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UNCERTAINTY EVALUATION IN SHIP REPAIR SPECIFICATION

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A B S T R A C T

The paper deals with uncertainties in ship repair specifications and their impact on docking duration. In some cases, on ships, repair specifications mention defects that are established by the crew when the ship is under exploitation. In the other part of the repair specifications, prepositions mentioned possible problems. Their current condition is determined when the ship is in dry dock, and they are considered indefinite. The paper analyses ten of the most common uncertainties in ship repair connected to hull condition, the condition of its underwater parts, steering gear mechanisms and machinery, and deck equipment. The evaluation of the impact on dry docking duration is done by the GUM method. On the basis of this method, the probability of clear information about ship repair is assumed to be 95%. The combined standard is evaluated with a safety coefficient of c = 1,00. The final result of the uncertainty evaluation for the first case is 3.70±7.45%, and for the second case it is 5.30±11.2%. Schematically, the Gant chart and GUM evaluation show the impact on ship repair duration and ship repair yard schedule.

1. INTRODUCTION

Very often, the repair specification sent to the yard is not absolutely full and clear. Some of these uncertainties are closely related to the main parts of the ship, requiring special personal skills and experience from one side and delays in the finalization of repairs from the other.

In the ship repair industry, successfully is applied Agile technology for reduction the risks from uncertainty. Using this technology creates effective collaboration between ship owners and repair yards (Frateev & Zaporozhets, 2020). Time for ship repair and downtime in the yard is a strategic component, serving as a basic component in repair schedule planning.

The ship repair industry is notorious for experiencing delays, cost overruns, and scope changes in projects. It is widely understood by both clients and the companies involved that the initial project estimates are likely to be modified during the course of the project. Typically, these changes are acknowledged and resolved as the project progresses (Galis, 2015). However, this situation may alter when there are shifts in the economic landscape. In order to shield the project outcome from the impacts of such changes, ship-owning companies can engage intermediary organizations that act as a buffer between them and the shipyard.

Planning for ship repair and maintenance yards poses greater complexities compared to building new shipyards due to the constraints of limited duration. The program evaluation and review technique (PERT) analysis has been employed to develop a plan based on

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data gathered from a shipyard in Turkey. The aim is to identify critical activities that have a significant impact on the overall duration of the project (Turan & Asar, 2019).

2. UNCERTAINTIES IN SHIP REPAIR SPECIFICATION

The uncertainties in ship repair specification can be divided into four main groups related with the ship hull regions shown in table 1.

Table 1. Uncertainties in ship repair specification

Item	Hull	Deck	Machinery	Independent
Steel work volume	+			
Underwater hull part condition	+			
Propeller condition			+	
Rudder stock condition			+	
Box cooler condition			+	
Achor chain cable diameter		+		
Spare part delivery	+	+	+	
Weather condition				+
Paint supply	+			
Dry docking duration				+

Uncertainties in ship repair specifications are divided into four major groups, considering the contents of the classical repair specification and the payment invoice. The first group is uncertainties, including those related to the hull; the second one is related to the deck; the third is machinery; and the fourth is independent uncertainties. Independent uncertainty groups include uncertainties that are independent of ship exploitation, maintenance, repair, and human conditions.

2.1 Hull steel work volume

Steel work takes a major place in the ship repair process. In a lot of cases, the thickness measurement process is done when the ship comes to the ship repair yard after a classification society surveyor agreement taking into account the ship's age (DNV-GL, 2016).

In preliminary repair specifications from ship owners, some steel work volume is mentioned, but it is not absolutely full. Based on its volume, the ship repair yard is planning hull repair teams. In the case of a lot of steel work, they used subcontractors for certain work to satisfy the repair period duration. When the final hull repair volume is clear, the necessary work hours, working teams, and money values are easy to evaluate by developing (Butler, 2000) coefficients.

2.2 Hull underwater part condition

The unknown condition of the underwater part of the hull leads to additional hull repair works on one side and difficulties and delays in painting work. When the ship was in floating condition for a long time and it was not docked or was anchored for a long time, the hull was overgrown with fouling.

There are some possibilities and research into underwater hull part inspections for condition assessment, thickness measurement (Blue eye, 2022), or damage investigation (Nord stream, 2008). These operations are useful but expensive for small and medium-sized ship owners who have a dozen ships.

2.3 Propeller condition

The possible and most frequent problems are erosion at the ends of propeller blades, intensive cavitation, blade deformations, and exceptionally rare forfeiting blades.
In cases where the ship repair yard has no possibilities for repair, they have to apply for subcontractor offers and send them back to the ship repair yard and shipowner. Considering that propeller materials are aluminum, nickel, and bronze alloys (Marine Inside, 2020), which require special skills for repair and fabrication, If the company does not have enough experience in this job, the propeller problems could be serious and irreparable.

