**International Journal of Science and Engineering and Technology (IJSE)**
**Maiden Edition**
**www.federalpolyoko.edu.ng**
**Volume 1; Issue 1; July 2025; Page No. 1-9.**

# USE OF MAIN CAUSE AND EFFECT APPARATUS IN THE ASSESSMENT OF THE IMPACT OF ENVIRONMENTAL FACTORS ON THE RUNNING COSTS OF TOYOTA HIACE BUSES OF FLEET OPERATIVE ENTERPRISE

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## Abstract
This study applied the use of main and cause effect apparatus to assess the environmental influences on the operational outlay of Toyota Hiace buses of Fleet Establishment. The outcome of the findings, indicated that the maintenance and replacement costs increase as the distance covered (km) increases and the reverse remains the case for the revenue generated. Whereas Precipitation, Temperature and Relative humidity had the maximum and lowest environmental effects for the maintenance costs, replacement costs and income generated at [(1696.4, 28.40, 129.68), (1695.0, 28.40,129.68), (1620.0,28.50,156.90)] and [(1620.0,29.20,156.90), (1620.0, 29.20,156.90), (1695.0, 28.40 and 129.68)] respectively. This disclosed that at the extreme environmental effect, the establishment would spend more on the upkeep and replacement of its vehicles and less income would be generated and vice versa. Consequently, it is suggested that, the case study company should employ the main and cause effect tool for the analysis of its automobiles to enhance proficient application, optimal utilization and can be customized to serve other functions.

**Keywords:** apparatus, buses, establishment, environmental factors, operational cost.

## Introduction
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 (2021). Automobiles 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, Antonio (2020). All conveyance facility providers in Nigeria uphold a large fleets of vehicles. This equipment represents a substantial investment and is a vital set of resources that is used to maintain roads and highways as buttressed by Martorell, Sanchez & Serradell (2020). Chee (2018), maintained that handling such a big volume of equipment is an imperative and tough task when deciding the appropriate maintenance decisions that should have a clearly documented economic impact as buttressed by David (2015), who opined that the ability of the fleet to provide required equipment when needed is dependent on the degree of prevailing maintenance policy. This has brought the role of maintenance and replacement as an important activity in the transportation industries, Latham (2018). Every vehicle requires maintenance even if it is best designed; the 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 equipment failures are influenced not only by the age-time usage but also by the external factor, Parida (2022). The external factors would be the effects of the environment (dust, humidity, precipitation, temperature and heat), human skills, product types and maintenance activities, Clarotti, Martinis & Murthi (2014). Vehicle maintenance expenses usually increase as the age of a vehicle advances, thereby triggering replacement. The vehicles are subject to breakdowns and deterioration; therefore, maintenance strategy can be beneficial in order to prevent failures during operation, Steven



*Cite this article as*:
Umeozokwere, A.O. (2025). Use Of Main Cause and Effect Apparatus in The Assessment of The Impact of Environmental Factors on The Running Costs of Toyota Hiace Buses of Fleet Operative Enterprise. *International Journal of Science and Engineering and Technology (IJSE), 1(1)* 1-9.

(2022). Besides, vehicle maintenance is an important service function of an efficient productive system. It helps in maintaining and increasing the operational efficiency of the transport facilities and thus contributes to revenue by reducing the operating costs and increasing the effectiveness of production, Zeqing & Price (2016). Conversely, poorly maintained vehicles may lead to more frequent equipment failures, poor utilization and delayed operation schedules. However, poor maintenance may mean more frequent vehicle replacement because of shorter life. Cause and Effect Analysis was devised by Professor Kaoru Ishikawa, a pioneer of quality management. Main cause and effect apparatus is a tool in Design Expert software. It is an experimental tool used for process or experimental design. It shows the effect of the variables in the process or system design. It is used to analyze the influence of variables in the system, Bhowmik (2010). The main aim of cause and effect analysis is to identify the likely influence of multi-variable factors on the output. Although, it was originally developed as a quality control tool, yet the tool can be used as well in other areas. Godwin & Okafor (2012). For instance, you can use it to: discover the root cause of a problem, uncover bottlenecks in your processes and identify where and why a process isn't working. Prior to this study, the Fleet Operator Company was confronted with high cost of maintaining the 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 main cause and effect model. This would help to show the impact of environmental factors on the operational costs of the case study company. Although, many approaches and models have been used in the past to analyze the operational costs of transportation industries, but could not because such models were grossly inadequate to handle a wide variety of situations, Dwaikat (2019). The manufacture of a more effective vehicle maintenance system would be of tremendous benefit both in potential labor and equipment Naira savings, Gregory (2017). Finally, the study would be used as a guide for establishments to advance or stimulate their maintenance policies and likewise benefit prospective investigators in this field on how to adopt maintenance and replacement measures. The objective of the study is to assess the impact of environmental factors on the operational costs of Toyota Hiace buses of Fleet Operator Establishment by the application of main cause and effect apparatus.

