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Health and Safety Compliance Index Optimization using Binomial Motivated Taguchi Method and Multicriteria Selection

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Previous research has examined how the safety conformity of a bottling process plant may be analyzed from the lens of machine guarding usage by operators. To advance knowledge, this study pioneers how to optimize safety conformity for all operations using the binomial motivated Taguchi method. Secondly, for the first time, this study analyzes the performance of segments in safety conformity of bottling plant segments using multicriteria methods. Development of binomial motivated Taguchi method includes data gathering, calculating the binomial distribution, determining levels and factors, orthogonal arrays, and the signal-to-noise ratios. Computations are made of optimal, global and specific parametric settings. The multicriteria models used the entropy method for weight determination and indices were obtained for 12 evaluation periods. The optimal parametric setting is obtained as A_3HT-A_2S-A_2O-A_3C_1, which is -1.92E+02 for segment 1, 1.29E-01 for segment 2, -1.15E+02 for segment 3 and -1.52E+02 for segments 4 and 5. The specific optimized values (SOVs) of workers shows that SOV (segment 2) > SOV (segment 3) > SOV (segment 1) > SOV (segments 4 and 5). The best performing operations in the five segments are the liberators (segment 1), technical operators and packer/unpacker operators (segment 2), Syrup lifters (segment 3), forklift technicians (segment 4) and supplier 3 (segment 5). The binomial motivated Taguchi method is an effective tool to optimize operational activities while the multicriteria models proved effective in rank performance for optimized results. The obtained results may be useful to plan for safety budgets.

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1. INTRODUCTION

Safety conformity is known as a bottling process plant problem wherein all stakeholders expect the workers operating production–related equipment to comply with the proper use of machine guards and safety gadgets while at work (Redinger and Levine, 1998; Onyegiri and Oke, 2016; Uzor and Oke, 2018; Priye and Manoj, 2020). The work environment is associated with hazards involving rotating parts, pointed machine parts, slippages and falls, which may trigger accidents or even death (Parker et al., 2015a, b; Uzor et al., 2018a,b; Gorny, 2019). Thus, before the start of manufacturing operations, machine operators are expected to check their machines to establish compliance of their states with guidelines. This includes the correct positioning and adequate fixing of guards, avoidance of conditions that may lead to slippages and falls. However, over the past several years, the safety philosophy has changed. It has been influenced by the company-wide performance improvement idea of total quality management that campaigns for the total improvement idea of total quality management that campaigns for the total improvement of safety conformity from the machine guards alone to include Beverage testing unit, Suppliers, Stockroom, and Vehicle fleet flotilla workshop.

A brief literature review is attempted here to reveal the knowledge gap that occurs in the food safety conformity literature. The area of safety conformity is very active in the food industry with interesting studies focusing on both equipment safety and the safety of the manufactured food. Equipment safety, popularly referred to as machine safety, was populated with studies due to Parker et al. (2015a,b) and Uzor et al. (2018a,b). Though these studies were conducted such as to be applied in diverse industries, conformity was limited to machine guards, which are the primary determinants of equipment safety. The literature on the safety of manufactured food dwells much on the microbiology and food evaluation processes; which is not the subject of discussion in this work (Miarka et al., 2019). The literature concerning this used three critical tools of SOP, HACCP and CCP to examine and accredit the food in a quality assurance process. These tools, respectively referred to as the standard operating procedure (SOP), hazard analysis and critical control point (CCP) could have made important changes if applied to machine guarding, but, scholars had not navigated in that direction of research to determine safety conformity.

Furthermore, Gorny's (2019) article to establish non-conformity in an engineering set-up is also an important contribution to the conformity literature. The report focused on workers' health and safety under the influence of environmental factors and ascertained that tasks are implemented at optimal thresholds. The subject discussed by the author is an inter-link between ergonomics, safety and conformity. Notwithstanding, the gap on optimization to take advantage of the unique attributes of the Taguchi method and the binomial distribution function in a synergic platform was not tackled. The idea of this binomial distribution is that each data creation process exhibits as probability *p* of the worker being assessed not complying with the stated guidelines or rules of safety. It further states that such non-compliance in a measurement occasion is independent of the other measurement occasions (Pal and Gauri, 2020). To date, there are no reports in the safety engineering conformity literature on the nature of the binomial process as it influences engineering applications. In addition, there is no information through this literature source on how to select the best performing team in the different units of the bottling plant. Furthermore, additional literature was contributed by Mjakuškina and Lapiņa (2018) to manufacturing compliances. The authors assessed the effectiveness of the conformity appraisal scheme using statistics of unsafe product notices using a quick response alert scheme. While manufacturing compliance is addressed, the researchers have not provided useful hints on the route to optimization for processes, which may be transferred to the bottling plant. Furthermore, no hint was given on the path to selecting the best performing team in the segments of the bottling plant.

