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A risk assessment of two automobile repair centres: A Nigerian case study

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Abstract

We do not understand the hazards and risks faced by auto-mechanics despite knowledge of their growing service responsibilities in recent years, coupled with the very hazardous work environment in which they operate. In this article, as a prospective antidote to this deficiency, an inventory of possible risks to which the workers of an automobile repair centre may be exposed, is created. Measures that should be taken to minimise these risks are proffered. The risks faced by automobile mechanics were investigated using two case studies of small and medium scale enterprises in a developing country. The study employed both quantitative and qualitative assessment methods. This approach used interviews and questionnaire approach for the qualitative method while a projected monetary approach was employed for the quantitative method. A major finding was that over-exertion ranked as the highest risk for all the workers combined. The result was corroborated by findings of the National Safety Council and will be of immense value to workshop managers in developing the most effective risk control practices at their centres.

Keywords: Hazards, Nigeria, Safety, Quantitative, Autocentre

1. Introduction

Transportation accounts for 3% of Nigeria's gross domestic product [1]. It is a crucial part of most economies, involving the movement of goods and people from one location to another. Of the various categories of transportation, road transportation accounts for 90%, or US$13,622,000 of the transportation sector. It is the most widely used means of transportation in Nigeria [1-2]. Vehicles are made of mechanical parts that undergo wear and tear overtime due to the frictional forces generated during their use. Automobile mechanics are largely responsible for maintenance services, engaging in diagnostic, overhauling and associated activities. Generally, in developing countries, numerous safety precautions and guidelines are not followed. This attitude towards safety is not only prevalent in the automobile repair and maintenance industry, but across the board, especially in small and medium enterprises. Automobile repair has been elevated to one of the most important technical activities, with a huge dependence on people. In developing countries, repairs usually involve some stooping, bending, standing, sitting and a combination of these while the environments to which automobile mechanics are often exposed have intense sunshine, rain and some good weather. It involves the working with uncovered hands, carrying heavy loads, using one's mouth to siphon fuel and blow air into carburetors. These conditions are hazardous and unwarranted.

In the USA, for example, automobile mechanics have a higher morbidity and mortality than other workers [3]. Between 2003 and 2005, 147 automobile mechanics lost their lives while working in the USA. The fatality rate was 5.3 out of every 10,000 employees, which was higher than that of all other occupations combined, which was only four out of every 10,000 employees [3]. The problems causing this high mortality include working conditions. It has been established that there is a high level of risk associated with the work at repair centres. Macher et al. [4] considered threat and risk evaluation approaches for automotive mechanics and proposed a method to categorise threats. López-Arquillos and Rubio-Romero [5] carried out analysis on the influence of parameters related to various kinds of injuries resulting from accidents due to occupational practices in automotive repair workshops. Chang [6] advanced the TOPSIS (technique for order preference by similarity to an ideal solution) method for risk evaluation. The continued economic prosperity of Nigeria depends on solutions to problems such as these. A huge part of the automobile mechanics workforce is employed by small-scale enterprises, which is the back bone of Nigeria's economy and industrial development. The health of these skilled individuals must be preserved. Our transportation sector relies on automobile mechanics. Their safety should be a priority from an occupational and economic standpoint. The current study focuses on safety in the automobile repair and maintenance industry using two case studies of small and

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medium scale enterprises, employing both quantitative and qualitative assessment methods.

2. Literature review

Various studies have been conducted of automobile mechanics at service repair centres. Comprehensive search conducted on automobile mechanics working at the service/repair centres returned a number of peer reviewed articles. The outcome of this search is summarized in the next sub-section.

2.1 Survey of the automobile mechanics literature

From Andresen et al.'s study, automobile mechanics exhibit a very high rate of suicide compared with other blue collar jobs [7]. Frustration from the inability to perform on the job may motivate suicide attempts. This calls for modification of training in technical schools, as advanced by Hall [8]. Meisenkothen [9] reported a situation concerning an automobile mechanic where plural mesothelioma followed by asbestos bodies was observed in the lung tissue where the only point of exposure was his workplace. Omokhodion and Osungbade [10], more than two decades ago, recognized the health challenges faced bycareer automobile mechanics in Nigeria. The authors reported a survey that revealed health issues related to their work, chronic illnesses leading to health aid requests by career automobile mechanics as a result of work-related sicknesses. Iwegbue [11] showed that the soil at sites where automobile mechanics dump their wastes contain metals such as Cd, Ni, Cr, Pb, Cu and Zn. These are harmful to human health. Okunola et al. [12] noted that industrial solid wastes have economic as well as environmental impacts by studying mutagenic substances found repair centres. It is quite well established that mutagens tend to also be carcinogens. Empirical findings connect mutagenicity and carcinogenicity as being evidently linked. An investigation revealed that roughly 90 percent of common carcinogens are as well mutagens [13]. Alabi et al. [14] examined the probable mutagenic as well as genotoxic influence of simulated leachates found in soils at automobile repair centres located in Sagamu, Nigeria. They conducted a physical chemical examination of these leachates and concluded that the auto mobile repairs centre soils had genotoxic substances posing generic risks to mechanics and their customers.

