]: (a) costs relating to acquisition, (b) costs of use, such as consumption of energy and other resources, (c) maintenance costs, (d) end of life costs, such as collection and recycling costs, and (e) costs imputed to environmental externalities linked to the product, service or work during its life cycle if their monetary value can be determined and verified, see Figure 1.

External costs may come from LCA analyses which assess the environmental impacts, such as greenhouse gas emissions, over the life cycle [4, 7].

LCA-method has only been used to a limited extent for sea-borne transportation means and confined to parts of the product chain and for a limited part of the system [1]. While environmental LCA has been in use since the 1960s and later standardized [11], environmental LCC is drawing on a long history of conventional LCC dating back as early as the 1930s, but is nevertheless a new tool within sustainability assessment as no standardized methods exist, but rather a range of different approaches [12].

LCC can play a role in public and private procurement and may be used to measure the profitability of

[1] 2014/23/EU (the Concessions Directive) [8], 2014/24/EU (the Public Sector Directive) [9] and 2014/25/EU (the Utilities Sector Directive) [10] – hereafter simply referred to as the 2014 Directives.

Table 1 An example of life cycle cost categories framework from the perspective of different actors [3]

	Perspective		
Life stage	**Producer**	**Consumer**	**Society**
Research and development	Market research Test equipment Wages, salaries, benefits Subscription to technical databases	School taxes	Public education buildings Investment subsidies
Component/product manufacture	Materials Energy Capital equipment Facility O&M Logistics Wage, salaries, benefits	Taxes Health insurance	Waste treatment Water treatment Health impacts Brownfield remediation Infrastructure
Use	Distribution & logistics Warranty Consumer support services	Taxes Transportation Consumables Energy Maintenance and repair	Waste disposal Pollution Health impacts Infrastructure
End of life	Take-back program	Disposal fees Recycling deposit	Recovery and disposal Pollution and remediation Landfill development, closure Health impacts

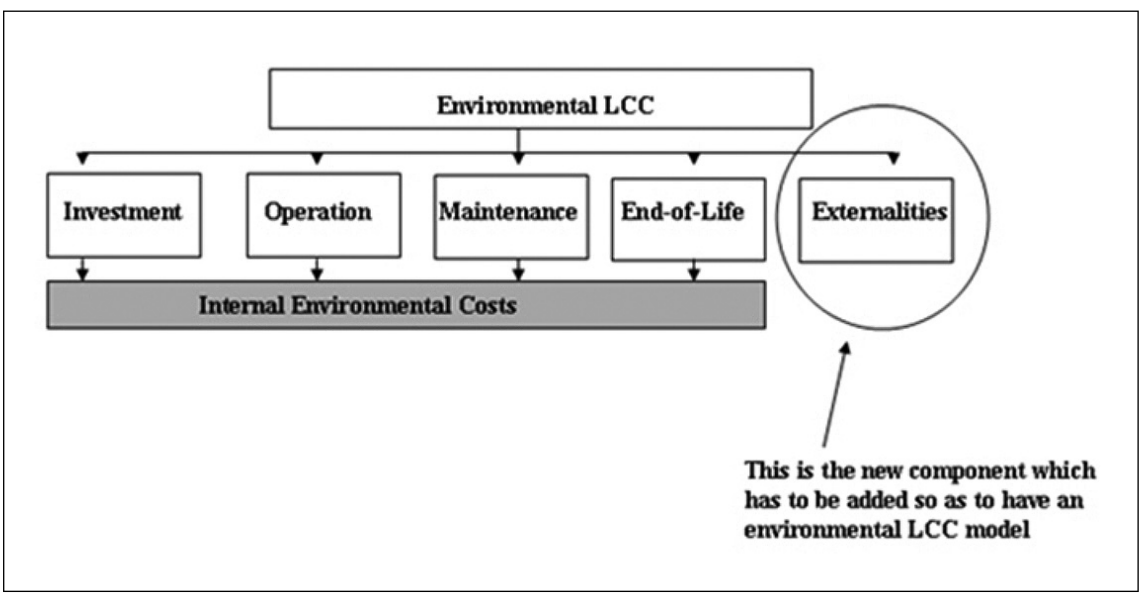

Figure 1 Environmental LCC structure [7]

environmentally adapted choices [12]. A relatively simple formula for calculating life-cycle cost used by US Forest Service [2] should in authors' opinion be extended by one more addendum, i.e. the externalities.

