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DEVELOPMENT OF VEHICLES MAINTENANCE AND REPLACEMENT SCHEMES: CASE OF A TRANSPORT COMPANY

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Abstract

This research work developed optimal maintenance and replacement schemes for a transport company vehicles. In this direction, dynamic programming technique was used to analyze the operational costs of the said vehicles as to obtain the optimal replacement policy of the vehicles when efficiently utilized. The results showed that non-adherence to the replacement policy would make the company to incur the loss of [₦21,894,500, ₦8,750,845, ₦8,616,176, ₦20,730,300, ₦23,295,750, ₦36,565,900, ₦18,438,28] for Nissan Urvan, Sienna ,Peugeot Expert, J5, Ford bus, Toyota Hiace, Taxi cab vehicles respectively. It is, however, interesting to note that, adherence to the policy year replace action would yield to the company the desired profit of [₦18,613,400, ₦7,264,015, ₦5,862,286, ₦16,329,730, ₦18,190,395, ₦33,837,700, ₦5,482,395] on the said vehicles. It is strongly recommended that the company should dispose of all its Nissan Urvan vehicles stated herein after eleven (11) years of usage, Sienna vehicles after six (6) years of usage, Peugeot Expert vehicles after seven (7) years of usage, J5 bus vehicles after eight (8) years of usage, Ford bus vehicles after seven (7) years of usage, Toyota Hiace vehicles after eight years (8) and Taxi Cab vehicles after eight (8) years of usage.

Keywords: Maintenance, Vehicles, Transportation, Cost, Replacement, and Dynamic programming Model.

1.1 Introduction

The challenges of intense international competition and market globalization according toRamdeen (2005) have placed enormous pressure on maintenance system to improve efficiency and reduce operational costs. These challenges have forced maintenance managers to adopt tools, methods, and concepts that could stimulate performance growth and minimize errors, and to utilize resources effectively. Bottazzi et al (1992) reported that poor maintenance management causes frustration in business because the machineries fail erratically and sometimes, when it is most needed. It is necessary that one knows everything, about the equipment he is operating. Therefore, Ezechukwu (2012) opined that staff training is extremely important in keeping the machineries in good working condition. The maintenance of complex equipment often accounts for a large portion of the costs associated with that equipment. In this regard, Abdul (2011) observed that the maintenance costs of military equipment comprise almost one third of all the operating costs incurred. One of the goals of a successful and efficient public transportation provider is to promote vehicle safety and extend vehicle life. Vehicle reliability and longevity can only be accomplished by implementing various maintenance practices. This practice requires extensive knowledge of the vehicle fleet as well as analysis of maintenance activities and failure trends. Responding to failures after they happen, instead of anticipating them, limits the ability of the agency to plan and schedule their maintenance. This, Goldberg et al (2004) noted would create continual failures and making emergency repairs to get vehicles back in service, thereby creating an unmanageable and costly situation. In all sectors of engineering, every effort is put on maintenance schedule; some need daily attention, others need weekly or monthly while some require annual maintenance, etc. The design life of most vehicles requires periodic maintenance, in this wise, Latham (2008) was of the opinion that failure to perform maintenance activities intended by the vehicle’s designer shortens the operating life of the vehicle.

Vehicles are subject to deterioration due to their use and exposure to environmental conditions as a result of wear and tear of parts in relative motion and improper lubrication of the sliding parts and should be fully utilized with minimum cost of stoppage and repair, Duffuaa et al (2001) reported that, if this deterioration and breakdown is not checked it may render the vehicles unserviceable, therefore, it is necessary to attend to them from time to time, repair and recondition them so as to enhance their life economically and protect them from failure .This has brought the role of maintenance and replacement as an important activity in the transportation industries. However, Godwin et al (2013) defined maintenance as the activity directed towards the upkeep and repair of plant facilities/equipment. Every vehicle requires maintenance even if it is best designed, in which Clarotti et al (2004) noted that maintenance must be done at such a period when it would have least disruptions of service, therefore, vehicles, machines undergo maintenance when not in use or their use may be postponed without affecting service and operation. However, in reality most of the vehicles failures are influenced not only by the internal factor (age-time usage) but also by the external factor. The external factors would be the effects of the environment (dust, humidity, precipitation, temperature and heat), human skills, product types and maintenance activities, which is in consonance with Adams (2015) observation. The timely maintenance of vehicles in the fleet is one of the fundamental programs that serve as a backbone of a successful transport system; Gertsbalch (1997) posited that vehicles maintenance expenses usually increase as the age of vehicle advances thereby triggering replacement. The vehicles are subject to breakdowns and deterioration therefore, maintenance policy can be beneficial in order to prevent failures during operation (Steven, 2009).Besides, vehicle maintenance is an important service function of an efficient transportation system. In this direction, Zeqing (2006) concurred that adequate maintenance would increase the operational efficiency of the transport facilities and thus contributes to revenue by reducing the operating costs and increasing the effectiveness of production. Conversely, Parida (2007) was of the view that poorly maintained vehicles may lead to more frequent vehicles failures, poor utilization and delayed operation schedules and frequent replacement because of shorter life. For many asset-intensive industries the maintenance costs are a significant portion of the operational costs, the maintenance expenditure accounts for 20-50% of the service cost for the industry as stated by Bhowmik (2010) depending on the level of the equipment.