Nwachukwu et al. [15] evaluated the depth as well as dispersion distance of selected trace metals in the soil profiles of near a Nigerian village where much automobile repair was done.The trace metals found were Ni, Mn, Cd, Pb, Zn, Fe and Cu. Badjagbo et al. [16] evaluated the concentration of benzene, toluene, ethyl benzene and xylene (BTEX) in the atmosphere of automobile repair centres in Montreal, Canada. This conclusion was that the levels of BTEX present at these automobile repair centres were below the standard thresholds. However, a caveat was noted, being that exposure to benzene at the threshold level still subjects workers to the risk of cancer. Suplido and Ong [17] investigated exposure of battery repairers and automobile radiator mechanics to lead. The conclusion was that repair tasks for radiators seem to approach the maximum tolerable level of the human body and repair tasks related to batteries highly increased the levels of lead in the technicians as well as their children. Blake et al. [18] evaluated the asbestos exposure in the course of fixing and removing gaskets containing asbestos. The conclusion was that automobile repair mechanics engaged with the upkeep of gaskets were exposed to asbestos at levels below the maximum permitted by authorities. Jiang et al. [19] investigated the probable exposure of automobile mechanics to airborne asbestos fibres in the course of working with clutch parts. It was concluded that these workers were working under conditions that were below the threshold endangering their safety in terms of exposure to asbestos.

From the available literature, a key argument is that there has been very little research to understand the risk associated problems of automobile mechanics, especially in developing countries such as Nigeria. For example, Hall's call [8] more than four decades ago for curriculum reengineering to mitigate risks has not been heeded until now. In fact, there is no evidence to show its actualization in any Nigerian technical school. The elevated suicide rates and the lack of adequate enrichment of the automobile mechanics' jobs have not been addressed.

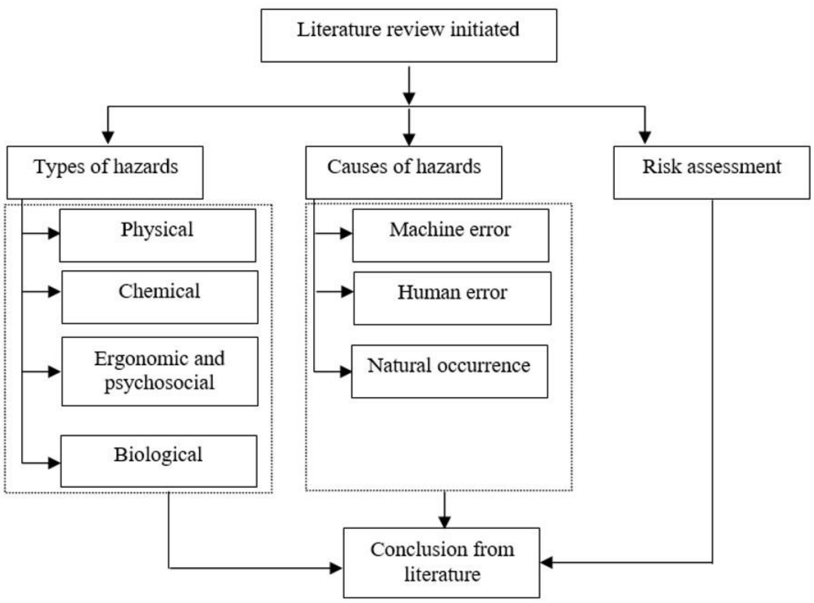

Figure 1 Literature review perspectives

More than five years has passed since Andresen's report [7] in 2010. The other call was made by Omokhodion and Osungbade [10] in 1996 and by Iwegbue [11] in 2007. The time has come to address the issue of risk quantification in the field of automobile repair in developing countries. The current study contributes to addressing this research gap. From our comprehensive literature review, it was be seen that the literature can be broadly classified based on the types of hazards that the workers of an automobile repair centres face (Figure 1). A detailed critical literature review on these aspects follows.

2.2 Types and causes of hazards and risk assessment

The types of hazards considered in the literature are discussed with respect to the way they affect automobile repair technicians and the maintenance centre. The sub-categories identified include physical, chemical, ergonomic/psychosocial and biological hazards (Table 1a).

The perspective of the causes of hazards is discussed based on the sources/causes of the hazards to which automobile repair/maintenance center employees are exposed. The causes identified include human error, machine error and natural occurrences (Table 1b).