Moreover, Redinger and Levine (1998) proposed an appraisal procedure on safety conformity. While this food-based article also included equipment certification (conformity) as a component of the assessment model, little information was provided on the equipment conformity process. There was no treatment concerning equipment conformity optimization. There was no mention also concerning Taguchi's route to optimization and there was no consideration on the synergic power of binomial function and the priority scheme to choose the best and worst-performing teams was missing.

At present, the manufacturing systems face stringent economic conditions and to survive, safety conformity must be company-wide. Unfortunately, very few useful leads in the literature exist on how to quantify and optimize the safety conformity of the whole bottling process plant in an innovative manner. The efforts by Martins and Oke (2021a,b), although recent, are still scanty and needs to be substantially complemented. Taguchi method, which is a classical tool of optimization while considering the economy of experiments have not been explored comprehensively in this domain. While Martins and Oke (2021a) considered the Taguchi method to model the safety conformity problem in the bottling plant, the approach follows the classical Taguchi method's application without attention to the conformity behavior in a distribution function context. But the present study is different from the work in the light of the elements considered. In the work, the orthogonal array, signal-to-noise ratio and optimal parametric settings are the principal elements considered. To diverge, this present study considers the binomial distribution in its characteristic chances of conformity of the system to the specified standards in multiple trials. Besides, this work considers the WSM, WPM, WASPAS and PROMETHEE multicriteria, which were ignored in the referenced article.

Although Martins and Oke (2021b) introduced a hybrid control chart-Taguchi method, the focus of the present study diverges from their study. The authors modeled to safety conformity problem in a control and optimization context and considered the following as the key elements of the safety conformity system: X bar and R bar charts, the upper and lower control limits and the Taguchi method's elements of an orthogonal array, signal to noise ratios and optimal parametric settings. While the criteria (factors) optimized in the work are the same as in the present work, the referenced work fails to consider the binomial function and the multicriteria analysis involving WSM, WPM, WASPAS and PROMETHEE are completely lacking in the work. Thus, the binomial distribution, a discrete quantitative method that has not been explored in its totality, integrated to Taguchi method in a unique approach. Also, there is no scientific way of ranking operations relative to one another in a segment. As a consequence of poor safety conformity, when accidents occur, loss of production man-hours and financial resources are made (Haeri, 2016; Wong and Lee, 2016; Couto da Silva and Amaral, 2019). This is detrimental to the survival of the bottling process plant and should be avoided. There is therefore the need for a measurement and optimization tool on safety conformity to curb the problem.

2. MATERIAL AND METHODS

2.1 Integrated binomial-motivated Taguchi method

In this article, an integrated binomial-motivated Taguchi method is proposed to solve the safety conformity optimization problem as the chances of conformity is known and the chances of k number of conformity in n cases of Bernoulli trials are determined ($k<n$, where k, $n>0$). The method combines the binomial distribution that examines the safety control parameters in an assurance effort to establish the workers' social and intellectual welfare together with their physical comfort in the bottling process plants. The binomial distribution model is located in the Taguchi framework at the phase where factors and levels of the safety conformity process are determined to nurture the orthogonal selection. Then the creative logical aptitude of the binomial is applied to adjust the procedure and consequently, develops the Taguchi scheme. The safety conformity index is specified as a random variable that has a chance of being adopted by a worker (when the worker complies with the stated rules) or refused in adoption (when the worker fails to comply with the guiding philosophy). In either case, the system is designed fairly such that it does not frustrate the efforts of the worker willing to comply and prompts him/her to do otherwise. The measurement activity of the worker in compliance or not complying is then taken as several events. From the actions, the numbers that emerge from a particular event could be either conforming or nonconforming. The interest of the researchers is to compute the probability. This is the random variable, which may take a value of zero (non-conformity to safety rules) or one (conformity to safety rules).

To evaluate the process, the number of possible outcomes from the worker's activities is established. Suppose the worker was examined ten times. In the first attempt, two possible ways are evident (i.e. compliant or non-compliant). Likewise, two possible ways are evident from the second to the tenth attempt. So the total number of possible ways becomes 2^{10}, which is 1024. This information will be of assistance since considering each value which the safety conformity index could take is determined. The idea of binomial co-efficient and combinatorics are then used in the final computation. In the illustration considered here, if $P(X = 0)$ and $P(X = 1)$ is the probability of compliance and non-compliance, respectively, then $P(X = 0)$ may be computed as ${}_{10}C_0/1024$ (ten combinations zero divided by one thousand and twenty-four), which gives 9.77E-04. Likewise $P(X = 1)$ is computed as ${}_{10}C_1/1024$ = 9.77E-03. The proposed method was applied with success to solve the problem of safety conformity in a bottling plant in an optimization context and embedding the viewpoint of the binomial distribution. The field data reveal the aptitude of the method to optimize the parametric values of the bottling plant process. Interestingly, it reveals results that are preferred to the traditional Taguchi scheme.