## Literature Review

The running or operational cost of a vehicle of a specific age is considered to be Weibull distributed and the optimal maintenance cost limit which minimizes the expected total cost of maintaining and replacing a vehicle over a fixed planning horizon is determined, Ascher, H.E., Feingold, H., (1984). Fleet managers and researchers in their bid to addressing the problem of equipment replacement identified long ago, developed a variety of strategies. In order to complete a comprehensive and a thorough overview of developed approaches, published models and studies were reviewed and a survey was carried out to answer how replacement and maintenance problems are managed in practice at various transport service providers, Allaoui, H., Artiba, A., (2004). This approach revealed among other things a difference between theory and practice. This assessment focused on equipment replacement studies and research that are applicable or motivated by replacement for bus fleets. He argued that the firm should maximize the present value of the "aggregate goodwill" of all replacement, where the goodwill is the present value of earnings of the future machine, replacements minus the present value of costs of all such machines. An intuitive method for identifying replacement candidates is to define a replacement standard such as an equipment age standard. Assets that exceed the age standard are candidates for replacement, Han, B.J., Pan, J., Fan, X.M., Ma, D.Z., (2004). A ranking can then be implemented that sorts equipment units by how much they exceed the standard. One of the most popular approaches to derive an age standard is the application of single asset replacement analysis to compute an "economic life," which is also known as life cycle cost analysis (LCCA). Goldberg, D., (1989), proposed also to consider repair costs for individual equipment units given that LCCA gives only one replacement criterion– namely the economic life – for a whole equipment class.

As a result, repair cost limits are computed in addition to an economic life. If a fleet member stays within the repair cost limits for each year, it is replaced only after reaching the economic life of its class. Westman, J.J., Hanson, F.B., (2000), applied LCCA to individual pieces of equipment in the Texas DOT fleet. Their results indicated that this approach combined with a multi-attribute ranking, is more cost


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efficient than utilizing a single age standard. Some literature provides evidence that repair cost limit policies have some advantages over lifetime limit policies. Limbourg, P., Kochs, H.D., (2006), came out with similar results having worked with fleet data from Postal Canada and compared economic age policies with repair cost limit policies. They derived economic ages analytically and repair cost limits were generated in a Markov simulation. Applied to the Postal Canada fleet, the repair cost limit policy was superior to the economic age policy. Instead of using repair cost limits for repairs that have occurred, Billinton, R., Pan, J., (2000), derived repair cost limits for estimates of future repair costs. He assumed that before any repair measure was conducted, fleet members were run through an inspection and repair costs were estimated. The actual repair was only undertaken if estimated costs were smaller than the derived repair cost limit. Their policy was characterized by defining a limit for the time a broken unit of equipment spends in repair measures. The problem of optimal replacement to the problem of optimal buy, operate and sell policies has been expanded by other approaches. Fard, N.S., Nukala, S., (2004), detailed data from an urban transit bus fleet. Equipment units in this fleet were operated at different levels and performed different tasks as a function of age or cumulative mileage, subject to varying capacity constraints. Consequently, newer equipment units had different acquisition and operating cost structures than older less sophisticated fleet members. In later works, Hartman was encountered with the same challenge, but asset utilization levels had to meet a stochastic demand, Hartman (*2004)*. With two equipment units and parallel operation of both assets in a much more simplified case, the author determined the optimal replacement schedules and utilization levels for both individual buses by applying dynamic programming. Both Simms and Hartman faced complex equipment replacement, and operating problems in bus fleets. They did not promote particular replacement criteria but presented optimization methodologies that led to cost efficient results for a specific fleet. Previous works reviewed specifically did not consider decreasing utilization levels of assets as they age and the impact of environmental factors. At the case studied Transport Sector, equipment utilization has been decreasing with equipment age, but constant utilization has been a widely spread assumption made in the replacement models literature. Cassidy, C.R., Bowden, R.O., Liew, L., Pohl, E.A., (1999), derived an optimal buy, operate and sell policy for an urban transit bus fleet whose members operated at different levels depending on equipment age. They reduced the problem to two levels of utilization: young buses were operated at a constantly high level meeting the base demand, while utilization was constantly low for buses older than ten years because they were only used when needed to meet peak demand.