Table 1a Categories of hazards in automobile repair and maintenance centres

Type of hazard	Author(s)	Purpose of study	Conclusion(s)
Physical hazards	Chung et al. [20]	Studied the effect of various assembly tasks such as driving screws on human physiology	Found an effect on heart rate
	Byard and Woodford [21]	Examined crush asphyxia by automobiles	Automobile related asphyxiation deaths may occur
	Hägg et al. [22]	Studied the stress inflicted on the forearm of automobile industry assembly station workers	Ulna deviation from a neutral plane was more prevalent than angular displacement in the extension/flexion plane of the forearm
Chemical hazards	Singh et al. [23]	Studied automobile shredder residue	Reported that automobile shredder residue is a hazardous substance since it contains a substantial heavy metal content
	Singh and Lee [24]	Further studies on automobile shredder residue	Water is an economic resource that is put to use in heavy metals extraction from ASR
	Umezawa and Takeda [25]	Investigated the effect of exhaust gases on the human respiratory system and organs	Maternal exposure to diesel exhaust severely affects the organs of offspring
	Rahman and Kim [26]	Experimented on the effects of back diffusion from vehicle exhaust systems on the condition of the air in the vehicle	Back diffusion poses a risk to health and one of the compounds that posed the highest threat was formaldehyde
	Wang et al. [27]	Findings address environmental pollutants, polychorinateddibenzo p-dioxins and dibenzofurans, released by automobiles	High concentrations of these substances found in workshops where melting is done can cause lung and liver cancer
	Lagalante et al. [28]	Measured the concentration of various forms of polybrominated diphenyl either (PBDE) in the dust from automobiles at dealer shops	Various levels of PBDE were found among the year/models of vehicles from several manufacturers
	Jiang et al. [19]	Determined the levels of asbestos associated with handling of boxes of automobile parts and disc brakes containing asbestos	Occupational allowable limits of exposure to asbestos were not exceeded
	Kim et al. [29]	Assessed the levels of carcinogens to which a painter at an automobile repair shop is exposed	Paint is detrimental to the health of the automobile body repair workers
Ergonomic and psychosocial hazards	De Carvalho and Callaghan [30]	Studied the effect of lumbar support on the pelvis and the spinal column of the human body	Lumbar support caused *lumber lordosis* while it does not affect pelvic posture
Biological Hazards	Schwake et al. [31]	Studied the survival of *Legionella* in windshield washer fluid	*Legionella* can be transmitted via windshield washer fluid

Table 1b Categories of hazards in automobile repair and maintenance centres

Causes of hazards	Author(s)	Purpose of study	Conclusion(s)
Human Error	Singh et al. [32]	Examined human error as well as prioritisation of risk in overhead crane operations using HTA, SHERPA as well as a fuzzy VIKOR method	Found human error a significant in hazard creation
Machine Errors	Jegadeeshwaran and Sugumaran [33]	Did brake failure error reporting implementing machine learning	Emphasised machine errors as significant in hazard creation
	Chaves [34]	Found that modern safety devices installed in automobiles will alleviate the impacts that machine/mechanical errors have in the automobile industry	Machine errors were found to be a main element in hazard creation
Natural Occurrence	Yanagawa et al. [35]	Found that automobiles are affected by electromagnetic waves generated by lightning	Advocated for the recognition of lightning as a naturally occurring hazard in the automobile industry
Risk assessment	Slovic et al. [36]	Described safety defects that prompted the call back of vehicles by automobile producers	Documented the influence of risk associated with automobiles
	López-Arquillos et al. [37]	Statistically analysed automobile maintenance procedures and the safety risks which they pose to workers	Found that the procedures which involved the highest risk levels were welding, asbestos handling and the charging and discharging of high rate capacitors

From the literature review (see also [38]), extensive research has been done on the effects of automobile emissions on life, especially human life. Also, other examination of other chemical hazards emanating from automobiles is quite common in literature. It was noted that psychosocial factors directly affect the physical state of the workers. For this reason it is advisable for employers in the automobile maintenance business to create an environmentally friendly working environment for their workers. Exposure to biological hazards in the automobile industry seems to be one of the least studied areas. More studies need to be done in this area. Qualitative and quantitative risk analyses are the most widely used methods presented in the literature for assessing risk.

2.3 Literature gaps and outlooks

The followings insights about the gaps and the outlook from the literature review undertaken in this work include:

(1) Scholars' submissions could be broadly classified according to hazard types, mainly physical, chemical, ergonomics and psychological and biological.
(2) Investigators viewed risks according to three additional perspectives, human errors, machine errors and natural occurrences.
(3) Despite the wide range of studies, no local contributions on risk analysis have been done in Nigeria. Additionally, testing such frameworks in small and medium scale garages has not been reported in literature.
(4) The financial losses or monetary gains obtainable from the employment of risk frameworks either for small scale or medium scale automobile repair centres in developing countries has not been documented.
(5) The concept of risk analysis with respect to automobile repair workshops has not been scrutinized using sensitivity analysis.
(6) The necessity of developing a framework that captures some or all the above issues was acknowledged.

