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SAFETY CONFORMITY PREDICTION FOR A BOTTLING PROCESS PLANT: A MULTIPLE REGRESSION APPROACH

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ABSTRACT

Safety conformity is an industrial practice to obtain enhanced safety performance and improved worker-management-government relationships. In this paper, a novel method to model and predict the conformity of bottling process operations and activities to safety rules and accident prevention is presented. Inspired by the machine guarding literature in safety compliance, this research extends the regression model beyond the machine operations domain, to cover activities in beverage testing unit (BTU), shuttle vehicle flotilla (SVF), stockroom, and suppliers. Data from practice in a bottling plant in Nigeria demonstrates the model's effectiveness. The coefficients of determination (R2 = 0.8454, 0.3891, 0.8156, 1 and 0.8156), showed the predictive competence of the warehousing, manufacturing hallway (MH), BTU, SVF, and suppliers' variables, respectively. These R2 values were derived from computations and tabulated by the software program used, and BTU and suppliers' values for R2 were obtained as the same from the program software. The relative importance of the bottling segmental factors was evaluated through ANOVA. The bottling process data results revealed the most significant variables at (p<0.05; calculated probability). This insight offers safety managers with useful practice information to plan and control.

KEYWORDS: Performance, appraisal, control, ANOVA, model analysis

1. INTRODUCTION

Scholars in recent times have paid growing attention to the analysis of accidents and their prevention (Luken et al., 2006; Kletz, 2009; Prem et al., 2010; Kidain et al., 2014). Their findings have revealed that workers in general exhibit many manipulative attempts to dislocate devices for protecting machines (for instance, effort to disable or by-pass adequate machine guards or even dismantle them (Anderson et al., 2010; Maghsoudipourand Sarfaraz, 2011; Samant et al., 2012a,b; Kica and Rosenman, 2017; Jeon et al., 2019). From the preliminary literature survey, it became evident that the literature concerning manipulative attempts by workers to displace or dismantle equipment protective devices has suffered substantial setbacks. There appears to be no useful and dependable statistics relating to the magnitude of the challenge of equipment, device or guard manipulations in organisations. However, guesses are not reliable but scientifically valid statistics promise some values for decision making and must be pursued with rigour. The restricted view of the literature limiting safety conformity to the evaluation machine guard usage should be broadened.

Few literature reports follow. Burstyn et al. (2000) employed manifold-phase Poisson and pessimistic binomial regression models to analyse the conformity results of over 29,000 administrative activities in Canada. Ortiz et al. (2000) studied warning action compliance through an appraisal of the impacts of a user's viewpoint concerning the product risk. Diaz and Resnick (2000) built up observations and rationale of a representation to envisage safety compliance for a manufacturing resource. Luken et al. (2006) reported on the motivations for removing safety devices for machinery moving parts protection and that it is poorly studied in safety research. Zin and Ismail (2011) established the compliance factors of safety from the viewpoint of employers' behaviour as employees in Malaysia. The JCGM 106 document (JCGM106:2012) established a connection between the conformity guidelines and how prediction may be attained in the context of machine guarding compliance. Griffin and Hu (2013) analysed the impacts of particular leadership behaviours on the worker's safety accomplishment. Li et al. (2013) appraised over 600 workers in crude oil production in China on safety compliance. Gressgard (2014) studied the association between information swapping scheme practice, information swapping in an establishment scheme, and compliance in safety. Ansary and Burna (2015) appraised the safety conformity for the ready-made garment industry in Bangladesh. Hu et al. (2016) adopted the technology acceptance model to build up representations for the safety conformity of workers. de la Vara et al. (2016) offered a metamodel to intervene in the safety assurance challenge in critical systems. Atamagwa (2016) exploited how environmental conformity could negatively interfere with health and safety issues at work. Washington et al. (2017) offered a Bayesian method that captures uncertainty in aviation systems conformity as a decision making scheme. Uzor and Oke (2018) studied the use of machine guards in company employees. Contract workers (external) were completely omitted from the research. Globally, the conformity literature has covered several contexts such as social psychology (Crawford et al., 2002), social influence (Cialdini and Goldstein, 2004), theoretical development (Forbes, 2006; Pendrill, 2014; Carobbi and Pennecchi, 2016), satellite remote sensing (Wildlowski, 2015), food safety (Pierna et al., 2015), product consumers (Chatterjee et al., 2017), and multi-component material (Kuselmanet al., 2017).

Despite the extensive work on conformity, the literature failed to consider the whole plant in safety conformity studies. In this paper, a multiple regression model was used to model the safety conformity of a bottling plant in terms of the five segments of SVF, BTU, suppliers, MH and stockroom. The highlights from the literature are as follows:

- There is a relationship between conformity, risk, cognition, and motivation.
- The technological acceptance model has been used to formulate the conformity of workers and critical systems have been studied.
- Conceptual models of technology acceptance and metal model assure safety.
- Application areas include board ships, environmental protection
- Investigations related to bottling plants are sparse and none has been done considering the company-wide parameters in major divisions of SVF, BTU, suppliers, MH and stockroom.

