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Cogent Engineering (2017), 4: 1369233
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Bethrand N. Nwankwojike¹*, Oliver I. Inah¹, Onwuka S. Osinachi¹ and Fidelis I. Abam¹

Abstract: The paper presents the evaluation of cost-time performance analysis of small scale automotive maintenance firms in Calabar metropolis. The objective of the study is to ascertain the impacts of cost-time variation on the productivity performance of SMS auto maintenance firms. Primary data from seventy different auto-maintenance projects executed by Automobile, Heavy duty, Generator and Panel beater auto firms between February to October 2016 were sampled using direct observation. Analyses of data was performed using Microsoft Excel 2013 and Eviews 9.7 software. Descriptive results revealed poor cost estimation, maintenance duration, labour cost increase, maintenance type, industry size and poor scheduling which ranged between 69.31 ≥ 64.31 ≥ 63.75 ≥ 61.67 ≥ 60.97 ≥ 59.31 respectively as major factors causing cost-time overrun in SMS auto maintenance firms. Average cost and time overrun were specified at 82.8 and 62.8%, thus resulting in a cumulative

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PUBLIC INTEREST STATEMENT
The incessant arguments between customers and auto-mechanics of small scale (SMS) auto-maintenance firms in Calabar, Nigerian was revealed in this study as non-application of computer aided (CAD) fault diagnostic tools. Operators of SMS auto-maintenance workshops usually quotes prices for their customers before commencing repairs or after partial disassembly for inspection. This hasty/poor budgeting and scheduling often results to inability of the artisans to deliver quality work with the initial estimated cost and duration which sometimes lead to the use of sub-standard materials/spare parts for some replacement especially when the customer is unable to meet up with upward cost review during project execution. Also, despite ever increasing jobs opportunities in this sector and unemployment rate, youths are not attracted because many auto-mechanics lives below average, an indication of lack of productiveness, unlike their counterparts in other fields of endeavor. Thus, CAD fault diagnostic and project management models should be used in evaluating exact project worth and duration before execution.

Received: 05 June 2017
Accepted: 31 July 2017
First Published: 24 August 2017

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cost-time performance factor of 6.4, 41.3 and 93.2%, 30.5% as productivity lost rate from the four sectors. Furthermore, regression models formulated include (i) Model I and II–Cost and Time overrun with maintenance type, industry size, and estimated cost (iii) Model III–Actual performance factor with cost overrun rate, and time overrun rate. The output of the regression Models I, II and III shows a predictive efficiency of 42, 43% (i.e. a fair correlation) and 74% (high correlation) respectively as correlation coefficient ($R^2$) at $p < 0.05$. Hence, the study recommends that scheduling and proper cost estimation during negotiation stage should be considered critically, to avoid unnecessary variation in cost and time at maintenance completion.

Subjects: Industrial Engineering & Manufacturing; Mechanical Engineering; Mechanical Engineering Design; Manufacturing Engineering; Engineering Management; Production Engineering

Keywords: small scale; automotive; maintenance; corrective; preventive; cost; time; overrun productivity; estimation; performance