Technical difficulties documented in the scientific and engineering literature motivated the investment of research resources for the present research. The current investigation directs attention at the following elements:

(1) The risk analysis results arising from model implementation in both small and medium enterprises should be comparatively analysed with a view to determining which of the two system has a better performance in terms of risk mitigation.
(2) The risk threshold may depend on the size of the floor space, provision of necessary tools, and illumination, among other factors. To develop a more general model, variation in floor size was taken into account as the only determining variable outside those earlier considered. The framework was then examined considering the problem at hand to observe possible changes, which were statistically tested.

3. Research methodology

The research scheme implemented in this study is depicted in Figure 2. Hazard identification involves assessing the tasks carried out and the working environment/ conditions at automobile repair centres. This enables identification of the various hazards to which workers are exposed. After identifying the hazards, they were classified into groups based on their nature. These included physical, chemical, biological ergonomic and psychosocial groups. The data acquisition procedure involved use of a questionnaire forgathering data from experts (the workers in the automobile repair centres) for quantitative and qualitative

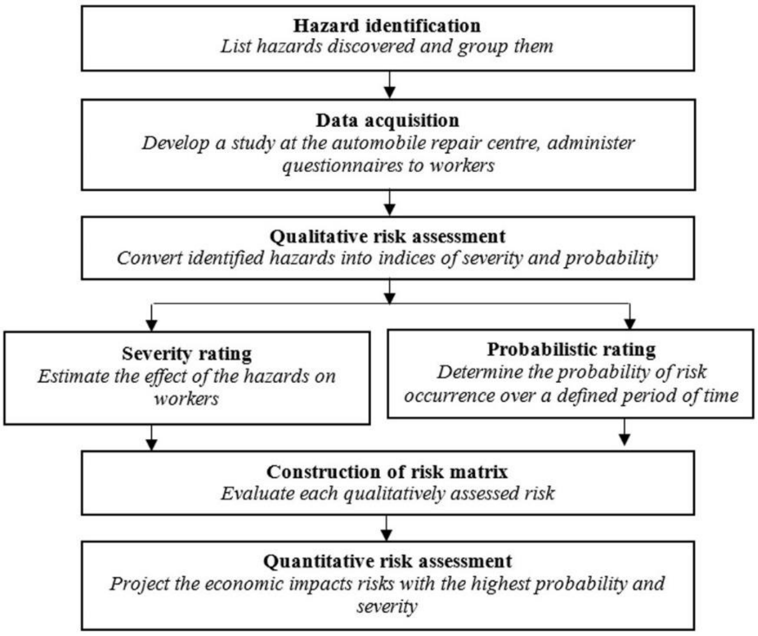

Figure 2 Research methodology

Table 2 Risk matrix

Severity / Probability	Trivial	Minimal	Mild	Substantial	Critical
Almost certain	Low	Medium	High	Very high	Very high
Highly probable	Very low	Low	Medium	High	Very high
Probable	Very low	Low	Medium	High	High
Improbable	Very low	Low	Low	Medium	High
Very improbable	Very low	Very low	Low	Medium	Medium

analyses. The questionnaire listed hazards and the workers ticked the boxes for probability and severity from their perspective.

Qualitative risk assessment was done for all of the identified hazards. It involved determining the severity of the hazards if they occur, i.e., how badly or the extent to which they affect the workers. The second aspect of the qualitative risk assessment involves determining the probability of occurrence of the identified hazard. This aspect involves defining a period over which the probability of occurrence is measured. Both of these steps require data acquisition. The severity rating is a numerical measurement (Table 2) of the magnitude of the effect of a hazard to the worker. Since it is not easy to measure how much a person is affected by an accident on a numerical scale, each number on the severity rating was defined to make the questionnaire as explicit as possible. The probabilistic rating involved determining the frequency of occurrence of a hazard over a specified time frame in the past to forecast the probability of its occurrence in the future. A risk matrix is a table (or matrix) used that clearly explains the levels of risk that are being qualitatively assessed and the associated levels of severity (en.wikipedia.org/wiki/risk_matrix/2016). The rows represent the levels of severity while the columns indicate the probability of occurrence. The levels of risk are indicated in each cell. An example of a risk matrix commonly shown in literature is depicted in Table 2.

In a case where results are discovered to be similar, recommended mitigation measures would also be similar. However, where results are statistically different, the recommended mitigation methods would be dissimilar depending on the degree of variation. This comparison is often done using the Student *t*-test, which is a significance test of the confidence of the results.