Prior to this study, the company was challenged with high cost of maintaining company’s vehicles which reduces and generally affect the total net profit of the said company. However, this research work is geared towards solving this maintenance problem by the application of dynamic recursive programming model. Although, many approaches and models have been used in the past to analyze the operational costs of transportation industries, but could not achieve the desired results because such models were less accurate and inconsistent which could not be applied to a wide variety of situations. With this proposed model an optimal replacement policy can be made so that a particular vehicle is replaced when it has reached its declined stage.The accomplishment of the dynamic programming based automobile replacement policy stated would assist the company and other Transport Service Providers nationwide to better access and manage vehicles need particularly maintenance and replacement. The creation of a more effective vehicle replacement system would be of tremendous benefit in money savings. Finally, the study would be used as a guide for organizations to improve or promote their maintenance strategies and also benefit future researchers in this field on how to adopt maintenance measures.

2.0 Methodology

In this study, the data on the types of vehicles, maintenance costs, replacement costs and income generated from 2005 to 2014 were obtained from maintenance workshop of the company as actual data. The types of vehicles considered in this work and their numbers include: Nissan Urvan (10), Sienna (9), Peugeot expert (8), J5 (15), Ford bus (12),Toyota Hiace (10),and Taxi cab(8).The actual maintenance costs considered are: Costs incurred by regular oil changes,alignment,removing and replacing vehicles spare parts, vulcanizing work, panel beating work, routine inspection, electrical works, servicing of air condition, and general engine servicing etc. The actual replacement costs include: all the costs incurred in procuring or purchasing any replaceable or serviceable parts of the vehicles (tyres, oil filters, fuel filters, fan belts, wipers, pumps, bulbs) etc. The data collected were analyzed using Dynamic Recursive Programming Model and was implemented using Microsoft Excel Software to find: the best sequence of maintenance or replacement action, the optimal replacement policy of each vehicle over the planned period; the maximum net profit in operation. Replace and keep analysis and plots were also made.

2.1 Data Presentation

The actual maintenance cost data collected from the case company for ten years period (2005-2014) are presented in table 1.From the data, it is observed that maintenance costs increase with increase in the age of the vehicles.

Table 1: Actual Maintenance Cost Collected

Time	Year	Nissan Urvan	Sienna	Peugeot Expert	J5	Ford Bus	Toyota Hiace	Taxi Cab
1	2005	1,969,000	1,900,000	2,090,000	2,337,000	2,165,400	2,205,000	1,890,000
2	2006	2,250,000	2,440,000	2,130,000	2,410,800	2,297,700	2,400,000	2,080,000
3	2007	2,520,000	2,905,000	2,590,000	3,665,400	3,115,800	2,510,000	2,160,000
4	2008	2,815,000	3,230,000	2,900,000	3,811,000	3,488,700	2,790,000	2,310,000
5	2009	3,030,000	3,700,000	3,050,000	3,990,000	3,590,000	3,020,000	2,500,000
6	2010	3,240,000	3,920,000	3,310,000	4,050,000	3,690,000	3,330,000	2,910,000
7	2011	3,360,000	4,405,000	3,505,000	4,210,000	3,780,000	3,515,000	3,012,000
8	2012	3,590,000	4,610,000	3,790,000	4,400,000	3,905,000	3,640,000	3,220,000
9	2013	3,995,000	4,880,000	3,980,000	4,650,000	4,100,000	3,713,200	3,370,000
10	2014	4,005,000	4,981,500	4,000,000	4,820,000	4,145,000	3,802,100	3,405,000

(Source: Case Company Maintenance Workshop)

Ten years data on replacement cost collected from the case company are presented in table 2. From the collected data, it is observed that replacement costs increase with increase in the age of the said vehicles.

