EDD – Economic Benefit Analysis of Extending Dry Docking Interval

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The possibility of interval extension between two dry docking is alternatively offered to the shipowners by classification societies. Although, for now, such a possibility is limited only to certain types of ships, a significant shift has been accomplished in accordance with today's technical and technological capacities. It is quite clear that not all shipowners will accept this option, as either five-year or even mid-interval might suit them well. The option introduces an economic benefit, but requires additional preparation to withstand the full interval without negative consequences, primarily related to the protection of underwater part of the hull. The relationship of economic benefits and the cost of investment to successfully pass the complete period gives a clear view to the shipowner for the decision of accepting an extended dry docking period between two consecutive dry dockings. This paper is presenting one of the approaches to calculate feasibility of prolonging dry docking interval. Calculation example represents an economic indicator, crucial for shipowner's decision to accept prolonged dry docking interval. The paper presents an analysis of underwater hull condition for the vessel with a composite coating. It is based on a collection of actual data registered in the period of seven years. Significant data have been derived from the analysis, allowing basic set up for theoretical assessment as well as the real justification of extended dry docking period between two consecutive dry dockings of the vessel. Some of the presented facts, related to underwater composite coating, might be used for similar calculations.

KEY WORDS
~ Extending dry docking interval (EDD)
~ Composite coating, Underwater cleaning
~ Fuel consumption
~ Dry docking

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1. INTRODUCTION

Dry docking of the ship is an integral part of the regular maintenance of underwater hull, propeller, bow-thruster, sea water chests, cathodic protection of the hull, rudder, etc. Regular inspections in dry docks are specified by the IMO and classification societies, and they are usually accommodated within interval two and a half and five years. With the occurrence of the possibility to extend docking interval to the period of seven and a half years, although applicable only for certain types of vessels, a discussion opens in which interested sides present arguments for and against, to reconcile opinions. Namely, it is indisputable that today's technology enables most of the inspections and the repairs of the ship's underwater hull in a floating condition (Hydrex Underwater technology, 2012), and accordingly, it is quite justified to introduce extended docking interval. Viewing from the side of the ship-owner docking is "necessary evil", considering that the ship makes the profit only when sailing, the time spent in the dock, aside of maintenance costs, includes the costs of deviation to the shipyard as well as the costs of lost profits while staying in the shipyard. However, the counter-arguments are related to the application of a high-quality underwater coating, and protection against the growth of the marine organisms. The efficiency of the ship's underwater hull coating is quite challenging for the five-year interval of

docking, and the extended interval additionally complicates the problem. Any mistake in the selection of underwater coating, manifested by increase of underwater hull fouling (Kovanen, 2012), is rapidly coming to the forefront in the form of increased fuel consumption, and accordingly, the increase in emissions of harmful gases, as well as the possibility of translocation of invasive marine organisms (Bodilis et al., 2012). This paper deals with the extended interval of docking based on the analysis of actual data from the field.