Mathematically, risk could be evaluated as:

$$Q_i = S_i p(S_i) \quad (1)$$

$$Q_{total} = \sum_i S_i p(S_i) \quad (2)$$

where i represents the serial number a particular hazard,
Q_i = risk value of the i^{th} hazard,
Q_{total} = total risk,
S_i = severity value of the i^{th} hazard,
$p(S_i)$ = probability of occurrence considering the i^{th} hazard

Quantitative risk assessment involves determining the financial/economic impact of the risks with the highest risk factors. This includes generating an estimate to cost of life and equipment if a hazard should occur. The final step to be taken is the development of methods by which the risks can be mitigated. The aim of this is to create a working environment with the lowest possible risk to workers since it is impossible to eliminate hazards completely. This step is one of the most important since it will directly impact the automobile repair centre and its workers. The methods selected to do this research (qualitative and quantitative risk analysis) were chosen because they analyse the hazards identified and make it easier for decision makers to understand the impacts of the hazards by assigning numerical magnitudes to each hazard. Quantitative and qualitative risk analysis is utilised in other industries such as the oil and gas sector, and has been proven to be very useful. An interview method was utilized in qualitative analysis and it is a commonly employed method in the process and chemical sectors when analysing the risk to a locality or individuals involved in certain activities [39]. It is the most arduous technique for analysing risks in the aforementioned sectors [38]. The techniques utilised under quantitative risk analysis include decision tree analysis, fault mode evaluation, and expected monetary value analysis, among others. The technique utilised in this research is the expected monetary value analysis, which calculates the economic/financial impact of the occurrence of a hazard.

4. Results and discussion

Data was gathered for this research so that the results provided can be applied to other automobile repair facilities in developing countries with little or no adjustments in the methodological framework. The major types of automobile repair facilities in developing countries, such as Nigeria, are small scale facilities (with less than 50 workers), and medium scale enterprises (50 to 250 workers) UNESCO-TVE [40].

Case study 1 is a university branch of a well-established automobile repair centre. It is a small scale establishment that was selected because of the size of its workforce. The establishment was setup to serve the needs of the entire university with respect to aftersales repair and maintenance of automobiles. There are four technical staff employed at the facility, who carry out the maintenance procedures. Other staff include a receptionist and a manager of the facility. Case study 1 was also selected to compare the risk values obtained from the small scale facility to those of a medium scale facility to determine of the degree of variation between these types of facilities. The shop has three automobile lifts, a service pit and diagnostic tools. Three questionnaires were administered to the staff at the facility of case study 1 and the results were entered into the spreadsheet. However, Table 12b in the appendix shows the template used. The columns represent numerical values of probability, severity and risk respectively. The risk calculation was based on the formulae presented in the methodology section.

The second case study examined a medium scale repair centre in Lagos, Nigeria. This repair centre has over 60 technical staff as well as more than 15 administrative and support staff. Questionnaires were administered to the 60 staff of the facility, however nine of the questionnaires were not completed and could not be utilised in this study, hereby leaving us with data from 51 questionnaires. Data from the questionnaires was analysed by first computing the numerical values for probability and severity obtained for each hazard. From this data we were able to deduce the risk associated with each of the hazards for each person who filled the questionnaire. A measure of central tendency, the mean, was applied to the probability, severity and the risk to obtain general values for risk associated with each hazard. Each column had 24 rows with each row representing a hazard. The values inputted for probability were 0.02, 0.1, 0.2, 0.5 and 1, which represent occurrences of the hazards once or twice, twice to ten times, ten times to twenty times, twenty to fifty times and fifty to hundred times per year, respectively. It was assumed that these values corresponded to various frequencies of occurrence per year. If a hazard occurs a hundred times or more in each of the past years, it is certain that workers will be exposed to such hazards over the coming years. This method was applied to creating a probability scale to give us a more accurate representation of the likelihood of occurrence of a hazard as opposed to a scale where the numerical values assigned are given in equal step sizes, as is common in questionnaires used for this type of data collection.

For the severity rating, we utilised a scale of 1,2,3,4 and 5 to represent trivial (minor wound), minimal (wound requiring treatment by therapeutic specialist), mild (treatment requiring hospitalization), substantial (temporary disability) and critical (permanent disability). This concurs with the ideas in López-Arquillos and Rubio-Romero [5] in which a trivial injury is superficial, minimal being equivalent to dislocations and sprains, mild being the same as bone fractures, while substantive is equivalent to concussion and internal injuries, and critical being of the nature of burns, scalding and freezing.

The model that we employed used an interview method of qualitative risk analysis. It gathered data from experienced personnel and utilised a feedback mechanism, which in this case was the questionnaire to record such data.This was done to predict the future occurrence of hazards and to curb their likelihood. Distinct risks were identified and classified as very low, low, medium, high and very high, as was done by Chang [6]. This method determined objective probability. Objective probability takes into consideration a number of people's opinions while subjective probability is based on an individual's assumptions. The concept of objective and subjective probability is widely used in the finance sector to predict market trends.

Risk score values (Table 3) calculated for each hazard were obtained by finding the arithmetic mean of the individual risk score from each questionnaire. The arithmetic mean is a measure of central tendency. Alternatively, categorical data could have been analysed utilising either the mode or median. The numbers written in parenthesis in the risk matrices below represent hazards listed in the appendix. Each hazard has an identifying number (1-24). Each of these hazards was subsequently grouped depending on their probability and severity obtained from analysis of questionnaire data. The arithmetic mean was computed for the probability and severity figures for the small scale facility, the medium scale facility and for a combination of both. This data is to assist upper management in these facilities make informed decision pertaining to the safety of their workers. The risk levels calculated from the data obtained from the small scale facility were low. One reason for this is that the small scale facility does not have the capacity to handle as many tasks as medium or large scale facilities (Table 4). Thus, workers of the small scale facility are exposed to less risk than those of larger facilities since they are also involved in fewer activities/maintenance procedures.

