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OPTIMIZING MARINE DIESEL ENGINE MAINTENANCE: A PROACTIVE COST-EFFICIENCY STRATEGY

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- Aim & objective
- Methodology
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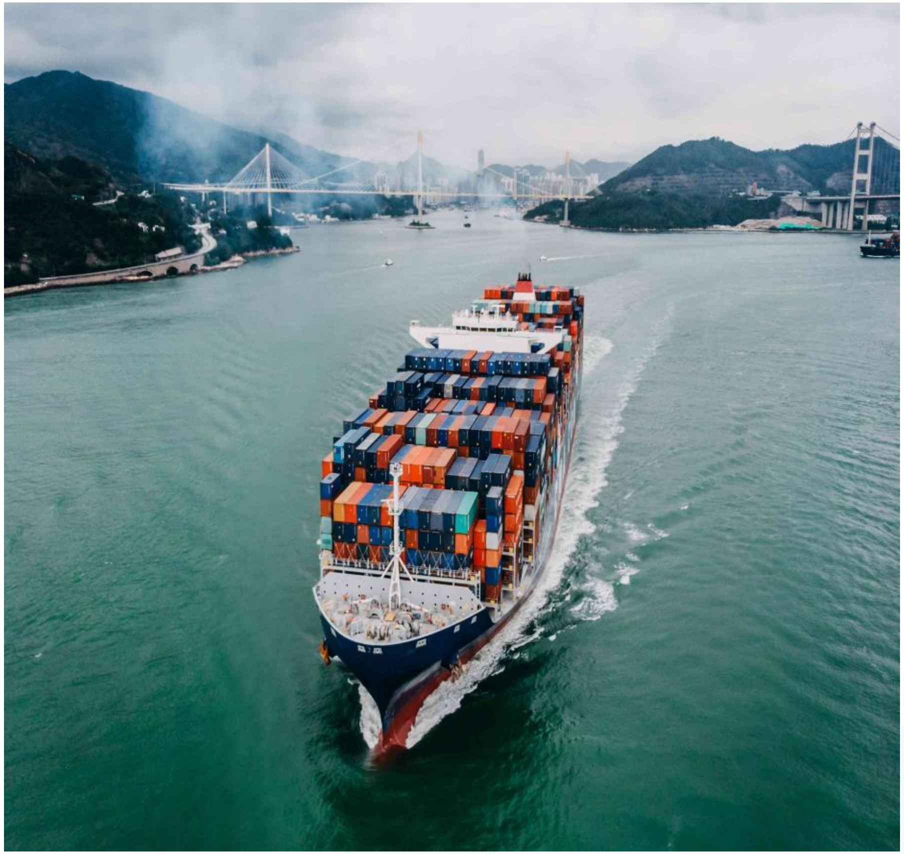
Introduction

Marine engines serve as the heart of any vessel, powering its propulsion system and auxiliary machinery. Given the harsh conditions of the marine environment, including exposure to corrosive saltwater and varying temperatures and pressures, reliable operation of marine engines is essential for smooth sailing and efficient transportation.



