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Multi-Response Optimization of Safety Conformity using Taguchi Scheme in a Bottling Process Plant

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Previous research has examined safety conformity in process plants in terms of machine guarding guideline compliance behavior of operators. However, it is not clear how the safety conformity of workers in non-equipment related activities could be evaluated. This paper proposes a new Taguchi based method to optimize the safety conformity of workers in equipment and non-equipment related activities in a bottling process plant. The unique elements of the paper are the introduction of global and specific value determination mechanisms for the process. The validity of the procedure was ascertained by field data from a developing country. The results obtained revealed that the conformity of the work to safety procedures leads to a healthy state of operation in the industry. The study's outcome may benefit the safety manager in the organization by raising conformity awareness among workers and enhances safety budget planning with information obtained from the methodology.

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1. INTRODUCTION

Work-related fatalities are increasing day-by-day (Stout, Frommer & Harrison, 1990; Harrison, Mandryk & Frommer, 1993; Driscoll, Ansari, Harrison, Frommer & Ruck, 1995; Day, 1999; Mitchell, Driscoll & Healey, 2004; O'Connor and O'Connor, 2006; Holizki, McDonald & Gagnon, 2015; Pierce, 2016; Selman, Spickett, Jansz, Mullins,2018; Anderson, Rees & Tekin, 2018; Liang and Fung, 2019, McInnes, Cleland, Cameron, Darton & Gabbe, 2019; Meredith, Thomson, Ekman, Kovaceva & Bálint, 2019; Knights and Scanlan, 2019).

Every year, manufacturing industries record high levels of injuries, near misses and deaths due to unsatisfactory workplace situations (Nenonen, 2011; Kin and Chao, 2016; Altunkaynak, 2018; Oah, Na & Moon, 2018). These accidents and incidents are different from previous experiences because newer and inexperienced workers are getting more involved in mishaps. This predicament in the manufacturing sector demands groundbreaking solutions (Kin and Cho, 2016, Oah et al., 2018). Furthermore, anxiety is increasing in labour unions on the predicament faced by non-conforming members to workplace safety (Kin and Cho, 2016).

Noticeably, in bottling process plant's workplace, safety, the evaluation and optimization of safety conformity remain unsolved (Uzor and Oke, 2018). At present, it is unclear how to measure the conformity indices of workers in all the segments of the bottling plant (Kim and Cho, 2016). As a solution to this predicament, this paper deals with the identification and optimization of dominant factors of the various segments of a bottling process plant in the perspective of Taguchi methodical optimization of process factors.

The following is a brief review of the papers on the Taguchi method to identify gaps in the literature. Margavio, Fink & Margavio (1994) used the Taguchi method for a financial reward system while the following used it for production activities: Aravindan, Devadasan, Dharmendra. & Selladurai (1995), Kumar, Motwani & Otero (1996), Dowlatshahi (2004), Besseris (2008) and Ordoobadi (2009). Perona (1998) noted that Taguchi's quadratic loss function is superior to the traditional function of 'zero defect'. Antony et al. (2004) asserted that the Taguchi method helps to improve process quality at a much-reduced cost. Sukthomya et al. (2005) discussed the neural network Taguchi scheme and the traditional Taguchi scheme. Antony et al. (2006) studied the neuro-fuzzy model and Taguchi design of the experiment to eliminate the problem of uncertainty. Antony et al. (2006) worked on the ignition coil of an automobile engine using the Taguchi method.

Zeydan (2008) worked on the relationship between the parameters of fabrics, the yarn and the fibre using the Taguchi design of the experiment. Besseris (2009) used a non-parametric comparison test with Taguchi's orthogonal arrays in optimiztion. Abhishek et al. (2013) studied the simultaneous optimization of quality and productivity in the manufacturing industry. Kumar et al. (2013) used the Taguchi method in the casting industry. Periyanan et al. (2014) used Taguchi technique in the micro-WEDG process. Mondal (2016) applied the Taguchi method in a steam power plant. Chen et al. (2016) studied the binder jetting process using the Taguchi method to significantly improve it.

From the above discussion, the following important gaps in knowledge were revealed:

- Numerous studies exist on the manufacturing safety practices but analysis and optimization of safety conformity using Taguchi technique for bottling plants have been completely omitted in literature.
- From literature search, very limited studies relate to safety conformity beyond machine guarding issues in the bottling plant.
- The optimal parametric settings, global optimized values and specific global values of the segments were not documented elsewhere in the literature.