Table 2: Actual Replacement Cost collected

Time	**Year**	**Nissan Urvan**	**Sienna**	**Peugeot Expert**	**J5**	**Ford Bus**	**Toyota Hiace**	**Taxi Cab**
1	2005	19,920,000	11,000,000	150,00000	18,030,000	18,035,000	18,924,000	10,000,000
2	2006	20,240,000	11,500,000	15,200,000	18,090,000	18,120,000	18,975,000	10,110,000
3	2007	21,000,000	12,500,000	15,500,000	18,170,000	18,130,000	19,000,000	11,020,000
4	2008	21,000,000	12,500,000	16,500,000	18,300,000	18,200,000	19,125,000	11,520,000
5	2009	21,568,000	12,800,000	16,600,000	18,520,000	18,250,000	19,328,000	11,640,000
6	2010	21,810,000	13,090,000	16,650,000	18,660,000	18,360,000	19,440,000	11,700,000
7	2011	22,015,000	13,290,000	17,005,000	18,840,000	18,400,000	19,500,000	11,950,000
8	2012	23,050,000	13,360,000	17,330,000	19,010,000	18,620,000	19,660,000	12,015,000
9	2013	23,160,000	13,524,000	17,720,000	19,200,000	18,760,000	19,670,000	12,060,000
10	2014	23,430,000	13,700,000	17,810,000	19,350,000	18,790,000	19,700,000	12,100,000

(Source: Case Company Maintenance Workshop)

The actual income costs data collected from the case company are presented in table 3.These data are also for ten years from 2005 to 2014.It is noticed that income generated decreases as the vehicles' age increase.

Table 3: Income generated data collected

Time	**Year**	**Nissan Urvan**	**Sienna**	**Peugeot Expert**	**J5**	**Ford Bus**	**Toyota Haice**	**Taxi Cab**
1	2005	9,807,300	9,000,000	8,830,000	8,910,000	9,200,000	10,012,000	7,890,000
2	2006	9,782,400	8,710,000	8,600,000	8,540,000	9,020,000	9,706,000	7,721,500
3	2007	9,600,000	8,420,000	8,420,000	8,330,000	8,713,000	9,550,000	7,500,000
4	2008	9,515,000	8,205,000	7,990,000	8,150,000	8,614,000	9,220,000	7,119,000
5	2009	9,020,000	8,150,000	7,755,000	7,920,000	8,290,000	9,019,000	6,830,000
6	2010	8,850,000	8,040,000	7,605,000	7,760,000	7,88,0000	8,812,000	6,615,000
7	2011	8,610,000	7,800,000	7,415,000	7,606,000	7,740,000	8,600,000	6,309,000
8	2012	8,489,700	7,710,000	7,050,000	7,500,000	7,550,000	8,330,000	5,880,000
9	2013	8,340,000	7,140,000	6,805,000	7,450,000	7,195,000	7,911,000	5,690,000
10	2014	8,300,000	7,015,000	6,760,000	6,980,000	6,875,000	7,880,000	5,405,000

(Source: Case Company Maintenance Workshop)

2.1.1 Method of Data Analysis

The problem stage and state variables are shown in Table 4 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

The problem is solved by backward dynamic programmingusing the recursive "Eq.(1)",etc., with the assumption that a vehicle can only be kept or replaced at the beginning of each year and vehicles considered are of the same age. The vehicle is again not subjected to catastrophic failure.

Dynamic Programming (Recursive) Model is used to analyze the data; it is an optimization tool, itsrecursive equation of an automobile replacement problem for either keep or replace decision with the aim of optimizing the appropriate life span of the vehicles under investigation can be written as follows:

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

Where: k (i) = Represent total cost at each stage (k) of an old bus;
$C_k(0)$ = Represent total cost at each stage (k) of a new vehicle.
$I_k(i)$ = Represent the old vehicle income at stage (k).
$I_k(0)$ = Represent the new vehicle income at stage (k).
$R_k(i)$ = Represent the vehicle replacement cost at stage (k).
$V_k(i)$ = Represent the total recursive cost for a vehicle of age (i) at stage (k).
$V_{k+1}(i + 1)$ = Represent the total recursive cost for a vehicle of age (i+1) at stage (k+1).
$V_{k+1}(1)$ = 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)
D_k= Represent the decision at stage k.
k= Represent the stage

3.0 Results and Discussion

The results of the Dynamic Programming (recursive) model are presented in figures (1-8).Table 5 provides the summary of optimal decision variable sequence and table 6 is a display of replace and keep comparison with profit margin for the studied vehicles as deduced from computational analysis and microsoft excel solver output.

Figure 1 presents the chart of Nissan Urvan Vehicles over the given period.

