QUALICHECK: AN INTEGRATED SENSOR SYSTEM FOR PRESCRIPTIVE MAINTENANCE FOR PRESCRIPTIVE MAINTENANCE THROUGH ANALYZING ENGINE OIL QUALITY

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Abstract

Abstract – As vehicle usage increases, the need for vehicle maintenance rises proportionally, and engine efficiency and economical maintenance need to be addressed. This work describes the creation of QualiCheck, a novel prescriptive analytics-based engine oil quality monitoring device. The transducer has a number of sensors to determine kinematic viscosity and viscosity index with a real-time assessment of engine oil quality. The system, controlled by a microcontroller, performs sensor readings and provides practical maintenance advice through an LCD interface. The developed device also remedies problems in conventional maintenance, such as early or late oil changes, that cause extra costs, engine wear, and environmental pollution. QualiCheck provides optimal oil change interval identification thanks to prescriptive analytics, reducing service costs and improving vehicle performance by minimizing unnecessary costs. The methodology comprises sensor fusion for data quality, rules-based programming for logical reasoning, and laboratory validation to guarantee accurate results.

The device was analyzed using fully synthetic engine oil under different operating conditions. Results showed its ability to track oil quality and schedule maintenance in agreement with laboratory data. This paper illustrates the role of prescriptive maintenance in refocusing automotive care as a source of economic, environmental, and performance gains. Utilizing QualiCheck can substantially improve the confidence of vehicle operation in safety and facilitate sustainability targets by improving the use of resources and oil waste.

1. 0 INTRODUCTION

With vehicle usage increasing rapidly around the world, routine maintenance has a critical role in maintaining peak engine performance and fuel economy. Nevertheless, vehicle maintenance costs are rising rapidly because of a shortage of service technicians and the increasing price of the parts. According to Motor lease, based on industry demand, an increase of 6% in technicians is needed by 2026 to address demand. Engine oil replacement is one of the critical parts of vehicle maintenance, failure of which can result in significant engine damage, overheating and higher emission.

The engine oil has a major effect on vehicle emissions and engine performance. In accordance with Armor Lubricants (2023) it was reported that lack of lubrication causes increase in the number of friction and emissions, and synthetic oils containing fewer contaminants give higher fuel operational efficiency and reduce the contamination of the environment. According to TotalEnergies USA (2022), engine oil is important in lubrication, temperature control, protection against rust and overall engine operation. Oil drain periods differ as a function of vehicle type and oil grade, 5000 km for mineral oil and through to 10000 km for fully synthetic oil (Lubricants, 2024). However, conventional maintenance schedules based on fixed intervals may result in unnecessary early oil changes, leading to increased costs, or delayed changes that cause engine damage (Aamco, 2023).

To address these inefficiencies, prescriptive analytics can offer data-driven, optimized recommendations for maintenance scheduling (Abby Fields, 2023). In this work, an engine oil quality system analyzer, using sensors to measure kinematic viscosity and viscosity index, is proposed. The system will acquire real-time data, process it by a microcontroller, and apply rule-based programming to predict oil conditions and suggest maintenance schedules.

The traditional engine oil maintenance schedules are imprecise and too expensive; it is an issue for car owners and car fleet managers. Present approaches are fixed oil change intervals (mileage or time) and not the condition of the oil, which can result in premature oil change (expenditure and wasted resources) or too much delayed change as both lead to engine damage, increased emissions and deteriorated performance. Even though the engine oil has been recognized as playing an important role in lubrication, temperature control, and engine life extension there is a dearth of real-time diagnostic tools that can be used to evaluate oil quality

1.1 Objectives of the Project

The main goal of this study is to create a device that uses multiple sensors to assess key parameters of engine oil quality and prescribe maintenance as needed. The study has the following specific objectives:

1. To identify the oil parameters and sensors that can be utilized to determine the condition of engine oil.
2. To gather and collect data of oil parameters and their conditions.
3. To determine the computational methodology for analyzing oil parameters to support prescriptive maintenance of engine oil.
4. To integrate parameter computation into a device for precise and reliable engine oil maintenance prescription.
5. To evaluate the operational performance of the device by comparing laboratory data and device data.

