Optimisation of River State Company (RTC) Fleet Management System

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Abstract: In the transportation industry, fleet maintenance is essential for ensuring operational efficiency, reducing costs, and extending vehicle lifespan. As fleets age, maintenance challenges escalate, impacting profitability. This study focuses on developing a maintenance reliability program for the Rivers State Transport Company (RTC) to optimize fleet management and enhance financial performance. The aim of this study is to assess RTC's maintenance activities and design a reliability-based program that minimizes costs and maximizes profits. A mixed-method survey research design was adopted, with secondary data collected from RTC's maintenance workshop records and financial reports spanning from 2014 to 2023. The dataset includes maintenance costs, replacement costs, and income for three vehicle models (Nissan Urvan, Toyota Hiace, and Ford Transit) across multiple years. The Dynamic Recursive Programming Model was employed to analyze vehicle age, cost, and income trends, and Microsoft Excel was used for data processing. The results show a significant rise in maintenance costs as vehicles age. For example, the Nissan Urvan's maintenance costs increased from ₦1.2 million in 2014 to ₦2.6 million in 2023, representing a 116.7% increase over 9 years. Replacement costs for the Toyota Hiace surged from ₦4 million in 2014 to ₦8.5 million in 2023. Income generated by older vehicles also declined by approximately 25%, with the Ford Transit generating ₦5.1 million in 2023 compared to ₦6.8 million in 2014 due to frequent breakdowns and reduced reliability. The analysis further revealed that replacing vehicles after 6-7 years of operation would maximize financial returns, based on the balance of maintenance and income. In conclusion, maintaining an aging fleet presents a substantial financial burden, with rising maintenance costs, diminishing income, and increasing replacement expenses. This study recommends that RTC adopt a structured vehicle replacement policy guided by the Dynamic Recursive Programming Model. Furthermore, reliability-based maintenance strategies should be implemented to reduce unnecessary expenses and improve the overall performance and profitability of the fleet.

Keywords: Maintenance, Reliability Financial Impact, Vehicle Aging and Replacement Cost

I. Introduction

The challenge of growing production demands with existing machinery and equipment forces companies to show constant productivity improvements and to get the most advantage from the existing machinery and equipment. The first step to achieve this aim is naturally the online monitoring of the processes in the equipment and the second step that follows is the interpretation of the operational data collected from these processes, so that process/equipment optimization and cost-effective productivity opportunities can be identified. Unfortunately, experience and research have shown that a large number of companies and organization that failed to break even have not followed the above-mentioned steps in the pursuit of their companies' goal in term of maintenance philosophy

One pervasive cost that drags down productivity improvements, hence process optimizations, is unplanned equipment and manufacturing process downtime. Harrison (2015) revealed the fact that machinery and equipment in US plants have availability between 85%-95% `of planned operating time. The cost associated with unplanned downtime might reach 30%-40% of profit. Rivers Transport Company is posed with a problem of poor maintenance procedure in her fleet. The company has no standard workshop and modern equipment for fleet maintenance activities RTC utilizes a lot of fairly used spare parts instead of new and original spare parts in the maintenance of the fleet. The company also has not been adopting an adequate reliability-based procedures in the maintenance of her fleet. These inadequate procedures in the maintenance of her fleet will cause low output quality, high operating cost, increased customer dissatisfaction and increase equipment failure. Also, it was discovered that the company spent a large percentage of their profit on unnecessary maintenance activities and if nothing is done to address this problem; the company will suffer from large number of breakdowns in her fleet.

Preventive maintenance, as the name implies, are specific tasks that are designed to prevent the need for corrective or breakdown maintenance, as well as prolong the useful life of capital assets and auxiliary equipment. Most preventive maintenance (PM) programmes are a loose conglomeration of inspections, cleaning, adjustment, lubrication, and similar tasks that do little, if anything, to preserve the reliability of critical production assets. The logic diagram is based on evaluation technique applied to each functionally significant item (FSI) using all available technical data, as well as the "native knowledge" of the maintenance personnel. Principally, the evaluations are based on the item's functional failure and failure causes.

The research highlights that as vehicles age, they incur escalating maintenance costs, decreased income generation, and a higher probability of failure, all of which negatively impact the company's profitability and operational efficiency. By adhering to the recommended maintenance and replacement schedules identified through dynamic programming models, RTC can significantly

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reduce these costs, minimize downtime, and extend the service life of its vehicles. The findings suggest that a structured, proactive approach to fleet management, which prioritizes timely maintenance and strategic vehicle replacement, will not only enhance the reliability and longevity of the fleet but also improve overall financial performance.