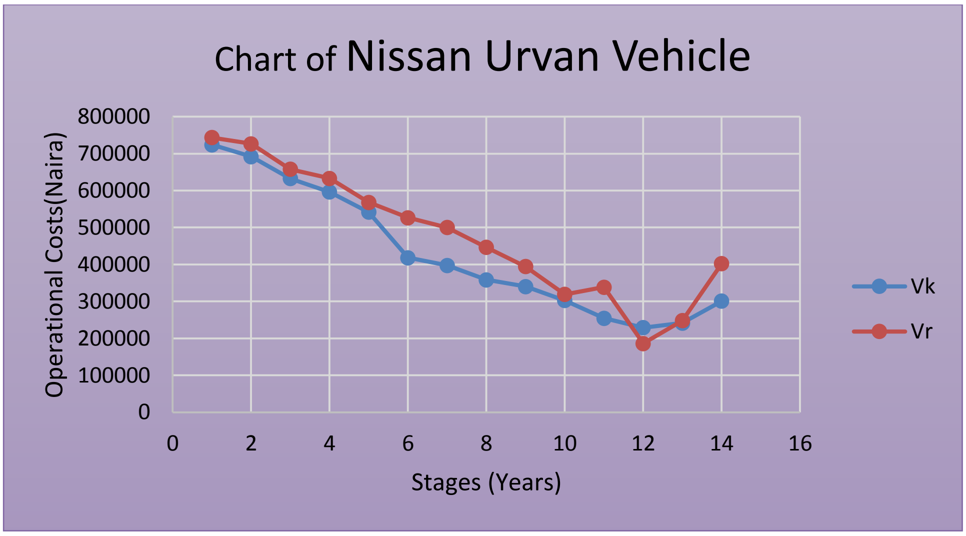

Figure1: Optimum Replacement Time for Nissan Urvan Vehicles

Figure 1 illustrates the optimum replacement time for average operational costs of Nissan Urvan vehicle over the given period. From the plot it is observed that as the total net recursive costs for keep (v_k) decrease, the vehicles service optimal years increase up to stage 12 where the total net recursive costs (v_r) for replace action becomes less than the total net recursive keep action. At this point the company would make a net profit of ₦18,613,400 if replace action is adhered to and a loss of ₦21,894,482 would be incurred for non-adherence to the optimum replacement policy. At the beginning of 12th year, therefore, the company is advised to replace all its Nissan Urvan vehicles.

Figure 2 provides the chart of Sienna Vehicles over the given years or stages.

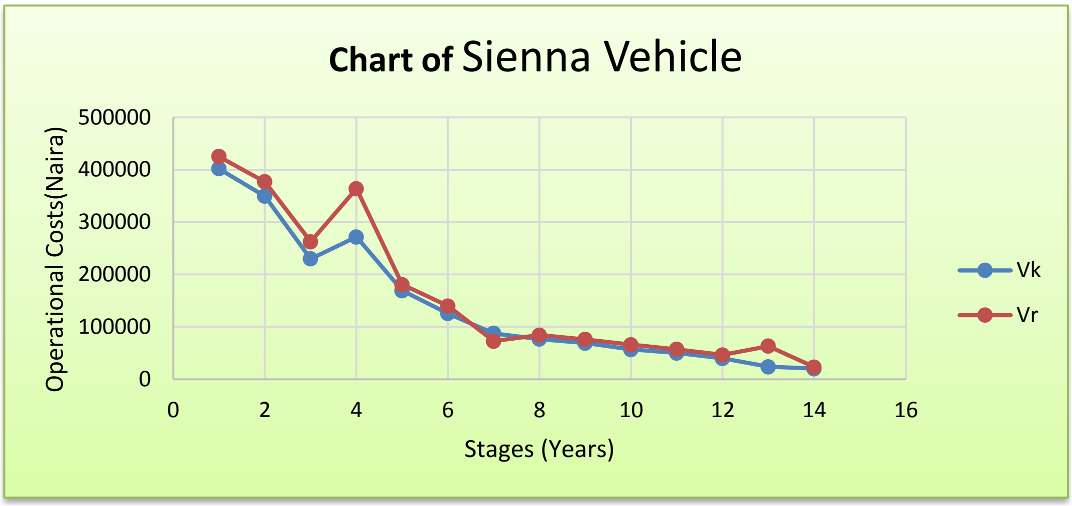

Figure 2: Optimum Replacement Time for Sienna Vehicles

The optimum replacement time for mean operational costs of Sienna vehicles over the given period is show cased in figure 2. From the chart, it is observed that as the total net recursive costs for keep (V_k) decrease, the vehicles optimal service years increase up to stage 7 where the total net recursive costs(V_r) for replace action becomes less than the total net recursive keep action. At this point the company would make a net profit of ₦7,264,015 if replace action is adhered to and a loss of ₦8,750,759 for non-adherence to the optimum replacement policy. At this point the company is advised to replace all its Sienna vehicles.

Figure 3 illustrates the operational costs of Peugeot Expert Vehicles over the given years or stages.