2.2 Principles of WSM, WPM, WASPAS and PROMETHEE

The principles of operations of the mentioned multicriteria method are discussed as follows. The weighted sum model is a multicriteria decision-making method that assesses the number of options regarding the number of decision criteria. The WSM is the acronym of this method and it is founded on the three principles of normalization, ranking and preference score evaluation. Normalization is a process whereby the parameters having different units are converted to the same scale of measurement, usually between 0 and 1 to permit a fair evaluation of all the parameters. Usually, a simple normalization method is followed where the normalized index is judged based on the beneficial or non-beneficial perspective of the parameter in the system. Increasing a parameter value that will bring a positive contribution to the safety system is referred to as the beneficial parameter. While such an increase will reduce safety conformity, it is a non-beneficial parameter. The second foundation is ranking which is stimulated by the generation of preference scores which gives outputs that are weighed against one another and are arranged in descending order of weights.

The principles of WPM, the weighted product method are the same as the WSM but the computation with the sum (sigma) is replaced with the product (pie symbol). The WPM shares the principles of normalization, ranking and preference score with the WSM. The WASPAS (weighted aggregated sum product assessment) method is the amalgamation of the WSM and WPM. The WASPAS technique hugely relies on the idea of rank accuracy, which focuses on the diverse degree of utility of the suggested parameter regarding their positions in the hierarchy of ranks. The PROMETHEE method is based on the theory of dominance order, which is a partial order considered for a group of partitions for a positive integer associated with combinatorics and representation principles.

Furthermore, the procedures taken in the Binomial motivated Taguchi method and the multicriteria methods are outlined in Fig. 1.

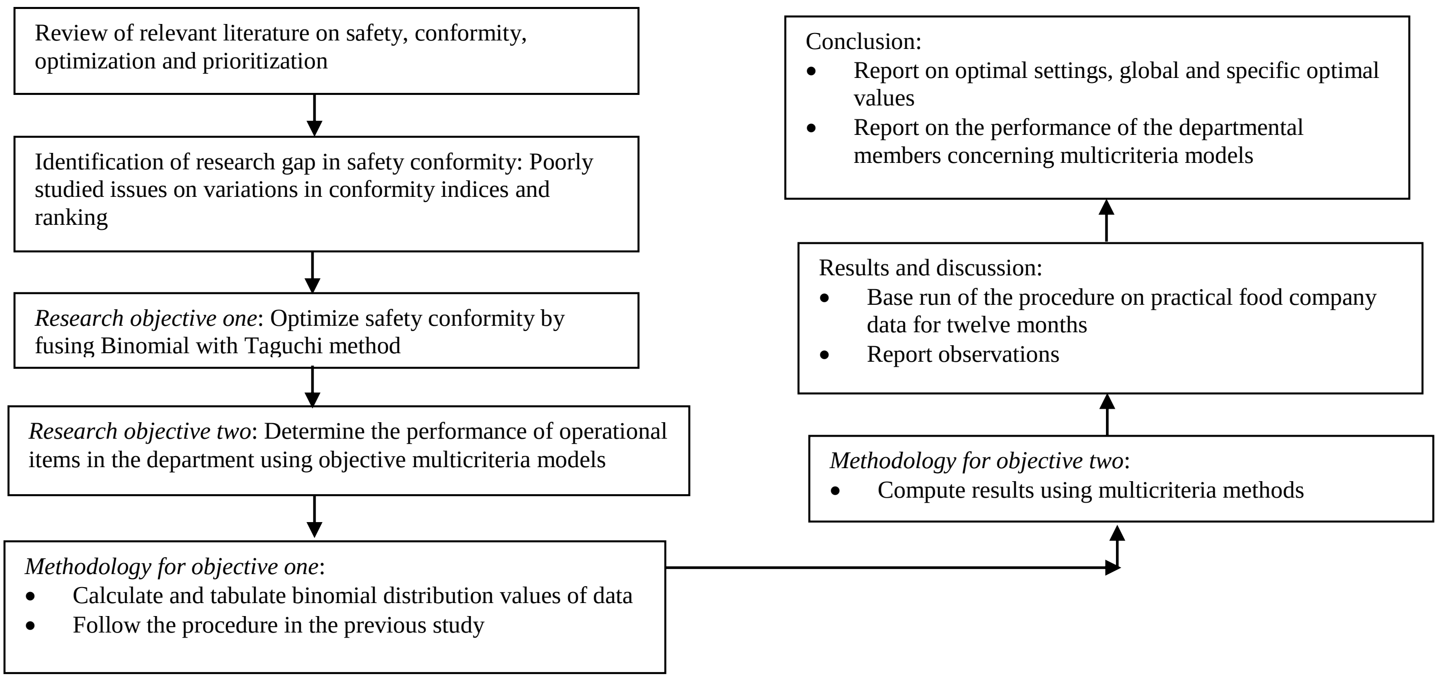

Fig. 1. Research scheme for the optimization and performance appraisal for safety conformity in a food company