The development of reliability-based PM programme is based on the following: (Mobley, 2008a)

i. Identification of FSIS

ii. Identification of applicable and effective task. A functionally significant item is an item whose failure would affect safety or could have significant operational or economic impact on the personnel or equipment or environment

Equipment information provides the basis for the evaluation and should be assembled prior to the start of the analysis and supplemented as the need arises. The following should be included.

i. Requirement for equipment and its associated systems, including regulatory requirement

ii. Design and maintenance documentation

iii. Performance feedback, including maintenance and failure data.

In order to guarantee completeness and avoid duplication, the evaluation should be based on an appropriate and logical breakdown of the equipment by using part list catalogue of the equipment.

System analysis involves identification of FSIs and maintenance tasks. It should be noted that the tasks can be tailored to meet the requirements of a particular industry and the emphasis placed on each task will depend on the nature of that industry.

Murthy and Pongpech (2008) presented preventive maintenance (PM) actions. According to the researcher, PM actions through leasing were more economical since experience maintenance equipment and highly trained maintenance were avoided, especially, if maintenance action is not the core business of the company. According to other reasons for company preferring leasing of PM actions were lesser initial capital investment and often there were tax benefit that makes it attractive. This researcher believed that for quicker response to PM actions, it is advisable for organizations like transportation company to set up her own in-house maintenance team to deal with maintenance needs as they arise to avoid long delays in maintenance actions.

Deaver and Colorade (2007) presented a maintenance scheduling for mechanical equipment. This paper established recommended preventive maintenance activities, and maintenance intervals. It defined PM as the practice of maintaining equipment on a regular schedule based on elapsed time or meter reading and gave reason for PM as "they prevent" maintenance problems or failures before they take place by following routine and comprehensive maintenance procedures. The researcher advanced PM goals to include fewer, shorter and more predictable outages. The following were put forward by the researcher as other advantages of PM

i. It is predictable, making budgeting, planning and resource leveling it generally prevents most major problems, thus reducing forced outages, reactive maintenance and maintenance costs in general.

ii. It assures managers that the equipment is being maintained

iii. It is easily understood and justified. According to the author, PM was not without some drawbacks.

iv. It is time consuming and resource intensive. It does not consider actual equipment condition when scheduling or performing the maintenance.

v. It can cause problem in equipment in addition to solving them (eg. Damaging seals, stripping threads)

To eliminate unnecessary PM, maintenance managers should apply a consciously chosen, effectively implemented and properly documented reliability-centered maintenance (RCM) programme. This paper added a model that was used to utilize a PM, RCM, or conditions - based maintenance (CBM) programme, or a combination of these Scheduled maintenance should be the primary focus of the in-house maintenance staff rather than reactive (emergency and corrective) maintenance Scheduled maintenance should have a higher priority than special projects and should be the number one priority (Lei, 2010).

Wang (2002) presented two types of maintenance policies for reactive/ corrective maintenance and PM. The paper defined PM as all actions performed in an attempt to retain the system in working order and reduce the risk of unexpected failure, the author presented schedule maintenance policies with or without priority assignment. This paper added a careful design of an effective maintenance policy could reduce the down time due to unexpected equipment failure and in turn the down time costs

Dhillion (2002a) presented an engineering maintenance inspection optimization model. The model was used to obtain the optimum numbers of inspections per facility per unit of time. The paper added that inspections are often disruptive, but they usually reduce down time because of lesser number of failures Total Facility Downtime is defined as

$$TD_t = \lambda \mathrm{T}_a + \frac{CT_b}{z} \quad (1)$$

Differentiating (1) with respect to y, we get

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$$\frac{dTD_t}{d\lambda} = \mathrm{T}_a - \frac{CT_b}{z^2} \tag{2}$$

Setting equation (2) equal to zero and then re-arranging, we obtain

$$Y^* = \frac{(CT_b)^2}{T_a} \tag{3}$$

Substituting equation (3) into (1) yields

$$TD_{t^*} = 2(\mathrm{CT}_a T_b)^2 \tag{4}$$

Dhillion (2002b) presented an optimum inspection frequency in order to minimize the per unit-of-time equipment/facility downtime. In the model facility/equipment (per unit time) total downtime is the function of inspection frequency. Mathematically, it is defined as follows

$$TD_{t(n)} + D\mathrm{T}_r + DT_i \tag{5}$$

$$= \frac{\lambda(n)}{\mu} + \frac{n}{\emptyset} \tag{6}$$

$$\frac{dTD_t(n)}{dn} = \frac{d\lambda(n)1/\mu}{dn} + {}^{1}\!/_{\emptyset} \tag{7}$$

Setting equation (6) equal to zero and rearranging yields

$$\frac{d\lambda(n)}{dn} + \frac{-u}{\emptyset} \tag{8}$$

This model concluded that the value of a will be optimum when the left and right sides of equation (8) are equal. At this point the equipment facility total downtime will be minimal.