The review of the literature reveals that substantial scope exists to examine safety conformity along with the following concerns:

- Field study analysis on safety conformity when control charts are used in the positions of levels and the current factors for the segments is maintained.
- Workers' performance analysis on safety conformity when the factors are prioritized using Taguchi-ABC and Taguchi-Pareto for preference and direction on factors that require more financial resources than others.
- With limited safety conformity information in a bottling plant it appears that grey relational analysis may be helpful for evaluation.
- Safety conformity evaluation in a case where surrogate outputs are compared with inputs to obtain the productivity of the plant in safety activities both from the static and dynamic perspectives.
- Analysis and optimization of safety conformity where a combination of the above-mentioned techniques could be implemented (i.e. Taguchi-ABC and grey relational analysis, Taguchi-Pareto and X-bar and R-Chart techniques among others).

- Safety conformity audit evaluation and certification process that may be quantitatively motivated.

From the gaps identified in the review, it becomes clear that optimizing the safety conformity process parameters concerning all the segments of the bottling plant will be of advantage to both workers and the management as improved productivity and drastically lessened accidents and liability claims could result. Furthermore, it will enhance the quality of safety decision making in budgetary practices and implementation in the manufacturing plants. This will help in achieving the full potentials of the organization is possible. By developing a qualitative tool as a guideline toward safety conformity evaluation and optimization, safety managers may follow an effective way to reduce accidents thereby promoting workers" confidence and wiping out fear at work.

2. MATERIALS AND METHODS

2.1 Materials

The materials used for this work are the conformity form, handy and movable form placement board, clock and pencils. The conformity form was prepared to contain the following elements; the name of company segment name, name of equipment studied, machine guard or facility description, activities, time of observation, option box for compliance and non-compliance to be ticked, remark column, name of workers. The clock is a simple handy clock for monitoring time at which observations are made. The pencil, the clock and the board were obtained from the local market while the conformity form was developed from a computer workstation. The handy placement board is of the size of an A4 paper which is 8.5 inches by 11 inches and the material could be plastic or plywood and it may or may not be painted.

In this paper, two key of software were used to compute, namely, Microsoft Excel and the Minitab. With Microsoft Excel, the researchers were able to classify, design and compute the safety conformity data with the application of the spreadsheet facility. For instance, the signal-to-noise ratios were set on the spreadsheet and the final value determined based on the particular ratio chosen. However, the Minitab was used to derive an orthogonal array from the combination of factors and levels that were found most important for the safety conformity problem. The ease of usage, minimal skill and training requirement are the attributes of the Minitab software that provided the most attraction to the authors.

2.2 Method

The Taguchi method was applied in this work and the following steps were adopted (Figure 1). There are 3 signal-to-noise ratios that are commonly used in Taguchi method:

1. Smaller the better,

$$S/N(\eta) = -10\log\frac{1}{n}\sum_{i=1}^{n}y^2 \quad (1)$$

2. Larger the better,

$$S/N(\eta) = -10\log\frac{1}{n}\sum_{i=1}^{n}\frac{1}{y^2} \quad (2)$$

3. Nominal the best,

$$S/N(\eta) = -10\log\ (\text{square of mean})/\text{variance} \quad (3)$$

For this work, we will make use of 'larger the better' as it has to do with conformity index. Here, the steps to be followed in the use of the Taguchi method to establish the conformity index of the workers in a bottling follow the elaborated (Fig. 1). An aligned orthogonal array was specified and experiments were conducted, which follows the computation made for the signal-to-noise quotient. The orthogonal arrays are novel tools to carry out the design of experiments rooted in properly oriented ideas that comprise of a special group of arrays. The way to carry out the least possible rounds of experiments that may yield comprehensive information for all the factors that impact on the accomplishment parameter is offered by the standard arrays.

In the orthogonal approach, establishing the combination of levels of the input factors is the pillar of the approach.