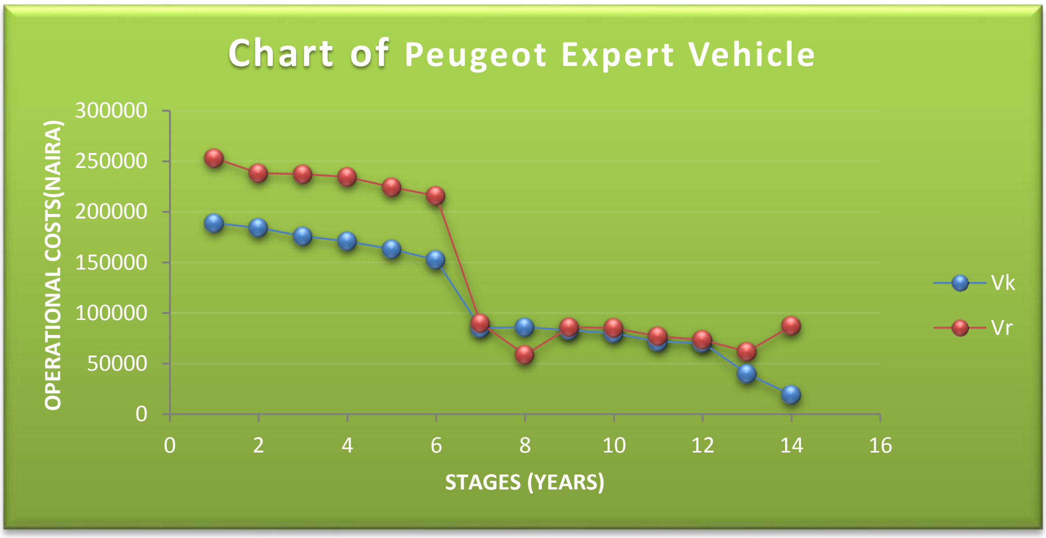

Figure 3: Optimum Replacement Time for Peugeot Expert Vehicles.

Figure 3 presents the optimum replacement time for the average operational costs of Peugeot Expert vehicles over the given period. From the plot, it is observed that as the total net recursive costs for keep (V_k) decrease, the number of optimal service years increase up to stage 8 where the net recursive replace action (V_r) becomes less than the total net recursive keep action. At this stage the company makes a net profit of ₦5,862,286 if replace action is adhered to and a loss of ₦8,616,168for non-adherence to the optimum replacement policy. At this time the company is advised to replace all its Peugeot expert vehicles.

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

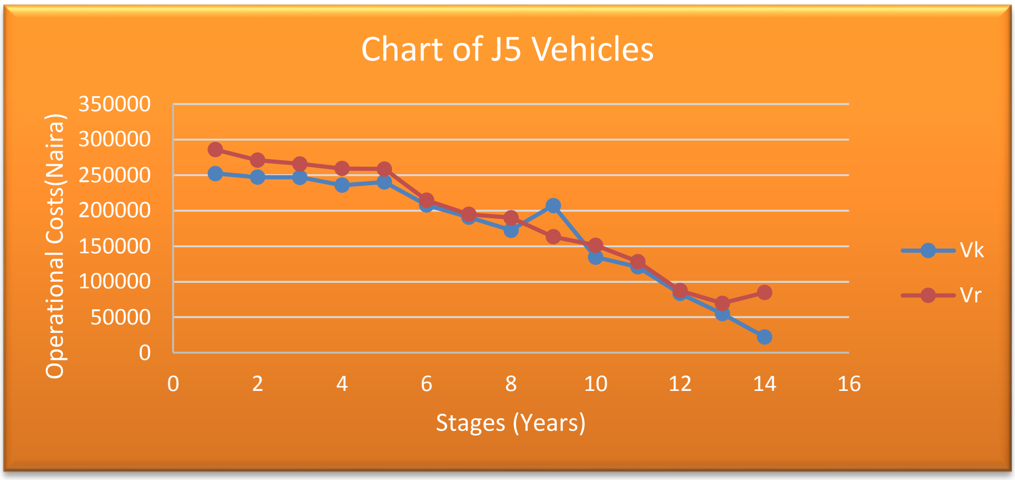

Figure 4: Optimum Replacement Time for J5 Vehicles

Figure 4 presents the optimum replacement time for the mean operational costs of J5 vehicles over the given period. From the chart, it is observed that as the total net recursive operational costs for keep (V_k) decrease the number of optimal service years increase up to stage 9 where the net recursive replace action (V_r) becomes less than the total net recursive keep action. At this stage the company makes a net profit of ₦16,329,730 for adhering to replace action and a loss of ₦20,730,290 for non-adherence to the optimum replacement policy. In this regard, the company is advised to replace all its J5 vehicles at beginning of the 9th year.

Figure 5 illustrates the operational costs of Ford bus vehicles over the given years or stages.