2. EXPERIMENTAL

2.1. Extended dry docking interval (EDD), the class requirements

Prolonged dry docking interval (Figure 1), although in the pilot phase, offers potential economic benefits to the shipowners by extending the range to seven and half years (Det Norske Veritas AS., 2012). However, it should note that it is necessary to consider an option as a package, with its "pro at contra." Apart from the savings, many possible problems are involved which needs to be considered. For now, the extended interval is primarily reserved for container ships in international sailing. The main problem of the prolonged docking interval is the adequate protection of the underwater hull as well as effective control of marine organisms fouling. The leading suppliers of marine coatings offer proven quality coatings that can withstand prolonged intervals without significant fouling of underwater hull, provided the sailing conditions, used for the calculation of dry film thickness, do not change significantly during the entire sailing period. Specifically, the thickness of the coating is estimated considering the amount and the rate of biocide release calculated concerning the speed of the ship, average sea temperature in the sailing area, and average time spent in the ports and anchorages. Significant deviation from the calculated conditions can result in increased or reduced biocidal consumption, which over the time contributes to inadequate protection against marine organisms fouling. If noticeable hull fouling has already occurred, resulting in significantly increased fuel consumption, underwater hull cleaning is an option to be considered (except for polymers based coatings). However, underwater cleaning process will usually take away a portion of biocide layer, which will reduce the duration of the bio-fouling protection of the hull. The exceptions are solid underwater coatings that do not contain any biocides. For them regular underwater cleaning of the hull is for these coatings the only way to control marine growth on the hull. The concept of these coatings relates to high ecological standards of safeguarding of the marine environment (Hydrex Underwater Technology, 2011). This paper analyses sailing interval of the vessel on which such a coating protects the underwater hull. A conventional type of stern tube could also be a problem at an extended interval, especially when considering the still unknown impact of EAL (Environmentally Acceptable Lubricants) on new sealing materials. New lubricants are in use, among other causes, due to the new rules VGP 2013 (EPA, 2013) issued by EPA (United States Environmental Protection Agency), which among controls of the effluents require ships to use EAL for stern tube bearings. Nevertheless, today there are completely green solutions of stern tubes that do not encounter this problem. One of the solutions is the installation of "Thordon" stern tube with sea water lubricated bearings (Carter, 2009) or some other manufacturer (Wärtsilä Corporation, 2018), (Lagersmit Corporation, 2018).
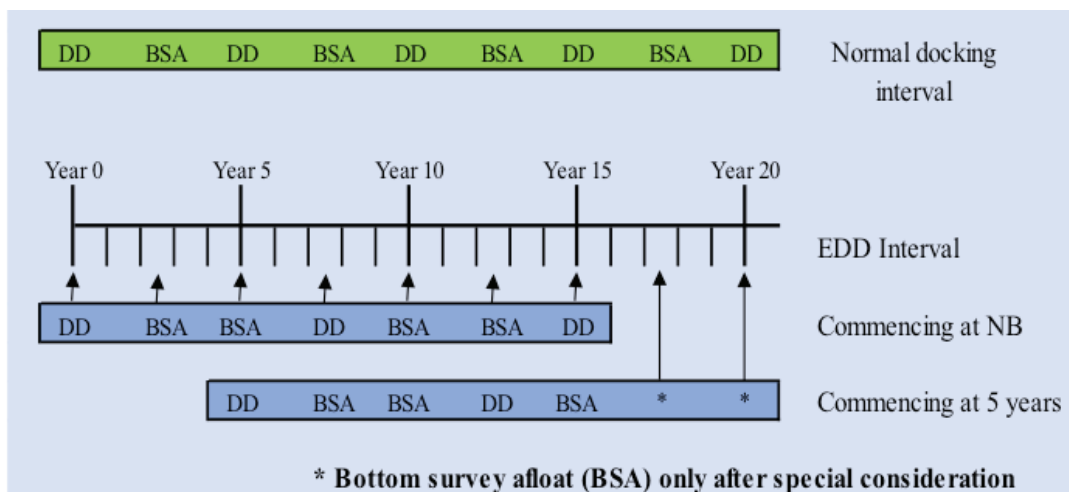

Figure 1.
Dry docking scheme (Det Norske Veritas AS., 2012).