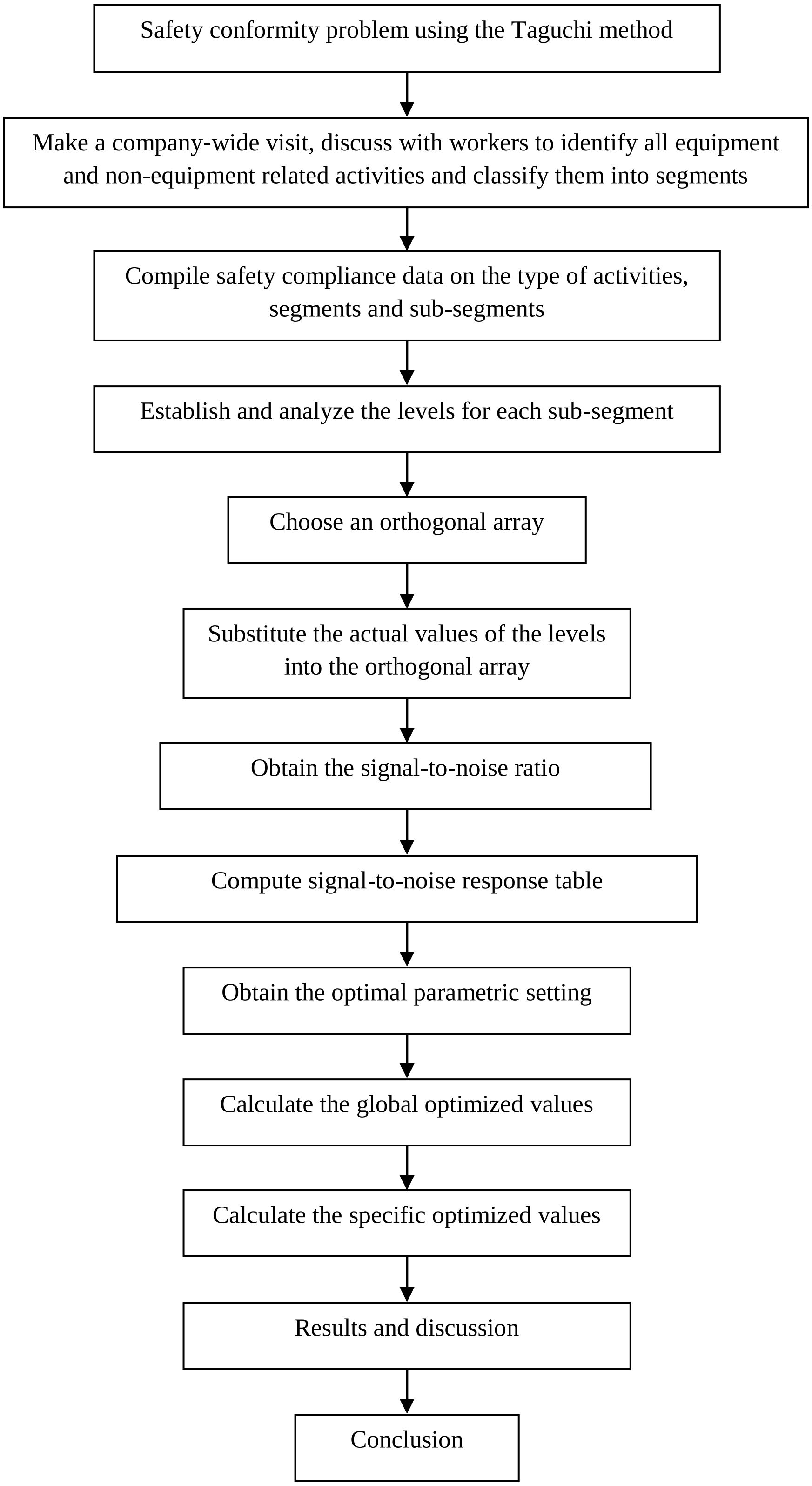

Fig. 1. Research scheme to obtain results for the Taguchi method

Such factors, for instance are the forklift drivers, organizers, rescuer, and syrup handlers, for the stockroom segment and each experiment is considered. The classical Taguchi method is known to avoid non-essential tasks. To attain the goal of this study of conformity problem, the potential of Taguchi method is exploited to the utmost in the creation of tests necessary following the application of the principles embedded in signal-to-noise quotient, response table arising from signal-to-noise quotient, orthogonal matrix, levels, factors, optimal parametric setting, specific optimized values and global optimized values, as highlighted in the current paper. Taguchi method is acclaimed to be innovative at substantially limiting the experimental data to a comfortable span. An important advantage of the Taguchi method is that it does not require specialized training or particular skill sets. This is an attribute that makes the method comparatively interesting weighed against competing methods.

3. RESULTS AND DISCUSSION

The bottling process plant engages an uninterrupted flow of the beverage products in a product-oriented approach, based on quality and feature standards, for high volume production in low diversity of brands. The plant does not produce bottles but is supplied in bulk by a manufacturer that translates pre-form tubes into bottles by passing them through equipment, which blows the plastic pre-form tubes into bottles in milliseconds. The manufactured bottles are delivered to the plant to be made up of used bottles from consumers. The used bottles undergo inspection to verify the absence of faults or defects and then washed and rinsed with caustic soda and water to ascertain that they are clean and ready to be filled with the beverage. The beverage is made of concentrate and a sweetener that is mixed into a syrup form. The water that mixes the concentrate undergoes treatment where a dedicated staff tests the hardness, its PH and filters it through specialized facilities to ascertain that it is delivered pure to the concentrate/sweetener mixing section.