1.1.1 Scope and Limitations of the Project

This study focuses on developing QualiCheck, a device that utilizes sensors and prescriptive analytics to assess engine oil quality and recommend maintenance. The system integrates a microcontroller, sensors for kinematic viscosity measurement, and a display module to provide real-time data analysis. The study is limited to four-wheeled vehicles using fully synthetic engine oil and does not cover other engine oil types or motorcycles. The device relies on existing rule-based programming for predictive maintenance but may require further calibration for broader applications. Additionally, the study does not include external environmental factors that may influence engine oil degradation, such as driving conditions. Despite these limitations, the research aims to enhance vehicle maintenance efficiency and reduce operational costs through data-driven decision-making.

2. 0 REVIEW OF RELATED WORK

Proper engine oil maintenance is crucial for vehicle performance and longevity. Neglecting oil changes can lead to engine failure due to the accumulation of contaminants such as wear debris, soot, and water. Amrani et al. (2022) highlighted that monitoring viscosity early helps detect potential failures, improving engine reliability. Khanna (2024) emphasized that used oil analysis allows technicians to assess physical and chemical properties, helping prevent engine failure and reducing maintenance costs. The increasing demand for four-wheelers has also driven the need for high-quality lubricants, with Philippine lubricant production rising to 81.5% in 2021 compared to 54.2% in 2020 (PR Newswire, 2021).

Engine oil provides lubrication, cooling, cleaning, and protection for engine components. Raposo et al. (2024) stated that maintaining good engine oil quality prevents corrosion, extends engine life, and improves efficiency. Additionally, failure to change oil regularly leads to increased greenhouse gas emissions and potential engine damage. Lubricants (2024) noted that degraded oil causes deposits to form on pistons, valves, and injectors, leading to incomplete combustion and higher emissions. The frequency of oil changes depends on factors such as oil type, driving conditions, and vehicle model.

The relationship between temperature and viscosity is crucial in determining oil performance. According to the kinetic theory of matter (2021), higher temperatures increase molecular movement, reducing internal friction and viscosity. This principle explains why engine oil must maintain optimal viscosity under varying thermal conditions to ensure proper lubrication and efficiency.

Viscosity index (VI) measures how oil viscosity changes with temperature. Figure 2 illustrates that higher VI values indicate minimal viscosity change, which is desirable for maintaining engine performance. A lower VI suggests greater sensitivity to temperature fluctuations, potentially compromising lubrication efficiency. The study emphasizes that monitoring VI is critical in determining oil quality and ensuring proper maintenance intervals.

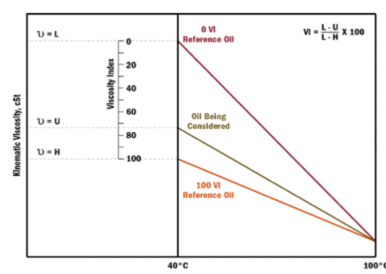

Figure 1. Viscosity Index and Temperature Relationship

3.0 METHODOLOGY

The present study follows a prescriptive design model, adopting a rigidly planned and systematic design for the development of a sensorized engine oil quality assessment system. The work combines sensor fusion and rule-based programming, demonstrated by prototype testing and system integration. The Input-Process-Output (IPO) approach is used for system component analysis, whereas functional and constraint analyses are used for performance optimization. These research design methods offer a structured and systematic approach to problem-solving, ensuring a comprehensive understanding of the system's components and processes.

The paper points out technical constraints limiting the accuracy and ease of use of the QualiCheck device. A key limitation is residual oil contamination in sensor readings after multiple measurements, which necessitates manual sensor cleaning to keep readings accurate. Another restriction is the dependence on some kind of sensor which can potentially identify only defined groups of engine oil degradation parameters, for instance, corrosion. Further, maintaining high data accuracy with fast processing speed is a challenge in prescriptive maintenance applications. Strategies for addressing these limitations include the accessibility of sensors for cleaning and the absorptive cleaning materials that allow the system to fully operate and be easy to clean manually.