Marusic, Galovic and Pita (2007) presented a reliability programme for achieving better operational performance, through decreased maintenance related problems in operation, and increased operational safety. The paper opined that reliability programmes are mandated by the regulations for all commercial o l operators. Depending on the size of the operator, they stated implementation of reliability programme can be carried out in various organizational forms. They however, stated that, organization with small number of fleets represent too small a statistical sample to collect enough information for obtaining significant and accurate data. Therefore, they doubted the usability of reliability programme in very small fleets.

Computerized Maintenance Management Models (CMMS) does most of the functions (usually performed by maintenance management system manually) automatically as programmed into the system and activated as necessary. This section will explain some of these methods and procedures for doing this.

i. Automatic CMMS work order creation model (Mobley, Lindley & Wikoff, 2008a) preventive maintenance plans define what is to be done, parts or materials required, craft/skill required and other relevant information, are created and stored on a CMMS file. Each plan is tied to one or more equipment/asset identification (ID) for which it is to be performed. When a frequency or execution schedule is triggered, the CMMS will automatically copy the PM plan into a work order. This model enables work order to be created and not a work request.

ii. CMMS Work Order and Resource Scheduling Model (Mobley, Lindley & Wikoff, 20085) stated that once the total planned hours for each craft/skills exceed the number of hours available in one work day, that should happen in the first day of planning, decisions will have to be made about scheduling the backlog. CMMS provides assistance in scheduling of work order. All open work orders are maintained on a file that is referred to as the work order backlog. Each work order will have indicators to be used in determining the schedule.

Reliability is concerned with failure free performance of a system and the duration of time over which this failure free performance is maintained. The term often used to describe the overall capability of a system to perform its intended function is system effectiveness System effectiveness is defined as the probability that the system can successfully meet an operational demand within a given time when operating under specified conditions. Reliability theory is the foundation of reliability engineering. For engineering purposes, reliability is defined as: The probability that a device will perform its intended function during a specified period of time under stated conditions (Mobley, Lindley & Wikoff, 20085).

Reliability engineering is concerned with four key elements of this definition. First, reliability is a probability this means that failure is regarded as a random phenomenon, it is a recurring event, and it does not express any information on individual failure, the causes of failures or relationships between failures, except that the likelihood for failures to occur varies over time according to the given probability function. Reliability engineering is concerned with meeting the specified probability of successes at a specified statistical confidence level.

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Secondly, reliability is predicted on "intended function" Generally, this is taken to mean operation without failure. However, even if no individual part of the system fails, but the system as a whole does not do what was intended, then it is still charged against the system reliability. The system requirements specification is the criterion against which reliability is measured.

Thirdly, reliability applies to a specified period of time. In practical terms, this means that a system has a specified chance that it will operate without failure before time t. Reliability engineering ensures that components and materials will meet the requirements during the specified time units other than time may sometimes be used. The automotive industry might specify reliability in terms of kilometer, the military might specify reliability of a gun for a certain number of rounds fired (Henley & Kumamoto, 1981). A piece of mechanical equipment may have a reliability rating value in terms of cycles of use.

Fourthly, reliability is restricted to operation under started conditions. This constraint is necessary because it is impossible to design a system for unlimited conditions. A military Rover will have different specified conditions than the family car. The operating environment must be addressed during design and testing. Also, that same rover, may be required to operate in varying conditions requiring additional scrutiny.

Recent advances in maintenance reliability programs include; IoT-enabled predictive maintenance uses real-time sensor data to adapt maintenance schedules and prevent major failures. Digital work management: optimizes job prioritization, job planning, job assignment, permitting, scheduling and dispatch. Predictive maintenance: detects early signs of equipment problems to prevent failures and reduce downtime. Condition-based monitoring: tracks equipment conditions to optimize maintenance schedules. Reliability-centered maintenance: prioritizes maintenance based on equipment reliability and Artificial intelligence in predictive analysis: uses machine learning and advanced analytics to predict equipment failures.