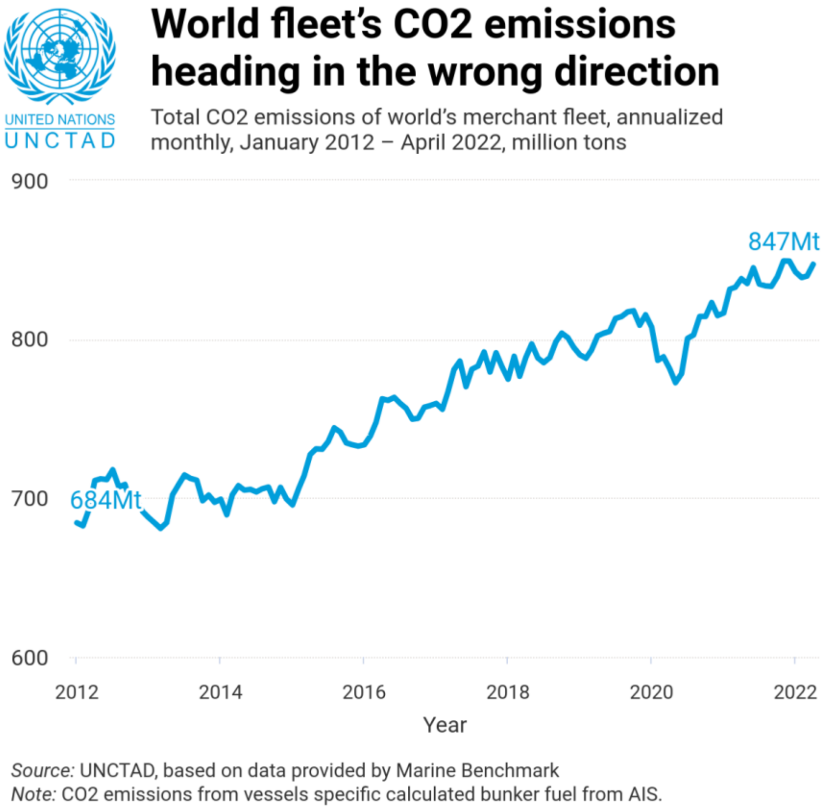
Introduction

Marine engines require routine maintenance to keep them in peak operational condition because of their demanding working circumstances. When it comes to profitability, efficiency, and safety, maintenance is crucial. This is because, in the absence of routine maintenance, engines are more likely to experience wear, failure, and equipment breakdown.

Maintenance for Environmental Sustainability

The global maritime fleet is emitting greenhouse gases at an unfavorable rate. They **increased by 4.7%** between 2020 and 2021.

The negative effects of maritime traffic on the environment are lessened by proper maintenance. It helps create a more sustainable and environmentally friendly maritime sector by reducing emissions, downtime, and fuel consumption.



UNITED NATIONS UNCTAD

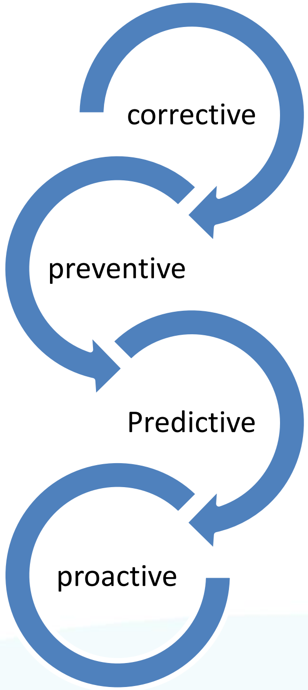
World fleet's CO2 emissions heading in the wrong direction

Total CO2 emissions of world's merchant fleet, annualized monthly, January 2012 – April 2022, million tons

Source: UNCTAD, based on data provided by Marine Benchmark
Note: CO2 emissions from vessels specific calculated bunker fuel from AIS.

survey

Marine engine maintenance techniques have developed throughout time to more efficiently address problems. With this progression, proactive methods that try to stop failures before they happen have replaced reactive (corrective) maintenance.



corrective

preventive

Predictive

proactive

survey

Corrective maintenance is addressing **malfunctions** that are found **during operation**. Although this method deals with problems right away, it may result in **higher expenses and downtime** because of unforeseen malfunctions.

survey

Preventive maintenance involves carrying out **planned maintenance** tasks on a regular basis to prevent future malfunctions. This approach often relies on manufacturers' recommendations and historical data to schedule maintenance activities.

survey

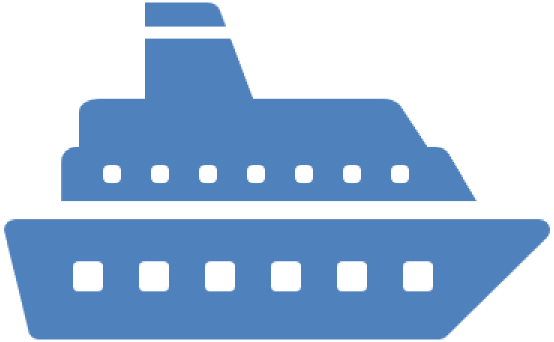
Predictive maintenance uses **data analysis** techniques to anticipate equipment flaws and operational irregularities. predictive maintenance aims to reduce unplanned downtime and maintenance expenses by **changing the time of maintenance** depending on the data and the condition of the equipment.