2.2 Analysis of extended period influence to the condition of the underwater hull

For the task of analysis of underwater hull condition and its influence on the fuel consumption (Molland et al., 2011) in the extended period between dockings, processing of the data has been done for the vessel of 42,276 DWT. Fuel consumption and vessel's speed data had been collected within the period from February 2010 to August 2017. In this period, the vessel completed two dockings, 2011 and 2015. Surface treated composite coating had been applied to the underwater hull, for the first time in 2011, classified as STC (Surface Treated Composite) coating that neither contains nor release biocides, thus regular underwater cleaning is the only way to control fouling of the hull. During the second docking, 10% of the total coated area has been renewed on the flat bottom, vertical sides and bootop. It has to be noted that vessel's permanent trade is Nord Europe – Canada and that during winter period the coating is exposed to the mechanical damages by ice. Taking into consideration such severe condition, mentioned the percentage of the renewed coating is rather minimal. Presented graph (Figure 2) summarizes all data of fuel consumption and vessel's speed within the period 2010-2017.
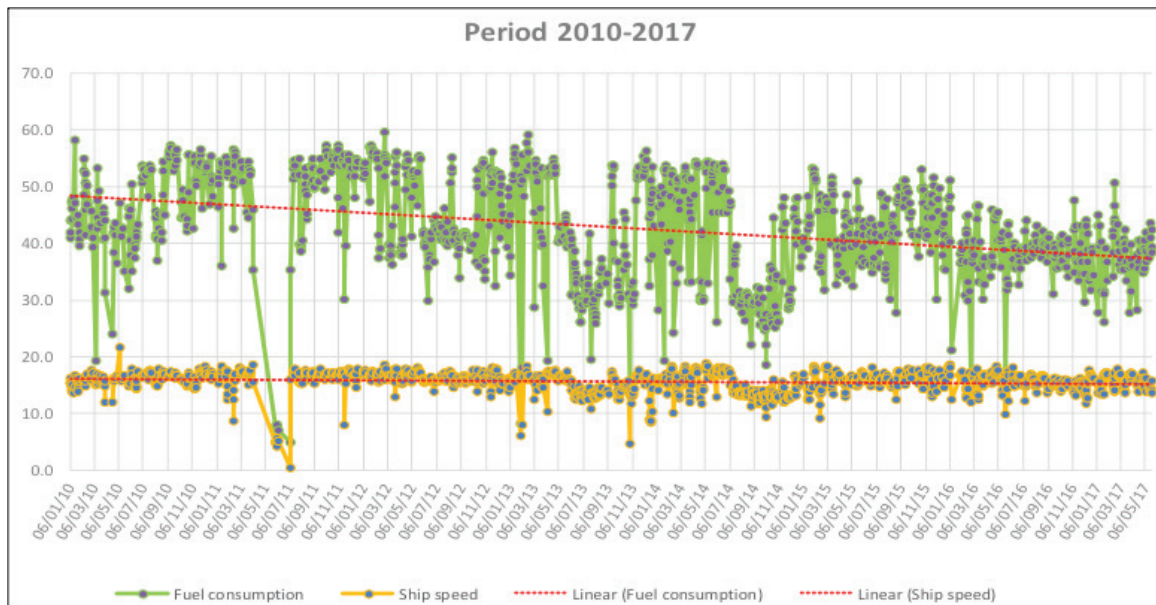

Figure 2.
Complete data for fuel consumption and ship speed in period 2010-2017.

Presented trends of fuel consumption and speed are linear, calculated by standard "Excel" functions. Linear equation for fuel consumption trend is:

$$y = -0.0041 \, x + 214.36 \tag{1}$$

where:
x - quantity of the fuel for the specified date.

Accordingly, the regression coefficient of determination (Note: The specific indicator of regression reliability is coefficient of determination R^2 that is, based on Chaddock's scale, within the range 0.0-1.0. The regression model is getting more reliable when the ratio of determination is closing value 1.0.) for fuel consumption ($R^2=0.1274$) has been calculated. Based on Chaddock's scale (Table 1), its value is within range for low correlation, and thus linear trend of fuel consumption is not reliable for fuel consumption prediction outside the observed interval.

Table 1.
Chaddock's scale (Moore et al., 2014).

R^2	Irl	Explanation
0	0	Negligible correlation
0.00-0.25	0.00-0.50	Low correlation
0.25-0.64	0.50-0.80	Moderate correlation
0.64-1	0.80-1.0	High correlation
1	1	Very high correlation

By using the same procedure, the equation of the linear trend of the ship speed and the regression coefficient of determination was obtained. Linear equation for ship speed trend is:

$$y = -0.0003\,x + 28.233 \tag{2}$$

where:
x - quantity of the fuel for the specified date.

The Regression coefficient of determination for speed data is 0.0152.