This work analyzes the conformity index data on different segments of the factor. Segment 1 analyze the Stockroom conformity index to obtain the best operation in the department considered. For the operations, the following are involved: Forklift drivers, organizers, liberators, syrup handlers, transport drivers, transport truck-mates, chip neck eradicators and extra bottle eradicators. The data are obtained for twelve months (Month 1 to Month 12). The index has different scores for each month for each operation. Normally, the criteria involved in this system are categorized into beneficial and non-beneficial criteria. In this case, since the performance of each operator is to be analyzed, for twelve months, it is assumed that all the criteria are of the desired properties. Conformity is adhering to standards laid down by the system controllers, which directs the daily activities concerning safety. The higher the conformity index, the closer the operator conforms to the expected standard set. An objective of this part of the work is to analyze the conformance of operators in different departments, which are segmented into smaller units, notably five in number.

Consider segment 1, four methods are used to analyze the problem, to find the best operation in segment 1, Stockroom.

3. RESULTS AND DISCUSSION

3.1 Binomial-related results and the multicriteria outcome

The data utilized for this work is from a larger pool from a project, part of which has been documented in Martins and Oke (2020), Martins and Oke (2021a), Martins and Oke (2021b). So, the procedures utilized in this work were adopted from the work but with the binomial functional input. Data relating to the rate at which the workers in the bottling plant conform to safety practices were obtained from each segment of the industry and tabulated accordingly. The binomial motivated Taguchi method was applied, to optimize the data obtained from the plant. Due to the optimization of the safety conformity parameters of workers in the bottling plant, the following findings were made. The rate at which the workers in each segment of the organization conform to the laid-down safety guidelines were measured and recorded. Eight factors were considered in segment 1, which is Stockroom. Seven factors were considered in segment 2, which is Manufacturing hallway, six factors were considered in segment 3, which is Beverage testing unit. Three factors were considered in segment 4, which is Vehicle fleet flotilla workshop, Five factors were considered in segment 5, which is a combination of Suppliers (in-house) and Suppliers (Others).

The data obtained was for twelve periods to verify the accuracy of the result. The individual factors serve as a yardstick in the determination of the specific optimized value. The specific optimized value of workers in segment 1, is lower compared to segment 2, which is, Manufacturing hallway, with 0.0135. The specific optimized value of workers in segment 1, compared to segment 3, which is Beverage testing unit, is lower with about 0.0102. When compared with segments 4 & 5, which is the combination of Vehicle fleet flotilla workshop and Supplier, the specific optimized value of segment 1, was found to be lower with about 0.0004 than that of segments 4 & 5.Comparing segment 2 and segment 3, revealed the specific optimized value of workers in segment 2 higher with 0.0033 than the specific optimized value of workers in segment 3. The specific optimized value of the workers in segment 3, Beverage testing unit, when compared to segment 4 & 5, which is the combination of Vehicle fleet flotilla workshop and Suppliers, was found to be higher with 0.0106.

Signal-to-noise ratio was introduced as a means to point out the factors that are the key in the study. Comparing the average signal to noise response of each segment to determine the factors and segments with the higher conformity index, it can be seen that, the average signal to noise ratio was observed to be highest in Segment 2 (Manufacturing hallway) with a total average signal to noise response of -1.11E+02, followed by Segment 3 (Beverage testing unit), with a total average signal to noise response of -1.73E+02. The segment with the least average signal to noise response is Segment 1 (Stockroom), with an average of -2.25E+02, followed by Segment 4 & 5 (Vehicle fleet flotilla workshop & Supplier), with an average of -1.85E+02.'Sighters' was the factor with the least average signal to noise response in the bottling plant, as it had -6.01E+01, as the average signal to noise ratio for level 1, 2 and 3, followed closely by 'Liberators and Syrup Handlers', with -2.28E+02 as the average signal to noise response for level 1, 2 and 3. The factors with utmost average signal to noise ratio for each segment are, Filler Operator and Packer/Unpacker Operators for Segment 2 (Manufacturing hallway) at -1.23E+02, ETP Technicians for Segment 3 (Beverage testing unit) at-1.741E+02, all factors for Segment 4 & 5 (Vehicle fleet flotilla workshop & Supplier) at -1.87E+02, Forklift Drivers, Organizers, Transport Drivers, Transport Truck Mates, Chip Neck Eradicators and Extra Bottle

Eradicators for Segment 1 (Stockroom) at -2.27E+02.