Both the manufactured bottles and the washed ones obtained from the consumers are transported to the filling machine where they are filled with beverages and then transported in sealing by closure process. Bottles are subjected to a carbonator and cooling where carbon dioxide that preserves the beverage is added and the product brought out chilled. Afterwards, the bottles are labelled and dated using laser technology. They are passed as satisfactory through an inspection process that rejects filled bottles lower than the necessary level and accepts those filled above the necessary marks. They are put in cases for onward delivery to the warehouse. Data were obtained from all segments in a bottling company to obtain the conformity index of the workers in the industry in adherence to safety rule as it relates to the mechanical equipment. The results of the optimization of the safety conformity parameters of workers in a manufacturing company using Taguchi method follow. Conformity was measured along with the line of the worker adhering to the guidelines for the use and operations of mechanical equipment in the bottling industry. The data gathered on the worker's safety conformity spans for twelve months for both equipment and non-equipment activities.

In this paper, the production company studied is concerned with the packaging and bottling of beverages. This is aided with the mechanical equipment in the bottling lines. This unit is referred to engage in equipment-based activities. The water treatment plant that purifies and supply water to the bottling lines uses a set of mechanical-driven equipment and are associated with the production activities. Hence, it engages in equipment-related activities according to the classification adopted here. However, the case is different when the equipment used does not relate to the core mandate of the bottling plant, such as lifts and hoists, dedicated auto parts tools, diagnostic and welding equipment for the shuttle vehicle flotilla workshop. Also in the security unit, digital camera, and flashlights are used. In the kitchen, blenders are used. Thus, the activities are non-equipment related, implying that the facilities used are not related to the core mandate of the business but only services to make the company work more efficiently.

Thus, conformity of non-equipment activities was evaluated from the perspective of adhering to safety standards on the use of non-production related equipment and tools within the workshop, and among the suppliers. In the workshop, the key workers are the forklift technicians, battery technicians and welders. However, the suppliers are grouped as the kitchen workers, security personnel and contractors. At present, most of the literature regarding safety conformity is limited to the production equipment but the intricate safety-related issues for kitchen activities are ignored. Yet if accidents occur, serious litigation costs may be incurred by the company as liability for injuries of kitchen workers. For instance, consider the kitchen safety, which is briefly illustrated. While cooking, it is expected that the worker ensures that the saucepan handles do not stick out to prevent being knocked off the stove. The saucepan handles are hazards that could be eliminated by correct placements on the stove. A second safety precaution is to prevent the worker from wearing loose clothing in the kitchen as they could catch fire easily.

The supplier sub-segment consists of security, kitchen and suppliers. These are service providers to the organization. The security unit in the beverage plant engages in diverse services, including security guard services, patrolling services, provision and implementation of surveillance services and crisis management. Each of these services has hazardous activities that should be controlled and eliminated if safety standards are conformed with. The kitchen unit in the beverage plant has the responsibility to cook food, prepare and store it, including dishwashing. Kitchen related activities of carrying items and preparing food, for instance, have hazards that should be controlled. Contractors may be suppliers of safety-related kits. While delivering the goods to the company, safety rules concerning vehicle driving and packing of vehicles need to be adhered to. If suppliers adhere to the safety practices of the organization hosting them then they will have higher productivity, the cost will be minimal and the workers will be safe.

Since for the five segments a total of twenty-nine sub-segments exist, there should be a total of three hundred and forty-eight data points in all. However, on summarizing values for each level, every repeated value is taken as a level. Consequently, the number of levels for each sub-segment may vary from one segment to another. In the collected data, the first sub-segment in the stockroom segment, which is forklift drivers has 100% conformity index for all the months except the six months where the performance was 92.31%. Here, the value 100% for each of the eleven months will be a level representation while 92.31% will be the second level representation. Hence, the forklift driver has two levels, 1 and 2 is 100% and 92.31%, respectively. Other segments and sub-segments are computed similarly and the results are shown in Table 1. It is noticed that for some sub-segments (factors) there is only one label of performance. It means that for all the twelve months that the data was collected, the sub-segment (factor) concerned showed an equal level of performance. If the team complied with safety guidelines in all the twelve months, a 100% performance for each month is the result. Since there is no variation in results only one label (level) will be shown.