II. Materials and Methods

Data for this study were collected through the means of questionnaire. Questionnaire was distributed to staff working in the maintenance department and also to the top management staffs in order to obtain the present maintenance activities of the company. These data obtained were analyzed using ABC approach, so as develop a good maintenance procedure and work order for the company. The descriptive survey aims to identify prevalent issues associated with RTC fleet failures in Nigeria's transportation industry. In contrast, the exploratory survey seeks to investigate the underlying causes and contributing factors to these failures. By merging these methods, the study will provide a well-rounded analysis, combining statistical data with in-depth insights from industry experts and stakeholders. The data for this study were sourced from secondary sources to ensure a comprehensive and well-rounded analysis. Specifically, data on vehicle types, maintenance costs, replacement costs, and income generated from 2014 to 2023 were obtained from the maintenance workshop of the Rivers State Transport Company (RTC) fleet.

Table 1: Types of Vehicles Considered and Their Quantities

Vehicle Type	Quantity
Nissan Urvan	10
Sienna	9
Peugeot Expert	8
J5	15
Ford Bus	12
Toyota Hiace	10

The specific instruments for data collection included:

Maintenance Workshop Records

Vehicle Types and Quantities: Detailed records of the types and quantities of vehicles in the RTC fleet.

Table 2: Types of Vehicles Considered and Their Quantities

Vehicle Type	Quantity
Nissan Urvan	10
Sienna	9
Peugeot Expert	8
J5	15
Ford Bus	12
Toyota Hiace	10

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Table 3: Actual Maintenance Costs Considered

Maintenance Task
Regular oil changes
Alignment
Removal and replacement of vehicle spare parts
Vulcanizing work
Panel beating work
Routine inspections
Electrical works
Servicing of air conditioning systems
General engine servicing

Replacement Costs: Records of costs incurred in procuring or purchasing replaceable or serviceable parts for the vehicles, such as, Tyres, Oil filters, Fuel filters, Fan belts, Wipers, Pumps and Bulbs.

Financial Reports

Income Generated (2014-2023): Financial reports detailing the income generated by the RTC fleet over the specified period. This data helped in analysing the financial performance and the cost-effectiveness of the maintenance program. By relying on these secondary data sources, the study was able to gather extensive quantitative information on vehicle types, maintenance costs, replacement costs, and income generated. These data provided a robust foundation for analysing the maintenance reliability program and identifying areas for improvement in the maintenance service of the RTC fleet.

The data collected were analyzed using a Dynamic Recursive Programming Model, implemented with Microsoft Excel Software. This analysis aimed to determine the best sequence of maintenance or replacement actions, establish the optimal replacement policy for each vehicle over the planned period, and maximize net profit in operation. Additionally, a replace and keep analysis was conducted, accompanied by relevant plots.

The Dynamic Recursive Programming Model to determine the most cost-effective approach over the 2014-2023 period

The problem stage and state variables are shown in Table 3.5 with columns 1and 2 representing various years (stages) and their corresponding state (age) variables respectively.

Table 4: The stage and state variables for the Case Company

k (Stage Variables)	i (State Variables)
1	0, 2
2	1, 3
3	1, 2, 4
4	1, 2, 3, 5
5	1, 2, 3, 4, 6
6	1, 2, 3, 4, 5, 7
7	1, 2, 3, 4, 5, 6, 8
8	1, 2, 3, 4, 5, 6, 7, 9
9	1, 2, 3, 4, 5, 6, 7, 8, 10
10	1, 2, 3, 4, 5, 6, 7, 8, 9, 11
11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12
12	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13
13	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14
14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15

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The problem is addressed using backward dynamic programming through the recursive Equation (1). It is assumed that a vehicle can only be kept or replaced at the beginning of each year and that all vehicles considered are of the same age. Additionally, the vehicles are not subjected to catastrophic failure. The Dynamic Programming (Recursive) Model is utilized to analyse the data. This optimization tool uses a recursive equation to determine the optimal decision to keep or replace a vehicle, aiming to optimize the appropriate lifespan of the vehicles under investigation. The recursive equation for the automobile replacement problem is written as follows:

$$V_k(i) = \min \begin{cases} C_k(i) - I_k(i) + V_{k+1}(i+1) Keep \\ C_k(0) - I_k(0) + R_k(i) + V_{k+1}(1) \mathrm{Re}\, place \end{cases} \tag{9}$$

Where:

k (i) = Represent total cost at each stage (k) of an old bus;

Ck(0) = Represent total cost at each stage (k) of a new vehicle.

Ik(i) = Represent the old vehicle income at stage (k).

Ik(0) = Represent the new vehicle income at stage (k).

Rk(i) = Represent the vehicle replacement cost at stage (k).

Vk(i) = Represent the total recursive cost for a vehicle of age (i) at stage (k).