The average signal to noise ratio of workers in segment 1, is lower compared to segment 2, with 1.14E+02. The average signal to noise ratio of workers in segment 1, compared to segment 3, is lower with about 5.16E+01. When compared with Segment 4 & 5 (Vehicle fleet flotilla workshop & Supplier), the average signal to noise ratio of segment 1, was found to be lower with 3.95E+01. Comparing segment 2 and segment 3, revealed the average signal to noise ratio of workers in segment 2 was higher with 6.22E+01 than the average signal to noise ratio of workers in segment 3. When compared with Segment 4 & 5 (Vehicle fleet flotilla workshop & Supplier), the average signal to noise ratio of workers in segment 2, was found to be higher with 7.42E+01 than that of Segment 4 & 5 (Vehicle fleet flotilla workshop & Supplier). The average signal to noise ratio of the workers in segment 3, Beverage testing unit, when compared to Segment 4 & 5 (Vehicle fleet flotilla workshop & Supplier), was found to be higher with 1.20E+01.

Here the results are shown, starting with the optimal parametric setting (Table 1).

Table 1. Optimal parametric settings, global and specific optimized values

Segment→ Level ↓	1	2	3	4 and 5
		Optimal parametric settings		
1	A_1EBR = -2.25E+02	A_1CNR = -1.15E+02	A_1ET= -1.70E+02	A_1FT = A_1W = A_1BC = A_1S =A1K = A_1C_2 = -1.87E+02
2	A_2HT = -2.24E+02	A_2S = 1.29E-01	A_2O = -1.15E+02	A_2C_1 = -1.85E+02
3	A_3HT = -1.92E+02	A_3PD = -1.05E+02	A_3SM = -1.66E+02	A_3C_1 = -1.52E+02
		Global optimized values		
1	0	0	0	1
2	4.38E-02	1	1	4.24E-02
3	1	8.43E-02	7.43E-02	1
		Specific optimized values		
Average	0.3479	0.3614	0.35813	0.3475

Table 1 also shows the optimized values. At this point, it is important to briefly explain what is meant by the optimal parametric setting in the context of the results presented in Table 1. From Table 1, the values obtained from the computations for the various segments and levels are shown for the optimal parametric settings. For instance, in segment 1 and considering level 1, the optimal value of the setting is A_1EBR = -2.25E+02. But this value may not be optimal except when compared with other values within the segment and that it has a higher positive result. So this value was compared with the values obtained at levels 2 and 3, which are A_2HT = -2.24E+02 and A_3HT = -1.92E+02, respectively. But maximum safety conformity of the workers is required. So the highest of the three options of segment 1 at levels 1, 2 and 3 is chosen as the optimum (i.e. A_1EBR). So it is asterisked as the best value for segment 1. By following the same procedure, all the three values at levels 1, 2 and 3 for segment 2 are compared. The outcome is that level 2 having A_2S = 1.29E-01 is optimum. Likewise, by following the procedure to obtain these optimal values for segments 3, the optimal value is obtained as A_2O = -1.15E+02. Furthermore, the optimal value for combined segments 4 and 5 is obtained at level 3 as A_3C_1 = -1.52E+02. But by combining these optimal points and values, the optimal parametric setting is obtained as

$A_3HT-A_2S-A_2O-A_3C_1$ which is -1.92E+02 for segment 1, 1.29E-01 for segment 2, -1.15E+02 for segment 3 and -1.52E+02 for segments 4 and 5. These are the best values obtainable for the system with which benchmarks of performance could be made.

By comparing the present study with that of Widjanarti et al. (2019) that discussed the influence of lighting intensity on worker's productivity in the textile industry in Surakarta, Indonesia, the authors approved safety as important while explaining the significance of occupational health and safety (K3) program within the work surroundings. Thus, there is an incentive to pursue safety conformity in this paper. Furthermore, Ramdan et al. (2018) mentioned the use of personal protective equipment and asserted that it is among the variables that exhibit an R square of 36.5%, which reveals that, there are 63.5% factors beyond the region of the model that clarifies the dependent variable. It concurs with this study in that at present emphasis in practice has been placed on the use of personal protective devices by we are arguing that outside these factors are responsible. It is known that safety conformity pursued in this paper is about hazard control and Andarini et al. (2019) concurs with this assertion but investigated chemical hazards in the hairdressing occupation. A further emphasis on safety in the same business of beauty saloon was offered by Agustin et al. (2019). The idea of hazard control was again emphasized in Phuspa et al. (2019) but with an application in a hospital.