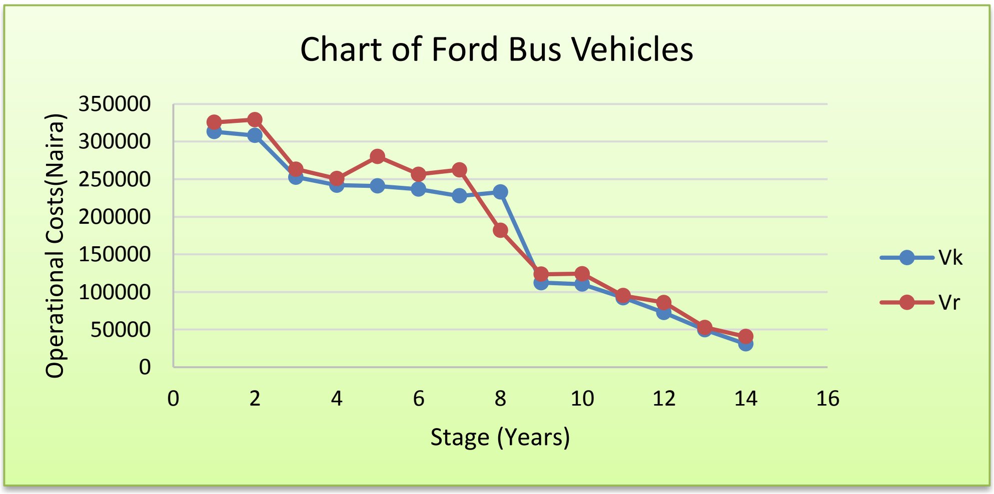

Figure 5: Optimum Replacement Time for Ford Bus Vehicles

The optimum replacement time for the average operational costs of Ford bus vehicles over the given period is presented in figure 5. The trend shows from the chart, that as the total net recursive operational costs for keep (V_k) decrease the number of years increase up to the 8th year where the total net recursive operational costs for replace action(V_r) becomes less than the total net recursive cost for keep action. At this stage, the company makes a net profit of ₦18,190,395 if replace action is taken and a loss of ₦23,295,735incurred for not obeying the optimum replacement policy. At this time a replacement action of the Ford vehicles is needful.

Figure 6 presents the operational costs of Toyota Hiace vehicles over the given years or stages.

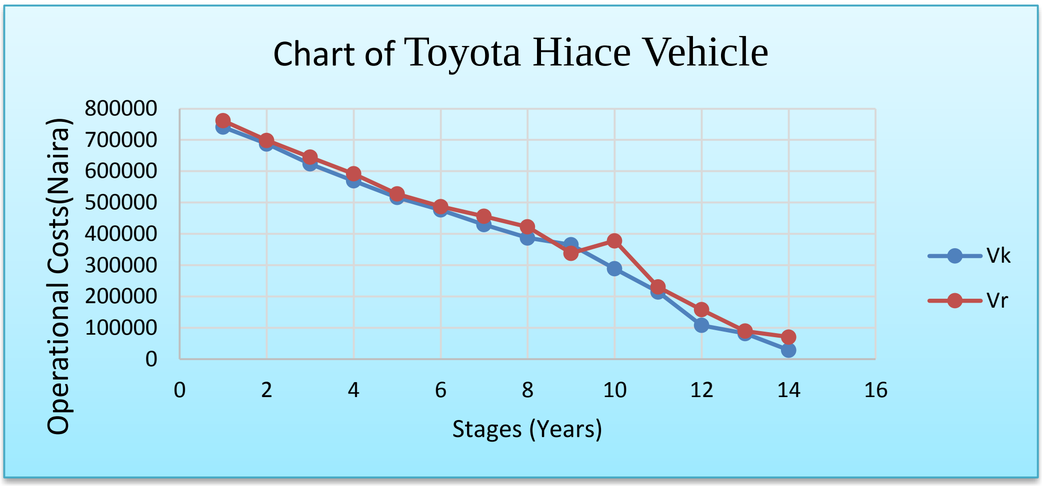

Figure 6: Optimum Replacement Time for Toyota Hiace Vehicles

Figure 6 displays the optimum replacement time for mean operational costs of Toyota Hiace vehicles over the given period. From the plot, it is observed that as the total net recursive operational costs for keep (V_k) decrease, the vehicles optimal years of service increase up to stage 9 where the total net recursive operational costs for replace action(V_r) becomes less than the total net recursive cost for keep action. At this instance the company is expected to make a net profit of ₦33,837,700 for adherence to the optimum replacement policy and a loss of ₦36,565,887for non-adherence. The company is therefore advised to replace all its Toyota Hiace vehicles at the beginning of the 9th year.

Figure 7 illustrates the operational costs of Taxi Cab vehicles over the given years or stages.

