Maritime vessel obsolescence, life cycle cost and design service life

2015 IOP Conf. Ser.: Mater. Sci. Eng. 95 012067

(http://iopscience.iop.org/1757-899X/95/1/012067)

Maritime vessel obsolescence, life cycle cost and design service life

O Dinu[1] and A M Ilie[1]
[1]Department Transport, Traffic and Logistics, Faculty of Transport, University Politehnica of Bucharest Spl. Independenţei, No.313, Bucharest, 060042, Romania

E-mail: aoana.dinu@upb.ro

Abstract. Maritime vessels have long service life and great costs of building, manning, operating, maintaining and repairing throughout their life. Major actions are needed to repair, renovate, sometime built or even replace those scrapped when technology or demand changes determine obsolescence. It is regarded as a concern throughout vessel's entire life cycle and reflects changes in expectation regarding performances in functioning, safety and environmental effects. While service live may differ from physical lives, expectations about physical lives is the main factors that determines design service life. Performance and failure are illustrated conceptually and represented in a simplified form considering the evolution of vessels parameters during its service life. In the proposed methodology an accumulated vessel lifecycle cost is analyzed and obsolescence is characterized from ship's design, performances, maintenance and management parameters point of view. Romanian ports feeding Black Sea are investigated in order to provide comprehensive information on: number and types of vessels, transport capacity and life cycle length. Recommendations are to be made in order to insure a best practice in lifecycle management in order to reduce costs.

1. Introduction

Maritime shipping has seen several major technical innovations aiming to improve the performance of ships or their access to port facilities [1]. Most important of them are: size, speed, specialization of ships and automation technologies. Ship design has significantly improved to steel, aluminum and composite materials hulls therefore the hulls of today's ships are the result of considerable efforts to minimize energy consumption, construction costs and improve safety.

Failure occurs if performance falls below levels that decision makers evaluate to be unacceptable, maritime vessels tend to be ineffective or is very likely to become so in the near future or maintaining and operating costs become considerably high [2].

There is no general consensus on how types of ship structural failures can be classified. Various methods including load type, stress type, degradation type, crack sizes and others have been used. Some studies grouped failure modes according to crack sizes - two levels of crack severity, namely, nuisance and fracture cracks were used in the classification [3]. Other identified five failure categories considering as a criterion longitudinal strength of a hull girder [4]. Vessels failure modes can also be categorized according to the severity of consequences resulting from failures (failure modes were classified into catastrophic, end of serviceability, serviceability limiting, non-limiting and nuisance failure modes) [5]. Ship structure failures are grouped into three types: primary, secondary and tertiary, the most important being the primary behavior, associated with the ship as a whole [6] or according to the type of load that induces the failure mode and consequently two categories, dynamic and static loading were used in the classification [7].

2. Vessel lifecycle cost analysis

The goal of life cycle analysis, therefore, is a holistic understanding of the long-term economic, social and environmental effects of design, construction, operation and maintenance and disposal of a vessel. This understanding is used for efficient management of the system. In a life cycle analysis, all the short-term and long-term costs (financial, physical, service, environmental), benefits and risks involved in operating the structural system are assessed, evaluated and used for optimal decision making [8, 9].