Again, in case of ship's speed there is a weak connection data with the linear trend, even in this case, the pattern does not have enough accuracy for the speed prediction outside graph timeline. Anyhow, the intention of the paper is not to deal with the time prediction of consumption/speed of the ship, but with general direction of the trends during the observed data period. Therefore, a small value of the regression coefficient is acceptable. However, it should be taken into account that the graph (Figure 2) does not give a realistic picture as fuel consumption varies widely, due to the different sailing conditions:
• State of the substantial sea,
• Default full speed.
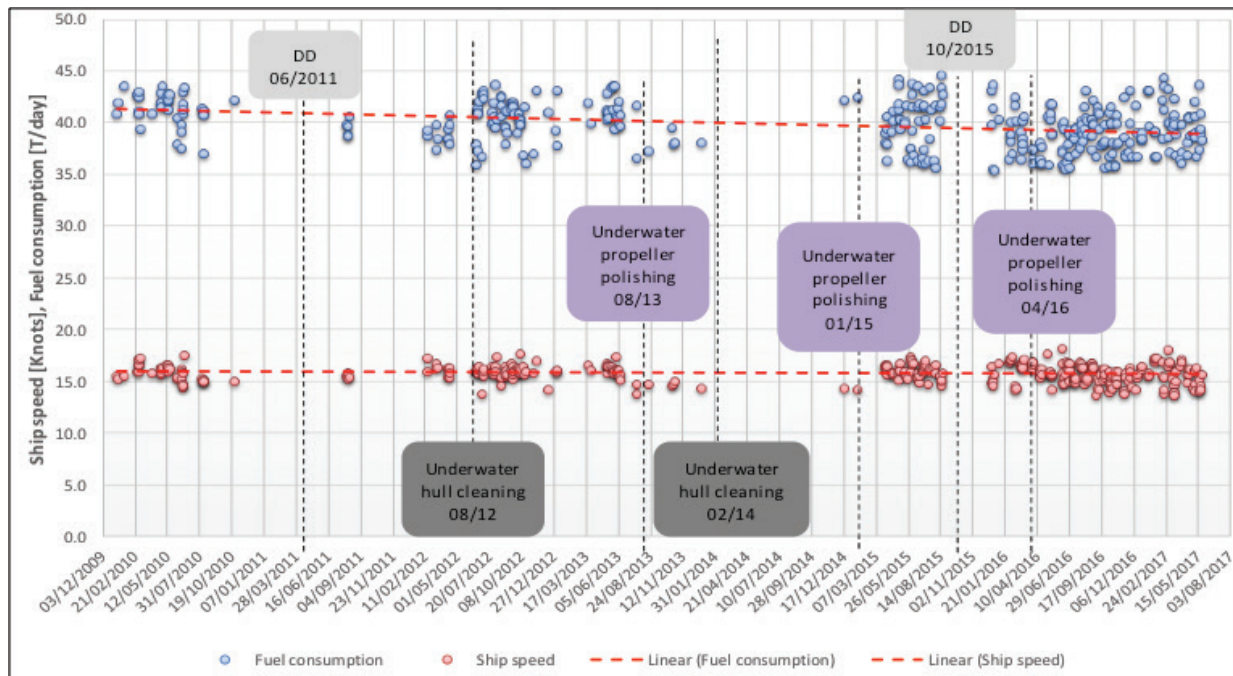• Default economic speed
• Default super-economic speed

Figure 3.
Fuel consumption and speed data for ECO sailing regime in period 2010-2017.

Therefore, it is necessary to eliminate the data collected regarding heavy sea and choose one of the defaults sailing regimes throughout the interval 2010-2017. Data for navigating with economic speed are the most numerous, and it is quite logical to analyze these data.

Figure 3 shows only data for ECO (economical sailing speed) navigation, to better analyze the trend of speed and consumption (Kovanen, 2012). There are apparently defined time periods for maintenance of underwater hull and propeller, components that directly affect ship speed and fuel consumption (Logan, 2012).

3. DISCUSSION

The graphs are presented to determine the trends of fuel consumption and ship speed (International Organization for Standardization, 2016) in the indicated specified period to find out whether it is possible to extend the interval between the two dockings without significant loss of ship speed or increase in fuel consumption at the end of the extended range. In this case, ship speed is kept constant, so the change in fuel consumption is variable which characterizes economy of sailing. In this

sense, at first glance, it is entirely illogical that the trend of fuel consumption tends to fall on all graphs. It is expected that the fuel consumption trend have a slight increase towards the end of the extended interval. Namely, since this underwater coating is hard and does not damage by underwater cleaning, the rotation of brushes to cleanse the collected marine organisms also polishes the underwater coat, and after each underwater cleaning, the roughness of the underwater coating becomes reduced.