The principal contributions of this paper are subsequently summarized:

- Formulating the conformity problem as a multiple regression model
- Elaborating and developing solution steps for the contemplated problem
- Implementing the described solution using practical field data.

2. RESEARCH METHODOLOGY

2.1 Safety compliance process parameters and definitions

Safety conformity is measured and predicted by a number of parameters, including:

- Conformity – relates to specific safety standards or behaviours laid down for workers and suppliers to a bottling plant, which directs their modes of interaction in their daily dealings

- Index, the level in which safety standard is related to the current attained value, indicated as a quotient, which can be weighed or measured.
- Conformity index is the appraisal of the level in which the standard of human behaviour set is strictly adhered to in order to obtain maximum efficiency and productivity.
- Stockroom is a massive storehouse where raw materials for the manufacturing process, parts of equipment and finished products are kept, pending distribution.
- MH is a large building for producing beverages in a bottling company
- BTU offers a technique used to ascertain if the product of a particular batch is up to standard.
- Shuttle vehicle flotilla (SVF) represents a large hall in which vehicles used for logistics purposes in the manufacturing plant are being serviced.
- Suppliers refer to individuals or organizations that are hired to provide goods or services for the bottling company.

In the bottling process plant, conformity is influenced by a myriad of factors that may be described as major while others are considered to be minor (Uzor and Oke, 2018). The size and activity levels of the stockroom, MH, the BTU procedure, the SVF, and suppliers' activities may be regarded as major influencing factors with a direct impact on conformance performance. On the other side, issues such as the psychological preparedness of the workers and their motivations for the day's work, the amount of budgeted expenditure and approvals for the various sections, the weather conditions in the environment of the plant such as the temperature (heat), humidity and pressure may be considered minor and indirectly impacting on the performance of the systems. However, whether considered major and directly influential or minor and indirectly impacting factors, they change in an inexplicable manner, and consequently, it is difficult to predict conformance in bottling plants with personal understanding. For this complicated prediction assignment, the multiple linear regression model is a superior alternative. With its principal advantage of authorizing numerous autonomous variables to partake in the regression modeling procedure, the multiple regression model permits us to develop a prediction representation, approximating future conformity indices by relying on the preceding ones.

Fig. 1 reveals the research scheme that explains the standard steps to take in order to accomplish the predictive goal of the bottling process plant safety conformity data evaluation process. The following is a brief mention of their meanings: FD –number of forklift drivers in the stockroom, S –number of sorters in the stockroom, R –number of rescuers in the stockroom, SH – number of sugar handlers in the stockroom, HD –number of haulage drivers in the stockroom, HT –number of haulage truck mates in the stockroom, CN –number of chip neck removers in the stockroom, SB – number of spare bottle eliminators in the stockroom, Si – number of sighters in the manufacturing hallway (MH), FO – number of filler operators in the MH, PD – number of palletizers/de-palletizers in the MH, WO – number of washer operators in the MH, CNMH –number of chip neck removers in the MH, TO – number of technical operators/utilities in the MH, PO – number of packer/unpacker operators in the MH, SL – number of sugar lifters in the beverage testing unit (BTU), SM –number of syrup mixers in the BTU, LT – number of lab technicians in the BTU, WT –number of water technicians in the BTU, ST –number of sewage treatment plant technicians in the BTU, O –number of other departments in the BTU, FT –number of forklift technicians in the SVF, W– number of welders in the SVF, BC –number of battery chargers/technicians in the SVF, SS –number of security personnel in the bottling plant, K – number of kitchen personnel in the bottling plant, C1 – number of personnel performing a particular task 1 in the bottling plant, C2 – number of personnel performing a particular task 2 in the bottling plant, and C3 – number of personnel performing a particular task 3 in the bottling plant

In short, the following steps dominate the path to attaining the plant’s safety conformity goal:

1. Establish the bottling process plant to be examined. Sectionalize the whole bottling plant to localize the computations of the safety conformity indices for the plant and build up a list of elements for each module. The distinct modules stockroom, MH, BTU, SVF, and suppliers.
2. Build up the compliance factor analysis to identify the dependent variables and the independent variables.
3. Compute the compliance indices.
4. Construct the multiple regression model and test using ANOVA (analysis of variance) to determine what factors contribute significantly to the model’s sensitivity and what factors are not.
5. Eliminate the non-contributing factors and recompute the multiple regression model
6. Prepare your report by analyzing and discussing the outcome.