This study employs multiple data collection methods, including literature review, focused interviews, and laboratory testing. For this purpose, a literature survey was performed to obtain the most important oil parameters as well as existing maintenance approaches. A focused interview with the Office of Transportation Cooperative (OTC) gathered data on common oil change practices in the Batangas Region which Ibaan specifically. Furthermore, laboratory testing at DOST-ITDI (Department of Science and Technology - Industrial Technology Development Institute) verified the accuracy of the proposed system by comparing sensor measurements with reference laboratory results to guarantee the validity of the proposed engine oil quality assessment system

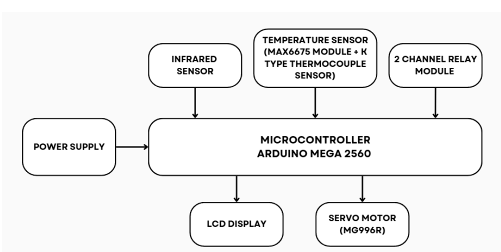

Fig. 2. Block Diagram of System Hardware

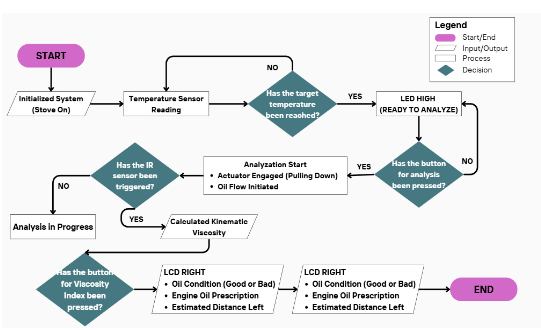

Fig. 3. Block Diagram of System Hardware

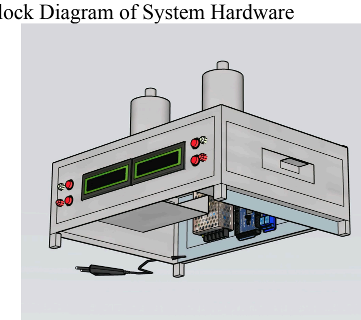

Fig. 4. Qualicheck Three Dimensional Model

This section identifies the process on how researchers will guarantee the correctness, stability, and validity of the QualiCheck engine oil evaluation system. This verification plan ensures that QualiCheck will deliver consistent advice leading to engine efficiency and reduced maintenance costs. The validation process includes several key steps

1. Oil Parameter Identification - Researchers perform a literature survey from 2019-onward and discuss key oil parameters with oil testing centers in order to determine the most relevant to quality assessment.
2. Sensor Calibration - Selected sensors are assessed based on its specification and their readings which are compared with laboratory results to ensure precision.
3. Software Validation (C++ Programming) - The C++ code is inspected, and its suitability is verified through unit, integration and system test and will enable smooth hardware-software interaction.
4. Prototype Setup and Testing - Sensor, microcontroller, and display hardware is built and tested in the field with engine oil samples.
5. Data Validation - Engine oil samples analyzed by the QualiCheck device are compared against oil testing center results (DOST) to confirm data integrity and device reliability.
6. Reliability and Safety Testing - Electrical integrity, power control, and system functionality are tested to provide a safe environment for the user and to prevent device failures.

The proposed engine oil quality device determines and analyzes various parameters and provides users with prescriptive maintenance. The system shall comprise the hardware and software components enumerated in Table 4.1. These components were analyzed to ensure they were suitable for the proposed system.