For a rough estimate of fuel savings over the processing time, data from Figure 4 is used. The "Ton-Mile" trend starts with a value of 1.08 and ends with a value of 1.04.
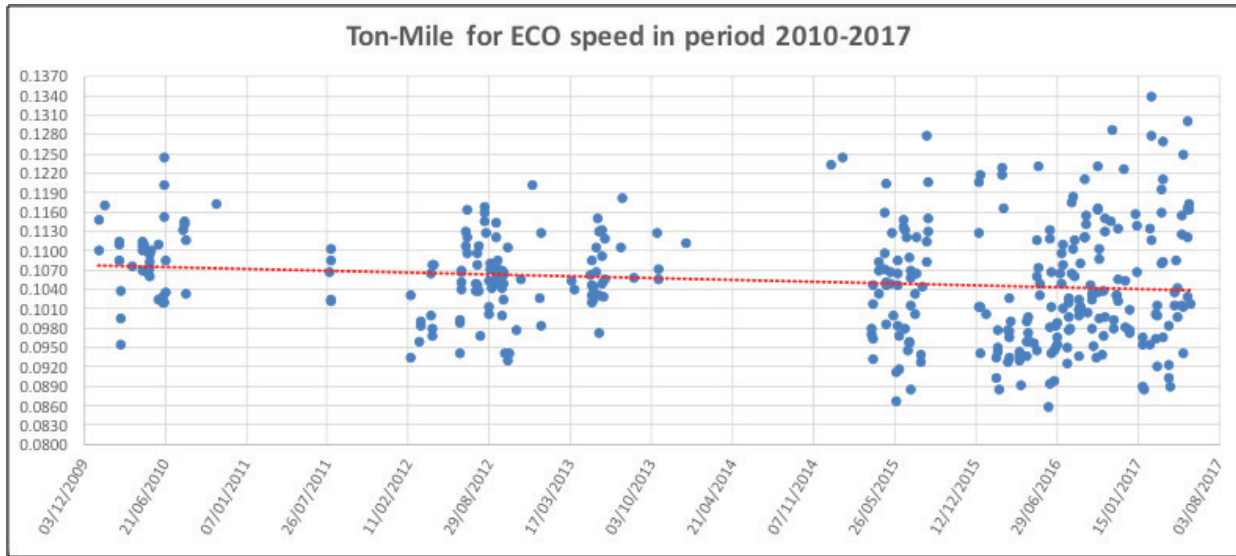

Figure 4.
Sailing distance in NM per one ton of consumed fuel.

From this, daily fuel consumption is calculated, considering that the "ton-mile" data used the average ship speed 15.8 knots.

$$"Ton\text{-}mile" = \frac{Daily\ fuel\ consumption}{Total\ daily\ distance\ sailed} \qquad (3)$$

By adding known values, the daily fuel consumption is:

$$0.108 = \frac{x}{378.9} \qquad (4)$$

As per (4) daily fuel consumption at the beginning of the period is 40.9 T/day. By the same process, daily fuel consumption at the end of the period found to be 39.4 T/day.

In the case of quality classical biocide-releasing coatings, the average drop in ship speed at the end of the five-year period ranges from 0.5-0.8 %. As data for the vessel with a classical biocide-releasing coating is not available, comparison of two types of layers is not feasible. Therefore, the best possible case for the classic coating will be surmised, without speed drop and increased fuel consumption over the observed period that is based on average 252 sailing days per year for period 2010-2017. Figure 5 shows such a hypothetical example. A decrease in fuel consumption in the ship with a composite underwater coating is simplified and displayed linearly. At the very end of the period, the fuel consumption of the vessel with a composite marine coating is 3.67 % lower than the ship with a classic underwater coat.