Furthermore, in this article, the specific optimized values obtained for all segments are lower compared to those obtained in Martins and Oke (2021b). For details, 0.3479 was reported here for segment 1 against 0.6667 in the referenced article. Segments 2, 3 and 4/5 yielded 0.3614, 0.35813 and 0.3475 in the present study against 0.6667, 0.3760 and 0.6667 in Martins and Oke (2021b). The lowered values in the present study reflect the impacts of the binomial distribution function on the model parameters. The referenced work has not captured the unique attributes of the binomial distribution function, which focuses on the chances of conformity being known and the chances of k number of conformity in n cases of Bernoulli trials being determined ($k<n$, where k, $n>0$). The present method combines the binomial distribution that examines the safety control parameters in an assurance effort to establish the workers' social and intellectual welfare together with their physical comfort in the bottling process plants. This attribute is missing in the literature but captured in the present study.

The other important results that relate to the multicriteria analysis are shown in Tables 2a to 2e. The results in Tables 2a to 2e show interesting insight into the best and worst-performing segments. Table 2a revealed similar results in the assessment of the eight groups of workers in segment 1 (Table 2a). The PROMETHEE, WSM, WPM and WASPAS each ranked the Liberators as the best performing sub-group within segment 1 while all the methods agreed that the Organizers sub-group is the worst in performance.

Table 2a. Final results from the application of four methods: PROMETHEE, WSM, WPM and WASPAS segment 1

	PROMETHEE (Calculation of the net outranking flow for each operator, φ(a)=φ+(a)-φ-(a))				WSM		WPM		WASPAS	
Operations	φ+(a)	φ-(a)	φ(a)	Rank	Preference score (Q1)	Rank	Preference score (Q2)	Rank	Qi	Rank
Forklift Drivers	0.002585	0.011397	-0.00881	2	0.995476	2	0.995303	2	0.995389	2
Organizers	0.178649	0.799616	-0.62097	8**	0.75	8**	0.75	8**	0.75	8**
Liberators	0	0	0	1*	1	1*	1	1*	1	1*
Syrup Handlers	0.027632	0.146129	-0.1185	5	0.951644	4	0.945875	4	0.94876	4
Transport Drivers	0.055528	0.202478	-0.14695	7	0.919971	7	0.91952	6	0.919746	6
Transport Truck Mates	0.038793	0.137754	-0.09896	4	0.943511	5	0.943307	5	0.943409	5
Chip Neck Eradicators	0.016497	0.088051	-0.07155	3	0.971131	3	0.968303	3	0.969717	3
Extra Bottle Eradicators	0.063926	0.187061	-0.12313	6	0.925427	6	0.913284	7	0.919355	7

*best, ** worst

Table 2b. Final results from the application of four methods: PROMETHEE, WSM, WPM and WASPAS segment 2

	PROMETHEE (Calculation of the net outranking flow for each operator, φ(a)=φ+(a)-φ-(a))				WSM		WPM		WASPAS	
Operations	φ+(a)	φ-(a)	φ(a)	Rank	Preference score (Q1)	Rank	Preference score (Q2)	Rank	Qi	Rank
Sighters	0.225367	0.032532	0.192836	3	0.993492381	3	0.993072337	3	0.993282	3
Filler Operator	0.185949	0.077097	0.108852	5	0.97224398	5	0.969506709	5	0.970875	5
Palletizers/Depalletizer	0.06032	0.587935	-0.52762	7**	0.8333	6	0.8333	6	0.8333	6
Washer Operators	0.082244	0.525911	-0.44367	6	0.742389268	7**	0.70542746	7**	0.723908	7**
Chip Neck Eradicators	0.225367	0.032532	0.192836	3	0.993492381	3	0.993072337	3	0.993282	3
Technical Operators	0.23838	0	0.23838	1*	1	1*	1	1*	1	1*
Packer/Unpacker Operators	0.23838	0	0.23838	1*	1	1*	1	1*	1	1*

*best, ** worst

Table 2c. Final results from the application of four methods: PROMETHEE, WSM, WPM and WASPAS segment 3