Table 1. Device Components

Hardware	Software

MAX6675 Module + K Type Thermocouple Sensor Infrared Sensor 5V Double-Channel Relay Module Servo Motor MG996R 5V Power Supply Arduino Mega 2560 LCD (20x4)	Arduino IDE C++

Table 2. Bill of Materials

No.	Description	Quantity	Price
1	Plain sheet	1	1800.00
2	Tubular S/S ½ x ½	1	450.00
3	Round Tubular 2x1.2mm SS 202	1	1100.00
4	Push Button	4	40.00
5	1k Resistor	8	8.00
6	Max 6675 + K Type Thermocouple Sensor	2	680.00
7	5V Power Supply	1	650.00
8	Arduino Mega	1	1150.00
9	LED (Green & Red)	4	40.00
10	Infrared Sensor	2	90.00
11	Electric Stove	2	3500.00
12	2 Channel Relay	2	170.00
13	20x4 LCD Display	2	300.00
14	MG9960 Servo Motor	2	340.00
TOTAL			**10,318.00**

4.0 RESULTS AND DISCUSSION

The Qualicheck device is an integrated system designed for prescriptive maintenance by analyzing engine oil quality. The prototype incorporates several essential components housed in a stainless-steel casing, including an Induction Coil that heats the oil sample to temperatures between 40°C and 100°C, a Thermocouple Sensor for temperature measurement, a Relay Component to control power flow, and a Power Supply to provide electrical energy to the system. The Arduino Mega 2560 microcomputer controller controls the whole system and the 20x4 LCD Display shows real-time data. Furthermore, a Servo Motor manages access to the oil, and an Infrared Sensor is used to determine the level of oil being analyzed. The prototype runs in a laboratory setting with constant temperatures and flat surfaces for accurate analysis. These characteristics allow Qualicheck to provide engine oil quality assessment and to suggest service recommendations according to its state of health.

The temperatures of 40°C and 100°C are selected as standard reference points for measuring kinematic viscosity based on ISO 3448:1992, which sets global standards for lubricant evaluation. At 40°C, the viscosity measurement reflects the oil's flow characteristics at normal ambient or low engine temperatures, particularly during startup conditions. This is essential for evaluating how well the oil circulates in the engine when cold, ensuring adequate lubrication and minimizing wear during ignition. At 100°C, the measurement represents the oil's viscosity under high-temperature operating conditions, which typically occur when an engine is running at full load or after extended operation. This temperature is significant because it indicates how much the oil thins out due to heat.

When assessing kinematic viscosity at 40°C and 100°C the Viscosity Index (VI) may be calculated, which gives the amount by which the viscosity of the oil varies with temperature. A higher VI means that the oil maintains a higher level of stability across their variations in temperature, thus this oil is more effective in the provision of engine protection under those variations.

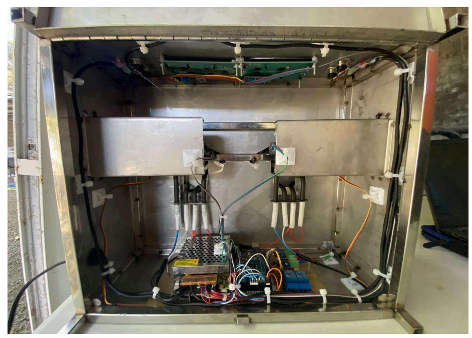

Fig. 5. Internal View of the Qualicheck

Fig. 6. Qualicheck Prototype Setup

Kinematic viscosity is a critical parameter in evaluating engine oil quality, determining its resistance to flow under gravity. It is measured at 40°C and 100°C following ASTM D445 standards. The formula for kinematic viscosity is expressed as:

$$KV = C \times T$$

where:

KV = Kinematic Viscosity (mm^2/s)
C = Calibration Constant of the QualiCheck
T = Flow time of the oil in seconds

The Viscosity Index (VI) is a measure of how an oil's viscosity changes with temperature. A higher VI indicates that the oil maintains a more stable viscosity across different temperatures. The VI is calculated using ASTM D2270 and follows two conditions:

If U > H

$$Viscosity\ Index = \frac{L - U}{L - H} x\ 100$$

If U < H

$$Viscosity\ Index = \frac{antilogN - 1}{0.00715} + 100$$

where:

$$N = \frac{logH - logU}{logY}$$

Table Link: [Kinematic Viscosity Table: L & H Values (40-100°C)]

Variables Description

L - Highest Viscosity Reference @40° Celcius
H - Lowest Viscosity Reference @40° Celcius
U - Kinematic Viscosity at 40°C (mm^2/s)