Vk+1(i + 1**)** = Represent the total recursive cost for a vehicle of age (i+1) at stage (k+1).

Vk+1(1) = Represent the total recursive cost for a vehicle of age (1) at stage (k+1)

i= Represent the vehicle age at stage k, (The state variable)

Dk= Represent the decision at stage k.

k= Represent the stage

Reliability

The majority of engineering component failures have characteristics with other failures that have been studied in the past. Therefore, the outcome of a practical investigation into this kind of failure could be applied as a preventative maintenance control procedure. A heuristic approach was used to examine the differential component's failure rate. The method made use of the likelihood of success as indicated by the differential component's reliability (R). The ratio of equipment failures to all repairs performed on the dump truck determines the component's probability. Equation (10) is used to evaluate it, and Equation (11) is used to estimate the equipment reliability (Khabibullin et al., 2013, KováŇc et al., 2021).

$$P = \frac{N}{T} \tag{10}$$

where

P = probability of failure

N= number of the failed component

T= total number of repair

$$R = 1 - P \tag{11}$$

where

R= reliability

Determination of the Mean Time between Failure (MTBF)

A comprehensive examination of the dump truck's operational availability over the course of the lease was done in order to calculate the MTBF. Important metrics were examined, such as the chance of failure, MTBF, and MTTR. The MTBF is a critical performance indicator that is used to evaluate the reliability of the dump truck. It measures the average interval between consecutive failures throughout the course of the lease.

Determination of the Mean Time to Repair (MTTR)

The Mean Time to Failure (MTTR) serves as a metric reflecting the lessor's proficiency in executing maintenance tasks aimed at preserving or reinstating the dump trucks to a predefined state. This metric quantifies the average duration needed to bring the

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dump trucks back to their optimal operational status following a failure. The time measurement is expressed in hours, as outlined in equation (12) according to the work of Khabibullin et al. in 2013.

$$MTTR = \frac{TRT}{NR} \tag{12}$$

where

TRT= the total repair time

NR= number of repairs or replacement events.

MTBF is a basic measure of dump truck reliability. It is expressed as shown in Equation (13).

$$MTBF = \frac{TOT}{NF} \tag{13}$$

where

TOT= total operating time of the dump truck

NF= number of failures over a given period.

III. Results

Evaluating the Financial Impact of Vehicle Aging

The actual maintenance cost data collected from the case company over a ten-year period (2014-2023) is presented in Table 5. The data reveals a trend where maintenance costs increase as the vehicles age.

Table 5: Actual Maintenance Cost Collected (2014-2023)

Year	Nissan Urvan	Sienna	Peugeot Expert	J5	Ford Bus	Toyota Hiace
2014	1,969,000	1,900,000	2,090,000	2,337,000	2,165,400	2,205,000
2015	2,250,000	2,440,000	2,130,000	2,410,800	2,297,700	2,400,000
2016	2,520,000	2,905,000	2,590,000	3,665,400	3,115,800	2,510,000
2017	2,815,000	3,230,000	2,900,000	3,811,000	3,488,700	2,790,000
2018	3,030,000	3,700,000	3,050,000	3,990,000	3,590,000	3,020,000
2019	3,240,000	3,920,000	3,310,000	4,050,000	3,690,000	3,330,000
2020	3,360,000	4,405,000	3,505,000	4,210,000	3,780,000	3,515,000
2021	3,590,000	4,610,000	3,790,000	4,400,000	3,905,000	3,640,000
2022	3,995,000	4,880,000	3,980,000	4,650,000	4,100,000	3,713,200
2023	4,005,000	4,981,500	4,000,000	4,820,000	4,145,000	3,802,100

(Source: Case Company Maintenance Workshop).

Table 5 presents ten years of data on replacement costs collected from the case company. The data reveal a trend where replacement costs rise as the vehicles age.

Table 6: Actual Replacement Cost Collected (2014-2023)

Year	Nissan Urvan	Sienna	Peugeot Expert	J5	Ford Bus	Toyota Hiace
2014	19,920,000	11,000,000	15,000,000	18,030,000	18,035,000	18,924,000
2015	20,240,000	11,500,000	15,200,000	18,090,000	18,120,000	18,975,000
2016	21,000,000	12,500,000	15,500,000	18,170,000	18,130,000	19,000,000
2017	21,000,000	12,500,000	16,500,000	18,300,000	18,200,000	19,125,000
2018	21,568,000	12,800,000	16,600,000	18,520,000	18,250,000	19,328,000
2019	21,810,000	13,090,000	16,650,000	18,660,000	18,360,000	19,440,000
2020	22,015,000	13,290,000	17,005,000	18,840,000	18,400,000	19,500,000
2021	23,050,000	13,360,000	17,330,000	19,010,000	18,620,000	19,660,000

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2022	23,160,000	13,524,000	17,720,000	19,200,000	18,760,000	19,670,000
2023	23,430,000	13,700,000	17,810,000	19,350,000	18,790,000	19,700,000

(Source: Case Company Maintenance Workshop)

Table 6 presents the actual income cost data collected from the case company over ten years, spanning from 2014 to 2023. The data indicate a decline in income generated as the vehicles age.