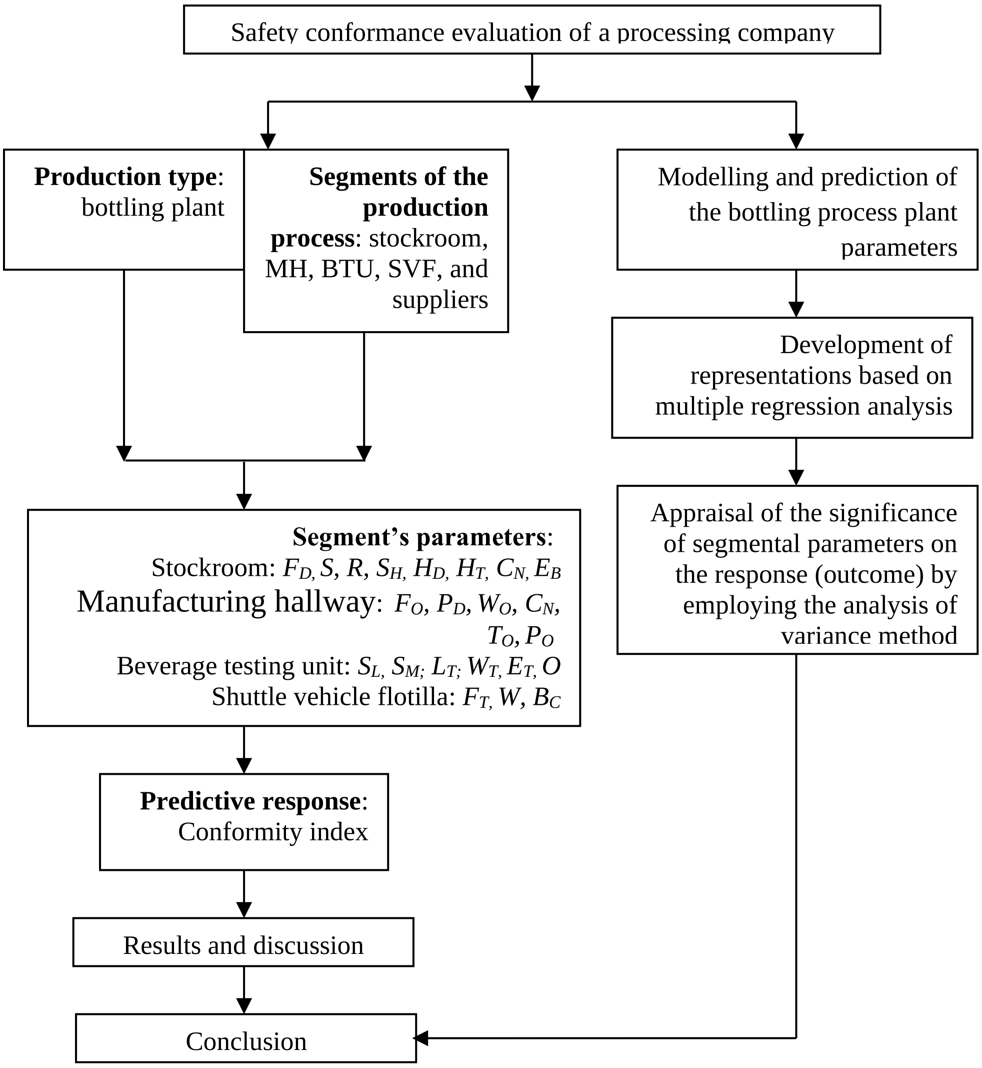

Fig. 1. Research scheme.

2.2 Model setting

The derivation of the multiple regression model used in this work was motivated by the reality in the bottling process plant; safety conformity issue is complex. Certainly, there are numerous possible casual agents related to the safety conformity problem and accordingly, numerous factors may be required to solve this complex safety conformity problem. In the context of this paper, and based on the literature review conducted, the researchers concluded that the suitable model needed should be able to deal with the complicated instances and should possess the following attributes. First, it is desired that the model should tackle intervals and quotient level variables. It is also important that the model appraise casual connections. Third, a model that may project the future outcomes is also desirable. The conclusion of researchers from the literature review is that the multiple regression model satisfies all these conditions and therefore adopted in the current research. The multiple regression (MR) is used in this work to predict the values of safety conformity in instances of none than two variables. In the literature, Uzor and Oke (2018) proposed a machine safety compliance model and was criticized by the current authors to be limited to the machines used for production purposes alone. At variance from the literature, this research argues that apart from the MH that is equivalent to the production floor cited in the literature, the viewpoint to safety compliance should be extended to other sectors of the manufacturing system, including the stockroom, BTU, SVF, and suppliers. The viewpoint, therefore, incorporates not only the internal workers to the bottling plant but also the external workers (suppliers). Thus, in this section, analysis of the major segments involved in the safety conformity assessment is made. First is the stockroom conformity prediction problem. It is executed through eight independent variables (parameters). The multiple regression method is employed to obtain the prediction based on the most influential factors contained in the model. These are forklift drivers, sorters, rescuers, sugar handlers, vehicle drivers, vehicle truck mates, chip neck removers and spare bottle eliminators in the case of the stockroom. Microsoft Office Excel 2013 was used to obtain the correlation among the stockroom conformity parameters since it has a powerful in-built statistical function for correlation analysis that safety professionals can easily understand without training. The analysis actually yielded good results. However the research could have been carried out using other specific programs like MATLAB with little training for the safety professionals to implement the results of the work. The stockroom safety conformity index was then computed with the aid of the multiple linear regression model. This shows an association between multiple predictors and a response, where the predictors are the independent variables and the response represents the dependent variable by fitting the observed data to a linear equation. The data for validating the model was obtained from a bottling plant in the south-west of Nigeria.