Table 1. Factors (sub-segments)-levels arrangement

Segments	Level 1	Level 2	Level 3
Stockroom			
Forklift drivers	100.00	92.31	-
Organizers	75.00	-	-
Rescuers	100.00	-	-
Syrup handlers	100.00	75.00	-
Transport drivers	91.30	100.00	86.96

Table 1. Factors (sub-segments)-levels arrangement (continued)

Segments	Level 1	Level 2	Level 3
Stockroom (cont'd)			
Transport truck mates	95.45	90.91	-
Chip neck removers	100.00	80.00	-
Extra bottle removers	100.00	66.67	-
Manufacturing hallway			
Viewers	100.00	87.50	-
Filler operators	100.00	80.00	-
Palletizers/Depalletizers	83.33	100.00	-
Washer operators	100.00	50.00	-
Chip neck removers	100.00	87.50	-
Technical operators	100.00	-	-
Packers/unpackers	100.00	-	-
Beverage testing unit			
Syrup lifters	100.00	-	-
Syrup mixers	100.00	50.00	62.50
Laboratory technicians	83.33	100.00	-
Water technicians	100.00	50.00	-
Electrical technicians	100.00	50.00	-
Others	94.12	100.00	-
Shuttle vehicle flotilla workshop			
Forklift technicians	100.00	-	-
Welders	100.00	0.00	-
Electric battery technicians	100.00	-	-
Suppliers			
Security	100.00	86.36	95.45
Kitchen	100.00	91.67	-
Supplier 1	92.86	100.00	-
Supplier 2	100.00	86.96	-
Supplier 3	100.00	-	-

The data was collected for 12 months to obtain reliable results (Tables 1 and 2). The 'factors/operations' were key in the determination of the specific optimized value. The operations of each factor determined the conformity index of the whole segment. For example, in segments 4, all factors had 100% conformity for all 12 months except 'welders'. This led to segment 4 being the segment with the highest specific optimized value. Conformity to safety procedures was observed in segments 2 and segment 4, both at 50%, to be the highest when compared with other segments in the industry. The segment with the least compliance to safety procedure is segments 5 (25.69%), followed closely by segment 3 (38.78%). The following summarises the orthogonal arrays used in the computation of the safety conformity indices (Table 2).

Table 2. Orthogonal arrays by segment

Segments	Orthogonal array
Stockroom	L54(3**7)
Manufacturing hallway	L32(2**7)
Beverage testing unit	L27(3**6)
Shuttle vehicle flotilla workshop	L32(2**3)
Suppliers	L27(3**5)

Signal-to-noise ratio was applied as an objective function to pick out the factors that are most important (Tables 4 to 8). The comparison was done between the signal-to-noise ratios of each factor of the segments to determine which has a higher conformity index. The average signal-to-noise (ASN) ratio of each segment was compared with all other segments. It was found that the ASN ratio was the highest in segments 5 (41.97%), followed by segment 1 (40.64%), and segment 4 (40.08%). The segment with the least ASN ratio is segment 3 (38.09%), followed by segment 2 (39.31%). 'Water Technicians' has the least ASN ratio in the bottling plant (38.69%) as the ASN ratio for level 1, 2 and 3, followed closely by 'Electrical Technicians', (38.70%). The factors with utmost ASN ratio for each segment are, forklift technicians and electric battery technicians for segment 4(45.08%), security for segment 5, forklift drivers and transport drivers for segment 1 (40.84%), viewers, filler operator, palletizers/depalletizer, washer operators and chip neck removal for segment 2 (39.38%) and syrup mixers for segment 3 (39.22%). The ASN ratio of workers in segment 1 is higher than segment 2, by 1.33%. The ASN ratio of workers in segment 1 compared to segment 3, is higher by 1.65%. When compared with segment 4, the ASN ratio of segment 1, was found to be higher by 0.56%. Comparing segment 1, with segment 5 revealed that the ASN ratio of segment 1 was lower with about 1.33% than that of segment 1. Comparing segment 2 and segment 3, revealed the ASN ratio of workers in segment 2 is higher with 0.32% than the ASN ratio of workers in segment 3. When compared with segment 4, the ASN ratio of workers in segment 2, was found to be lower by a percentage decrease of 0.78% than that of segment 4. The ASN ratio of workers in segment 2, is lower, compared to segment 5 by 2.66%. The ASN ratio of the workers in segment 3, beverage testing unit, when compared to segment 4, was found to be lower by 1.09%. The same comparison was done between segment 3, and segment 5 and it was discovered that segment 3, had a lower ASN ratio of 2.98% to segment 5. The ASN ratio of workers in segment 4, when compared to segment 5 showed that segment 4, is lower by about 1.89%. The signal-to-noise response table reveals the factors with the highest signal-to-noise ratio for each level (Table 3).