Optimal Replacement Time for Vehicles

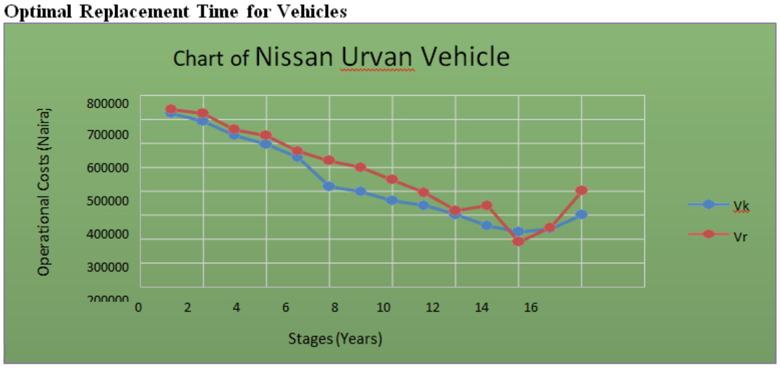

Figure 1: Optimum Replacement Time for RTC Nissan Urvan Vehicles

Figure 1 depicts the optimal replacement time for minimizing average operational costs of RTC Nissan Urvan vehicles over a specified period. The plot shows that as the total net recursive costs for keeping the vehicles (vk) decrease, the optimal service life of the vehicles extends, reaching a peak at year 12. At this stage, the total net recursive costs for replacement (vr) become lower than the costs for keeping the vehicles. Adhering to the replacement action at this point would yield a net profit of ₦18,613,400 for the company, whereas failing to follow the optimal replacement policy would result in a loss of ₦21,894,482. Therefore, it is recommended that the company replace all its Nissan Urvan vehicles at the beginning of the 12th year.

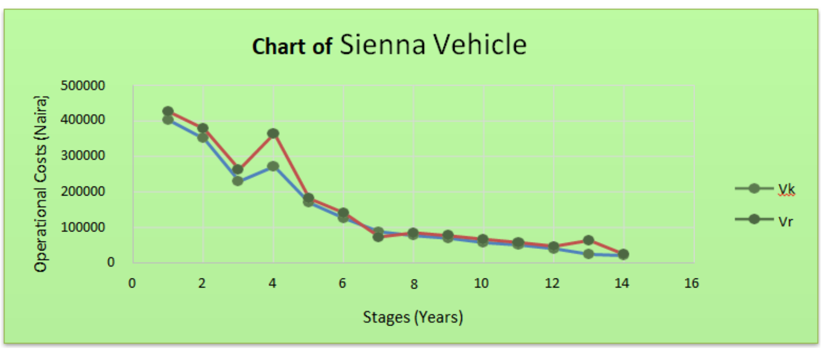

Figure 2: Optimum Replacement Time for Sienna Vehicles

Figure 2 illustrates the optimal replacement time for minimizing the mean operational costs of Sienna vehicles over the given period. The chart reveals that as the total net recursive costs for keeping the vehicles (Vk) decrease, the optimal service life of the vehicles extends, reaching a peak at year 7. At this stage, the total net recursive costs for replacement (Vr) become lower than the costs for keeping the vehicles. Adhering to the replacement action at this point would result in a net profit of ₦7,264,015 for the company, while failure to follow the optimal replacement policy would lead to a loss of ₦8,750,759. Therefore, the company is advised to replace all its Sienna vehicles at this stage.