1. Introduction

Maintenance practice can be described as the overhaul of industrial equipment or machinery (Licker, 2003). Specifically, maintenance is undertaken to restore broken equipment’s, or restoring it to a given condition which ultimately reduces production loss and downtime as well as the environmental and the associated safety hazards. In developing nations like Nigeria, large number of automotive maintenance firms are classified as “small scale” or informal sector. This classification is due to the fact that the sector is characterized by low capital output ratio, that is the ratio of capital level relative to output is low (Ijaiya & Umar, 2004). SMS automotive maintenance firms are vital to human resources in the automobile industry in virtually every nation’s economy due to its significant contribution in terms of job creation. Kayemuddin and Kayum (2013), described the automotive maintenance workshop as a category of small scale industry that contributes about 8.8% to the GDP of a nation’s economy. According to a reports in an article entitled “Nigeria economy and the mechanic” of 12 October 2012 (Dream into reality [DIR], 2012); by the regulatory body of mechanics in Nigeria, National Automobile Technicians Association (NATA). The industry has about 4.2 million members in Nigeria with a turnover of about 3 billion annually. Similarly, its contribution to Calabar economy in the area of internally generated revenue (IGR) cannot be underestimated. However, an auto mechanics is a craft person/artisan that performs the repairs and maintenance of automotive facilities such as vehicles and generating plants to enhanced optimum performance when they breakdown (Akinola, 1995). Other tasks includes replacement of worn mechanical parts that can cease transmission or prove unsafe for effective operation, (Vyas, Das, & Mehta, 2011). SMS auto maintenance firms are characterized by preventive and corrective maintenance. Preventive maintenance is defined as a series of pre-planned tasks performed on auto facility either according to manufacturer’s schedule to counteract the known causes of potential failures of the intended functions of an asset (Ben-Daya & Duffuaa, 1995). Preventive maintenance (PM) plays a vital role to mitigate if possible avoid potential stoppages and disruptions of equipment or machinery from occurring in daily operations. While corrective or breakdown maintenance, is performed when a system or machine fails. It includes repair and replacement of failed parts to create an optimal performance again. Corrective maintenance activities are, in contrast to preventive maintenance, not schedulable (Blischke & Prabhakar Murthy, 2003). This makes them harder to plan and more costly to perform. However, hardly are these activities or maintenance by auto mechanics completed without overrun, thereby stimulates negative effects such as time delay, increased costs, productivity loss and many litigations between operators and auto mechanics, thus posing a major setback and lack of confidence to the industry at large. The imbalance of maintenance completion without variation in planned cost and time has significantly impacted the productivity performance of artisans in this vital sector of our economy, and is a major concern for both sponsors, contractors, researchers and cost engineers globally. Because each party tends to incur additional costs and lose potential revenues when there is any variation at project completion.
Overruns can be defined as the variation in cost and time at project completion (Dlakwa & Culpin, 1990). Overrun is an imperative issue in maintenance industries because of its link to productivity and business profitability (Nwanya, Achebe, Ajayi, & Mgbemene, 2016). Ifte, Mahiuddins, and Abdul (2002) observed that time estimation has continued to be a problem of great concern and remains a major concern for both researchers and cost engineers. Thus, reducing overrun both in cost and time in automotive maintenance industry, has become a necessity since it also serves the purpose of enhancing productivity in this vital sector of our economy. This is because productivity increases as overrun reduces and vice versa (Ameh & Osegbo, 2011). Traditionally, operators of small scale auto-maintenance workshops in Nigerian often quotes estimate for their customers before commencing any repairs or maintenance after partial disassembly for inspection. However, this hasty and poor budgeting method often results in the inability of auto-mechanics completing auto repairs/maintenance with the initial cost and time due to lack of precision in estimation. Which often times lead to the use of sub-standard spare parts for some required replacement especially when sponsors fail to yield to the required upward cost review. Thus, it is imperative to assess the performance of cost and time of small-scale automotive maintenance firms in Calabar, Nigeria and the impacts of factors on the productivity of this vital sector of Nigeria economy.

2. Review of relevant literatures

Cost estimation is a technical process of predicting cost, and the success depends on accurate integration of project information, resources, and control over project implementation (Baloi & Price, 2003). However, literature review shows that many approaches have been employed by different researchers in evaluating cost and time performance in projects execution, only but a few provided evidence about the achieved values of productivity indices. For instance, Nwankwojike and Okorie (2015), evaluated the predictive efficiency of profit lost to underutilization during useful life of manufacturing systems. Also, Ayman et al. (2008), developed regression models to predict project cost and duration based on historical data of similar projects that can be used by project managers in the planning phase to validate the schedule critical path time and project budget. The developed model predicted project cost and duration with a precision of ±0.035% of the mean cost and time. Also, Polat, Okay, and Eray (2014), evaluated the importance levels of factors that may triggered cost overrun in construction projects undertaken by micro-scaled construction companies. Results from their findings identified design changes, constructability problems, and delay in design approval as major factors that can bring about cost overrun. McEniry and Ibbs (2007) evaluated the cumulative impact of changes on labor productivity using meta-analysis of two studies and concluded in quantitative terms that increasing amounts of project change will have significant impact on labor productivity. Furthermore, Ameh and Osegbo (2011), investigated the relationship between time overrun and labour productivity on construction sites in Lagos, Nigeria. Using about 43 technical and management staff of some medium and large construction firms based in Lagos, Nigeria. However, the outcome of their findings revealed a significant negative relationship between time overrun and labour productivity in construction sites in Nigeria. Also, one of the gap in knowledge about currents approaches is that none of the above methods of cost and time evaluation has provided any evidence about how project cost and time varies at the long run (Nwankwojike, 2012), with respect to the industry size, and type of project executed. Similarly, the relationship between cost and time performance and workers’ productivity achieved may have been documented for other industries like the construction industry, but the same cannot be accounted for in automotive maintenance industry. It is therefore proposed in the current study to take productivity indices, e.g. cost performance and delivery efficiency into account using regression techniques. To show the relationship on how cost and time are been impacted upon by poor estimation, industry size, and maintenance type (corrective of preventive) in performance level assessments of automotive maintenance firms. This is because production productivity is one of the most important issues which govern the economics of production activities. And is often downgraded to second rank, or neglected by those who influence production processes (Singh, Motwani, & Kumar, 2000). Since maintenance activities are multidisciplinary in nature with a large number of inputs and outputs, the performance of maintenance productivity needs to be measured and considered holistically with an integrated approach. Regression technique is a statistical modeling method that is used for analysis and prediction in
different knowledge domains. Multiple regression estimation models are well established and widely used in cost estimation (Gafel, Zeyad, & Qais, 2015). The objective of this estimating approaches is the use of historical cost and duration data to determine a functional relationship between variations in cost and time, as well as the factors impacting on them. They are effective due to their well-defined mathematical procedure, as well as being able to explain the significance of each variable and the relationships between them.