3. RESULTS AND DISCUSSION

The data shown in Table 2 is the percentage conformity of each factor in the warehouse segment as obtained from the field work carried out in the bottling company. Here, CF is average conformity index through all the factors in the segment.

$$CF=0.21875+0.125FD+0S+0R+0.125SH+0.125HD+0.125HT+0.125CN+0.125SB \qquad 1$$

R2 = 1, 0.2185 is the constant, 0.125 is the slope for FD, SH, HD, HT, CN and SB

where the following are defined

CF average conformity index through all the factors in the segment, which is the value of the dependent variable that is being predicted

Note: Other factors are as previously defined for Fig. 1.

R2 coefficient of determination

Hypothesis: CF is influenced by, FD, S, R, SH, HD, HT, CN, and SB

Null hypothesis: CF is not influenced by, FD, S, R, SH, HD, HT, CN, and SB

Table 2. Stockroom conformity statistic parameters.

Month	Parameters								
	C_F	F_D	S	R	S_H	H_D	H_T	C_N	S_B
1	0.9522	1.0000	0.7500	1.0000	1.0000	0.9130	0.9545	1.0000	1.0000
2	0.9631	1.0000	0.7500	1.0000	1.0000	1.0000	0.9545	1.0000	1.0000
3	0.9468	1.0000	0.7500	1.0000	1.0000	0.8696	0.9545	1.0000	1.0000
4	0.9153	1.0000	0.7500	1.0000	0.7500	0.9130	0.9091	1.0000	1.0000
5	0.9522	1.0000	0.7500	1.0000	1.0000	0.9130	0.9545	1.0000	1.0000
6	0.9426	0.9231	0.7500	1.0000	1.0000	0.9130	0.9545	1.0000	1.0000
7	0.9465	1.0000	0.7500	1.0000	1.0000	0.9130	0.9091	1.0000	1.0000
8	0.9272	1.0000	0.7500	1.0000	1.0000	0.9130	0.9545	0.8000	1.0000
9	0.9522	1.0000	0.7500	1.0000	1.0000	0.9130	0.9545	1.0000	1.0000
10	0.9631	1.0000	0.7500	1.0000	1.0000	1.0000	0.9545	1.0000	1.0000
11	0.9105	1.0000	0.7500	1.0000	1.0000	0.9130	0.9545	1.0000	0.6667
12	0.9522	1.0000	0.7500	1.0000	1.0000	0.9130	0.9545	1.0000	1.0000

CF – Conformity; FD – Forklift drivers; S –Sorters; R – Rescuers; SH Sugar handlers; HD – Vehicle drivers; HT – Vehicle truck mates; CN – Chip neck removers; SB – number of spare bottle eliminators

Equation (1) was derived with the aid of Microsoft Office Excel 2013. The fits of the standard on the variable were executed while R2, which is known as the coefficient of determination was obtained as 100%, the highest value affirming that the model is in good relation with the data obtained. The regression statistics related information are Multiple R, R Square, Adjusted R Square, Standard Error and Observations as 1, 1, 1, 9.7458E-18 and 12, respectively. By applying the ANOVA technique to the multiple regression equation, Table 3 was obtained with the values of p checked in relationship with 0.05. This value (i.e. p(0.05)), the most commonly used limit in multiple regression, is the significant level at which one rejects the null hypothesis, and was selected randomly in this study. In principle, the 5% (below one chance in twenty chances of being incorrect) level is commonly used in literature (Uzor and Oke, 2018) and adopted in the current study. A low p-value reveals that one can reject the null hypothesis. This p-value gives insights on what terms to keep in the regression model. For those with values greater than 0.05, the corresponding factors are considered insignificant and hence taken out of the equation. Also, factors to which no values were obtained were neglected.

It was discovered that three out of the eight factors were insignificant as their contributions to the output were negligible, hence removed from the analysis (Equation 2). These factors include S, R, and SH. This is as a result of the values in the column p. Another analysis was done with the new result, following the previous steps, running the multiple regression equation and the

ANOVA (Table 4). The re-computed regression statistics related information are Multiple R, R Square, Adjusted R Square, Standard Error and Observations as 0.9195, 0.8454, 0.6908, 0.0099 and 11, respectively. Due to the re-computation of ANOVA, a new regression equation was derived and Table 4 was obtained.

Table 3. ANOVA for stockroom conformity statistics parameter.