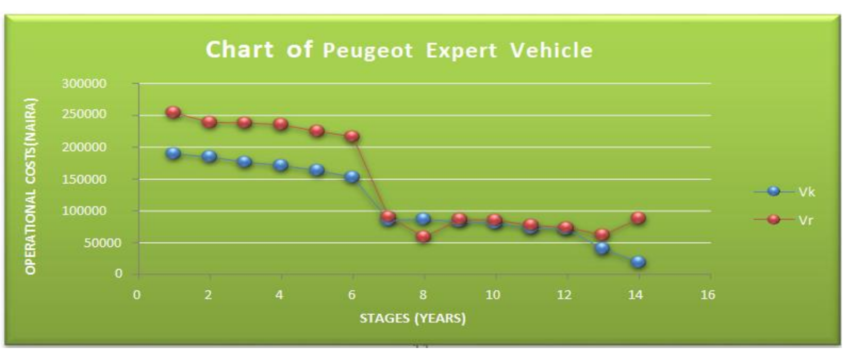

Figure 3: Optimum Replacement Time for Peugeot Expert Vehicles.

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Figure 4.3 displays the optimal replacement time for minimizing the average operational costs of Peugeot Expert vehicles over the given period. The plot indicates that as the total net recursive costs for keeping the vehicles (Vk) decrease, the optimal service life of the vehicles extends, reaching a peak at year 8. At this stage, the total net recursive costs for replacement (Vr) fall below the costs for keeping the vehicles. Following the recommended replacement action at this point would yield a net profit of ₦5,862,286 for the company, whereas failure to adhere to the optimal replacement policy would result in a loss of ₦8,616,168. Therefore, the company is advised to replace all its Peugeot Expert vehicles at this time.

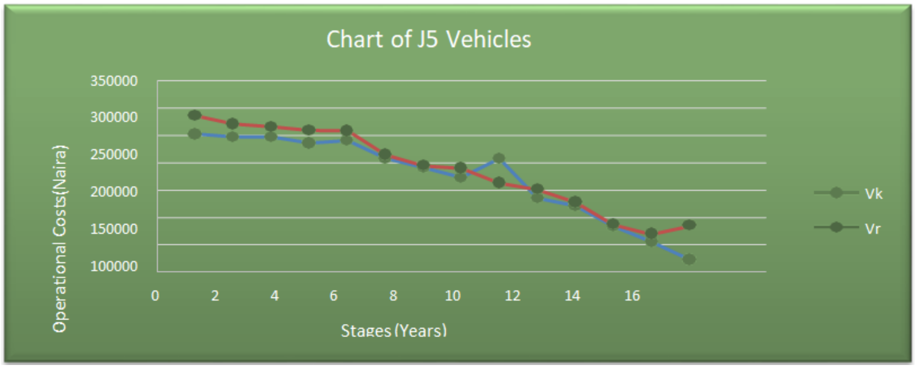

Figure 4: clarifies the operational costs of RTC J5 vehicles over the given years or stages.

Figure 4.4 illustrates the optimal replacement time for minimizing the mean operational costs of RTC J5 vehicles over the given period. The chart reveals that as the total net recursive operational costs for keeping the vehicles (Vk) decrease, the optimal service life extends until year 9. At this point, the net recursive costs for replacement (Vr) fall below those for keeping the vehicles. Adhering to the replacement action at this stage would result in a net profit of ₦16,329,730 for the company, while failing to follow the optimal replacement policy would lead to a loss of ₦20,730,290. Therefore, the company is advised to replace all its J5 vehicles at the beginning of the 9th year.

Probabilities of failure of the RTC Fleets

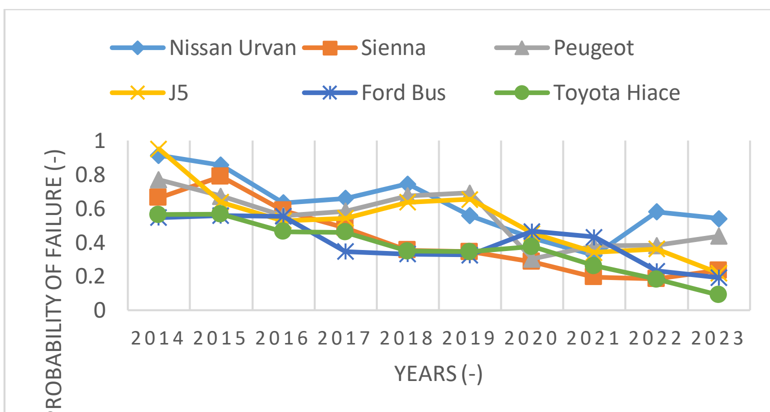

Figure 5: Probabilities of the RTC Fleets

The analysis of vehicle maintenance, replacement costs, and income generation over a ten-year period (2014-2023) provides valuable insights into the financial impact of vehicle aging and the optimal replacement strategies for RTC's fleet. The key findings are discussed below:

The data presented in Table 5 clearly shows that maintenance costs for all vehicle types increase as the vehicle age. This trend is consistent across all vehicle models, with costs rising significantly over the ten-year period. For instance, the maintenance costs for the Nissan Urvan increased from ₦1,969,000 in 2014 to ₦4,005,000 in 2023, representing more than a 100% increase. This trend suggests that older vehicles require more frequent repairs and part replacements, leading to higher costs. The increasing maintenance costs align with the general understanding that vehicles become less reliable as they age, resulting in more frequent breakdowns and higher repair costs. This finding underscores the importance of implementing a structured vehicle replacement strategy to minimize operational expenses.