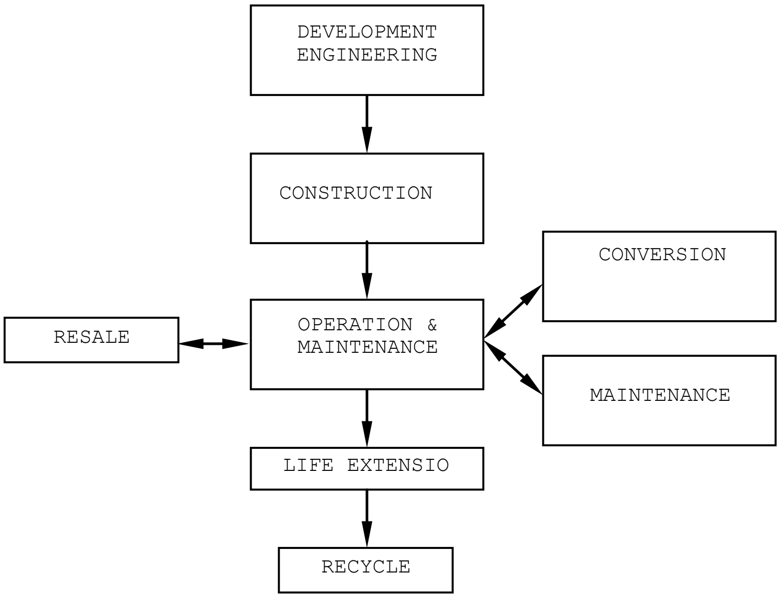

Figure 1. Life Cycle of a Vessel System (Source [8]).

Three of the phases presented in figure 1 are considered major in a vessel life cycle, as follows:

Regarding construction, ship structural systems in particular have traditionally been constructed from steel. Highly stiffened thin steel plates are commonly used to achieve minimum weight structure at optimal cost. The life cycle of a structure depends on the quality of construction, which is affected by the type of welding technique, type of electrode, nature of the surface, qualification and experience of the welders and inspection of the welds.

Modern ship operation is a big and sophisticated process and in order to insure appropriate performance levels maintenance is needed. Larger repair work or rebuilding may occur as part of maintenance, vessel operator is the one that choses how often and the level of maintenance during lifetime. Data shows that approximately 10% of the steel amount is added during vessel’s lifetime. It is estimated that half of the materials from the construction phase is changed over a ship lifetime. For each docking 50% of the area below the water line is painted with primer and antifouling.

Recycle takes place after 25 – 30 years of service or when repairs cannot be financial justified. Normally the ship owner sells the ship to a ship scrap yard for demolition. At the yard all the steel and some of the equipment is reused or sold in the secondhand market. Once a ship has completed is commercial life, it will be brought to a scrapping yard to be disassembled and recycled.

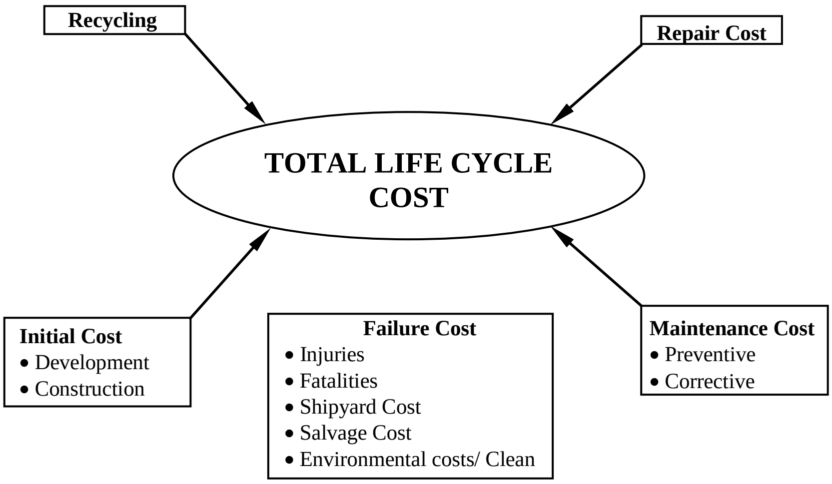

Figure 2. Costs involved in life cycle analysis.

Life-cycle cost is the expected net cost over the lifetime of the structure. Initial cost and all subsequent expected costs of significance, as well as disposal costs, are included in economic life cycle cost. For a vessel, the total economic life cycle cost is illustrated in figure 2, is given by equation (1) and the time value of money needs to be considered in evaluating.

$$C_T = C_O + C_M + C_F + C_D \quad (1)$$

where C_T represents total life cycle cost;
CO - initial cost;
CM - maintenance cost (this could include inspection, repair, layup, conversion and modification and resale costs);
CF - failure cost and
CD - disposal cost (this could include resale cost).