The risk matrix for the medium scale facilities shows higher risk levels than the small scale facility (Table 5) since it has a greater number of tasks done by the workers. These included hazardous tasks such as resurfacing brake discs, welding components, and grinding valves, among others.

A summary of the probability and severity values obtained was computed in an excel spreadsheet to obtain a general risk rating matrix table depicting all the risk values. The arithmetic means of these values were used in the construction of the risk matrix (Table 6). This approach considered the result of each interview/questionnaire of equal importance in the final outcome. Furthermore, the worker-based arithmetic mean considered each of the workers in the survey with equal weight. Basically, it considers the risk results obtained from each worker before carrying out the arithmetic mean of all the results, regardless of the facility in which they were obtained. The risk matrix obtained by utilising a facility based arithmetic mean can be applied to facilities with a workforce value intermediate between small and medium scale establishments (Table 7). The effect of the low risk ratings obtained for the small scale establishment is more pronounced since we considered the risk ratings from both facilities to be of equal importance in the final results. Additionally, for the facility-based arithmetic mean (Table 7), a risk value (score) was obtained for each facility and then an arithmetic mean of both values was calculated (for small and medium-sized facilities). It can be seen from Tables 6 and 7 that overexertion hazard 12 increases to a 'high' level because we are considering more variables than just small or the medium facilities. We are examining a combination of results gathered from both facilities. Thus, we obtained higher values for severity and probability than in Tables 4 and 5. The outcome of the data pool is interesting. There is need to gain more insight into the situation. For instance, as opposed to the expectation, the values are meant to be intermediate between the small and medium scale when the data set are combined. Future research could find out why the values increase when these data sets are combined.

The Student *t*-test was done on the risk values for each hazard in the small and medium scale repair facilities (Table 8). This was done to determine whether the values obtained for the risk ratings were significantly different. It was assumed that the variances of the two samples are not equal as a research strategy towards the statistical analysis. The result of this test is what determines if it would be advisable to carry out similar mitigation procedures for both the small scale and medium scale facilities, and also if the risk can be ranked given similar priorities.

Table 3 Risk score ratings

Risk	Small Scale Rating	Medium Scale Rating
1	0.03	0.25
2	0.05	0.31
3	0.04	0.48
4	0.14	1.53
5	0.05	0.79
6	0.04	0.44
7	0.08	0.81
8	0.05	0.47
9	0.03	0.59
10	0.14	0.78
11	0.14	2.42
12	0.35	1.27
13	0.02	0.47
14	0.15	2.15
15	0.02	1.87
16	0.03	1.70
17	0.02	1.72
18	0.21	1.88
19	0.02	1.77
20	0.19	2.32
21	0.02	0.71
22	0.03	0.36
23	0.03	0.29
24	0.02	1.59

Table 4 Risk matrix for the small scale establishment

Severity / Probability	Trivial {1}	Minimal {2}	Mild {3}	Substantial {4}	Critical {5}
Almost certain{1}	Low	Medium	High	Very high	Very high
Highly probable {0.50}	Very low (12)	Low	Medium	High	Very high
Probable {0.20}	Very low (18, 20)	Low	Medium	High	High
Improbable {0.10}	Very low (4,11, 14)	Low	Low	Medium	High
Very improbable {0.02}	Very low (1, 2, 5, 7, 8, 13, 15, 16, 17, 19, 21, 24)	Very low (3, 6, 9, 22, 23)	Low	Medium	Medium

Table 5 Risk matrix for the medium scale establishment

Severity / Probability	Trivial {1}	Minimal {2}	Mild {3}	Substantial {4}	Critical {5}
Almost certain{1}	Low	Medium	High	Very high	Very high
Highly probable {0.50}	Very low	Low (12)	Medium (4, 11,14, 15, 16, 17, 18, 19, 20, 24)	High	Very high
Probable {0.20}	Very low	Low (3, 5, 9, 10, 13, 21, 22, 23)	Medium (7, 1)	High	High
Improbable {0.10}	Very low	Low (1, 2, 8)	Low (6)	Medium	High
Very improbable {0.02}	Very low	Very low	Low	Medium	Medium

Table 6 Risk matrix for the two facilities (Worker-based arithmetic mean)

Severity / Probability	Trivial {1}	Minimal {2}	Mild {3}	Substantial {4}	Critical {5}
Almost certain{1}	Low	Medium	High (12)	Very high	Very high
Highly probable {0.50]	Very low	Low	Medium (4, 11, 14, 15, 16, 17, 18, 19, 20, 24)	High	Very high
Probable {0.20}	Very low	Low (3, 5, 7, 9, 10, 13, 21)	Medium	High	High
Improbable {0.10}	Very low	Low (1, 2, 8, 22, 23)	Low (6)	Medium	High
Very improbable {0.02}	Very low	Very low	Low	Medium	Medium