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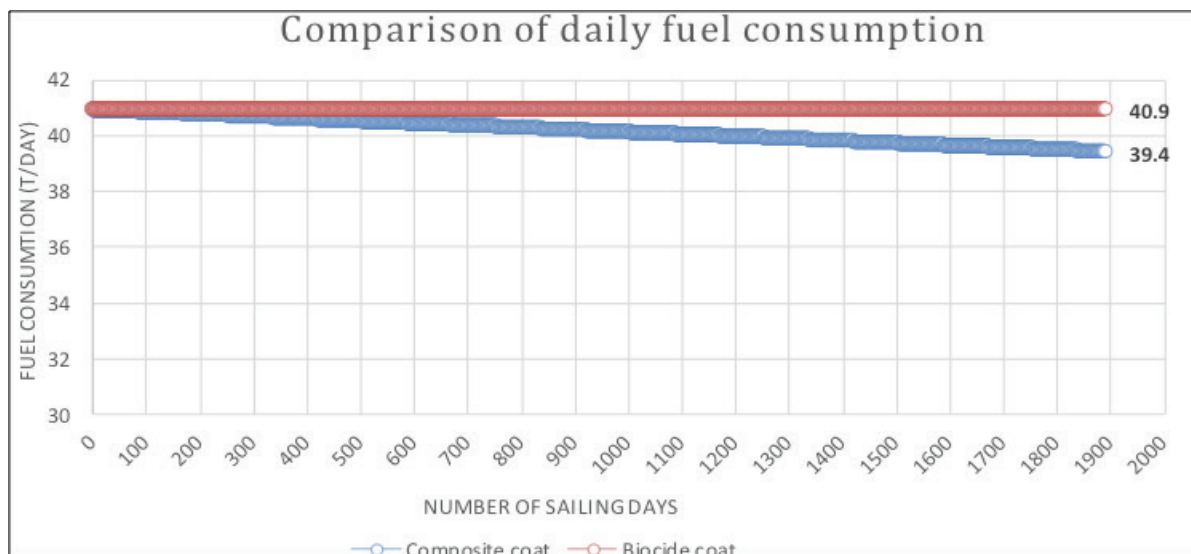
Figure 5.
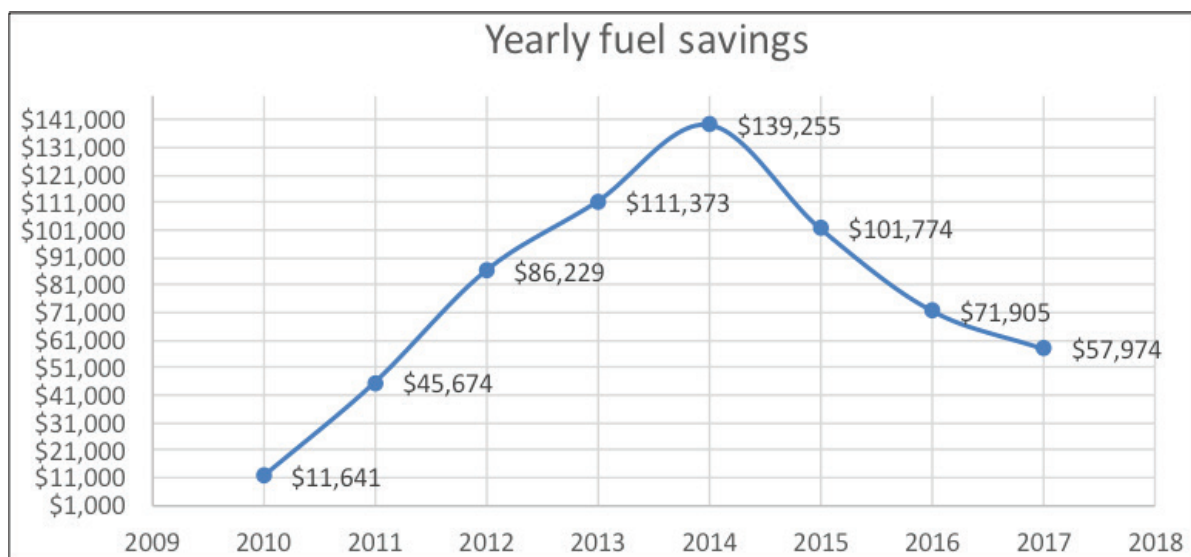Comparison of daily fuel consumption for vessels with composite and biocide coatings.