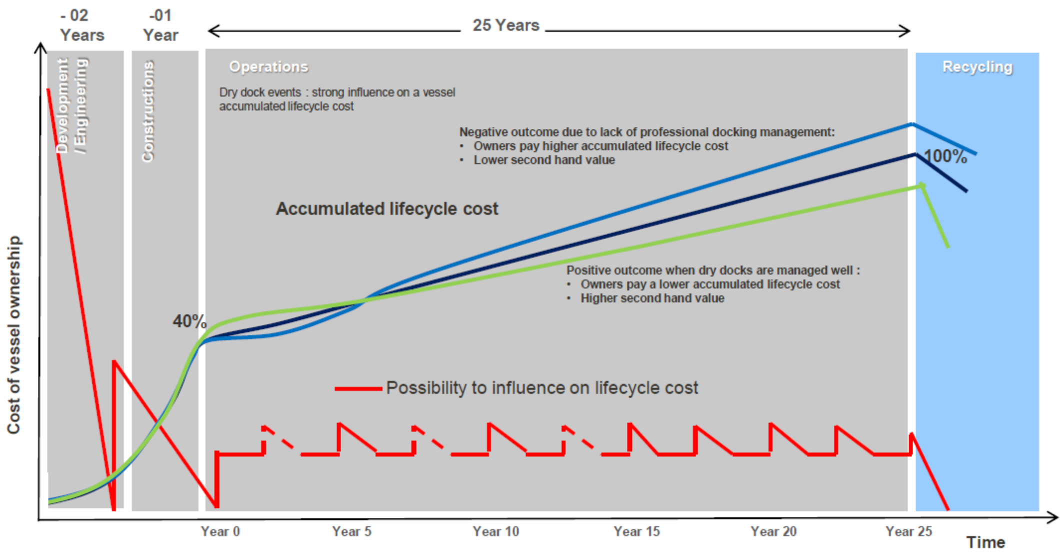

Figure 3. Vessel lifecycle cost analysis (Source [10]).

Since designers and operators of ship structural systems cannot see into the future, then all the above components of life cycle cost are uncertain. Therefore, probability-based techniques should be used in the costing process. The costing process should be based on analysis, data and experience.
In figure 3 are shown the opportunities to influence ship life cycle costs during the ship's life span. The red curve shows that first of all design and then construction determines the future costs. During operation the dry dock maintenance works also enable measures to raise efficiency. The operation costs consist of fuel costs, administration costs, crew costs, insurances, spares and maintenance costs.

3. Obsolescence and design service life

Obsolescence appears when changes in requirements or anticipations considering the utility of the vessel are registered. In most cases, vessels continue to function but at levels below standards [2]. One of the defining characteristics of a ship is the long service life, of many decades [11].

There is a large number of obstacles faced trying to predict vessels design life including uncertainties on climate and variables influencing deterioration, our limited knowledge of mechanisms of ships' degradation, lack of sufficient information and inherent complexities of the problem.

In mathematical terms, vessels performance may be represented in equation (2):

$$Performance = P(S_j, D_j, t) \tag{2}$$

where S_j represents supply vector of services *j* that the vessel provides to various groups (e.g., users, owners);

D_j = demand vector of services j that the vessel provides to various groups (e.g., users, owners);

t = time, measured from the vessels completion of construction and start of commissioning.

In general, the supply of services, S_j, is characterized or predicted as a function (equation (3)) of design and operational characteristics of the facility and its management

$$S_j = S(X_j) \tag{3}$$

where X_j represents a vector of descriptive and functional characteristics *i* of the facility (load type, stress type, degradation type, crack sizes, steel modulus of elasticity)

If performance falls below levels that decision makers evaluate to be unacceptable, maritime vessels tend to be ineffective or is very likely to become so in the near future or maintaining and operating costs become too high. Mathematically, failure can be shown as

$$P(t) < P^T \tag{4}$$

In equation (4), P^T represents minimum acceptable performance.