Unlike the replacement decision at other transport service providers however, they assumed utilization was controllable. Redmer (*2005*) derived the optimal lifetime limit or economic life for freight transportation fleet, which showed decreasing utilization as equipment grew older and constant utilization levels within age classes. Problems related to equipment replacement in fleets were analyzed by Konak, A., Coit, D.W., Smith, A.E., (2006), Davenport et al. (*2005*) and Rezg, N, Chelbi, A, Xie, X., (2005). This made a replacement demand forecast by simulating the steady process of deterioration and equipment breakdown within a Markov type network. Wang and Hwang (2004), presented a Markov model that could be applied to construct the relationships among maintenance cycle, maintenance personnel allocation, human recovery factor, and system's tolerance time. Zhou et al. (2015) presented a dynamic opportunistic condition-based predictive maintenance policy for a continuously monitored multi-unit series system that was proposed based on short-term optimization with the integration of imperfect effect into maintenance actions. In their research, it was assumed that a unit's hazard rate distribution in the current maintenance cycle could be directly derived. Alardhi, M., Hannam, R.G., Labib, A.W., (2017), presented a simulation-based optimization method for strategically optimum maintenance of monitoring-enabled multi-component systems using continuous-time jump deterioration models. Moreover, the time scale assumed discrete and the true state of the system (excellent, medium and bad) was not directly observable. What is observed was the performance of the system measured in terms of number of defectives 'per time period. At the end of each period, a decision was to be made: whether to replace the system or not and the objective was to minimize the total cost in the long run. The application of the optimization models were presented via numerical examples and the computational results of both models were analyzed but none was as effective and efficient as the main cause and effect apparatus being proposed. The accomplishment of the exploration of multi-variables on the operational costs of automobiles-based policy would assist the case study company and other Transport Service Providers nationwide to better access and manage vehicle need particularly maintenance and replacement.

## Methodology

In this study, the data on the type of vehicle, maintenance cost, replacement cost, income generated, environmental factors, and distance (km) travelled by Toyota Hiace vehicles from 2014 to 2023 were obtained from maintenance workshop of the fleet operator company and Meteorological Institute of Nigeria as actual data and the analysis was done using cause and effect tool. While using this tool, the analysis was done by deploying the four under listed steps :(1) the problem was identified (2) Factors involved were worked out (3) Possible causes were identified and (4) Finally, the analysis was done.

## Data Presentation

**Table 1: Data collected on the environmental factors and Maintenance Cost of Toyota Hiace vehicle over the given period**

| Time | Year | Precipitation ($cm^3$) | Temperature ($^oC$) | Relative Humidity | Toyota Haile (km) | TOYOTA HIACE (maint. cost, ₦) ×10,000 |
|---|---|---|---|---|---|---|
| 1 | 2014 | 1620 | 29.2 | 148 | 161059.2 | 2205 |
| 2 | 2015 | 1500 | 28.5 | 156.9 | 173774.4 | 2400 |
| 3 | 2016 | 1650.3 | 28.96 | 176.98 | 185430 | 2510 |
| 4 | 2017 | 1507 | 28.15 | 159.56 | 186489.6 | 2790 |
| 5 | 2018 | 1579.1 | 28.3 | 126.2 | 187549.2 | 3020 |
| 6 | 2019 | 1506.6 | 27.8 | 122.65 | 188608.8 | 3330 |
| 7 | 2020 | 1695.4 | 28.85 | 129.7 | 190728 | 3515 |
| 8 | 2021 | 1662 | 27.9 | 148.0 | 191787.6 | 3640 |
| 9 | 2022 | 2294.7 | 28.3 | 122.65 | 194966.4 | 3713 |
| 10 | 2023 | 1695 | 28.4 | 129.68 | 201324 | 3802 |

Table 1 presented the effect of precipitation, temperature, relative humidity and the distance travelled by the said vehicle on the maintenance cost over the given period. The trend shows that the maintenance costs increase with increase in distance travelled and as the age of vehicles increases the maintenance costs increase.