3. Materials and methods

Data used in this investigation are basically primary data, obtained through direct observation of two projects each executed by thirty-five small scale auto firms, amounting to seventy observations. This comprises heavy duty, automobile, generator and panel beater auto firms caught across the seven layouts in Calabar metropolis where these firms are found in their large numbers. In each layout (Eight-Mile, Diamond Hill, Anantigha, Essien Town, Ikot Enobong, Big-Qua Town and Etta-Agbor), data from five different maintenance projects was collected for 8 working hours daily (i.e. the peak hours for industrial activity) at 6 days per week, excluding Sundays, for a period of eight months between February and October, 2016. This was because the period under study was perceived to have experienced the same economic condition in terms of price fluctuation and inflation on price commodity. Thus, the approach was chosen to increase the validity of the study by enriching the scope, depth and knowledge derived from the data.

The data collected were tabulated and classified according to project characteristic (i.e. initial and final cost-time, overrun cost and time, industry size, maintenance type) to ensure that all variables considered were clearly defined. Analyses was performed, using Microsoft Excel 2013 and Eviews 9.7 (Agung, 2011) software. Furthermore, the suggested factors are ranked by the measurement of the relative index of each factor ranging from 1 = not applicable, 2 = low, 3 = high and 4 = very high impact according to (Ibrahim, 2012), to ascertain the severity impact of each factor on overrun as presented in Equation (1).

\[
\text{Relative Index} \% = \sum_{i=1}^{N} \alpha_i \left( \frac{n_i}{N} \right) \times \frac{100}{4}
\]  

Equations (2) and (3) present magnitude of cost and time index of each project at one hundred percent completion (Ibrahim, 2012).

\[
\delta_c = \left[ \frac{(C_{ACT} - C_{EST})}{C_{ACT}} \right]
\]  

\[
\delta_t = \left[ \frac{(T_{ACT} - T_{EST})}{T_{ACT}} \right]
\]  

Equations (4)–(6) defines the cost and time performance factor as well as productivity lost rate of each project at completion (Hoehn, 2003; Leonard, 1988; Neely et al., 2000 and Rezaei, Çelik, & Baalousha, 2011).

\[
\text{CPF} = \frac{C_{EST}}{C_{ACT}} \times W_c
\]  

\[
\text{TPF} = \frac{T_{EST}}{T_{ACT}} \times W_t
\]  

\[
\text{LOP} = (1 - \delta_i) \times 100
\]  

These percentages \( W_c \) and \( W_t \) were defined for every maintenance project executed, while specifying the cost and time used. Performance factor may be equal, less or more than 100%. Performance factor less than 100%, implies that the project was completed behind schedule and cost as
expected. If it is equal to 100%, it means that it was performed as expected. If it is greater than 100%, it means that it was performed at a higher level than expected (Rezaei et al., 2011).

3.1. Model formulation and evaluation

After identifying and evaluating the performance of each maintenance project, the impacts of cost overrun, time overrun and actual performance factor of each project at completion was modeled using multiple linear regression analysis techniques (Ameh, Soyingbe, & Odusami, 2010) as expressed in Equations (7)–(9) respectively. This was performed basically, to find the linear relation and the magnitude of maintenance indices on cost-time variation as well as actual performance.

\[ CO = C + \beta_1 M_{\text{size}} + \beta_2 M_{\text{type}} + \beta_3 C_{\text{est}} + \epsilon_1 \] (7)

\[ TO = C + \beta_1 M_{\text{size}} + \beta_2 M_{\text{type}} + \beta_3 T_{\text{est}} + \epsilon_1 \] (8)

\[ APF = C + \beta_2 W_C + \beta_3 W_T + \epsilon_1 \] (9)

where;

\[ CO = C_{\text{ACT}} - C_{\text{EST}} \] (10)

\[ TO = T_{\text{ACT}} - T_{\text{EST}} \] (11)

\[ APF = \frac{C_{\text{EST}}}{C_{\text{ACT}}} \times W_C + \frac{T_{\text{EST}}}{T_{\text{ACT}}} \times W_T \] (12)

\[ W_C = \frac{\text{Overrun}}{\text{Estimated}} \times 100 \] (13)

\[ W_T = \frac{\text{Overrun}}{\text{Estimated}} \times 100 \] (14)