$$LCC = I + Repl - Res + E + W + OM\&R + O + Ext \quad (1)$$

where LCC is the total life-cycle cost in present value (PV) dollars of a given alternative, I is initial cost, Repl is capital replacement cost (PV), Res is residual value (PV-resale value, salvage value) less disposal costs, L is desired useful life in years of the building or system, E is total energy cost (PV), W i total water costs (PV), OM&R is total operating, maintenance, and repair costs (PV), O is total other costs, if any, e.g. contract administration costs, and Ext is externalities.

3 EXTERNALITIES

Effective business practice requires clear definition of what is to be included in a financial transaction. Few could commit money to a poorly defined and open-ended obligation. But clear definition of what is included also means certain effects of the transaction are purposely excluded. These ignored costs, or “externalities”, are imposed on the broader society. Noise, tire wear, and tailpipe emissions along those same roads impose costs on society for health effects and environmental damage. Ignored effects can become lost opportunities for new markets or future financial liabilities or regulatory costs imposed on the business. LCC can also be used as a tool for social decision support. A prime example is the discussions on the cost of nuclear energy, which extend into the future well beyond the operating time of the facility [3].

Externalities can be more or less established in the society as: (a) those that are already paid by someone along the value chain and are not included in the market transaction, for example municipal waste disposal, health costs, increased safety features of a product beneficial for the society (e.g. pedestrian protection), job security, and benefits of improved infrastructure for society, (b) those that can be monetized, are not intentionally paid, benefited, or gained by someone, and are not included in the market transaction (e.g. impacts from CO_2 emissions), (c) those that can be monetized, are intentionally benefited by an actor, and are not included in market transaction (e.g. free rider), and (d) those that are difficult to monetize (e.g. the aesthetic value of a species or product, or wellness) [13].

4 TRANSPORT SECTOR

Transport has a wide-ranging impact on the environment ranging from operational pollution, land-use, congestion and the risks inherent to the transport of dangerous goods. The measures should pursue the reduction of transport intensity and emission, reduction of land use, and the choice of carrier under considerations of sustainable aspects [14]. An integrated transportation and land use life-cycle assessment (LCA) framework [15] should also be a useful instrument and basis for environmental LCC.

European legislation requires the tailpipe emissions of CO_2 to be measured during the type approval procedures for new vehicles. This approach, known as tank to wheel (TTW) only counts the CO_2 emissions produced when fuel is burned by the vehicle engine. This however is a poor indicator of climate impact as much of that impact actually occurs during the production of the fuel – especially for alternative vehicle fuels. This is obvious in the case of electric and hydrogen vehicles which don’t have tailpipe emissions. For these fuels the climate imp act occurs when the electricity or hydrogen is produced. If the electricity used to run the car is generated from coal or natural gas power stations the overall climate impact of the vehicle will still be high. If the electricity is generated from renewable sources, such as wind, solar or hydro power, then the overall impact may be close to zero. For biofuels like ethanol or biogas the CO_2 emitted from the tailpipe is actually the same CO_2 which was absorbed from the atmosphere when the plant was growing. Theoretically biofuels can therefore be climate neutral. However, energy is required to produce the fuel, and other emissions such as methane can be released during production – these factors must also be considered when assessing climate impact. A comprehensive assessment of vehicle climate impact needs therefore to consider both fuel consumption and the climate performance of the fuel used – this approach is known as well to wheel (WTW) [16].

Transport sector must take part in the effort to limit its impact on the environment by suggesting improvements in the design of the materials used but also the organisation of transport itself [17]. In authors’ opinion, environmental aspects should be considered in three major areas: transport means (vehicles, ships, etc.), construction of infrastructure (with particular reference to land use) and also logistics services provided in supplying the goods, services and executing the works.