**Table 2: Data on the environmental factors and Replacement Cost of Toyota Hiace vehicle over the given period**

| Time | Year | Precipitation ($cm^3$) | Temperature ($^oC$) | Relative Humidity | Toyota Hiace(km) | Toyota Hiace (Replac. Cost, ₦)×10,000 |
|---|---|---|---|---|---|---|
| 1 | 2014 | 1620 | 29.2 | 148 | 161059.2 | 1893 |
| 2 | 2015 | 1500 | 28.5 | 156.9 | 173774.4 | 1898 |
| 3 | 2016 | 1650.3 | 28.96 | 176.98 | 185430 | 1900 |
| 4 | 2017 | 1507 | 28.15 | 159.56 | 186489.6 | 1912 |
| 5 | 2018 | 1579.1 | 28.3 | 126.2 | 187549.2 | 1933 |



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| | | | | | | |
|---|---|---|---|---|---|---|
| 6 | 2019 | 1506.6 | 27.8 | 122.65 | 188608.8 | 1944 |
| 7 | 2020 | 1695.4 | 28.85 | 129.7 | 190728 | 1950 |
| 8 | 2021 | 1662 | 27.9 | 148.0 | 191787.6 | 1966 |
| 9 | 2022 | 2294.7 | 28.3 | 122.65 | 194966.4 | 1967 |
| 10 | 2023 | 1695 | 28.4 | 129.68 | 201324 | 1970 |

Table 2 clarified the collected data on the replacement costs of Toyota Hiace vehicle, the distance travelled by the said vehicles and the environmental factors over the given period. The trend indicated that the replacement costs vary directly with the age of the said vehicle.

**Table 3: The collected data for Income generation of Toyota Hiace vehicle with environmental factors over the given period**

| Time | Year | Precipitation | Temperature ($^{o}$C) | Relative Humidity | Toyota Hiace(km) | Toyota Hiace (Incom. Generat, ₦)$\times 10{,}000$) |
|---|---|---|---|---|---|---|
| 1 | 2014 | 1620 | 29.2 | 148 | 161059.2 | 1001 |
| 2 | 2015 | 1500 | 28.5 | 156.9 | 173774.4 | 9706 |
| 3 | 2016 | 1650.3 | 28.96 | 176.98 | 185430 | 9550 |
| 4 | 2017 | 1507 | 28.15 | 159.56 | 186489.6 | 9220 |
| 5 | 2018 | 1579.1 | 28.3 | 126.2 | 187549.2 | 9019 |
| 6 | 2019 | 1506.6 | 27.8 | 122.65 | 188608.8 | 8812 |
| 7 | 2020 | 1695.4 | 28.85 | 129.7 | 190728 | 8600 |
| 8 | 2021 | 1662 | 27.9 | 148.0 | 191787.6 | 8330 |
| 9 | 2022 | 2294.7 | 28.3 | 122.65 | 194966.4 | 7911 |
| 10 | 2023 | 1695 | 28.4 | 129.68 | 201324 | 7880 |

Table 3 exemplified the data on the Income generation of Toyota Hiace vehicles, the distance travelled by the said vehicles and the environmental factors over the given period. The trend showed that income generated decreased with increase in the age of the vehicles under review.

**Method of Data Analysis**
The figures examination mode used include the under listed:

**Main Cause and Effect Apparatus Model**
Main cause and effect apparatus is a tool in Design Expert software. It is an experimental tool used for process or experimental design. It shows the effect of the variables in the process or system design. It is used to investigate the impact of variables in the organization. The system uses a diagram-based approach for discerning over all of the possible roots of a problem.