	Df	*SS*	*MS*	*F*	*Significance F*
Regression	8	0.0032	0.00041	4.2619E+30	1.7128E-46
Residual	3	2.8494E-34	9.4981E-35		
Total	11	0.0032			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
	0.2188	2.6706E-16	8.1911E+14	4.0129E-45	0.2188	0.2188	0.2188	0.2188
F_D	0.125	1.3690E-16	9.1313E+14	2.8965E-45	0.125	0.125	0.125	0.125
S	0	0	65535	-	0	0	0	0
R	0	0	65535	-	0	0	0	0
S_H	0.125	5.5131E-17	2.2673E+15	-	0.125	0.125	0.125	0.125
H_D	0.125	8.0699E-17	1.5490E+15	5.9339E-46	0.125	0.125	0.125	0.125
H_T	0.125	2.3187E-16	5.3909E+14	1.4076E-44	0.125	0.125	0.125	0.125
C_N	0.125	5.2635E-17	2.3749E+15	1.6465E-46	0.125	0.125	0.125	0.125
S_B	0.125	3.1584E-17	3.9577E+15	3.5575E-47	0.125	0.125	0.125	0.125

$$C_F = 0.01525 + 0.125F_D + 0.125H_D + 0.4692H_T + 0.125C_N + 0.125S_B \quad (2)$$

The interpretation of the equation is that only F_D, H_D, H_T, C_N and E_B are to be the independent variables.

The value of R2 for the average conformity index in Equation (1) was used to predict the conformity index in the stockroom section of the bottling processing plant. R2 which is otherwise known as the regression coefficient value for CF, the average conformity index was 1 at first. From the second regression equation, it was seen that the regression coefficient associated with the forklift drivers is positive, which means that as the number of forklift drivers increases, the level of conformity to safety rules and precautions also increases, the reason is not far-fetched, the forklift drivers are not cumbered with too much of responsibilities, hence, have enough time to adhere to safety rules.

Notice that the Equations (1) to (9) in this work were obtained from the multiple regression table. The first column remains the factors while the second column contains the coefficients for the corresponding factor. CF, which is average conformity index through all the factors in the segment can be written mathematically as

CF= C0 + C1F1+ C2F2 + C3F3 +.... CnFn

where C = Coefficient and F = Factor

The procedure followed for stockroom parametric prediction was applied to the MH and the results in Table 5 are obtained. Equation (3) shows the regression model for MH.

$$C_F = 0.4048 + 0.1429\ S_i + 0.1429F_O + 0\ P_D + 0.1429W_O + 0.1429\ C_{NMH} + 0\ T_O + 0P_O \qquad (3)$$

R2 = 1, 0.4048 is the constant, 0.1429 is the slope for S, FO, WO, and CN

where the terms are as defined in Fig. 1. R2 coefficient of determination

Table 4. Recomputed ANOVA for stockroom conformity statistics parameter.

	Df	*SS*	*MS*	*F*	*Significance F*
Regression	5	0.0027	0.0005	5.4691	0.0428
Residual	5	0.0005	9.7656E-05		
Total	10	0.0032			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
	0.0152	0.2623	0.0581	0.9559	-0.6591	0.6896	-0.6591	0.6896
F_D	0.1250	0.1408	0.8879	0.4152	-0.2369	0.4869	-0.2369	0.4869
H_D	0.1250	0.0830	1.5062	0.1924	-0.0883	0.3383	-0.0883	0.3383
H_T	0.4692	0.1821	2.5761	0.0497	0.0010	0.9373	0.0010	0.9373
C_N	0.1250	0.0541	2.3093	0.0690	-0.0141	0.2641	-0.0141	0.2641
S_B	0.1250	0.0325	3.8485	0.0120	0.0415	0.2085	0.0415	0.2085

Table 5. MH conformity statistics parameters.

	Parameters							
Months	C_F	S	F_o	P_D	W_o	C_N	T_O	P_O
1	0.9762	1	1	0.8333	1	1	1	1
2	0.9583	1	1	0.8333	1	0.875	1	1
3	0.9762	1	1	0.8333	1	1	1	1
4	0.9119	1	0.8	0.8333	0.75	1	1	1
5	0.9762	1	1	0.8333	1	1	1	1
6	0.9762	1	1	0.8333	1	1	1	1
7	0.9762	1	1	0.8333	1	1	1	1
8	0.9048	1	1	0.8333	0.5	1	1	1
9	0.9583	0.875	1	0.8333	1	1	1	1
10	0.9762	1	1	0.8333	1	1	1	1
11	0.9762	1	1	0.8333	1	1	1	1
12	0.9762	1	1	0.8333	1	1	1	1

C_F – Conformity; S – Sighters; F_o –Filler operator; P_D – Palletizers/Depalletizer; W_o – Washer operator; C_N – Chip neck removers; T_O – Technical operators/utilities; P_O – Packer/Unpacker operators

By following the same protocol carried out for stockroom parametric prediction to obtain values for MH conformity, Equation (4) was developed and Table 6 summaries the re-computation.

$$C_F = 0.5278 + 0.0794S + 0.2818F_O + 0.0794C_N \qquad (4)$$

The interpretation of the equation is that only S, F_O and C_N are to be the independent variables.