Laboratory Data Results

Table 3. DOST Results

Sample	Fully Synthetic Oil - New	Fully Synthetic Oil – 5,000km	Fully Synthetic Oil – 8,000km	Fully Synthetic Oil – 10,000km	Test Method
Kinematic Viscosity at 40˚C, mm^2/s	70.6	74.5	62.6	67.0	ASTM D445
Kinematic Viscosity at 100˚C, mm^2/s	11.9	11.4	10.7	11.0	ASTM D445
Viscosity Index	166	145	162	156	ASTM D2270

The table shows the outcomes of four completely fully synthetic engine oil extract samples tested across various mile intervals based on Department of Science and Technology (DOST) data. The Viscosity Index (VI) is 166 for a new oil but it decreases to 156 after 10 000 km of operation. High Viscosity Index stresses the limited viscosity changes under temperature swings, whereas low Viscosity Index stresses sensitivity to temperature changes. The ISO 3448:1992 standard requires oil behavior testing at 40° Cand 100°C to determine oil behavior under both normal operating conditions (40°C) and high-temperature, engine load conditions (100°C). These standard temperatures help assess the oil's ability to maintain proper lubrication during startup and extended operation.

The samples that are tested are new oil, 5000 km, 8000 km, and 10,000 km. While most samples were from diesel engines, the 5000 km sample was from a gasoline engine, which degrades oil faster due to its chemical composition. According to the data obtained in the laboratory, the VI superior to 160 is in very good oil condition.VI between 150-160 is quite acceptable and still can be used. A VI below 150 is used to characterize the oil as highly degraded and therefore an immediate oil replacement is required. Calculations of viscosity index are as described in the ASTM D2270 standard, where viscosity index calculations are based on kinematic viscosity at 40°C and 100°C which are used to define the oil quality and performance.

Prototype Results

Table 4. New Fully Synthetic Engine Oil Trials

Trials	Flow of time at 40° Celcius	Flow of time at 100° Celcius	Viscosity Index
1	20 sec	7 sec	194
2	23 sec	7 sec	167
3	19 sec	6 sec	165
4	20 sec	6 sec	155
5	21 sec	6 sec	146
Average	20.6 sec	6.4 sec	
Constant	KV = C x t $C = \frac{70.6}{20.6}$ $C = 3.43\ mm^2/s$	KV = C x t $C = \frac{11.9}{6.4}$ $C = 1.86\ mm^2/s$	

Table 4 shows the trials of the new engine oil through the Qualicheck Device, measuring the engine oil flow at the maintained temperature of 40° Celsius and 100° Celsius until the flow of oil stops. The table also shows how the Kinematic Viscosity constant has been calculated from the average of the trials. Through these trials and prototype testing in Trials 2 and 3, the device somehow managed to reach the Kinematic Viscosity test acquired from the DOST, achieving 165 mm^2/s and 167 mm^2/s.

Table 5. Fully Synthetic Engine Oil at 8000km Trials

Trials	Flow of time at 40° Celcius	Flow of time at 100° Celcius	Viscosity Index
1	10 sec	5 sec	162
2	9 sec	4 sec	126
3	10 sec	5 sec	167
4	20 sec	5 sec	162
5	10 sec	6 sec	240

Average	9.8 sec	5 sec	
Constant	KV = C x t $C = \frac{62.6}{9.8}$ $C = 6.26$ mm^2/s	KV = C x t $C = \frac{10.7}{5}$ $C = 2.14$ mm^2/s	

Table 5 shows the trials of the fully synthetic engine oil through the Qualicheck Device, measuring the engine oil flow at the maintained temperature of 40° Celsius and 100° Celsius until the flow of oil stops. The table also shows how the Kinematic Viscosity constant has been calculated from the average of the trials. Through these trials and prototype testing in Trials 1 and 4, the device somehow managed to reach the Kinematic Viscosity test acquired from the DOST, achieving both 162 mm^2/s.