**Discussions and Outcomes**
The facts composed on the environmental factors, maintenance cost, replacement cost ,income generation and distance(km) moved by the said vehicles are displayed in Tables (1,2,3) and the outcomes of the exploration of the influence of environmental factors on the operational costs using the main cause and effect tool are demonstrated in Figures(1,2,3).

The result of the influence of environmental factors on the upkeep charge of Toyota Hiace Buses over the assumed period is revealed in figure 1 as presented under.

Figure 1 showed the main effect of the measurable environmental factors on the maintenance cost of Toyota Hiace Vehicles.



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**Figure 1**: illustrated the effect of environmental factors on the maintenance cost of Toyota Hiace vehicle over the given period.

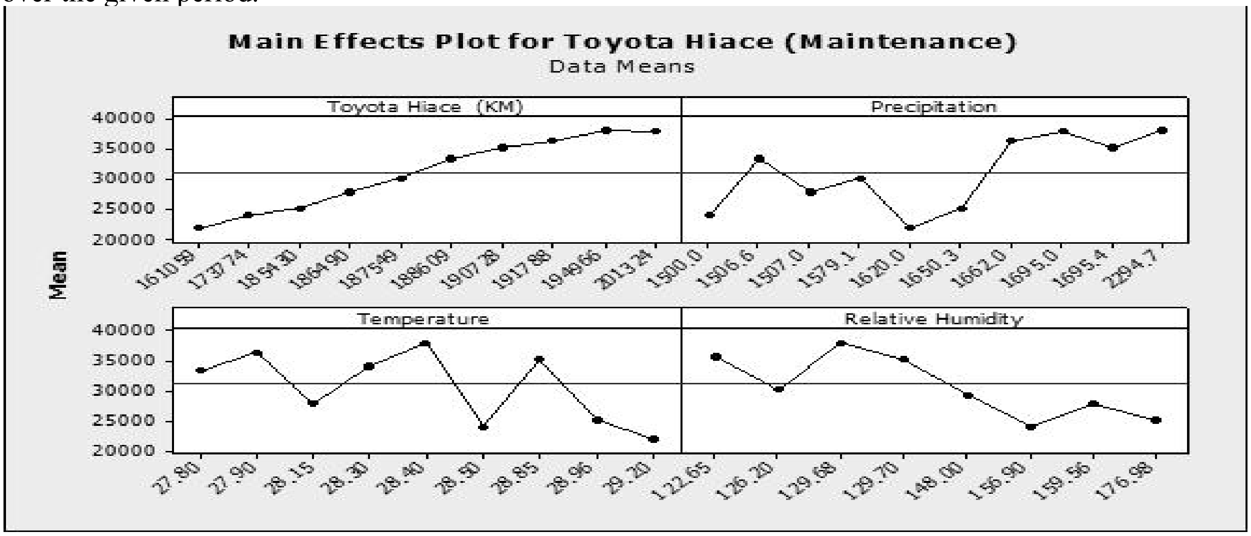


**Figure 1: Main Effects Plot for TOYOTA HIACE (Maintenance Cost) vs. environmental factors.**

Figure 1 explained the main effect of the measurable environmental factors on the maintenance cost of Toyota Hiace vehicles over the given period. From the plot, it was observed that the maintenance cost increases as the length of the road (km) increases, but at kilometers of (11852), there was a decrease in maintenance cost, a pointer to the fact that there is a possibility of having a good road. Precipitation, Temperature and Relative Humidity had the highest effect at 1696.4, 28.40 and 129.68 respectively while the lowest environmental influences were experienced at 1620.0, 29.20 and 156.90 respectively on maintenance costs of Toyota Hiace vehicle. The plots showed also that at the maximum environmental effect, the company would spend more on the maintenance of its vehicles and less income would be generated.

The results of the effect of environmental factors on the replacement cost of Toyota Hiace vehicles are presented in figure (2).

Figure 2 exemplified the effect of environmental factors on the Replacement cost of Toyota Hiace vehicle over the given period.