survey

Proactive maintenance represents a new approach focused on identifying and a**ddressing potential faults before they lead to failures**. By taking preventive measures, by using advances in technology, such as **machine learning and AI algorithms**, offer opportunities to further enhance maintenance. These technologies can improve **decision-making**, optimize maintenance schedules, and reduce downtime.

Gap analysis

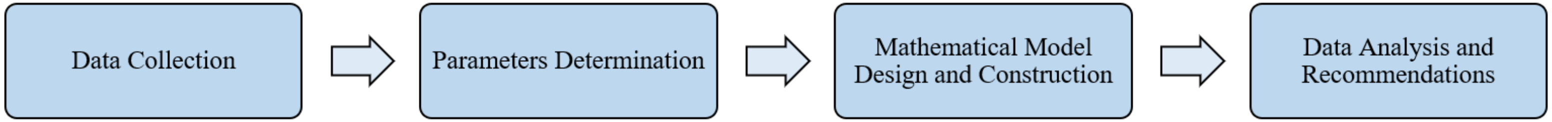
In the maritime industry until now, proactive maintenance has **not been implemented by anyone**, particularly regarding main engines. This is because advanced technology is not integrated into maintenance. That might save a considerable amount of money, minimize downtime, and lower the average emissions.



Aim & objective

The primary goal of this study is to provide a **mathematical model** for calculating the costs and benefits of proactive maintenance. The study was carried out by applying a mathematical model and estimating the maintenance costs for every kind of maintenance plan on every piece of equipment.

Methodology



Data Collection

Parameters Determination

Mathematical Model Design and Construction

Data Analysis and Recommendations

The systematic method includes data collecting with a particular emphasis on marine diesel engines and the application of formulas for computations including the prices of spare parts, the consequences of downtime, and services. Through gathering and examining data from actual circumstances.

Case studies

To gather additional information and provide more precise findings, three case studies were put together based on the data collected from marine diesel generators.

- 500kv diesel generator
- 600kv diesel generator
- 800kv diesel generator

Data from 500kv diesel generator

Different components have varying **lifespans and related expenses**. In this case, the alternator has a shorter lifespan 250 days and a higher failure cost than the injection pump, which lasts 950 days. Long-term cost-effective replacements and proactive maintenance are made easier by these insights.

Component	Lifetime (Days)	Failure cost	Replacement cost	Maintenance cost
Injection pump	950	$ 160	$ 113.75	$ 85
Valve Calibration	1080	$ 425	$ 225	$ 40
Ring Cutting	1090	$ 262.5	$ 212.5	$ 100
Cylinder top gasket	1170	$ 325	$ 228.75	$ 100
Radiator	1050	$ 120	$ 45	$ 20
Oil pump	1005	$ 100	$ 100	$ 20
Injector nozzle	900	$ 337.5	$ 337.5	$ 100
Air filter	1160	$ 150	$ 100	$ 50
Alternator	250	$ 192.5	$ 106.25	$ 57.5
Water pump	1050	$ 108.75	$ 67.5	$ 50

Data from 600kv diesel generator

Parts have different pricing and lifespans. In comparison, Ring Cutting has a short lifespan of 470 days and a failure cost of 300$, while the Injection pump lasts 1100 days at a failure cost of 160$. These specifics direct cost-effective replacements and the best maintenance planning.