Table6. Fully Synthetic Engine Oil at 10000km Trials

Trials	Flow of time at 40° Celcius	Flow of time at 100° Celcius	Viscosity Index
1	8 sec	3 sec	159
2	7 sec	4 sec	176
3	6 sec	3 sec	131
Average	7 sec	3.33 sec	
Constant	KV = C x t $C = \frac{67.0}{7}$ $C = 9.57$ mm^2/s	KV = C x t $C = \frac{11.0}{3.33}$ $C = 3.30$ mm^2/s	

Table 6 shows the trials of the fully synthetic engine oil through the Qualicheck Device, measuring the engine oil flow at the maintained temperature of 40° Celsius and 100° Celsius until the flow of oil stops. The table also shows how the Kinematic Viscosity constant has been calculated from the average of the trials. Through these trials and prototype testing in Trial 1, the device somehow managed to reach the Kinematic Viscosity test acquired from the DOST, achieving 159 mm^2/s.

Device Prescription

The Qualicheck device classifies the engine oil into three states according to the degree of Viscosity Index (VI) and mileage to provide timely maintenance suggestions. The excellent condition (VI>160, 0–5000 km) represents low viscosity variation and proper lubrication with no necessity for replacing immediately. A good condition (VI 150-160, 8000 km) indicates degradation but still usable oil with an oil change advised at intervals between 2000–3000 km to achieve optimum performance. The condition (VI<150, above 10,000 km) with a highly degraded state represents strong viscosity deterioration, which leads to diminished lubrication efficiency and increased wear, so that the oil change is urgent. This classification system aids to better utilize the oil and ensure that the engine does not prematurely break down.

Parameter Correlation

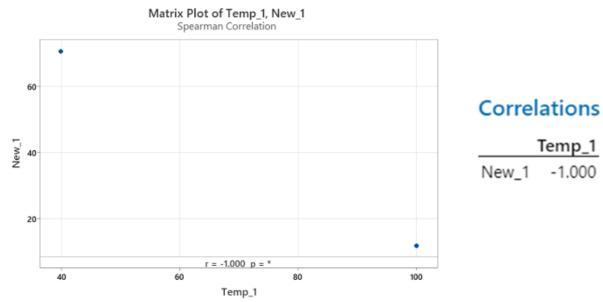

Figure 7. Temperature and Viscosity Correlation

In order to see the correlation between the temperature and the viscosity of the Engine Oil The Spearman correlation method was implemented in using Minitab's correlation analysis to examine the association between temperature and the viscosity. Analysis indicated a correlation coefficient of -1, indicating, accordingly, perfect inverse correlation. This result will confirm that increases in temperature decrease in viscosity proportionally. This behavior is consistent with the predictions of theory because the oil thins and so loses its protective characteristic as the temperature increases. This analysis highlights the relevance of viscosity monitoring for the efficient engine lubrication and maintenance. This means that they are inversely proportional to each other.

5.0 CONCLUSION

The QualiCheck project developed an integrated sensor system for prescriptive maintenance by analyzing engine oil quality, minimizing unnecessary oil changes. The system, powered by an Arduino Mega, utilized a MAX6675 module with a K-Type thermocouple for temperature sensing, an infrared sensor for oil level detection, and an MG996R servo motor for actuation. It classified engine oil samples based on mileage into "excellent," "moderately acceptable," or "degraded," displaying results on an LCD. Data collection and analysis were conducted, ensuring that oil samples were classified based on mileage which in the testing compromised the oil from new oil, 5000km, 8000 km and 10000 km. The system's accuracy was validated against laboratory results, adhering to ASTM D445, D2270, and ISO 3448:1992 standards. The successful automation of oil condition assessment and maintenance recommendations highlights its potential in optimizing vehicle performance and longevity.

The study confirmed that the QualiCheck system effectively assessed engine oil quality by accurately measuring kinematic viscosity and viscosity index, the primary indicators of oil degradation. The device automated the testing routine, such as heating, time determination and calculation, providing accurate and high-quality operation. Its outputs correlated well with laboratory-computed values, confirming their utility. Following international oil analysis standards, the system served as a proof-of-concept within the context of automotive maintenance and its real-world usefulness. The results indicate that the QualiCheck is a promising methodology for monitoring the state of the engine oil and for setting maintenance intervals.