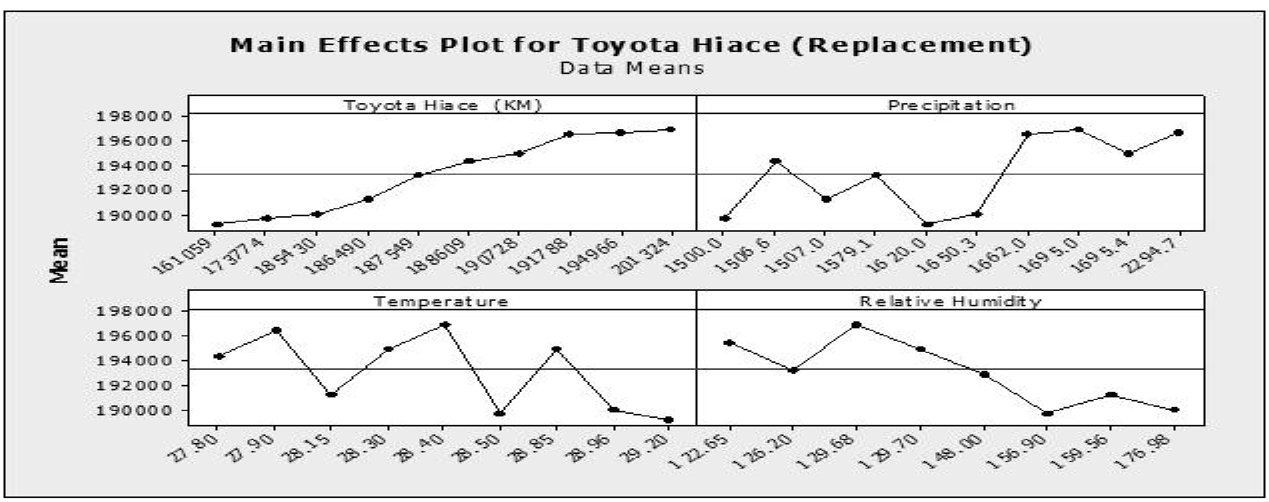


**Figure 2: Main Effects Plot for Toyota Hiace (Replacement Cost) vs. environmental factors.**



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Figure 2 demonstrated the effect of the environmental factors on the replacement cost of Toyota Hiace vehicle over the given years. The plots showed that precipitation, temperature and relative humidity had the highest environmental influence at 1695.0, 28.40 and 129.68 respectively while the lowest environmental effects of precipitation, temperature and relative humidity were at 1620.0, 29.20 and 156.90 respectively for the replacement costs of Toyota Hiace vehicles. The plots showed also that at the maximum environmental control, the company would spend more on the replacement of its vehicles and less income would be generated, on the other hand, at the minimum environmental impact, the company would spend less on the replacement of its vehicles, thereby making more profit. From the plots, it was observed that replacement costs increase as the length of the road increases. Figure 3 highlighted the effect of environmental factors on the income generation of Toyota Hiace vehicles.