Planers and vessel designers generally seek to assure that effectiveness, reliability and cots are balanced to achieve „optimum” performance during the design lifetime as in equation (5):

$$t \le T^D, P(t) \ge P^F \tag{5}$$

where T^D represents design service life. „Optimum” in this context generally means reliable effective service at lowest possible cost. In practice, however, it may imply lowest construction cost, tolerance of what some users will view as reliable service and other compromises.

Figure 4 illustrates conceptually and in simplified form the progression of a vessel's performance during its service life. Performance immediately following the completion of construction, at commissioning, is typically less than the design ideal (optimum performance). The new constructed vessel will continue to deliver the performance at a reasonably steady level for some years (barring catastrophe and with proper operations and normal maintenance) and then, a slow decline inevitably begins, owing to wear and aging - eventually performance falls to a level judged to be the minimum acceptable.

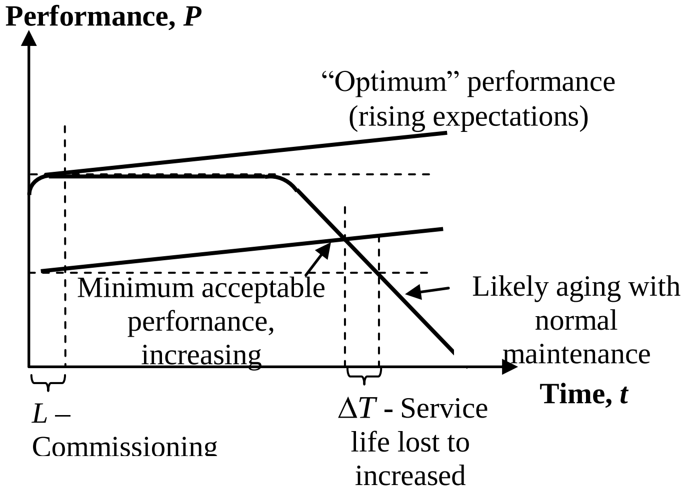

Figure 4. General representation of performance (Source [2]).

More typically, peoples' expectations change over time as a result of newer facilities development, introduction of new products and materials and increased experience, leading to the reach of minimum acceptable performance levels much sooner than they would otherwise

4. Investigation of Romanian ports feeding Black Sea

Globally, on 2013 year level, maritime shipping industry is serviced by more than 100.000 commercial vessels of more than 100 tons falling into four broad categories [1]: passenger vessels (subdivided into two categories: passenger ferries, where people are carried across relatively short bodies of water and cruise ships, where passengers are taken on vacation trips of various durations, usually over several days), bulk carriers (differentiated into liquid bulk and dry bulk vessels), general cargo and Roll on-Roll off (RORO) vessels.

For the same year, in Romanian ports 71.079 ships entered, 64.631 of them interior navigation vessels, representing 90,92% and 6.448 of them maritime vessels, representing 9,08%. Total number of ships that exit Romanian ports was 72.505, 66.236 of them interior navigation vessels, representing 91,35% and 6.269 of them maritime vessels, representing 8,65% [12]. Regarding most important Romanian Ports feeding Black Sea, Constanta Port, from all registered maritime vessel number, it attracted 4764, meaning 75% of Romanian maritime traffic.

Table 1. Maritime vessels type distribution in Constantza Port (Source [13]).

Types of vessels	2008	2009	2010	2011	2012	2013
Bulk carriers	415	386	419	401	439	533
Container ships	1201	694	523	577	651	579
General cargo	2881	2748	3145	2879	2692	2525
Oil tankers	957	724	647	632	673	636
Others	415	356	411	341	550	492
All vessel types	5869	4908	5145	4830	5005	4764

As presented in table 2, in 2013, the average age (per ship) was highest for general-cargo ships (25 years), followed by other types (22,6 years), oil tankers (16,7 years), container ships (10,8 years) and dry-bulk carriers (9,9 years). Following the surge of new buildings in the dry-bulk segment, almost half of the dry-bulk dead weight tonnage is only 4 years old or younger, overtaking for the first time container ships as the youngest vessel category.

Table 2. *Maritime* vessels age distribution in 2013 (Adapted from [14]).