6.0 RECOMMENDATIONS

To all the future researchers and actions the authors recommended to focus the work by enlarging the sample pool to encompass oil samples from different travel ranges in order to provide more accurate quality assessment. Further trials with semi synthetic and mineral oils under a variety of operational conditions are also suggested in order to enhance the robustness of the system. Searching for alternative sensors that can resist higher temperatures may improve the accuracy. Developing more straightforward and user-friendly oil quality assessment measures may help to extend the system's accessibility. Testing oil samples should be properly disposed to avoid polluting the environment, and maintenance of the user's knowledge on the importance of oil condition monitoring in vehicle longevity is encouraged

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8.0 REFERENCES

[1] Amrani, Mokhtar & Haddad, Yara & Abdulhameed, Mohammed & Hyder, Omar & Saif, Amin & Ghaleb, Atef & Mejjaouli, Sobhi. (2022). A Lubricating Oil-Based Maintenance for Diesel Engines at the End-user: An Effective Predictive Approach. https://www.researchgate.net/publication/366020340_A_Lubricating_Oil-Based_Maintenance_for_Diesel_Engines_at_the_End-user_An_Effective_Predictive_Approach/citations

[2] Fields, A., & Fields, A. (2024, July 16). What is prescriptive analytics? Definition and examples. WebFX.https://www.webfx.com/blog/marketing/prescriptive-analytics/

[3] How a single missed oil change impacts your vehicle health. (2023, October 11). AAMCO Transmissions and Total Car Care - Boardman, OH | Transmission Repair, Auto Repair, Total Car Care. https://www.aamcoboardmanoh.com/how-a-single-missed-oil-change-can-impact-your-vehicle-health/

[4] Khanna, V. (2024, December 27). Engine oil Grades explained | Know your car engine oil.TheGoMechanicBlog.https://gomechanic.in/blog/car-engine-oil-grades-explained/

[5] Lubricants, A. (2023, January 7). Blog on Engine oil Effect Emissions and fuel - ARMOR. Armor Lubricants. https://armorlubricants.com/blog/engine-oil-effect-on-emissions-and-fuel/

[6] Motorlease. (2024, February 29). Vehicle Maintenance Costs are on the Rise: Here's Why | Motorlease Fleet Management & Leasing Solutions. Motorlease Fleet Management & Leasing Solutions. https://motorlease.com/article/vehicle-maintenance-costs/

[7] Raposo, H., Farinha, J. T., Fonseca, I., & Galar, D. (2019). Predicting condition based on oil analysis – A case study. Tribology International, 135, 65–74. https://doi.org/10.1016/j.triboint.2019.01.041

[8] Research, K. (2023, February 7). The Philippines lubricants market is expected to generate over PHP 250 bn revenue in 2026F owing to the rising demand of personal vehicles and future expansion strategies of market players: Ken Research.Thesis.https://www.prnewswire.com/news-releases/the-philippines-lubricants-market-is-expected-to-generate-over-php-250-bn-revenue-in-2026f-owing-to-the-rising-demand-of-personal-vehicles-and-future-expansion-strategies-of-market-players-ken-research-301740331.html

[9] Team, L., & Team, L. (2023, May 24). What is a Degreaser and How Do You Use it? | Lubchem. Lubchem, Inc. | Lubricants, Grease, Oilfield Lubricants. https://lubchem.com/blog/lubrication-systems/what-is-a-degreaser-and-how-do-you-use-it/

[10] The importance of changing your engine oil | Chevron Lubricants (US). (n.d.).

https://www.chevronlubricants.com/en_us/home/learning/from-chevron/personal-rec-vechicles-and-equipment/the-importance-of-changing-your-engine-oil.html

[11] TotalEnergies USA. (n.d.). Uses and benefits of engine oil | TotalEnergies. https://services.us.totalenergies.com/uses-and-benefits-of-engine-oil