Figure 6.
Calculation of fuel savings for the ship with a composite underwater coating in relation to the fuel consumption of the ship with a classic coating.

For Figure 6, the assumption of a linear reduction in fuel consumption was used, starting from the initial consumption of 40.9 T/day to consuming 39.4 T/day at the end of the observed period. The calculation is based on the average fuel prices on the world market, as shown in Table 2.

During the observed seven-and-a-half year, total fuel savings on the vessel with a composite coating compared to the ship with a classic underwater layer is 1.62 % or $625,825.00. Comparative Table 3 greatly gives precedence to the vessel with a composite coat and confirms that the prolongation of the docking interval, in this case, is feasible and economically beneficial. However, it should be emphasized that a good part of the calculation is in the sphere of assumptions; thus, the conclusion has only theoretical potential.

Table 2.
Fuel prices during observed period.

Average yearly fuel price at the world market	Observed period	Source
US 487.48	1st Oct 2009 – 1st Oct 2010	LQM Petroleum Services, Inc.
US 606.56	1st Oct 2010 – 1st Oct 2011	LQM Petroleum Services, Inc.
US 686.00	1st Oct 2011 – 1st Oct 2012	LQM Petroleum Services, Inc.
US 632.44	1st Oct 2012 – 1st Oct 2013	LQM Petroleum Services, Inc.
US 614.81	1st Oct 2013 – 1st Oct 2014	LQM Petroleum Services, Inc.
US 367.55	1st Oct 2014 – 1st Oct 2015	ClearLynx LLC
US 219.69	1st Oct 2015 – 1st Oct 2016	ClearLynx LLC
US 314.99	1st Oct 2016 – 1st Oct 2017	ClearLynx LLC

The following assumptions have been used in this paper:

1. For the vessel with classical underwater coating

a. Data for ship speed and fuel consumption during the observed period were not available, so experience data applied (rebuilding underwater coating after five years).

b. It is incorrect assumption that there is no increased fuel consumption throughout the period. Most manufacturers, for quality classical coats, specify the average speed drop rate of 0.5-0.8 % at the end of the interval. Incorporating the value of increased fuel consumption would additionally increase the overall cost of the ship with the classic coating in comparison with the vessel with a composite underwater layer.

Table 3.
Comparison of maintenance costs for underwater hull for the vessels with classical coating and the composite coating.

		Initial docking	1st year	2nd year	3rd year	4th year	5th year	6th year	7th year	End of period
The vessel with clasical biocide coating	Cost for coating	$120,000					$100,000			
	Lost of profit due to 12 days in SY ($22,000/dan)	$264,000					$264,000			
	Cost of increased fuel consumption due to hull fouing									
	Total cost in observed period					$748,000				
The vessel with composite coating	Cost for coating	$285,000					$40,000			
	Lost of profit due to 12 days in SY ($22,000/dan)	$264,000					264,000			
	Cost for underwater hull cleaning		$30,000			$30,000	$30,000			
	Fuel consumption savings due to hull cleaning		**$11,641**	**$45,674**	**$86,229**	**$111,373**	**$139,255**	**$101,774**	**$71,905**	**$57,974**
	Total cost in observed period					$317,175				

2. For the vessel with composite underwater coating
a. The assumption is that the ship will retain the same performances and without second docking in 2015 (the assumption based on the trend).
b. The hull cleaning frequency is the actual data, but in some other sailing areas, such rate would not be sustainable without significant fouling of the hull.

c. The lost profit due to time spent in the dock was in the calculation (actually there was), but in the extended interval, this cost does not exist.

Considering limited number of underwater hull cleanings (Table 3), a new Table 4 was created with the more realistic frequencies of underwater cleaning over the entire observed period.

Table 4.
Costs of maintaining a composite coating in case of increasing underwater cleaning frequency.