Table 6. Recomputed ANOVA for MH conformity statistics parameter

	Df	*SS*	*MS*	*F*	*Significance F*			
Regression	3	0.0029	0.0010	1.6983	0.2440			
Residual	8	0.0045	0.0006					
Total	11	0.0074						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
	0.5278	0.3346	1.5775	0.1533	-0.2437	1.2993	-0.2437	1.2993
S	0.0794	0.2008	0.3953	0.7030	-0.3836	0.5424	-0.3836	0.5424
F_O	0.2817	0.1255	2.2452	0.0550	-0.0076	0.5711	-0.0076	0.5711
C_N	0.0794	0.2008	0.3953	0.7030	-0.3836	0.5424	-0.3836	0.5424

The procedure carried out previously for stockroom and MH conformity determination is extended to BTU and Table 7 summarises the essential information.

Table 7. BTU conformity statistics parameters

	Parameters						
Months	C_F	S_L	S_M	L_T	W_T	E_T	O
1	0.9624	1	1	0.8333	1	1	0.9412
2	0.9722	1	1	0.8333	1	1	1
3	0.8791	1	1	0.8333	0.5	1	0.9412
4	0.8791	1	0.5	0.8333	1	1	0.9412
5	0.9902	1	1	1	1	1	0.9412
6	0.9624	1	1	0.8333	1	1	0.9412
7	0.8791	1	1	0.8333	0.5	1	0.9412
8	0.9624	1	1	0.8333	1	1	0.9412
9	0.9624	1	1	0.8333	1	1	0.9412
10	0.9624	1	1	0.8333	1	1	0.9412
11	0.9624	1	1	0.8333	1	1	0.9412
12	0.8166	1	0.625	0.8333	1	0.5	0.9412

C_F – Conformity; S_L – Sugar lifters; S_M –Sugar solution blenders; L_T – Lab technicians; W_T – Water technicians; S_T – sewage treatment plant technicians; O – Others

$$C_F = 0.1667 + 0\,S_L + 0.1667\,S_M + 0.1667L_T + 0.1667W_T + 0.1667S_T + 0.1667O \quad (5)$$

$R^2 = 1$, 0.1667 is the constant, 0.1667 is the slope for S_M, L_T, W_T, E_T and O

where the following are defined

R^2 coefficient of determination

Hypothesis: C_F is influenced by, F_D, S_L, S_M, L_T, W_T, E_T, and O

Null hypothesis: C_F is not influenced by F_D, S_L, S_M, L_T, W_T, E_T, and O

Equation (5) was derived and the procedure carried out for the sections repeated here and the important results are summarised in Table 8

$$C_F = 0.0060 + 0.2381L_T + 0.1429W_T + 0.2679E_T + 0.3691O \quad (6)$$

The interpretation of the equation is that only L_T, W_T, E_T and O are to be the independent variables.

Table 8. Recomputed ANOVA for BTU conformity statistics parameter.

	Df	*SS*	*MS*	*F*	*Significance F*			
Regression	4	0.0263	0.0066	7.7384	0.0104			
Residual	7	0.0060	0.0009					
Total	11	0.0323						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
	-0.0060	0.5325	-0.0113	0.9913	-1.2653	1.2533	-1.2653	1.2533
L_T	0.2381	0.1870	1.2731	0.2436	-0.2041	0.6803	-0.2041	0.6803
W_T	0.1429	0.0468	3.0551	0.0185	0.0323	0.2534	0.0323	0.2534
E_T	0.2679	0.0623	4.2962	0.0036	0.1204	0.4153	0.1204	0.4153
O	0.3691	0.5302	0.6962	0.5087	-0.8845	1.6228	-0.8845	1.6228

Multiple regression model was developed in order to solve the bottling plant SVF conformity prediction problem through the execution of three independent variables, as the case may be, at a time. The multiple regression method is employed to obtain optimal results in the evaluation of values of the independent variables for which the bottling plant SVF conformity index is either lowest or highest. In computing the polynomial to the data collected from the bottling plant, the conformity level was derived from the variables such as technicians and welders as in the case of the SVF. In the recent model development, the SVF multiple-regression model tends to be linear in behavior. Microsoft Office Excel 2013 was used to obtain the correlation among the SVF conformity parameters such as technicians and welders. The SVF safety conformity index was then computed with the aid of the multiple linear regression model. The multiple linear regression model stimulates the association between multiple predictors and a response, where the predictions are the independent variables and the response represents the dependent variable by fitting to the observed data a linear equation. In this case, the data was obtained from a bottling plant in the south-west of Nigeria. The data is shown in Table 9.

Table 9. SVF conformity statistics parameters

	Parameters			
	C_F	F_T	W	B_C
1	1.0000	1	1	1
2	1.0000	1	1	1
3	1.0000	1	1	1
4	1.0000	1	1	1
5	1.0000	1	1	1
6	1.0000	1	1	1
7	0.6667	1	0	1
8	1.0000	1	1	1
9	1.0000	1	1	1
10	1.0000	1	1	1
11	1.0000	1	1	1
12	1.0000	1	1	1

C_F – Conformity; F_T – Forklift technicians; W –Welders; B_C – Battery chargers/Technicians

$C_F = 0.1667 + 0\ F_T + 0.3333\ W + 0B_C$ (7)

R2 = 1, 0.1667 is the constant, 0.3333 is the slope for W

Hypothesis: CF is influenced by FT, W, BC

Null hypothesis: CF is not influenced by FT, W, BC

where the following are defined

R2 coefficient of determination

Equation (7) was derived and the procedure carried out for the sections is repeated here and the important results are summarised in Table 10.