2.4 Steering gear condition

Possible issues with the steering gear include the water tightness of the rudder and the current condition of the rudder stock or active rudder stock, if an active rudder is available. Repairing the disrupted water tightness of the rudder doesn't take much time and doesn't delay the dry docking period.
If the crew notices any deviation from the normal condition of the rudder, it indicates a problem. When this problem is mentioned in the preliminary repair specification, the ship repair yard will be able to fabricate a new one according to the original rudder stock drawing.

2.5 Anchor and anchor chain condition

Often, anchors and anchor chains lack inspection and maintenance during ship exploitation (Marine Inside, 2021). This leads to disinformation about the actual condition of anchor cables and anchors too. In ships, anchor uncertainty appears in slack between fluke and shank in anchor types D'Hole, Pool, and most commonly used the hall from one side and anchor fluke deformation from the other side.

2.6 Box coolers condition

The main reason for the uncertainty of box coolers is the possibility of inspections when the ship is afloat. In this condition, engineers can't determine their current condition. There are two main reasons for their indefinite problems. The first one is intensive corrosion caused by sea water in the area of the mounting flange (Norwegian hull club, 2020) and box cooler pipe distortion. The main reason for distortion is very often a lack of proper coating on pipes. Very often, they are made of aluminium or brass (Safety4sea, 2016), which increases their corrosion effect. If some of these problems appear during dry docking periods, they have to be repaired.

2.7 Weather condition at dry docking duration

The weather is the biggest uncertainty in the ship repair and ship building processes. It is the only uncertainty that is not influenced by the human factor. The weather plays a major role in the process connected through blasting and paint operations as well as the welding process and water tightness tests of the ship hull.
In some regions of the world during the autumn seasons, where it is constantly cloudy, rainy, and humid, the time for launching the ship into the water is significantly delayed. These circumstances have to take into account ship repair yard selection and dry docking period duration.

2.8 Spare parts and paint delivery

The spare parts delivery situation is the same as paint delivery. Very often, they are ordered when the ship is in the shipyard, not preliminary. When they are ordered from third parties, the delivery is significantly delayed. Furthermore, the big delay in repair time comes when a shipowner or one of its representatives orders the wrong spare part for a diesel engine, pumps, etc. In the case of paint delivery from abroad and the shipowner's failure to timely request it, a delay in its delivery is possible. The delay in paint delivery delays the overall ship repair process. The ship cannot be launched and put into operation.

2.9 Dry docking duration

In dry docking, duration is taken into account, and the days offered are preliminary repair specifications. The offers in the preliminary repair specification days are not satisfied for ship repair finalization. They are subject to additional specifications when all repair jobs are finished. In cases of small ship repairs, the repair period is the same as that offered in the preliminary repair specification before the ship enters dry dock.

3. IMPACT OF UNCERTAINTIES ON DRY DOCKING DURATION

The uncertainties in the ship repair context are connected mainly with imperfections in the repair specification or the unclear technical condition of different mechanisms and equipment. Together or each one separately leads to a repair delay or to finishing earlier, but in most cases, a delay in repair The repair continues closely depending on the ship's technical condition and work volume.

$$t = f(W1 + W2 + \cdots \ldots \ldots .. Wn + 1) \qquad (1)$$

Where: W1….,Wn+1 are different repair jobs form ship repair specification;

The continues of repair taking into account Uncertainties will be explain by:

$$ti = f(W1i + W2i + \cdots \ldots \ldots .. Wni + 1 + \sum Wi) \qquad (2)$$

Where: W1i…., Wni+1 are different indefinite repair jobs which are not include in repair specification;
Wi- repair works included in repair specification.

Work hours or work days for different repair jobs are different, and the cost of each one of them is a function of work hours. In the case of normal repair, i.e., full and clear repair specifications, it is easy to distribute the offered ship owner repair duration, while in the second case, it is not easy. has to take into account the risks and delays caused by uncertainty.

In shipbuilding and ship repair, management of the projects is easy with Gantt charts. On the left side of the graph shown in Figs. 1 and 2, repaired jobs are shown, and on the right side, the duration of the repair in time is shown.

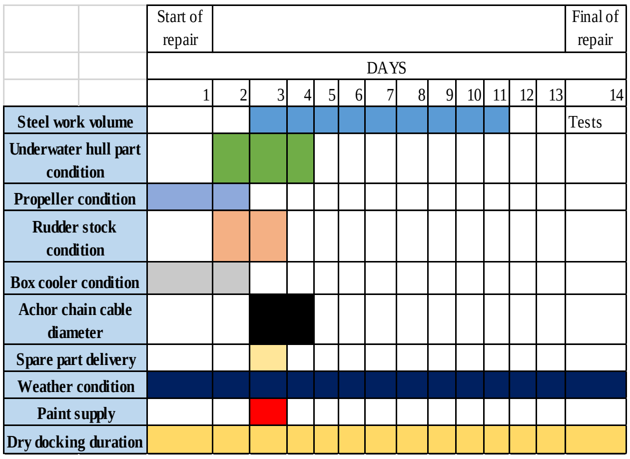

Figure 1. Gant chart of repair jobs in normal cases.