5 MARITIME TRANSPORT AND THE ENVIRONMENT

Besides climate change which presents an enormous challenge for shipping sector, sulphur oxides (SO_x), nitrogen oxides (NO_x) and particulate matter (PM) emissions are typically very high for shipping, especially when no abatement technologies are applied. Today shipping accounts for about a quarter of the world’s NO_x emissions, which causes smog and contributes to global warming [18]. Moreover, NO_x lead to eutrophication (over-fertilisation), which negatively affects biodiversity both on land and in coastal waters. The shipping emissions are growing significantly as the marine transportation increases. Emissions of SO_2 and NO_x furthermore cause acidification of soil and water [19]. The share of shipping in environmental impact is also through routine or accidental water pollution, noise emissions, as well as underwater noise and collisions with marine mammals, ballast water exchanges affecting the maritime environment, release of biocides from antifouling paints, oil spills, waste and sewage handling, hazardous materials released in ship scrapping [18], and also soil and sediment contamination, erosion, biodiversity loss and habitat degradation from port activities [20]. Various IMO regulations address some of these issues, but with the shipping industry continuing to be absent from international climate conventions, greenhouse gases can be considered the least regulated area [21].

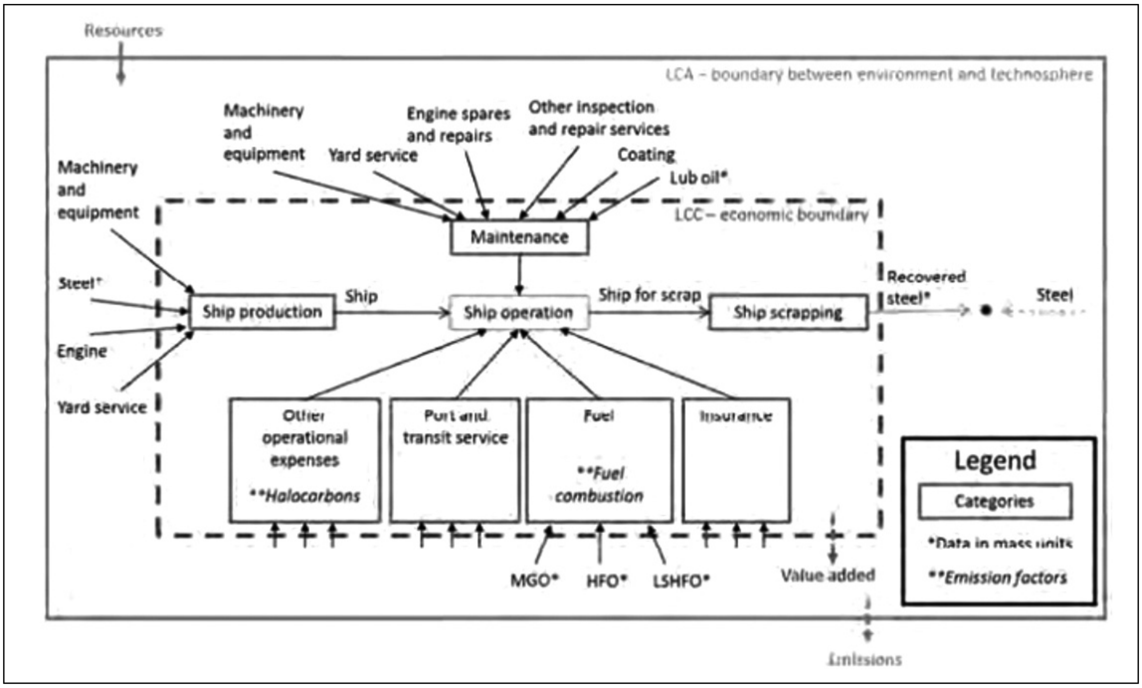

Figure 2 Cash flows allocated to life cycle stages and categories for medium range tanker ship [21]

Figure 2 shows how cash flows were allocated to life cycle stages and categories as well as the economic boundaries for LCC and LCA from the study of a medium range tanker ship by Kjaer et al. [21] which in presenting the costs and environmental burden alongside each other shows where there are potential misalignments between the two and where there is a risk of external costs (e.g. pollution from fuel combustion) being internalized in the future (e.g. through taxes). For example, in the case study, fuel accounts for 89% of the CO_{2e} but only 36% of the cost. Life cycle management of the ship itself is elaborated in [22] and life cycle of ship structure [23]. LCC and sustainability in fishing fleet is studied in [6].