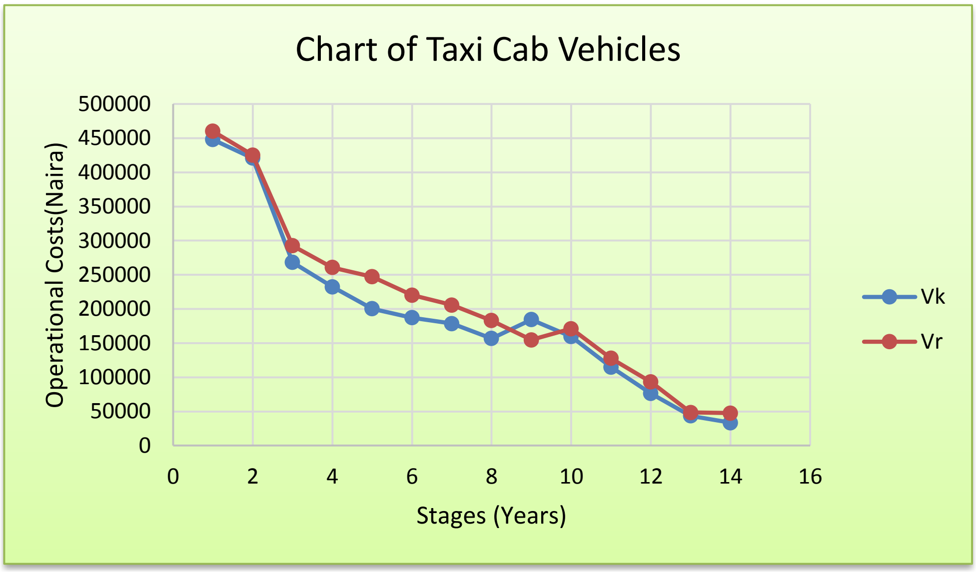

Figure 7: Optimum Replacement Time for Taxi Cab Vehicles

The optimum replacement time for the average operational costs of Taxi Cab vehicles over the give period is highlighted in figure 7. From the graph, it is observed that as the total net recursive operational costs for keep (V_k) decreases ,the vehicles optimal service years increase up to stage 9 (nine), where the total net recursive cost(V_r) for replace action becomes less than the total net recursive cost for keep action. At this stage the company makes a net profit of ₦15,482,395if replace action is adhered to and a loss of ₦18,438,288 for non-adherence to the optimum replacement policy. At this time the company is advised to replace all its Taxi cab vehicles.

3.1 Summary of the vehicles Optimal Decision Variable Sequence

The optimal decisions variable sequence for vehicle types of the company are presented in table 5.

Table 5: Summary of Vehicles Optimal Decision Variable Sequence

Vehicles	**Stage 14**	**Stage 13**	**Stage 12**	**Stage 11**	**Stage 10**	**Stage 9**	**Stage 8**	**Stage 7**	**Stage 6**	**Stage 5**	**Stage 4**	**Stage 3**	**Stage 2**	**Stage 1**
Nissan Urvan	**K**	**K**	**R**	**K**	**K**	**K**	**K**	**K**	**K**	**K**	**K**	**K**	**K**	**K**
Sienna	**K**	**R**	**K**	**K**	**K**	**K**	**K**	**R**	**K**	**K**	**K**	**K**	**K**	**K**
Peugeot Expert	**K**	**K**	**K**	**K**	**K**	**K**	**R**	**K**	**K**	**K**	**K**	**K**	**K**	**K**
J5	**K**	**K**	**K**	**K**	**K**	**R**	**K**	**K**	**K**	**K**	**K**	**K**	**K**	**K**
Ford Bus	**K**	**K**	**K**	**K**	**K**	**K**	**R**	**K**	**K**	**K**	**K**	**K**	**K**	**K**
Toyota Hiace	**K**	**K**	**K**	**K**	**K**	**R**	**K**	**K**	**K**	**K**	**K**	**K**	**K**	**K**
Taxi Cab	**K**	**K**	**K**	**K**	**K**	**R**	**K**	**K**	**K**	**K**	**K**	**K**	**K**	**K**

Where, K = Keep, R = Replace

This means that Nissan Urvan Vehicles come with the optimal policy (K,K,K,K,K,K,K,K,K,K,K,R,K,K) with a corresponding total net profit of ₦18,613,400 .The company should keep the vehicles for first eleven years of service and replace at the beginning of the twelfth year and then follows with the keep decision till the end of the planned horizon. On the other hand, Sienna bus is characterized with the optimal policy (K,K,K,K,K,K,R,K,K,K,K,K,R,K) with a corresponding net profit of ₦7,264,015,which means that keep action is initiated in the first six years then followed by replace decisions at the start of seventh year and then keep action up to the twelfth year and replace again at the start of year thirteen then follows with keep decision till the end of the planned horizon. In the same direction, Peugeot Expert comes with the optimal policy (K,K,K,K,K,K,K,R,K,K,K,K,K,K) with a corresponding total net profit of ₦5,862,286 which means the company should keep the vehicle for seven years and replace at the start of the eight year and keep again at the beginning of the ninth year till the end of the planned horizon. In the same vein, the optimal policy for the J5 bus is (K,K,K,K,K,K,K,K,R,K,K,K,K,K) with a corresponding total net profit of ₦16,329,730, in which case the company keeps the vehicles for eight years, replace at the beginning of the ninth year and keep again throughout the planned period. For the Ford bus, the optimal policy is (K,K,K,K,K,K,K,R,K,K,K,K,K,K) with the net profit of ₦18,190,395 which means that the company should keep the vehicles for seven years ,start replacing at the beginning of the eighth year and then keep again till the end of the planned horizon. More so, Toyota Hiace comes with the optimal policy of (K,K,K,K,K,K,K,K,R,K,K,K,K,K)with the net profit of ₦33,837,700,a pointer to the fact that the company should keep the vehicles for eight years and start replacing it from the beginning of the ninth year, then keep again till the end of the planned period. Finally, Taxi Cab comes with an optimal policy of (K,K,K,K,K,K,K,K,R,K,K,K,K,K) and a corresponding net profit of ₦15,482,395, an indicator that the company should keep the vehicle for eight years and start replacing at the beginning of the ninth year ,keep again till the end of the planned horizon.