		Initial docking	1st year	2nd year	3rd year	4th year	5th year	6th year	7th year	End of period
Cost for composite coat maintenance (underwater hull cleaning every 12 months)	Cost for coating	$285,000					$100,000			
	Lost of profit due to 12 days in SY ($22,000/dan)	$264,000					$264,000			
	Cost for underwater hull cleaning		$30,000	$30,000	$30,000	$30,000	$30,000	$30,000	$30,000	$30,000
	Fuel consumption savings due to hull cleaning		$11,641	$45,674	$86,229	$111,373	$139,255	$101,774	$71,905	$57,974
	Total cost in observed period					$163,175				
Cost for composite coat maintenance (underwater hull cleaning every 6 months)	Cost for coating	$285,000					$40,000			
	Lost of profit due to 12 days in SY ($22,000/dan)	$264,000					264,000			
	Cost for underwater hull cleaning		$60,000	$90,000	$60,000	$60,000	$60,000	$60,000	$60,000	$30,000
	Fuel consumption savings due to hull cleaning		$11,641	$45,674	$86,229	$111,373	$139,255	$101,774	$71,905	$57,974
	Total cost in observed period					$403,175				
Cost for composite coat maintenance (underwater hull cleaning every 4 months)	Cost for coating	$285,000								
	Lost of profit due to 12 days in SY ($22,000/dan)	$264,000								
	Cost for underwater hull cleaning		$90,000	$90,000	$90,000	$90,000	$90,000	$90,000	$90,000	$30,000
	Fuel consumption savings due to hull cleaning		$11,641	$45,674	$86,229	$111,373	$139,255	$101,774	$71,905	$57,974
	Total cost in observed period					$583,175				

Table 4 presents three frequencies of hull cleaning that, based on experiential data, could be applied in the case of cold seas (12 months), combined sailing areas (6 months), and tropical seas (4 months). In all cases, the extended interval shows significant savings over the standard five-year docking period. These savings are:

•   In the case of hull cleaning every 12 months, the total savings in the observed period for a ship with the composite underwater coating compared to the classic hull coat would amount to $ 584,825.

•   In the case of hull cleaning every 6 months, the total savings in the observed period for a ship with the composite underwater coating compared to the classic hull coat would amount to $344,825.

•   In the case of hull cleaning every 4 months, the total savings in the observed period for a ship with the composite underwater coating compared to the classic hull coat would amount to $164,825.

4. CONCLUSION

A prolonged interval between the two dockings is the option offered by classification societies. It is quite clear that there will be contradictory opinions among shipowners, primarily related to the economic viability of the transition to an extended interval. Although this paper undoubtedly proved the economic viability of the change to the prolonged interval, the particularities of each case should account. For example, use of composite underwater coatings requires regular underwater cleaning as it is the only way to control the growth of marine organisms. Therefore, underwater cleaning should be available in the vessel's trading areas, according to maintenance plan of the hull. Unfortunately, the availability of ports that allows "classic" underwater cleaning is limited. Under "classic" underwater cleaning, it is considered the use of cleaning tools that do not collect products of cleaning, but they remain in the marine environment of the port. For a good reason this type of underwater cleaning become strictly prohibited in most of the ports around the world since, besides contamination of biocides from marine coatings, there is a great danger in the transmission of invasive marine organisms. However, this does not mean that underwater cleansing will be banished, on the contrary, underwater cleaning is a necessity as more and more ports do not accommodate vessels alongside if they have excessive hull fouling. Those vessels are forced to perform underwater hull cleaning before they can get alongside. However, this type of underwater cleaning means that all products of cleansing should collected and safely disposed outside marine environment. Unfortunately, such technology is not widely available, and this can be one of the arguments against the use of composite underwater coatings. In the case of biocidal coatings for an extended interval, which are not a unique brand of the coats, but conventional marine coating with an increased DFT (dry fil thickness), calculated to withstand extended interval. Most of the biocide underwater coat manufacturers have reserve towards a prolonged interval just because of the increased DFT, because with a significant increase in the thickness of the layer, the elasticity decreases and the possibility of cracking occurs and ultimately partial or complete destruction of the underwater coating of the hull is a likelihood. Considering all the above the extended interval has the potential of economic justification, but the process of deciding to switch to a prolonged interval must be well conceived and comprehensive in the analysis of all costs. Of great significance, for making the final decision, could be an analysis of the area and conditions of navigation of each ship separately.

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