Table 3. Segments with S/N(η)

S/N	Segment 1	Segment 2	Segment 3	Segment 4	Segment 5
1	39.45	39.74	39.61	43.01	40.66
2	39.45	40.16	38.03	43.01	41.59
3	39.45	38.70	41.31	43.01	41.59
4	38.79	39.03	36.94	43.01	40.37
5	38.79	41.46	36.02	44.77	41.24
6	38.79	41.20	37.78	44.77	41.24
7	42.90	38.91	40.23	44.77	44.77
8	42.90	38.32	38.46	44.77	47.78
9	42.90	40.67	42.27	44.77	47.78
10	41.86	39.81	41.76	44.77	41.41
11	41.86	38.45	40.00	44.77	42.54
12	41.86	37.92	42.83	44.77	42.54
13	41.18	39.66	39.33	47.78	41.22
14	41.18	40.08	38.24	47.78	42.30
15	41.18	38.65	39.91	47.78	42.30
16	40.51	38.97	37.78	47.78	40.95
17	40.51	40.86	36.99	44.77	41.96
18	40.51	39.97	38.18	44.77	41.96
19	40.88	38.56	40.00	44.77	41.33
20	40.88	38.02	37.73	44.77	42.44
21	40.88	39.81	40.00	47.78	42.44
22	42.91	40.25	39.69	47.78	41.30

Table 3. Segments with S/N(η) (continued)

S/N	Segment 1	Segment 2	Segment 3	Segment 4	Segment 5
23	42.91	38.76	37.54	47.78	42.41
24	42.91	39.10	39.69	47.78	42.41
25	40.12	39.26	40.33	47.78	41.66
26	40.12	39.63	37.92	47.78	42.87
27	40.12	38.32	40.33	47.78	42.87
28	39.47	38.62	-	47.78	-
29	39.47	40.77	-	0.00	-
30	39.47	39.89	-	0.00	-
31	40.34	38.51	-	0.00	-
32	40.34	37.97	-	0.00	-
33	40.34	-	-	-	-
34	40.10	-	-	-	-
35	40.10	-	-	-	-
36	40.10	-	-	-	-
37	39.68	-	-	-	-
38	39.68	-	-	-	-
39	39.68	-	-	-	-
40	42.42	-	-	-	-
41	42.42	-	-	-	-
42	42.42	-	-	-	-
43	41.44	-	-	-	-
44	41.44	-	-	-	-
45	41.44	-	-	-	-
46	40.95	-	-	-	-
47	40.95	-	-	-	-
48	40.95	-	-	-	-
49	41.14	-	-	-	-
50	41.14	-	-	-	-
51	41.14	-	-	-	-
52	41.00	-	-	-	-
53	41.00	-	-	-	-
54	41.00	-	-	-	-

The results obtained from the calculation of the signal-to-noise ratio for all segments. To obtain the signal-to-noise response table, the average of the signal-to-noise ratio for levels 1, 2 and 3 respectively for each of the factors in the segment is calculated and tabulated (Table 4). It contains the highest value obtained from the signal-to-noise response table for each level. The normalization of the Optimal Parametric Setting (Table 5) is known as the Global Optimized Value (Table 6).

Table 4a. Signal-to-noise response table (Segment 1)

Level	Forklift Drivers	Organizers	Rescuer	Syrup Handlers	Transport Drivers	Transport Truck Mates	Chip Neck Remover	Extra Bottle Remover
1	40.96	40.17	40.38	40.73	40.77	40.63	40.70	40.91
2	40.73	-	-	40.27	41.01	40.61	40.45	40.06
3	-	-	-	-	40.75	-	-	-

Table 4b. Signal-to-noise response table (Segment 2)

Level	Organizers	Filler operator	Palletizers/ Depalletizer	Washer operators	Chip neck removers	Technical operators/ Utilities	Packer/ Unpacker operator
1	39.48	39.55	39.23	40.20	39.44	39.08	39.12
2	39.27	39.20	39.52	38.55	39.31	-	-

Table 4c. Signal-to-noise response table (Segment 3)

Level	Syrup Lifters	Syrup Mixers	Lab Technicians	Water Technicians	Electrical Technicians	Others
1	38.96	40.14	38.76	39.44	39.52	38.99
2	-	38.35	39.32	37.94	37.88	39.05
3	-	39.16	-	-	-	-

Table 4d. Signal-to-noise response table (Segment 4)

Level	Forklift Technicians	Welders	Electric battery technicians
1	45.08	45.08	45.08
2	-	35.08	-
3	-	-	-