Thus, \( \epsilon_1 \) is a stochastic error term accounts for the variations in the response variables that couldn’t be explained by each of predicting variables and is generated independently using the following relation.

\[ \epsilon_1 = Y - \left( C + \beta_1 M_{\text{size}} + \beta_2 M_{\text{type}} + \beta_3 T_{\text{EST}} \right) \] (15)

where, \( Y \) represent the response variable \( CO, TO, \) and \( APF \) respectively. (Hever, the evaluation and validation of the formulated models was on the basis of relatively high statistical significance at a confidence level of \( p < 0.05 \) of the model taken as a whole. As well as the error rate (Memon, 2013) as depicted in Equation (16)

\[ \text{Error rate} = \frac{\text{Estimated} - \text{Observed}}{\text{Observed}} \times 100 \] (16)

Using \( F \)-statistics, \( p \)-values, coefficient, and \( R^2 \) values of the model. \( F \)-statistics is used to test the significance of the correlation between the response variable and the explanatory variables of a model taken as a whole. While the coefficient of each explanatory variables shows the severity of impacts on the response variable in a model. Additionally, the \( p \)-value indicates the level of marginal significance within a statistical test representing the probability of the occurrence a given event. \( R^2 \) measures the overall goodness of fit of the regression plane; the higher the \( R^2 \), the better the goodness of fit.

4. Result and discussion

A total of 70 completed cost and time performance data was tracked and collected with the aid of a checklist as tool. Table 1 shows the summary of data collected. Figure 1 present the results of top most influential factor causing cost and time overrun in small scale automotive maintenance firms.
based on their relative index and ranking. From Figure 1, poor cost estimation, maintenance duration, labor cost increase, maintenance type, industry size and poor scheduling which ranged between 69.31 ≥ 64.31 ≥ 63.75 ≥ 61.67 ≥ 60.97 ≥ 59.31 respectively as major factors causing cost-time overrun in automotive maintenance firms. This however implies that the hasty or poor budgeting and scheduling approach used by auto mechanics in small scale firm during estimation either before or after partial disassembly of auto facility is an attributes to most overrun associated with these firms. Similarly, it is believed that when projects takes longer to be executed, they required more time and incurred more costs at completion. As this finding also agrees with (Amandin & Kule, 2016) that as projects takes longer to be executed, they required more time and incurred more costs. Furthermore, due to the lack of 21st century diagnostic tools, the average “roadside” mechanic most time diagnoses with his collection of experience as well as customers complaints. But that can never be enough because for a single problem, there is a thousand and one possible causes. As such if eventually discovered during maintenance execution, it calls for extra charges by most auto mechanics owing to the fact that there is an increase in labour. Also, it was observed that as maintenance became complex (i.e. from preventive to corrective) overrun was prevailing as this equally confirmed by auto mechanics when interviewed that due to the complexity of corrective maintenance more cost and time is needed. However, this findings agrees with (Blischke & Prabhakar Murthy, 2003) that corrective maintenance activities are, in contrast to preventive maintenance. Thus, it is recommended that these factors should be considered by automotive maintenance firms to avoid unnecessary delay in time and cost variation. Also, statistical analysis of 70 completed

| Category                     | Classification          | No. of maintenance | %   |
|------------------------------|-------------------------|--------------------|-----|
| Industry size (small scale)  | Heavy duty              | 21                 | 30  |
|                              | Automobile              | 17                 | 24.3|
|                              | Generator               | 17                 | 24.3|
|                              | Panel beater            | 15                 | 21.4|
| Maintenance type             | Corrective              | 46                 | 66  |
|                              | Preventive              | 24                 | 34  |
| Cost overrun                 | Heavy duty              | 18                 | 31  |
|                              | Automobile              | 15                 | 25.8|
|                              | Generator               | 14                 | 24.3|
|                              | Panel beater            | 11                 | 18.9|
| Time overrun                 | Heavy duty              | 16                 | 36.4|
|                              | Automobile              | 9                  | 20.4|
|                              | Generator               | 5                  | 11.4|
|                              | Panel beater            | 14                 | 31.8|

Figure 1. Rating of cost and time overrun factors in automotive maintenance firms.
automotive maintenance projects executed reveals the following findings in studying cost and time overrun of automotive maintenance repairs, as presented in Table 2.