Similarly, Table 6 reveals a steady rise in the replacement costs of vehicles over the studied period. The replacement cost for a Nissan Urvan, for example, increased from ₦19,920,000 in 2014 to ₦23,430,000 in 2023. This upward trend in replacement costs can be attributed to factors such as inflation, increased costs of manufacturing, and possibly the introduction of newer vehicle models with more advanced features that come at a higher price. This finding suggests that delaying vehicle replacement could lead to higher future costs, making it financially prudent to replace vehicles before these costs escalate further.

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The dynamic programming model's results indicate the optimal replacement time for each vehicle type to minimize overall operational costs. The model suggests replacing vehicles at specific stages to maximize profitability. For instance, the Nissan Urvan should ideally be replaced at the beginning of the 12th year, while the Sienna should be replaced at the 7th year. Adhering to these optimal replacement policies would result in significant net profits for the company.

The comparison of profit and loss margins for keeping versus replacing vehicles reveals that replacement generally offers a higher profit margin compared to keeping vehicles beyond their optimal service life. For example, replacing the Nissan Urvan at the 12th year results in a net profit of ₦18,613,400, while keeping it would incur a loss of ₦21,894,482. These findings emphasize the financial benefits of adhering to a well-planned vehicle replacement strategy. The margins also highlight the importance of timely decision-making to avoid unnecessary losses and to optimize the fleet's operational efficiency.

The probability of failure analysis in Figure 5: Probabilities of the RTC Fleets, particularly for the Nissan Urvan and Sienna vehicles, demonstrates that as vehicles age, their likelihood of failure increases, although some vehicles show improved reliability after initial fluctuations. The analysis indicates that while maintenance can temporarily improve reliability, the long-term trend of increasing failure probability underscores the need for timely replacement to avoid disruptions in operations.

The primary goal was to optimize the maintenance strategy, improving fleet reliability and longevity while minimizing costs and maximizing profitability. The findings revealed that as vehicles aged, maintenance costs increased significantly across all types, with older vehicles requiring more frequent repairs. For instance, maintenance expenses for the Nissan Urvan rose from ₦1,969,000 in 2014 to ₦4,005,000 in 2023. Replacement costs also grew steadily, driven by inflation and technological advancements, with the cost of a new Nissan Urvan increasing from ₦19,920,000 in 2014 to ₦23,430,000 in 2023.

The study also found a decline in income generated by aging vehicles, primarily due to reduced reliability and increased downtime. The Nissan Urvan's income, for example, dropped from ₦9,807,300 in 2014 to ₦8,300,000 in 2023. Through dynamic programming models, the study identified optimal maintenance and replacement intervals, recommending that the Nissan Urvan be replaced after 12 years and the Sienna after 7 years to avoid excessive costs and income loss.

Financial analysis showed that implementing a structured maintenance reliability program significantly improved profit margins by reducing unexpected breakdowns and maintenance costs. For the Nissan Urvan, adhering to the recommended program resulted in a net profit of ₦18,613,400 over its service life. In conclusion, the study underscored the importance of a proactive maintenance strategy for RTC. By adopting the recommended schedules, RTC can enhance fleet efficiency, reduce operational costs, and increase profitability, ensuring long-term sustainability.

IV. Conclusion

This study concludes that the development and implementation of a maintenance reliability program is essential for the Rivers State Transport Company (RTC) to optimize the performance and sustainability of its vehicle fleet. The research highlights that as vehicles age, they incur escalating maintenance costs, decreased income generation, and a higher probability of failure, all of which negatively impact the company’s profitability and operational efficiency. By adhering to the recommended maintenance and replacement schedules identified through dynamic programming models, RTC can significantly reduce these costs, minimize downtime, and extend the service life of its vehicles. The findings suggest that a structured, proactive approach to fleet management, which prioritizes timely maintenance and strategic vehicle replacement, will not only enhance the reliability and longevity of the fleet but also improve overall financial performance. Implementing such a program will enable RTC to better manage its resources, reduce unexpected expenses, and ensure a more sustainable and profitable operation in the long term.

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