Types of vessels		Age [years]					
		0-4	5-9	10-14	15-19	+20	Average
Bulk carriers	[%] of total vessel number	41	10	9	16	24	11,77
	Average size [DWT]	80772	65854	60514	75693	47053	
Container ships	[%] of total vessel number	21	23	15	25	17	12,83
	Average size [DWT]	56530	41481	28210	22545	13619	
General cargo	[%] of total vessel number	11	12	5	8	63	25,38
	Average size [DWT]	6396	4194	5808	4342	3102	
Oil tankers	[%] of total vessel number	24	14	7	12	43	18,69
	Average size [DWT]	64176	59987	74818	37046	6404	
Others	[%] of total vessel number	20	15	9	11	45	20,19
	Average size [DWT]	5112	5269	4909	4265	4224	
All types	[%] of total vessel number	20	14	8	11	46	20,21
	Average size [DWT]	35193	22382	25060	23249	6856	

More, 20% of all seagoing merchant ships were younger than 5 years, representing 40% of the world's deadweight tonnage. New container ships are on average three times the size of those built 20 or more years ago, and only 5 per cent of the container ship tonnage is older than 20 years. Oil tankers, too, tend to be replaced relatively early; only 4 % of the existing oil-tanker tonnage was built more than 20 years ago. As a reflection of most recent ships being larger than older ones, the global average age per ship shows an age of 20,3 years.

5. Conclusions

Most of the time, service life differs from physical lives therefore expectations about physical lives determines, for the most part, the designed service life that is typically recommended to be 20 – 30 years. Vessels design service life and expectations of service life are based mainly on experience and testing. Considering data from Table 1 and Table 2 most common type of maritime vessel in Constanta Port is the general cargo vessel, 53% from total traffic and in the same time average age for this specific type of vessel is of 25,38 years, the biggest registered value. As number of vessels, is followed by oil tanker, 13,35% average age for this specific type of vessel is of 18,69 years. Concluding, almost tree thirds of maritime vessels entering and exiting Constanta Port are at their life cycle limit, most of them reaching the recommended designed service life of 25 years.

References

[1] Rodrigue J P 2013 The Geography of Transport Systems (Rutledge Publishing)
[2] Lemer A 1996 Infrastructure Obsolescence and Design Service Life *Journal of Infrastructure Systems* pp 153-161
[3] Stambaugh K A and Wood W A 1990 Ship Fracture Mechanisms Investigation *Report SSC 337* Parts **1, 2**
[4] Daidola J C and Basar N S 1980 Probabilistic Structural Analysis of Ship Hull Longitudinal Strength *SSC 301*
[5] Ayyub B M and all 1989 Estimation of the Structural Service Life of Boats *Naval Engineers Journal American Society of Naval Engineers* **101(3)** pp 156-166
[6] Mansour A E & all 1997 Structural Safety of Ships *Trans SNAME* **105** pp 61-98
[7] Ma K-T and Bea R G 1995 A Repair Management System for Fatigue Crack in Ships *Society of Naval architects and Marine Engineers* (Transactions) pp 343-369

[8] Ayyub B M & all 2000 Risk-based Life Cycle Management of Ship Structures *Report SSC 416* pp 149 -167
[9] Pawlik T 2011 Ship life cycle assessment and management *Gesellschaft für angewandten Umweltschutz und Sicherheit im Seeverkehr GmbH* (Bremen)
[10] Srinath M 2014 Efficient Ship Operations – through vessel lifecycle management *Wilhelmsen Ship Management*
[11] Ayyub B M and White G J 1990 Structural Life Expectancy of Marine Vessels *Marine Structures* **3(4)** pp 301-317
[12] Cazan L A 2013 Autoritatea Navală Română *Raport privind Incidentele Navale*
[13] Information on http://www.portofconstantza.com, Constantza Port Anual Report 2013.
[14] Duval Y and Pawlik T 2013 Review of Maritime Transport *UNCTAD/RMT/2013 United Nations Publication* pp 35-50