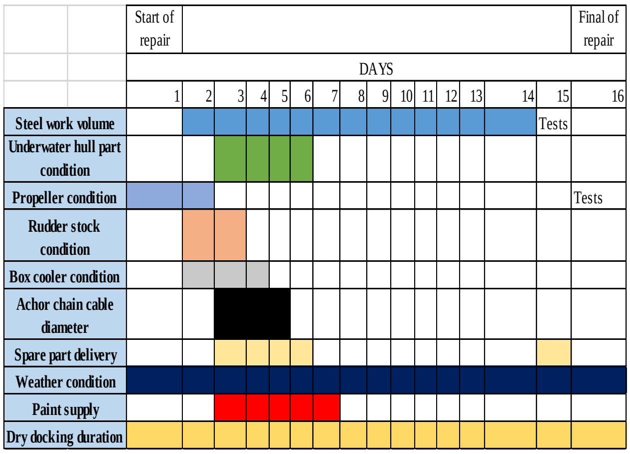

Figure 2. Gant chart of repair jobs in case of uncertainties.

From Figs. 1 and 2, it is shown that uncertainties in the ship repair project delayed its finalization. In this case, the delay is two days, but this is just on plan. In real-life cases, the delay is possible to be longer than two days. The delay is unacceptable to ship owners and ship repair yards. It has to be compensated by a discount on the final cost of repairs or with extra charges for additional jobs.

For the evaluation of uncertainties, the Guide to Expression of the Uncertainty in Measurement (GUM method) is based on two types of data. The mathematical expressions for evaluating uncertainties explain the error in the preliminary ship repair specification and the level of its reliability. The combined standard is evaluated by the following equation (Zhao, 2020):

$$u_c^2(I) = \sum_{i=1}^{n} \left(\frac{\partial f}{\partial xi}\right)^2 \quad u^2(xi) + 2\sum_{i=1}^{n}\sum_{j=i=1}^{n} (\frac{\partial f}{\partial xi})((\frac{\partial f}{\partial xj}) \qquad (3)$$

Where: N is the number of variables;

The $\partial f/\partial xi$ is possible to be replaced by sensitivity coefficient, which role is to simplify the equation. After its application the equation is:

$$u_c^2(I) = \sum_{i=1}^{n}(ci)^2\ u^2(xi) \qquad (4)$$

In some areas of industry in partly ship repair is necessary uncertainties to be measured and evaluated properly. For this purpose, following equation is used:

$$U = ku_c(I) \qquad (5)$$

Where: k- coefficient of coverage, its value is k=2 in 95% probability.

Taking into account the use of the equations for uncertainties on fig.1 and 2, is calculated that the standard deviation is 0.44% for normal repair and 0.024% for repair with uncertainties. If it is assumed that the probabilistic fullness of the repair specification is normally distributed, the deviation for repair with uncertainties is far away from point 0, which means that it is not so reliable for shipyard planning.

The combined standard with safety coefficient c = 1,00 is U = 7.45% for normal repair specifications and U = 11.2 for repair specifications with uncertainties. The final result from uncertainty evaluation for every case is 3.7±7.45% for the first case and 5.30±11.2% for the second case.

4. CONCLUSIONS

The uncertainties play a major role in the duration of dry docking. For their evaluation, two real cases are shown with repair specifications and continuous duration times. The first is in normal condition, which means that all the repair specifications are full and clear. In this case, the duration of the repair is within the period of the shipowner. In the second case, taking into account ship repair specifications, repair continues longer than offered by the shipowner's period. Theoretically, this is two days, but it really is more than 6–8 days. This is mainly caused by additional jobs that are not mentioned in preliminary specifications or order delays.

The evaluation of the impact on dry docking duration is done by the GUM method. On the basis of this method, the probability of clear information about ship repair is assumed to be 95%. The combined standard is evaluated with a safety coefficient of c = 1,00. The final result of the uncertainty evaluation for the first case is 3.70±7.45%, and for the second case it is 5.30±11.2%.

According to the results from the evaluation, the clarity of information about ship repair has to be improved by precision measurement and evaluation of the ship's steel hull. This job takes a lot of time and, in a lot of cases, delays her launch and breaks the ship repair yard production program.

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