An important benefit with ship transportation is the limited need for land areas. Methods to calculate the land use requirements for ship transportation and the pollution contribution from ports should be established. Furthermore, methods have to be developed to allocate the environmental impact of port activities to ship transportation. The scrapping phase has to be addressed as well. These problems are important to address to enable consistent comparison of alternative transportation modes [1]. The advantages of short sea shipping compared to road transport and integral environmental effect of shipping are analysed in [18].

Available research on sustainable procurement intensively focuses on international product suppliers and less on service suppliers such as logistics services providers. However, in addition to their well-known economic role, logistics processes have a strong impact on the environment (e.g. transportation-induced greenhouse gas emissions, noise and land consumption) and social issues (e.g. transport safety and physically draining occupations) [24].

6 PUBLIC PROCUREMENT

Sustainable public procurement can have a role in indirectly stimulating social and environmental benefits through exerting pressure on suppliers to reduce their own impacts [25]. In fact, LCC was developed and standardized in the United States after World War II to support public procurement [3].

As mentioned hereinabove, Article 68 of Directive 2014/24/EU enshrines a concept which did not exist in Directive 2004/18/EC, namely life-cycle costing (LCC). The aim is to send a political signal to public purchasers. This is clearly a powerful lever to change the production and consumption habits of public authorities [26]. Social protection and employment promotion have not been included in the calculation of the life-cycle cost [27].

The EU public procurement directives enable authorities and operators that have already developed appropriate methods in environmental LCC to continue improving this procedure.

7 DISCUSSION

The success of LCC is dependent on its scope (meaning the inclusion of environmental externalities or/and other externalities) and the methodology used (which in many cases is incomplete and based on experts' perceptions, not on hard scientific evidence) [25].

The use of LCC is often limited to quantifying the monetary value of selected costs. Moreover, purchasers tend not to be able to use LCC to inform bigger, more strategically advantageous decisions. Despite being aware of the benefits of procuring LCC cost-effective assets, procurers will continue to face the high capital outlay dilemma, and give way to selecting „best value for money at the time of purchase“ unless there is a express mandate for them to do otherwise [28].

There is no standard definition of environmental costs and environmental cost savings. Also, it may be difficult to determine the discount rates and the time horizon for discounting. In economic analyses it is often assumed that a given benefit or cost has a higher value now than in the future. For environmentalists, however, the discount value is zero [29]. An example may be that acidification is weighted less and less into the future, which means that if discounting occurs, the less important the losses due to acidification will be. Thus, discounting gives a bias against future generations and may seem inconsistent with sustainability [5].

From a social perspective, failure to consider all feasible options for transport effectively locks in the current system and supports the continued externalizing of environmental and social impacts. The goal of LCC is to better understand these costs in order to promote more sustainable practices [3].

8 CONCLUSION

Clean and energy-efficient transport initially has a higher price than conventional one. With pricing being the most widely used standard in comparing various alternatives for making investment decisions, environmental life cycle costing provides a viable framework for including all other costs which are incurred throughout life cycle of a product, service or works. A lot of interdisciplinary effort is still needed to fully integrate environmental aspect in the LCC instrument, in particular in the shipping industry characterized by long term investments, very sensitive to fuel prices, and capital intensive with regard to purchasing, operating and building the ships, marine equipment and port infrastructure. The challenge is to devise simple and sound calculator of externalities and here the role of policy makers in standardizing the approaches to LCC.

In project preparation stage an analysis of various possible alternatives should be carried out using environmental LCC which integrates numerous known impacts on the ecosystems, health, natural resources, the climate, as well as social aspects.

Public authorities and entities, being important actors in placing maritime contracts, particularly the concessions for shipping services as well as port infrastructure and services, can play an important role in fostering the inclusion of environmental externalities in calculation of LCC. In authors' opinion, the Directives on public procurement are a significant initial upgrade in the legal framework of harmonizing transport environmental awareness criteria at the European Union level.

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