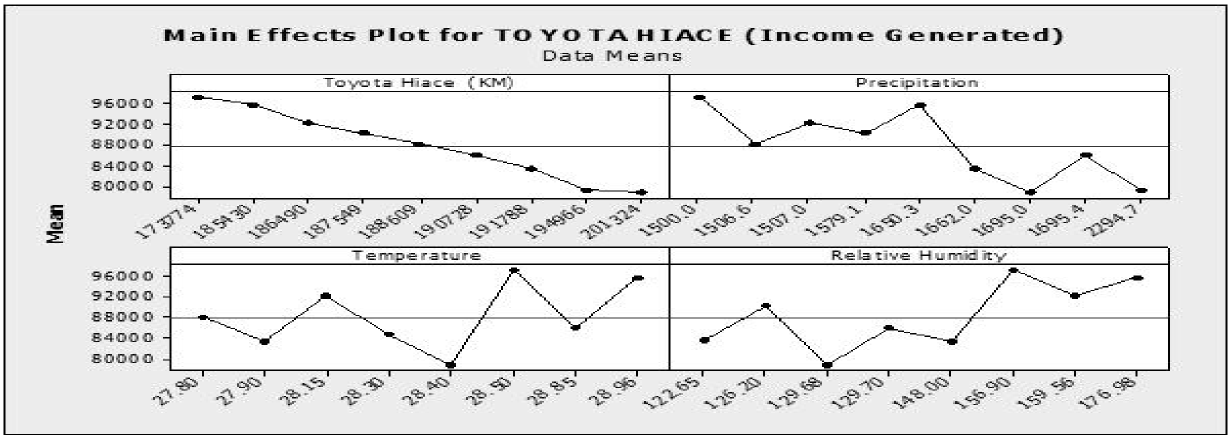

**Figure 3: Main Effects Plot for TOYOTA HIACE (Income Generated) vs. environmental factors.**

Figure 3 displayed the influence of environmental factors on the income generation of Toyota Hiace vehicles. The outcome revealed that precipitation, temperature and relative humidity had the highest environmental effect at 1620.0, 28.50 and 156.90 respectively while the lowest environmental effects of precipitation, temperature and relative humidity were at 1695.0, 28.40 and 129.68 respectively for the Income generation of Toyota Hiace vehicle. Besides, the plots showed that as the distance (km) increases, there is a corresponding decrease in income generation and vice versa.

## Discussion

The information gathered on the ecological elements (precipitation, relative humidity, temperature), distance covered and operational outlays (maintenance costs, replacement costs, revenue produced) are displayed in Tables [1, 2, 3] and the results of the examination are revealed in Figures [1, 2, 3] correspondingly. Figure 1 presented the main effect of the quantifiable environmental factors on the upkeep cost of the assumed buses. From the charts, it was witnessed that the maintenance cost rises as the distance moved (km) increases. Rainfall, Temperature and Relative humidity had the peak influence at 1697.4, 28.50 and 129.69 in turn while the lowermost environmental impacts were at 1619.0, 29.18 and 156.85 in turn on maintenance cost of Toyota Hiace buses. The graphs displayed that at the extreme ecological control, the establishment would expend more on the maintenance of its buses and fewer revenue would be produced. Figure 2 specified the control of environmental causes on the replacement prices of the said buses. The charts confirmed that, precipitation, temperature and relative humidity had the uppermost environmental consequence at 1696.0, 28.35 and 129.67 correspondingly whereas the bottommost environmental stimulus of precipitation, temperature and relative humidity were at 1620.0, 29.20 and 156.90 respectively for the replacement costs of Toyota Hiace buses. The graphs disclosed too that at the supreme environmental influence, the enterprise would expend extra on the replacement of its buses and fewer revenue would be made, on the other hand, at the minimum environmental effect, the company would spend less on the replacement of its vehicles, thereby making more profit. Additionally, the plots signposted that the replacement costs differ directly with the distance moved (km). Figure 3


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proved the consequence of the quantifiable environmental aspects to the income produced of the said buses. The charts also unveiled that precipitation, temperature and relative humidity had the peak environmental influence at 1620.0, 28.50 and 156.90 respectively while the lowest environmental effects of precipitation, temperature and relative humidity were at 1695.0, 28.40 and 129.68 respectively for the Income generation of Toyota Hiace vehicles. The plots additionally shown that as the distance toured increases, the income generated declines and vice versa.

## Conclusion

The analysis was done using the main cause and effect tool to obtain the impact of the multivariable (internal and external factors) on the operational cost of Toyota Hiace vehicles. From the results obtained, it was observed that the maintenance cost and the replacement cost increase as the distance covererd (km) increases and vice versa for the income generation of the said vehicle while Precipitation, Temperature and Relative humidity had the highest and lowest environmental effect for the maintenance cost, replacement cost and income generated at [(1696.4, 28.40, 129.68), (1695.0, 28.40, 129.68), (1620.0,28.50,156.90)] and [(1620.0, 29.20, 156.90), (1620.0, 29.20, 156.90), (1695.0, 28.40 and 129.68)] respectively. This showed that at the maximum environmental effect, the company would spend more on the maintenance and replacement of its vehicles and less income would be generated and vice versa. It is therefore recommended that the case study company should employ the main and cause effect tool for the analysis of its vehicles for efficient utilization and profitability.

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*Cite this article as*:
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*Cite this article as*:
Umeozokwere, A.O. (2025). Use Of Main Cause and Effect Apparatus in The Assessment of The Impact of Environmental Factors on The Running Costs of Toyota Hiace Buses of Fleet Operative Enterprise. *International Journal of Science and Engineering and Technology (IJSE), 1(1)* 1-9.