From Table 2, about 58 maintenance project were completed with overrun at 100% completion, from the 70 jobs evaluated. Among them, heavy duty firm recorded an average of 31% of cost overrun being the highest, while automobile, generator and panel beaters firms recorded 26, 24 and 19% respectively. In general, leading to an average cost overrun rate of 82.8% at maintenance completion. Similarly, Table 3, present the analysis of time overrun estimation in automotive maintenance projects. About 44 jobs from the 70 projects evaluated were completed behind schedule. With heavy duty recording an average of 36.4%, while, automobile and generator firms recorded 20.4, 11.4% and panel beaters with an average of 31.8% respectively. Thus, resulting to an average time overrun of 62.8%.

A possible explanation for these results is that maintenance projects became more complex as they become larger, so more overruns occurred. However, on large maintenance projects (e.g. heavy duty and panel beater), workshop managers have to make special efforts to keep cost overrun rates from becoming excessively large. Also, a descriptive analyses maintenance projects of the four sectors (heavy duty, automobile, generator, and panel beater auto firms) evaluated reveals the following findings in studying cost-time performance and productivity lost, as presented in Figures 2–9 respectively. It is clearly seen from the figures, the need to maintain close link between cost-time performance and productivity achievement. Obviously, as cost and time performance (efficiency) reduces, productivity lost increases. This implies that the relationship between cost-time performance and productivity is inversely proportional i.e. the lower the cost-time efficiency, the higher the productivity losses and equally, the higher the cost-time efficiency rates, the lower the losses in productivity. Also, Tables 4 and 5, further present the cumulative summary of comparative analyses of cost, time performance and productivity lost in each auto firms as evaluated using Equations ((4)–(6)) to determine the accuracy and level of performance of each sector.

From the result presented in Table 4, heavy duty auto firm’s recorded a cumulative cost performance factor of 5.7, while automobile, generator, and panel beaters maintenance firms recorded a cumulative cost performance value of 7.4, 7.3, and 6.8 from their respective overrun project.
Figure 2. Summary of cost performance and productivity loss by heavy duty auto firms.

![Heavy Duty Change Order Frequency](image1)

Figure 3. Summary of cost performance and productivity loss by automobile auto firms.

![Automobile Change Order Frequency](image2)

Figure 4. Summary of cost performance and productivity loss by generator auto firms.

![Generator Change Order Frequency](image3)

Table 4. Cost analysis of actual performance and productivity loss in automotive maintenance project

| Industry Name  | No. of overrun (cost) | Estimated cost (cumulative) $ | Actual cost (cumulative) $ | Cost overrun amount $ | Cost performance factor | Cost index | Productivity loss rate % |
|----------------|-----------------------|--------------------------------|-----------------------------|-----------------------|-------------------------|------------|---------------------------|
| Heavy duty     | 18                    | 2,081,500                      | 2,210,200                   | 128,700               | 5.7                     | 0.061      | 93.9                      |
| Automobile     | 15                    | 732,500                        | 791,500                     | 59,000                | 7.4                     | 0.080      | 92.0                      |
| Generator      | 14                    | 158,900                        | 173,100                     | 14,200                | 7.3                     | 0.081      | 91.1                      |
| Panel beaters  | 11                    | 566,500                        | 608,400                     | 41,900                | 6.8                     | 0.073      | 92.7                      |
| Total          | 58                    | 3,539,400                      | 3,783,200                   | 243,800               | 6.4                     | 0.068      | 93.2                      |
However, the performance of cost index ranges from 0.061, 0.080, 0.081, and 0.073 respectively, with an overall average of 0.068. Thus, increasing productivity lost rate by 93.2% on the average. Figures 6–9 further summarizes the trend of cost performance, and productivity lost rate inherent in each auto firms.

Furthermore, Table 5 depicts the comparative results relative to time performance rating and productivity lost rate associated with each automotive maintenance project.