	PROMETHEE (Calculation of the net outranking flow for each operator, φ(a)=φ+(a)-φ-(a))				WSM		WPM		WASPAS	
Operations	φ+(a)	φ-(a)	φ(a)	Rank	Preference score (Q1)	Rank	Preference score (Q2)	Rank	Qi	Rank
Syrup Lifters	0.289374431	0	0.289374431	1*	1*	1*	1*	1*	1*	1*
Syrup Mixers	0.197825797	0.181932345	0.015893452	4	0.886049592	5	0.860169089	4	0.873109	4
Lab Technicians	0.102552396	0.471487907	-0.368935511	6	0.853953625	6	0.852341925	6	0.853148	6
Water Technicians	0.223615871	0.206158297	0.017457575	3	0.88670131	4	0.854648218	5	0.870675	5
Etp Technicians	0.22454521	0.111897414	0.112647796	2	0.926363902	3	0.902956132	3	0.91466	3
Others	0.180530168	0.24696791	-0.066437742	5	0.944682571	2	0.944584185	2	0.944633	2

*best, ** worst

Table 2d. Final results from the application of four methods: PROMETHEE, WSM, WPM and WASPAS segment 4

	PROMETHEE (Calculation of the net outranking flow for each operator, φ(a)=φ+(a)-φ-(a))				WSM		WPM		WASPAS	
Operations	φ+(a)	φ-(a)	φ(a)	Rank	Preference score (Q1)	Rank	Preference score (Q2)	Rank	Qi	Rank
Forklift Technicians	0.225367	0.032532	0.192836	1*	0.99996	1*	1	1*	0.984418	1*
Welders	0.185949	0.077097	0.108852	2	0.91663	3**	0	3**	0.985846	3**
Battery Charger/Technicians	0.06032	0.587935	-0.52762	3**	0.99996	1*	1	1*	0.94031	1*

*best, ** worst

Table 2e. Final results from the application of four methods: PROMETHEE, WSM, WPM and WASPAS segment 5

	PROMETHEE (Calculation of the net outranking flow for each operator, φ(a)=φ+(a)-φ-(a))				WSM		WPM		WASPAS	
Operations	φ+(a)	φ-(a)	φ(a)	Rank	Preference score (Q1)	Rank	Preference score (Q2)	Rank	Qi	Rank
Security	0.225367	0.032532	0.192836	1*	0.984802273	5**	0.984034166	3	0.984418	5**
Kitchen	0.185949	0.077097	0.108852	2	0.986077222	4	0.985614438	2	0.985846	4
Supplier 1	0.06032	0.587935	-0.52762	5**	0.94046238	5**	0.940156872	5*	0.94031	5**
Supplier 2	0.06032	0.587935	-0.52762	5**	0.978227536	4	0.976991159	4	0.977609	4
Supplier 3	0.06032	0.587935	-0.52762	5**	0.99996	1*	1	1*	0.99998	1*

*best, ** worst

For segment 2 (Table 2b), there are seven subgroups. However, all four methods of evaluation concurred that the technical operators are the best subgroup. But there is disagreement in the findings regarding the worst sub-group. While three methods, namely the WSM, WPM and WASPAS agrees that the worst sub-group is the Washer Operators, the PROMETHEE method opposed this suggestion by picking the sub-group named Palletizers/Depalletizers as the worst sub-group. However, since the majority of methods agree with the Washer Operators as the worst sub-group, the current researchers concur with this suggestion.

For segment 3 (Table 2c), there are six sub-groups but all four methods agree that the sub-group Syrup Lifters is the best performing team. Furthermore, there is a consensus among all the four methods that Laboratory Technicians are the worst sub-group. Besides, for segment 4 (Table 2d) there are three subgroups involved. However, all the four methods agree that the Forklift Technicians are the best performing group. However, in addition, three other methods, namely WSM, WPM and WASPAS agree that the Battery Charger/Technicians' sub-group also tie-up as the best performing team. Besides, the PROMETHEE method disagrees with this view but proposes that the subgroup Battery Charger/Technicians is positioned third. Nonetheless, for the third position, the three methods of WSM, WPM and WASPAS picked the Welders subgroup as the worst-performing subgroup.

For segment 5 (Table 2a), only three methods, namely the WSM, WPM and WASPAS choose Supplier 3 as the best performing team but the PROMETHEE method disagrees with this suggestion by picking Supplier 3 as the worst-performing team and suggesting Security team as the best performing sub-group. Also, the three methods of WSM, WPM and WASPAS suggested the Security team as the worst sub-group. But given the majority of opinions, the present researchers concur with the suggestion by the majority of methods on this last issue.