Multiple regression method was adopted in order to solve the bottling plant supplier's conformity prediction problem through the execution of five independent variables, as the case may be, at a time. The multiple regression method is employed to obtain optimal results in the evaluation of values of the independent variables for which the bottling plant supplier's conformity index is either lowest or highest. In computing the polynomial to the data collected from the bottling plant, the conformity level was derived from the variables such as security, kitchen and a few others as in the case of suppliers. In the recent model development, the supplier's multiple regression model tends to be linear in behavior. Microsoft Office Excel 2013 was used to obtain the correlation among the supplier's conformity parameters such as security, kitchen and so on. The supplier's safety conformity index was then computed with the aid of the multiple linear regression model. The multiple linear regression model stimulates the association between multiple predictors and a response, where the predictions are the independent variables and the response represents the dependent variable by fitting to the observed data a linear equation. In this case, the data was obtained from a bottling plant in the south-west of Nigeria. The data is shown in Table 10.

$$C_F = 0.2 + 0.2\ S_S + 0.2\ K + 0.2C_1 + 0.2C_2 + 0C_3 \quad (8)$$

$R^2 = 1$, 0.2 is the constant, 0.2 is the slope for S_S, K, C_1, and C_2

Hypothesis: C_F is influenced by S, K, C_1, C_2, C_3

Null hypothesis: C_F is not influenced by S, K, C_1, C_2, C_3

where the following are defined

R^2 coefficient of determination

Equation (8) was derived and the procedure carried out for the sections repeated here and the important results are summarised in Table 11.

$$C_F = 0.2 + 0.2\ S_S + 0.2\ K + 0.2C_1 + 0.2C_2 \quad (9)$$

The interpretation of the equation is that only *S*, *K*, C_1 and C_2 are to be the independent variables.

Table 10. Supplier's conformity statistics parameters.

	Parameters					
	C_F	*S*	*K*	C_1	C_2	C_3
1	0.9857	1	1	0.9286	1	1
2	0.9857	1	1	0.9286	1	1
3	0.9857	1	1	0.9286	1	1
4	0.9584	0.8636	1	0.9286	1	1
5	1.0000	1	1	1	1	1
6	0.9691	1	0.9167	0.9286	1	1
7	0.9857	1	1	0.9286	1	1
8	0.9857	1	1	0.9286	1	1
9	1.0000	1	1	1	1	1
10	0.9691	1	0.9167	0.9286	1	1
11	0.9505	0.9545	1	0.9286	0.8696	1
12	0.9596	1	1	0.9286	0.8696	1

C_F – Conformity; *S* – Security; *K* –Kitchen; C_1 – Supplier 1; C_2 – Supplier 2; C_3 – Supplier 3

Table 11. Recomputed ANOVA for BTU conformity statistics parameter

	Df	*SS*	*MS*	*F*	*Significance F*
Regression	4	0.0029	0.0007	7.94E+30	2.3E-107
Residual	7	6.39E-34	9.13E-35		
Total	11	0.0029			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
	0.2	1.5E-16	1.33E+15	3.5E-104	0.2	0.2	0.2	0.2
S	0.2	7.43E-17	2.69E+15	2.6E-106	0.2	0.2	0.2	0.2
K	0.2	9.58E-17	2.09E+15	1.5E-105	0.2	0.2	0.2	0.2
C_1	0.2	1.12E-16	1.79E+15	4.5E-105	0.2	0.2	0.2	0.2
C_2	0.2	5.98E-17	3.34E+15	5.7E-107	0.2	0.2	0.2	0.2

From an extensive literature review, it was found that through the model by Uzor and Oke (2018) was developed in the recent past and limited to machine guarding operation in manufacturing organizations, it exhibits scope for development and application with respect for safety conformity evaluation in a process plant. As such, the insight gained from the literature review reveals that the problem of safety conformity evaluation resembles what would have been solved by the use of a multiple regression model and consequently applied. The multiple regression model was utilized to establish the significant association between each of the principal criteria, such as stockhouse, MH, SVF, BTU, and suppliers. The multiple regression models also serve the purpose of establishing the impact of these principal criteria (parameters) on the response (conformity indices) of the safety system regarding the manufacturing process. By adopting this perception, the goal of the current research is linked to establish those factors, which are largely significant to improve the safety conformity indices of the bottling process plant such as it become clear and convincing to direct attention in the expenditure of resources to the top priority factors identified by the Taguchi-Factor scheme. An innovative characteristic of the model is that it predicts the association between the principal criteria, i.e. dependent factors) and the sub-criteria i.e. independence factors. As noted in the literature, only one study has revealed that the principal criteria of the various process components impact on the outcome of safety conformity while the association is created within them and the component parameters. Nonetheless, the perception is limited to machine guarding and the scope of application excludes external workers (suppliers) servicing the company written and outside the company premises. The scope of the study analysed (Uzor and Oke, 2018) also evades the analysis and incorporation of the SVF. As such, from a perspective, this study is novel and no such recorded previously in the literature concerning safety conformity.