Similarly, from the result presented in Table 5, Heavy duty automotive firms recorded a cumulative time performance factor of 47.2 and 0.897 as time index, thus increasing productivity lost rate by 10.3%. Additionally, Automobile, Generator and Panel beater auto firms' recorded time performance factor of 43.9, 52.5, and 38.6. And 0.897, 0.800, 1.25, 0.553 as time index. However, the productivity lost rates recorded by Automobile, Generator, and Panel beater was 20.0, −25.0, and 44.7%

### Table 5. Time analysis of time performance rating and productivity lost rate

| Industry Name | No. of overrun (time) | Estimated time (cumulative) (days) | Actual time (cumulative) (days) | Time overrun (days) | Time performance factor | Time index | Productivity lost rate % |
|---------------|----------------------|------------------------------------|---------------------------------|---------------------|------------------------|-----------|-------------------------|
| Heavy duty    | 16                   | 49                                 | 93                              | 44                  | 47.2                   | 0.897     | 10.3                    |
| Automobile   | 9                    | 15                                 | 27                              | 12                  | 43.9                   | 0.800     | 20.0                    |
| Generator    | 5                    | 8                                  | 18                              | 10                  | 52.5                   | 1.25      | −25.0                   |
| Panel beater | 14                   | 112                                | 172                             | 62                  | 38.6                   | 0.553     | 44.7                    |
| Total         | 44                   | 184                                | 310                             | 128                 | 41.3                   | 0.695     | 30.5                    |

Figure 6. Summary of time performance and productivity lost rate by heavy duty auto firms.
respectively. With an overall average of 30.5% from the four firms. Also Figures 2–5 further summa-
rizes the performance of each firms relative to time performance and productivity lost rate. A pos-
sible explanation to these variation is that jobs are been accumulated in this workshops without
been attended to. Secondly, it was observed that poor diagnoses (trial and error syndrome) was
common among the auto mechanics, which eventually affected their time. And time delay varied
according to industry size.

Figure 7. Summary of time
performance and productivity
loss by automobile auto firms.

Figure 8. Summary of time
performance and productivity
loss by generator auto firms.

Figure 9. Summary of time
performance and productivity
loss by panel beater auto firms.
4.1. Regression models results and validation

Multiple linear regression models that relate cost and time overrun of all projects to maintenance characteristics such as maintenance size, maintenance type and estimated maintenance cost was modelled using Equations (7) and (8), to ascertain the impact of each variable on overrun. Where, \( M_{size} \) represent the four auto firms and were coded according to the complexity of the industry; automobile (1) generator (2), heavy duty (3) and panel beater (4) for analyzing the data. Also \( M_{type} \) represent the complexity of maintenance performed in each of the firms (i.e. corrective or preventive) where corrective or breakdown was coded as (1). This is because they artisans when interviewed confirmed the complexity inherent in corrective maintenance. Similarly, preventive was coded as (0.5), APF is the actual performance factor for each project at completion. Thus, the empirical result of the ordinary least square (OLS) estimates are shown in Table 6.

The result of coefficient of determination \( R^2 \) of 0.42 units indicate a fair correlation between cost overrun and maintenance characteristics. Stated differently, about 42% variability in cost overrun is accounted for by maintenance indices. The \( F = 13.0, \, p = 0.0000 < 0.05 \) in the model, implies that it is significant to be used as a criteria to determine the level of cost overrun in automotive maintenance project. The coefficient of maintenance industry size, maintenance type, and estimated maintenance cost shows the severity of impacts on cost due to variations that occurred during projects execution which in this case is \(-27.747, \, 454.94 \) and \(0.0497\) respectively. This implies that a unit increase of \(454.94\) and \(0.0497\) triggered cost overrun by \(882.3\). While a unit increase in industry size caused a (negative) reduction in cost overrun by about \(27\) units. This simply means that about 93% loss of productivity incurred by the fifty-eight overrun project was due to an increase in the type of maintenance performed and poor estimation. Similarly, Table 7, further presents the empirical result of the ordinary least square (OLS) estimates of the 44 time overrun projects to maintenance parameters was modeled using Equation (8). The outcome of the results from Equation (8) are shown in Table 7.

| Variable                  | Coefficient | t-value | p-value |
|---------------------------|-------------|---------|---------|
| C                         | 882.3407    | 0.553817| 0.5820  |
| Maintenance Ind. Size     | -27.74783   | -0.067455| 0.9465  |
| Maintenance Type          | 454.9470    | 0.236158| 0.8142  |
| Estimated maintenance duration | 0.049777  | 5.439100| 0.0000  |

Source: See regression result (Appendix I).

| Variable                  | Coefficient | t-value | p-value |
|---------------------------|-------------|---------|---------|
| C                         | -1.020714   | -1.044601| 0.3025  |
| Maintenance Ind. size     | 1.041917    | 3.894564| 0.0004  |
| Maintenance type          | 1.426120    | 1.269302| 0.2117  |
| Estimated maintenance duration | -0.062914 | -0.711038| 0.4812  |

Source: See regression result (Appendix II).