3.2 Practical significance, contributions and advantages of the work

This paper examines the responsibility of the employee to keep to safety guidelines and enhance the safety status of the bottling plant by eliminating hazards that may potentially develop into accidents by obeying safety rules on machine guard usage and other associated safety rules. Violation of safety rules through the displacement of engine and machine covers is increasingly noticed in manufacturing plants of developing countries in the past few years. This often leads to accidents. Litigation and cost of an accident have therefore become disturbing and drives to stop this trend have been initiated. In the context of the highlights given on the safety problem in the bottling process plant, an efficient and rational method to the weaknesses and strengths of the worker is considered with the understanding that the management of the bottling plant is proactive in response to safety demands by the system. This paper indicates the limits of the present system of safety conformity in measurement to an extended form that introduces the optimization scheme while being influenced by the binomial distribution. It advocates for changes in mindset and attitudes toward safety conformity beyond complying with safety rules and guidelines in the presence of the superior to adhering to rules and guidelines all the time given the exigencies to avoid accidents. This study may assist process engineers to establish more effective safety plans.

Furthermore, this paper contributes to the safety conformity literature by:

- Emphasizing safety conformity parameters and attributes undecided in past studies, which could help researchers to enlarge their understanding of the appraisal parameters and the process of appraisal.
- Employing both binomial distribution and Taguchi scheme theories with the potentials to provide innovative analysis and improvement of the current conceptualization in examining safety conformity parameters.
- Ascertaining flaws on safety conformity prediction to accurately place new research interests.
- Featuring multi-criteria selection methods absent in prior research that will stimulate

researchers' insights on the selection parameters and the scheme of selection.
- Utilizing the theories of PROMETHEE, WSM, WPM and WASPAS with the potentials to offer pioneering analysis and enhancement of the current ideas in analysis safety conformity.

Besides, the following are the advantages of using the present proposed optimization and selection models.

- With binomial distribution, the probability of detecting the number of conforming cases or non-violation of safety rules as measurements are made over the work periods in a month is known as either conforming or non-conforming. This brings the advantage of clarity and the binomial distribution model should be incorporated into the optimization model for a clear state of performance of the factory workers.
- To optimize the safety conformity process parameters in a bottling process plant implies expecting enhanced efficiency. Thus, the results obtained from optimization may be the best that the safety conformity process could produce concerning the system's limitations. More so incorporating the Taguchi method into the binomial distribution brings about a synergy of the advantages from this list.
- An important benefit of the multi-criteria models is the ability to modify the parameters of interest.

3.3 Limitation of the study and future research

The present study shows that the binomial-motivated Taguchi method is an important approach to achieve the optimization of safety conformity in a bottling plant. A binomial distribution is assumed to guide the evaluation of the system. However, in some instances, the behavior of the system may not be according to the binomial function but normal behavior or exponential. Thus, it is felt that there are additional questions that should be answered as future research aspects of the work. First, is it possible to replace or combine the binomial aspect of the method with the normal distribution/exponential function and still optimize the method by adopting the Taguchi method? If this is successful, it is important to answer the question that what will be the outcome of a future study if the Taguchi method aspect is replaced with the Taguchi-Pareto method or the Taguchi-ABC method. Besides, some useful information may be obtained if the sensitivity analysis of some important method's parameters is done.

4. CONCLUSIONS

In this paper, a new approach to optimize safety conformity using the binomial enhanced Taguchi method was successfully utilised on bottling process data from a developing country. However, the procedure to optimization appears to differ from Poisson motivated Taguchi currently offered by researchers in the literature (Ajibade et al., 2019; Raji and Oke, 2019). The difference lies in the power of binomial distribution to assume discrete quantitative values in the computation of optimized values while Poisson is based on the probability that an event transpires in a known time and that each event is autonomous of every other event (Ajibade et al., 2019; Raji and Oke, 2019). Under a similar situation, the Poisson distribution behaved differently. In addition, for the first time, the non-operational technical activities for the bottling plant were optimized with the proposed model, revealing the competence of the procedure even to monitor activities that are to date loosely controlled. Such include the compliance of welders, forklift technicians and battery chargers, even security staff to safety guidelines laid down by the bottling plant management. In this work, the second objective was to prioritise the segments in the bottling plant and locate the best and most performing work, teams, using multicriteria analysis. The use of PROMETHEE, WSM, WPM and WASPAS reached a consensus on the outcome of performance for all the segments. The above methods were successfully utilised to treat the data from a bottling plant.

Research suggests that the best performing operations in the five segments of the bottling plant studied are the liberators (segment 1), technical operators and packer/unpacker operators (segment 2), Syrup lifters (segment 3), forklift technicians (segment 4) and Supplier 3 (segment 5). However, the worst and least performing operations in the respective five segments are organizers (segment 1), washer operators (segment 2), lab technicians (segment 3), welders (segment 4) and security and Supplier/(segment 5). There is evidence to suggest that non-operational technical activities can also be evaluated for the optimization of safety conformity; the binomial motivated Taguchi method is an effective tool to optimize both operational-related and non-operational based technical activities in a bottling process plant.

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