Table 4e. Signal-to-noise response table (Segment 5)

Level	Security	Kitchen	Supplier 1	Supplier 2	Supplier 3
1	43.00	41.84	41.65	41.90	41.52
2	41.91	41.64	41.86	41.55	-
3	42.19	-	-	-	-

Table 5. Optimal parametric settings

Segment → Level ↓	1	2	3	4	5
1	A_1F_1 = 40.96	A_1WO =40.20	A_1SM=40.14	Same	A_1S = 43.00
2	A_2HT = 40.61	A_2PD =39.52	A_2LT =39.32	A_2W = 35.08	A_2S = 41.91
3	A_3HD =40.75	-	A_3SM =39.16	-	A_3S = 42.19

Table 6. Global optimized value

Segment → Level ↓	1	2	3	4	5
1	1	1	1	1	1
2	0	0	0.1633	0	0
3	0.4	-	0	-	0.2569

η = (Current level – Minimum level)/ (Maximum level – Minimum level)

The average is calculated for the Global Optimized Value to get the Specific Optimized Value. The optimal parametric settings were derived from the corresponding signal-to-noise ratio (Table 5). They were then used to obtain the global optimized value using normalization method. Similar to studies on tapped density optimization (Ajibade et al., 2016), tensile property optimization (Ajibade et al., 2019), cast geometry optimization (Nwafor et al., 2019) and downtime optimization (Raji and Oke, 2019), the outcome of this research indicates that irrespective of the system considered, once the parameters are specified, the factors and levels, and orthogonal array defined, the optimal level could be determined and is often the highest value in the instance of maximizing a positive effect and the lowest when a negative influence is considered. Out of the eight factors in segment 1, the optimal parametric settings are forklift driver, at 40.96, transport truck mates at 40.61 and transport driver at 40.75 for levels 1, 2 and 3, respectively.

This finding is consistent with Uzor and Oke's (2018) study that the highest threshold of compliance for operators in the use of machine guards occurred during the 3rd, 1st, 1st and 23rd trials in four scenarios, with values of 275, 272, 269 and 269, respectively. The pattern of behavior here is consistent with all the other four segments analysed subsequently in this section. The two sets of results (Uzor and Oke (2018) and the current paper) are as expected. However, an additional approach to the evaluation of segments was the specific optimized value, which was obtained as 46.67% for segment 1. This value is the expectation of the worker in segment 1 if the anticipated productivity and efficiency of the safety conformity issue is to be guaranteed.

Of the seven factors in segment 2, the optimal parameter settings are washer operator at 40.20 and palletizer/depalletizer at 39.52 for level 1 and level 2 respectively. These optimal levels for each factor are to achieve the best productivity in the plant. The specific optimized value is 0.5. Segment 3 reveals the optimal parametric setting for syrup mixers at 40.14, others at 39.05 and syrup mixers at 39.16 at level 1, 2 and 3 respectively. The specific optimized value is 0.3878. Segment 4 consist of three factors namely, forklift technicians, welders and electric battery technicians, these factors are grouped into two levels with all the factors having the same levels of parametric settings of level 1 at 45.08 and level 2, at 35.08. The specific optimized value is found to be 0.5. In segment 5, the factor with the most optimal parametric setting for level 1, 2 and 3 is security at 43.00, 41.91 and 42.19 respectively. The specific optimized value for the segment, suppliers is 0.2569. For the optimization process of the factors in the segments, using Taguchi method, three signal-to-noise ratios are generally used, and in this study, 'Larger the better' was used because the increase in the conformity index of the worker leads to higher productivity in the industry. Segment 2, and segment 4, have the highest value for specific optimal value.

The average of the global optimized value was taken to derive the specific optimized value (SOV) (Table 6). This is the least value in which there can be a healthy state of operation in the plant. The SOV of workers in segment 1 is lower compared to segment 2, unlike the ASN ratio, with 0.033%. The SOV of workers in segment 1, compared to segment 3, is higher with about 0.0789%, just like in the case of the ASN ratio. When compared with segment 4, the SOV of segment 1, was found to be lower with 0.033, unlike in the case of the ASN ratio. Comparing segment 1, with segment 5 revealed that the SOV of segment 5 was higher with about 0.2098 than that of segment 1. Comparing segment 2 and segment 3, revealed the SOV of workers in segment 2 lower with 0.1122 than the SOV of workers in segment 3. When compared with segment 4, the SOV of workers in segment 2, was found to be exactly same as that of segment 4, which is 0.5. The SOV of workers in segment 2, is higher, compared to segment 5 with 0.2431. The SOV of the workers in segment 3, when compared to segment 4, was found to be lower with 0.1122. The same comparison was done between segment 3, and segment 5 and it was discovered that segment 3, had a higher SOV of 0.1309 to segment 5. The SOV of workers in segment 4, when compared to segment 5 showed that segment 4, when compared to suppliers is higher with about 0.2431.