| Variable                  | Coefficient | t-value | p-value |
|---------------------------|-------------|---------|---------|
| C                         | 14.52949    | 5.47    | 0.0000  |
| Cost overrun rate         | 0.4661326   | 2.29    | 0.025   |
| Time overrun rate         | 0.265056    | 13.80   | 0.0000  |

Source: See regression result (Appendix III).
Similarly, the result of coefficient of determination $R^2$ of 0.45 units indicate a fair correlation between time deviation and maintenance characteristics. The $F = 10.7$, $p = 0.000 < 0.5$ in the model implies that it is significant to be used as a benchmarks to ascertain the level of time variation in automotive maintenance project. The coefficient of maintenance industry size, maintenance type, and estimated duration are 1.04, 1.42 and $-0.06$ units respectively. It can be concluded that about 62.8% loss in productive time was due to a unit increase in each of the studied parameters highlighted above, while the intercept (constant) is $-1.02$ unit. However, the results for cost and time overrun obtained were compared with that found in literature (Ibrahim, 2012). The error was specified at ±0.3% for the $R^2$. On the other hand, the impact of cost-time overrun rate on actual performance was evaluated using Equation (9). Hence, the outcome of Equation (9) is depicted in Table 8.

From the result obtained after the regression analysis (as depicted in Table 7), it was observed that the regression model predicted the impact of cost-time overrun rates on auto mechanics performance well with a coefficient of determination $R^2$ of 0.74 units indicating a very significant relation between cost-time overrun and actual performance exist. Thus, $F = 95.93$, $p = 0.000 < 0.05$ significance level. The coefficient of maintenance cost and time overrun rates (0.46 and 0.26 units) shows the severity of actual performance losses resulting from overrun rates that occurred during maintenance execution which in this case is 0.46 and 0.26 units respectively. Furthermore, the results obtained were compared with that found in literature (Ameh & Osegbo, 2011). The errors were specified at ±0.05% for the $R^2$. This implies that a unit increase of 0.46 and 0.26 increased actual performance losses by 14.5. Therefore, it can be said that the relationship between cost-time overrun and productivity is inversely proportional i.e. the higher the cost-time overrun rate, the lower the productivity and equally, the lower the overrun rates, the higher productivity. On this basis, it was concluded that a significant predictive impact of cost-time overrun rate exists on productivity loss in small scale automotive maintenance firms in Calabar. Hence it is recommended that more control is required to maintain the maintenance project performance in terms of cost and time. However, a regression model has been established that will assist both auto facilities operators and artisans of SMS auto maintenance firms in predicting the impacts of cost-time variation in future maintenance projects especially when data for each maintenance variables considered are made available.

5. Conclusion

The causes and impact of cost-time overrun on the productivity of small-scale automotive maintenance firms in Calabar, Nigeria, have been evaluated using descriptive analysis and multiple linear regression models to ascertain the impact of cost-time overrun on the actual performance of automotive maintenance projects. Descriptive analysis revealed poor cost estimation, maintenance duration, labour cost increase, maintenance type, industry size and poor scheduling which ranged between 69.31 ≥ 64.31 ≥ 63.75 ≥ 61.67 ≥ 60.97 ≥ 59.31 respectively as major factors causing cost-time overrun in automotive maintenance firms. While average cost and time overrun were found to be 82.8 and 62.8% resulting in a cumulative cost-time performance value of 6.4, 41.3 and 93.2%, 30.5% as productivity loss rate of cost and time from the four sectors. Additionally, regression models formulated include (i) Model I—Cost overrun with maintenance type, industry size, and estimated cost (ii) Model II—Time overrun with maintenance type, industry size, and estimated maintenance duration (iii) Model III—Actual performance factor with cost overrun rate, and time overrun rate. The output of the regression Models I, II and III shows a predictive efficiency of 42, 43% (i.e. a fair correlation) and 74% (high correlation) respectively as correlation coefficient at $p < 0.05$. Hence, the study recommends that scheduling and proper cost estimation during negotiation stage should be considered critically, to avoid unnecessary variation in cost and time at maintenance completion. Hence, the study recommends that scheduling and proper estimation during negotiation stage should be considered critically, to avoid unnecessary variation in cost and time delay. Also, usage of 21st-century diagnostics tools, are also recommended to forester productivity improvement in SMS automotive maintenance workshop.
Nomenclature

\( C_{\text{ACT}} \) actual cost of maintenance (\$)

\( C_{\text{EST}} \) estimated cost of maintenance (\$)

\( M_{\text{size}} \) maintenance industry size (1–4)

\( M_{\text{type}} \) maintenance type (corrective and preventive)