Component	Lifetime (Days)	Failure cost	Replacement cost	Maintenance cost
Injection pump	1100	$ 160	$ 113.75	$ 85
Valve Calibration	800	$ 425	$ 225	$ 40
Ring Cutting	470	$ 300	$ 237.5	$ 100
Cylinder top gasket	1020	$ 387.5	$ 236.25	$ 100
Radiator	1020	$ 120	$ 45	$ 20
Oil pump	800	$ 100	$ 100	$ 20
Injector nozzle	900	$ 337.5	$ 337.5	$ 100
Air filter	1200	$ 200	$ 137.5	$ 50
Alternator	990	$ 262.5	$ 143.75	$ 95
Water pump	780	$ 108.75	$ 87.5	$ 50

Data from 800kv diesel generator

The cost and lifespan of components vary. For example, the oil pump lasts 1015 days and costs of failure of 120$, whereas the valve calibration lasts 1050 days and costs 425$ when it fails. These specifics help with cost-effective replacements and strategic maintenance decisions.

Component	Lifetime (Days)	Failure cost	Replacement cost	Maintenance cost
Injection pump	900	$ 160	$ 113.75	$ 85
Valve Calibration	1050	$ 425	$ 225	$ 40
Ring Cutting	1050	$ 262.5	$ 212.5	$ 100
Cylinder top gasket	980	$ 42	$ 36	$ 8.4
Radiator	1010	$ 387.5	$ 236.25	$ 100
Oil pump	1015	$ 120	$ 45	$ 20
Injector nozzle	1020	$ 100	$ 100	$ 20
Air filter	1030	$ 337.5	$ 212.5	$ 100
Alternator	1010	$ 337.5	$ 212.5	$ 100
Water pump	1110	$ 150	$ 100	$ 50

Mathematical model

Total number of failures during the part's lifetime is calculated by $F = T \times \alpha$ where α is the equipment's maintenance factor.

Mean time between failures (MTBF) is given by $\mathrm{MTBF} = \frac{T}{F}$

And the Failure rate (λ) : $\lambda = \frac{1}{\mathrm{MTBF}} = \frac{F}{T}$

reliability function is calculated by : $R(t) = e^{-\lambda(t)}$

Mathematical model

cost of corrective maintenance (CM): $C_{cor} = \left(C_m + \left(C_{dt} \times MDT\right)\right) \times \lambda \times T$

cost of preventive maintenance (PM): $C_{pm} = \left(C_m + \left(C_{dt} \times MDT\right)\right) \times M$

cost of predictive maintenance (PdM): $C_{pdm} = \left(C_m \times R(t)\right) + \left(C_{rp} \times M\right) + \left(C_f \times \left(1 - R(t)\right)\right) + \left(MDT \times C_{dt}\right)$

Research specifically focused on proactive maintenance (PA) has shown that it can reduce predictive maintenance costs by 5 to 10%.

Results

The 500kv diesel generator is showing a drop in maintenance cost by (8% - 9%) when using a preventive maintenance plan. And an average reduction of 46%. When changing to a predictive approach.

Component	Corrective maintenance cost	Preventive maintenance cost	Predictive maintenance cost
Injection pump	$ 1988	$ 1815	$ 902
Valve Calibration	$ 3013	$ 2752	$ 1955
Ring Cutting	$ 3352	$ 3061	$ 1731
Cylinder top gasket	$ 4414	$ 4031	$ 2090
Radiator	$ 1355	$ 1237	$ 528
Oil pump	$ 1930	$ 1762	$ 850
Injector nozzle	$ 3443	$ 3144	$ 2201
Air filter	$ 2088	$ 1907	$ 935
Alternator	$ 696	$ 635	$ 637
Water pump	$ 1496	$ 1366	$ 712

Results

For the 600 kV diesel generator, transitioning from corrective to preventive maintenance results in an 8%–9% cost reduction. The predictive maintenance strategy results in an average reduction in maintenance costs of 46%.