Table 7 Risk matrix for the two facilities (Facility-based arithmetic mean)

Severity / Probability	Trivial {1}	Minimal {2}	Mild {3}	Substantial {4}	Critical {5}
Almost certain{1}	Low	Medium	High (12)	Very high	Very high
Highly probable {0.50}	Very low	Low (12, 20)	Medium	High	Very high
Probable {0.20}	Very low	Low (2, 4, 5, 10, 11, 15, 16, 17, 18, 19)	Medium	High	High
Improbable {0.10}	Very low (1, 13)	Low (3, 6, 7, 8, 9, 21, 22, 23, 24)	Low	Medium	High
Very improbable {0.02}	Very low	Very low	Low	Medium	Medium

Table 8 Student *t*-test results

t-test: Two-sample assuming unequal variances		
	Small scale rating	***Medium scale rating***
Mean	0.07861111	1.123578
Variance	0.00668205	0.522647
Observations	24	24
Hypothesized Mean Difference	0	
P(T<=t) two-tail	2.83E-07	
Critical t-value, two-tail	2.06389856	

From the above result we can see that the *p*-value obtained from the t-test is 0.000000283. Hence, the risks ratings were significantly different and different levels of risk mitigation would be required for small and medium scale establishments. The level of urgency of mitigation is presented subsequently from three perspectives, the standard, that for the small scale establishment and that for the medium scale establishment.

The current study utilised quantitative risk analysis and expected monetary value of the various hazards to calculate the economic/financial impact associated with the highest priority risks. From the risk matrices in the above sections, it is clear that the highest priority risk is overexertion. This is the most common factor attributed to non-fatal disabling work injuries [41]. It is also the most prevalent cause of days away from work (DAFW). It is the second most common nonfatal injury, after falls, in the general populace, with 4.6 million reported cases in 2006. So, our study is in agreement with the National Safety Council [41]. Their findings reported that overexertion most commonly affects the back (52%), while the lower extremities are the least affected (5%).

The calculations were done as follows. It was assumed that a working week consists of five days. The average salary of a worker at the small scale establishment is ₦40,000 per month, while that in a medium scale establishment, it is ₦60,000 per month. According to National Bureau of Labour Statistics, the average number of days away from work due to overexertion is 15 in the time frame of one year. The estimated profit made by a company per worker per day for a small scale facility, assuming employee salary is 50% of company revenue is ₦40,000/(20x0.5), which is ₦4,000. In a medium scale facility, this would be₦60,000/(20x0.5), which is ₦6,000. Ideally, workers are entitled a health care package, i.e., the company is responsible for hospital bills. The average cost of treating overexertion cases per day is ₦1,000. The probability of occurrence of overexertion for the small scale facility obtained from spreadsheet was 0.35 over a month. Then, the probability of occurrence of overexertion for the medium scale facility obtained from spreadsheet was 0.41 over a month. To calculate the expected monetary value per year, we express it as:

Expected Monetary Value Per Year
= Total Cost x Probability of Occurrence x Population
Thus, for the small scale facility, total value lost
= No. of days away x Cost per day = 15 x (1,000 + 4,000) = ₦75,000
For the medium scale facility, total value lost
= No. of days x Cost per day = 15 x (1,000 + 6,000) = ₦ 105,000
Then, the expected monetary value for the small scale facility per year
= 75,000 x 0.35 x 4 = ₦ 105,000
The expected monetary value for the small scale facility per year
= 105,000 x 0.41 x 60 = ₦ 2,583,000
Note: $1 = ₦ 350

A risk mitigation table similar to that in Table 9 was presented by Popov et al. [42]. Specific tables similar to this have been developed to suit both case studies considered in this work and useful information can also be obtained from the literature [43-44]. These tables indicate the level of importance associated with each risk level.

The risk mitigation in Table 10 considers a low risk level as a high priority because of the relatively general low values of risk rating in the facility. Since the results of prioritizing the risks give us a metric for arranging the hazards relative to each other, hazards that rank the Highest should be given utmost attention, as they will ultimately be more costly if they do occur. See Table 11 for additional information. Tables 10 and 11 present solutions appropriate for each level of risk in the previous tables (Tables 4 and 5). These tables are meant to assist decision makers in taking the most effective steps to reduce the risk present at their facilities.

Table 9 Risk mitigation

Risk Level	Required Level of Mitigation
Very high	No task should be done without risk mitigation.
High	Mitigation should be given high priority.
Medium	Should be attended to at an appropriate time, i.e., when tasks which expose workers to such hazards are done.
Low	As deemed fit by the decision maker

Table 10 Risk mitigation for the small scale facility

Risk Level	Required Level of Mitigation
Low	Mitigation should be given high priority.
Very low	Should be attended to at an appropriate time, i.e., when tasks which expose workers to such hazards are done.