3.1.1 Replace and Keep Comparison

The replace and keep comparison with profit or loss margin is shown in table 6.

Table 6: The Replace and Keep Comparison with Profit/Loss Margin

Vehicles	Loss obtained from Keep(₦)	Profit obtained from Replace(₦)	policy Year	Loss obtained from Keep (%)	Profit obtained from Replace (%)	Margin (%)
Nissan Urvan	21,894,482	18,612,943	12	54.05	45.95	8.1
Sienna	8,750,759	7,264,037	7	54.64	45.36	9.3
Peugeot Expert	8,616,168	5,862,300	8	59.51	40.49	19.02
J5	20,730,290	16,329,690	9	55.94	44.063	11.88
Ford Bus	23,295,735	18,190,386	8	56.15	43.85	12.3
Toyota Hiace	36,565,887	33,837,687	9	51.94	48.06	3.88
Taxi Cab	18,438,288	15,482,388	9	54.36	45.64	8.72

Table 6 provides the comparison of profit and loss for keeping and replacing the vehicle types of the company with percentage margin. It is observed from the table 6 that: Nissan Urvan, Sienna, Peugeot Expert, J5, Ford Bus, Toyota Hiace and Taxi Cab has the percentage margin of 8.1,9.3,19.02,11.88,12.3,3.88 and 8.72 respectively.

Figure 8 further illustrates the comparison of profit and loss for keeping and replacing the vehicle types of the company over the given period.

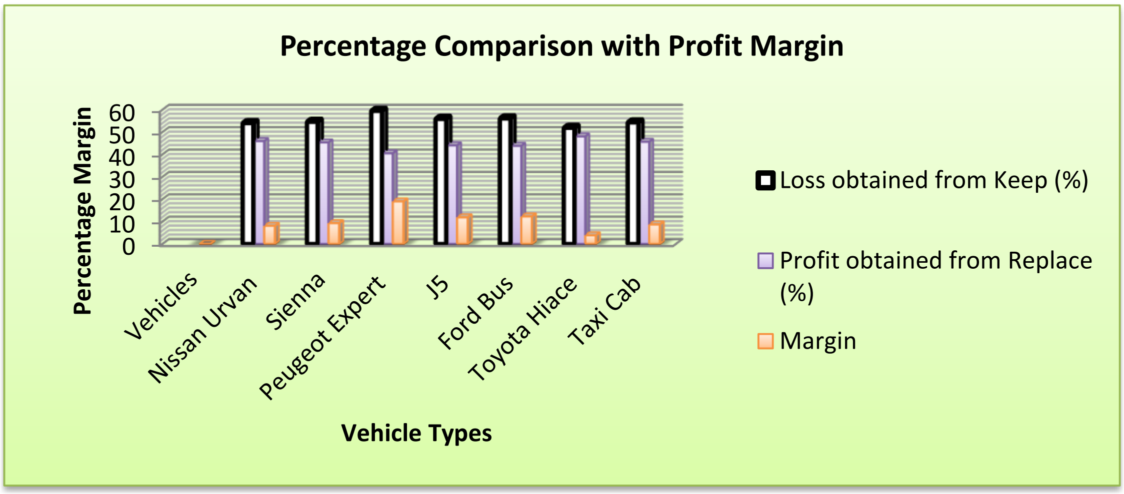

Figure 8: illustrates the plot of percentage comparison with profit margin

Figure 8 is the comparison graph of profit and loss for keeping and replacing the vehicle types of the company. It is observed that in each of the policy years, the loss of keeping and the profit of replacing the vehicles were revealed. However, the percentage profit and loss margins for replacing and keeping each of the vehicles after its policy year were also highlighted.

4.0 Conclusion

Recursive dynamic programming model was applied to obtain the optimal replacement policy of the company and implemented using Microsoft excel solver software. The model revealed the vehicle optimal decision variable sequence of the vehicles: Nissan Urvan, Sienna, Peugeot Expert, J5, Ford Bus, Toyota Hiace and Taxi Cab to have its optimal replacement for the stage (year) of 12, 7, 8, 9, 8, 9 and 9 respectively.

5.0 Recommendation

It is strongly recommended that the case company should dispose its vehicles after 11, 6, 7, 8, 7, 8 and 8 years of usage respectively.

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