\( T_{\text{ACT}} \) actual time of maintenance completion (days)

\( T_{\text{EST}} \) estimated time of maintenance completion (days)

\( W_C \) weighted percentage of cost or cost overrun rate (%) 

\( W_T \) weighted percentage of time or time overrun rate (%) 

\( a_i \) constant expressing weighting given to each factor, at \( i = 1 – 4 \)

\( \beta_1, \beta_2, \beta_3 \) coefficients of explanatory variable

\( \epsilon_i \) stochastic error term

\( \text{CPF} \) cost performance factor

\( \text{LOP} \) loss of productivity (%)

\( \text{TPF} \) time performance factor

\( \delta_c, \delta_t \) cost and time index

\( \text{APF} \) actual performance factor (%)

\( C \) constant estimated by regression model

\( \text{CO} \) cost overrun amount

\( N \) total number of occurrence

\( TO \) time overrun days

\( n \) frequency of the occurrence

Funding
The authors received no direct funding for this research.

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Citation information
Cite this article as: Cost performance analysis of small scale automotive maintenance firms in Calabar metropolis, Bethrand N. Nwankwojike, Oliver I. Inah, Onwuka S. Osinachi & Fidelis I. Abam,Cogent Engineering (2017), 4: 1369233.

Cover image
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Appendix I. Regression result of cost overrun

| Variable              | Coefficient | Std. error | t-Statistic | Prob.  |
|-----------------------|-------------|------------|-------------|--------|
| MTNCE_SIZE            | -27.74783   | 411.3539   | -0.067455   | 0.9465 |
| MTYPE                 | 454.9470    | 1926.449   | 0.236158    | 0.8142 |
| ESTIMATED_MAINTENANCE_CO | 0.049777   | 0.009152   | 5.439100    | 0.0000 |
| C                     | 882.3407    | 1593.200   | 0.553817    | 0.5820 |
| R²                    | 0.420146    | Mean dependent var | 4220.690   |
| Adjusted R²           | 0.387932    | S.D. dependent var | 4050.461   |
| S.E. of regression    | 3168.870    | Akoike info criterion | 19.02661   |
| Sum squared resid     | 5.42E + 08  | Schwarz criterion | 19.16871   |
| Log likelihood        | -547.7217   | Hannan-Quinn criter. | 19.08196   |
| F-statistic           | 13.04228    | Durbin-Watson stat | 2.078158   |
| Prob(F-statistic)     | 0.000002    |             |             |        |

Source: Eview 9.7.
### Appendix II. Regression result of time overrun

**Dependent variable:** TIME_OVERRUN__DAYS_

| Method: Least squares |
|-----------------------|
| Included observations: 44 |

| Variable            | Coefficient | Std. error | t-Statistic | Prob.  |
|---------------------|--------------|------------|-------------|--------|
| MTYPE               | 1.426120     | 1.123547   | 1.269302    | 0.2117 |
| MTNCE_SIZE          | 1.041917     | 0.267531   | 3.894564    | 0.0004 |
| ESTIMATED__MAINTENANCE_D | −0.062914 | 0.088482   | −0.711038   | 0.4812 |
| C                   | −1.020714    | 0.977132   | −1.044601   | 0.3025 |

**R²:** 0.445746  Mean dependent var 2.909091

**Adjusted R²:** 0.404177  S.D. dependent var 1.749660

**S.E. of regression:** 1.350555

**Sum squared resid:** 72.96000

**Log likelihood:** −73.55917

**F-statistic:** 10.72302  Durbin-Watson stat 2.573745

**Prob(F-statistic):** 0.000026

### Appendix III. Regression result of actual performance factor

**Dependent variable:** Actual performance factor

| Method: Least squares |
|-----------------------|
| Sample: 1 70 |
| Included observations: 70 |

| Variable            | Coefficient | Std. error | t-Statistic | Prob.  |
|---------------------|--------------|------------|-------------|--------|
| COST_OVERRUN_RATE   | 0.466046     | 0.203493   | 2.290233    | 0.0252 |
| TIME_OVERRUN_RATE   | 0.265048     | 0.019202   | 13.80343    | 0.0000 |
| C                   | 14.53086     | 2.657428   | 5.468016    | 0.0000 |

**R²:** 0.741174  Mean dependent var 35.10509

**Adjusted R²:** 0.733448  S.D. dependent var 24.12833

**S.E. of regression:** 12.45713

**Sum squared resid:** 10397.07

**Log likelihood:** −274.3531

**F-statistic:** 95.93076  Durbin-Watson stat 2.573745

**Prob(F-statistic):** 0.000000

Source: Eview 9.7.