The most important aspect in the predictive task is to obtain the final equations after the removal of non-significant terms from the regression model. A support for this task was declared in Uzor and Oke (2018). The final equations may be used to determine the level of safety conformity in each segment of the bottling process plant. However, the main issue is the predictive accuracy of the model. The approach to tackling this problem has been demonstrated in Uzor and Oke (2018) where the error analysis was used as the most reliable indicator of predictive accuracy. Usually, error metrics such as the mean absolute deviation (MAD), and the mean squared error (MSE) are used. Thus, the accuracy of the predictive models formulated is discussed from the viewpoints of mean squared error (MSE) and an aspect ratio that evaluates the MSE to the average compliance in all periods. In analysing the field data, the theme that appeared was the accuracy of the predictive models. For all the segments (warehouse, MH, BTU, SVF, and suppliers), the mean squared error ranged from 0.0251 (least for suppliers) to 0.25 (highest for SVF) with an average value of 0.0554. Benchmarked against the literature (Uzor and Oke, 2018), the differences in values are over 8940. The differences between the multiple regression model of Uzor and Oke (2018) and the current research may be due to the number of variables incorporated in the models; large for the literature model (seven variables) and smaller for the current study (ranged from two to five variables). It is known that the more the number of variables considered in a work, the more the variability of the measures and the less the accuracy of the prediction from such a model may be. The aspect ratio is another emerging theme form the work. By positioning based on the aspect ratio, the order is SVF > suppliers > warehouse > BTU > MH. However, the value obtained from the literature (Uzor and Oke, 2018) in comparison with the current study is more than 34.

Sticking differences in the approach could be found in the literature (Uzor and Oke, 2018) and in the current study. While the literature considered the characteristics of the workforce, including the age of machine and operators, number of damaged and functioning guards, non-compliance index, operator's experience and material factor, the current study did not treat these workforce characteristics but compliance to stated guidelines within the group. In the literature, the coefficient of determination (R^2) was obtained as 0.9980, an extremely dependable value that approves the use of the model (Uzor and Oke, 2018). On the other hand, the current study reveals segmental coefficient of determination of 1 for all the analysis carried out.

In this study, the duration is spread over twelve months while noise and the physical characteristics of the equipment and operator, such as age of machine and experience of operator were not considered. However, these factors may impact on the validity of results. Noise emerging from a functional guard may distract the operator's attention and motivates the worker to by-pass guards. Nonetheless, an extended period covering up to sixty months would have enhanced the validity of the data. In addition, the multiple regression used assures linearity among variables. However, non-linear associations may be suspected among the variables and a new model such as non-linear mathematical platform of response surface methodology may have enhanced the validity of the data also. The most significant problem in this research is the unusual commitment of the workers to work during the study period; the consciousness that their performance is monitored stimulated more commitment, giving a false impression of their performance. Perhaps an alternative approach of video recording coupled with no previous announcements of study to workers would improve the validity of the work. In a future study, it is recommended to consider optimising the variables using Taguchi method. Notwithstanding, any conclusions relating to the safety conformity of workers would be restricted to the semi-automated plants in developing countries of the world.

4. Conclusions

In the current research, the safety conformity of a bottling process plant was investigated. The subsequent observations are pointed out:

1. Multiple regression analysis offers a competent and methodical approach to predict bottling process parameters for response evaluation. The technique adjusts the process such that non-significant parameters are not sensitive to the impact of the system, thus promoting a robust blueprint method

2. The outcome reveals that (a) for stockroom conformity, only F_D, H_D, H_T, and E_B are the most significant independent variables; (b) the MH shows only S, F_o and C_N to be the most significant independent variables (c) the BTU conformity assessment has only L_T, W_T, E_T and O to be the relevant and most significant variables (F_T, W and B_c) to be the most significant independent variables (e) for suppliers' conformity, only S, K, C and C_2 are the independent variables
3. The contributions of the most significant parameters of the total contribution for the parameters jointly considered are H_T (stockroom), F_o (MH), O (BTU), W (SVF) and S_S, K, C_1, and C_2 (suppliers). These are obtained as 46.92%, 28.17%, 36.91%, 100%, and 20.00%, respectively
4. The present research includes other sections of the bottling plant such as stockroom, BTU, SVF, and suppliers, which constitute significant bottling plant investments in human and non-human resources, and the most appealing compared to machine guarding that is a sub-set of the MH
5. With the consideration of other parts of the bottling process plant in addition to the MH, more realistic measures and reliable assessment of conformity is made and this assures the system of more stability in performance if properly motivated
6. The result obtained agree with the earlier work in literature, which focused mainly on machine guarding

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