Component	Corrective maintenance cost	Preventive maintenance cost	Predictive maintenance cost
Injection pump	$ 2302	$ 2102	$ 995
Valve Calibration	$ 2232	$ 2038	$ 1609
Ring Cutting	$ 1516	$ 1384	$ 1111
Cylinder top gasket	$ 3894	$ 3556	$ 2007
Radiator	$ 1316	$ 1202	$ 521
Oil pump	$ 1536	$ 1403	$ 738
Injector nozzle	$ 3443	$ 3144	$ 2201
Air filter	$ 2430	$ 2219	$ 1253
Alternator	$ 3200	$ 2923	$ 1341
Water pump	$ 1112	$ 1015	$ 582

Results

The cost of maintenance for the 800kV diesel generator decreases (8%–9%) with preventative maintenance. The predictive maintenance approach yields the biggest cost savings of the three diesel generator models 51%.

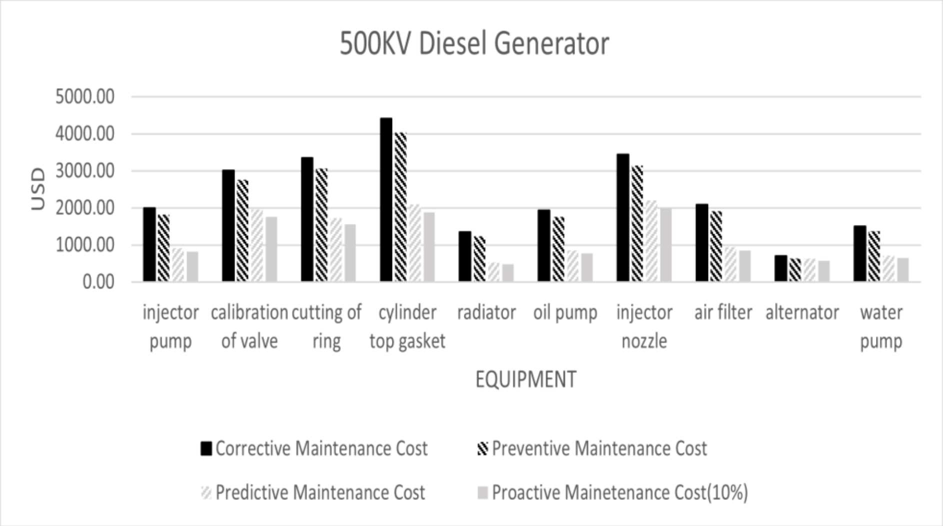
Component	Corrective maintenance cost	Preventive maintenance cost	Predictive maintenance cost
Injection pump	$ 1883	$ 1720	$ 871
Valve Calibration	$ 2930	$ 2675	$ 1918
Ring Cutting	$ 3229	$ 2949	$ 1684
Cylinder top gasket	$ 2025	$ 1849	$ 535
Radiator	$ 2947	$ 2691	$ 1844
Oil pump	$ 1614	$ 1474	$ 570
Injector nozzle	$ 1958	$ 1788	$ 859
Air filter	$ 2858	$ 2610	$ 1686
Alternator	$ 3712	$ 3390	$ 1812
Water pump	$ 1665	$ 1521	$ 858

Results

Proactive maintenance can save overall maintenance expenses by anywhere from 5% to 10%. The effectiveness with which the proactive maintenance approach is implemented, the maintenance management system, and other variables all affect the percentage of cost savings.