Table 11 Risk mitigation for the medium scale facility

Risk Level	Required Level of Mitigation
Medium	No task should be carried out without risk mitigation
Low	Mitigation should be given high priority.

5. Conclusion

We outlined an approach to study both the quantitative and qualitative dimensions of the risk concept in terms of exposures of automobile mechanics to hazards in their workplaces. The following are the conclusions made from this investigation:

1. Over-exertion was found as the most prevalent risk in small and medium scale facilities in the Nigerian case studies.

2. The risk rating scores were much lower for small scale facilities than for medium scale establishments because fewer tasks which were done in small scale facilities.

3. The associated economic/financial impact of risks faced by small scale facilities was lower than for medium scale facilities.

The results of this risk assessment are relevant in assisting decision makers in automobile repair centres in developing countries to make informed decisions pertaining to the impact of hazards and mitigating these undesirable events in their establishments. This study ascertained that these procedures can be applied to fields in which workers are exposed to risks on the job. It is important to thoroughly review the hazards that such workers are exposed to obtain accurate results. Hazards that have not been identified cannot be mitigated. The higher risk rating scores for medium scale facilities are because they handle a wider range of operations. The data presented in the risk matrices has been simplified to make it very easy for to decision makers which risks are of high importance, i.e., those which need to be mitigated. In further studies, it is recommended that data collection be done from an even larger subset of the population and more comparisons should be made.

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Appendix 1

Questionnaire for data acquisition in a risk assessment of two automobile repair centres

Generalinformation

1. Name of the company :
2. Address :
3. Telephone :
4. Size of company :

Table 12a Research Questionnaire

Part – 1: Probability of hazard occurrence						
S/N	**Physical hazards**	**Extremely Low (1-2 year)**	**Low (2-10 per year)**	**Medium (10-20 per year)**	**High (20-50 per year)**	**Extremely high (50-100 per year)**
1	Falls into inspection pit and from height					
2	Falls on ground					
3	Injuries from failure of jacking equipment					
4	Cuts and bruises from working on sharp engine parts					
5	Burns from coming in contact with objects at high temperatures, e.g., exhaust pipes					
6	Electrical shock due to coming in contact with exposed wires					
7	Muscle strain from working in uncomfortable positions					
8	Injury to the eye from splinters and chips when resurfacing brake discs					
9	Hit by a vehicle in motion					
10	Hit by tools accidentally					
11	Exposure to loud noises					
12	Over-exertion					
	Chemical Hazards					
13	Exposure to asbestos					
14	Exposure to DOT3 and DOT4 brake fluid					
15	Exposure to paint and solvent (isocyanates)					
16	Exposure to glycol and methanol in coolant					
17	Exposure to silica dust during sanding					
18	Exposure to exhaust gases					
19	Exposure to refrigerants					
20	Exposure to lubricating oil and grease					
21	Exposure to sulfuric acid and lead from batteries					
	Ergonomic and Psychosocial hazards					
22	Trapped in equipment					
23	Injured by powertools					
	Biological Hazard					
24	Exposure to *Legionella* via windscreen washer fluid					

Table 12b Research Questionnaire

Part – 2: Severity of risk						
S/N	**Physical hazards**	**Trivial (minor wound)**	**Minimal (wound requiring treatment by therapeutic specialist)**	**Mild (treatment requiring hospitalization)**	**Substantial (temporary disability)**	**Critical (permanent disability)**
		1	**2**	**3**	**4**	**5**
1	Falls into inspection pit and from height					
2	Falls on ground					
3	Injuries from failure of jacking equipment					
4	Cuts and bruises from working on sharp engine parts					
5	Burns from coming in contact with objects at high temperatures, e.g., exhaust pipes					
6	Electrical shock due to coming in contact with exposed wires					
7	Muscle strain from working in uncomfortable positions					
8	Injury to the eye from splinters and chips when resurfacing brake discs					

Table 12b Research Questionnaire (Cont.)

S/N	Physical hazards	Trivial (minor wound) 1	Minimal (wound requiring treatment by therapeutic specialist) 2	Mild (treatment requiring hospitalization) 3	Substantial (temporary disability) 4	Critical (permanent disability) 5
9	Hit by a vehicle in motion					
10	Hit by tools accidentally					
11	Exposure to loud noises					
12	Over-exertion					
	Chemical hazards					
13	Exposure to asbestos					
14	Exposure to DOT3 and DOT4 brake fluid					
15	Exposure to paint and solvent (isocyanates)					
16	Exposure to glycol and methanol in coolant					
17	Exposure to silica dust during sanding					
18	Exposure to exhaust gases					
19	Exposure to refrigerants					
20	Exposure to lubricating oil and grease					
21	Exposure to sulfuric acid and lead from batteries					
	Ergonomic and Psychosocial hazards					
22	Trapped in equipment					
23	Injured by powertools					
	Biological Hazard					
24	Exposure to *Legionella* via windscreen washer fluid					