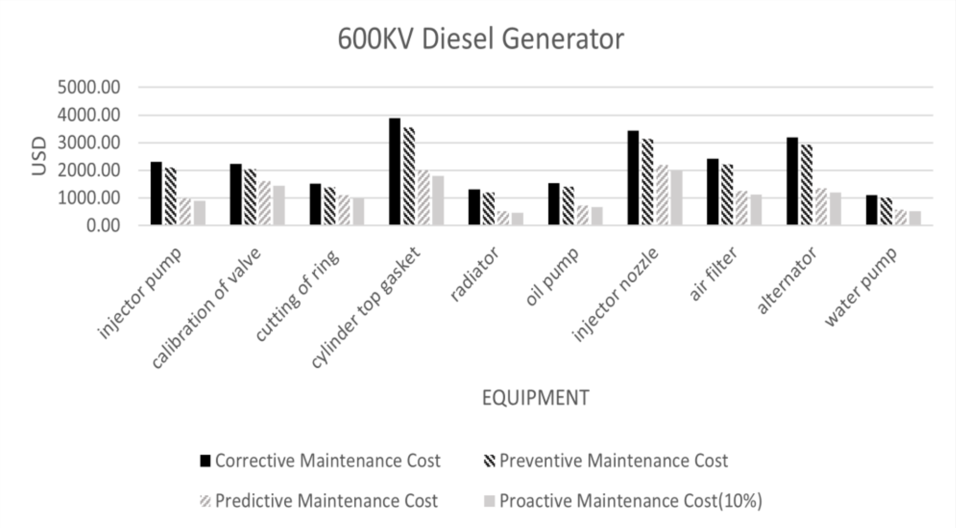
Results

Maintenance expenses drop for every piece of equipment. when changing to a newer strategy of maintenance.



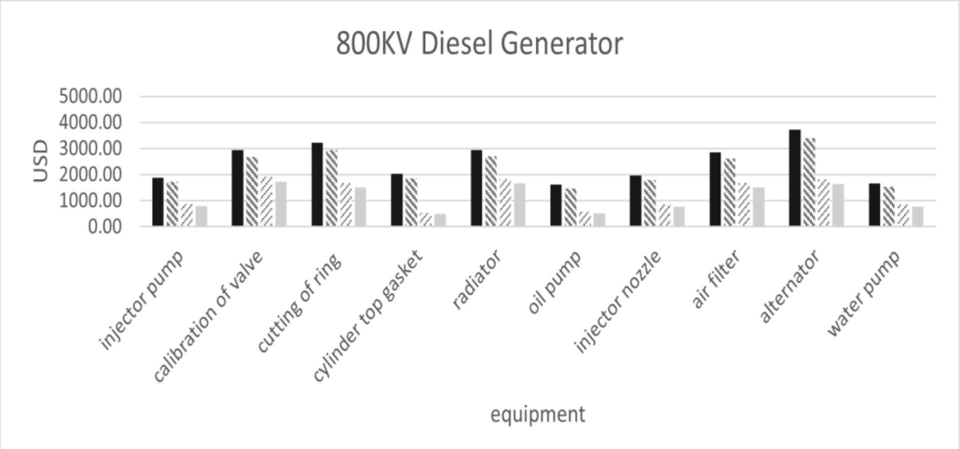
Results

The total expense of corrective maintenance 22979$, preventive maintenance 20985$, predictive maintenance 12359$ for the 600 kV diesel generator. However, the total cost of proactive maintenance 10% efficiency for every piece of equipment comes to $11123.



Results

Corrective maintenance for an 800 kV diesel generator costs $24,820, preventive maintenance costs $22,667, predictive maintenance costs $12,635, and proactive maintenance (10% efficiency) costs $11,371.



Conclusions

preventive maintenance in the three generators **saved roughly 9%.** Predictive maintenance, however, reduced maintenance costs by an **average of 48%.**

By applying proactive maintenance at a maximum efficiency of 10%, it saved:

- 1254$ in the 500kv diesel generator.
- 1236$ in the 600kv diesel generator.
- 1264$ in the 800kv diesel generator.

Future work

The approach described in this work will be improved by additional study. We intend to utilize effective machine learning and real-time sensor data to improve proactive maintenance models, create a comprehensive model to determine the **likelihood of failure**, and evaluate the **environmental impact**. Reducing downtime, ensuring the strategy's sustainability in the maritime sector, and enhancing overall maintenance efficiency are the goals.

Acknowledgement

I would like to express my sincere gratitude to the enthusiastic Marine and Offshore Engineering Department professors who made a substantial contribution to our study. Your excellent help and expertise have added much value to our project. I want to sincerely thank you for all your efforts and dedication. We have progressed in our understanding together. We appreciate your unwavering dedication and cooperative attitude.

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