In the current research, the classical Taguchi method is built to understand that the optimization process yielded positive results. This means that the conformity of the workers to safety procedure leads to a healthy state of operation in the industry. Optimization to safety procedure was discovered to yield positive results. This concurs with previous work by Ajibade et al. (2019), which also optimized some desired properties of a system and a feasible outcome was obtained. The individual factors were found to play an important role as they are responsible for the compliance to safety procedure and guidelines in each segment. This suggests that the factors are the key in each segment and they may play a crucial function to maintain a healthy operating environment for the bottling plant.

3.1 Interpretation of the Taguchi analysis

To interpret the results of Taguchi analysis, the analysis of variance (ANOVA) was conducted to establish whether the factors are significantly related to the response data and state each factor's relative importance in the model. The *p*-values are often used to judge the relevance or otherwise of the factors to the response data. Often *p*-values of less than 0.05 that associated with particular factors are taken to be significant. In this work, a 95% level of significance has been assumed, which motivates the researchers to accept *p*-values less than 0.05 to reflect significant factors. In this respect, for the stockroom, which consists of eight factors, the significant ones are forklift drivers, transport driver, transport truck mate, chip reck removers and extra bottle removers. For the manufacturing hallway, the significant factors are viewers, forklift operators, chip neck removers. For beverage testing unit, the significant factors are laboratory technician, water technicians, electrical technicians and others. For the shuttle vehicle flotilla workshop, there is no factor with *p*-values less than 0.05 and hence, all the factors are not significant. For suppliers, the significant factors are security, kitchen, supplier 1 and supplier 2.

Another aspect of this analysis is to determine each factor's relative importance in the model. This is an approach by considering the magnitude of the values. It thought that the least values among the factors represent the factors that have the most relative importance in the model. However, factors having the highest magnitude of values have the least importance in the model. Consequently, each segment is judged as follows. For the stockroom, the most and least important factors to the model are extra bottle removers and transport truck mates, respectively. For the manufacturing hallway, the most and least important factors are forklift operators while the viewers and chip neck removers tie-up as the least important factors. For beverage testing unit, water technician and other as the most and least factors, respectively. In shuttle vehicle flotilla workshop, there is neither the most nor the least important factor in the model. For the supplier, the most and least impotent factors are supplier 2 and supplier 1, respectively.

For the stockroom, an adjusted R^2 of 1, which is 100% was obtained. This is greater than the acceptable level of 65%. Thus, the assertions concerning factors given earlier could be accepted. For the manufacturing hallway, the adjusted R^2 is 80%, which is greater than 65%. Hence, our assertion on the relevant factors made earlier is acceptable. For beverage testing unit, the adjusted R^2 is 100%, which is greater than 65%, the acceptable value. It makes our earlier assertion correct. For the shuttle vehicle flotilla workshop, the adjusted R^2 is 100%, which is greater than 65%, a limit of acceptance. It makes our chain made earlier acceptable. For suppliers, the adjusted R^2 is 100%, which is greater than 65% and makes our assertion earlier stated correct.

It was interesting to find out which of the segments has the greatest impaction on the bottling production process. To achieve this, the researchers deployed the sum of squares (total) to differentiate the contributions of each segment to the bottling plant. To the surprise of the authors, the shuttle vehicle flotilla workshop is the segment of the bottling plant with the greatest impact on the system. This was based on the following sum of squares (total): stockroom (0,0032), manufacturing hallway (0.0032), shuttle vehicle flotilla workshop (0.1019) and suppliers (0.0029).

Furthermore, the researchers' interest was drawn to the sum of square (SS) values for factors as the factor with the biggest sum of squares has the greatest impact. Consequently, when the stockroom was observed for the SS, forklift drivers with the highest value of 11.92 was the most impactful factor. This suggestion is confirmed by the earlier result that places the forklift driver as a significant factor in the segment. By considering the manufacturing hallway, the viewers and chip neck removers had a tie in performance as the most impactful factors. However, contrary to the results obtained earlier, only the chip neck removers were captured as an impactful factor while viewers were excluded. For the beverage testing unit, the SS from the ANOVA, syrup lifters has the highest SS of 12 and the most impactful factor in the segment. Matched against the previous results, surprisingly syrup lifters were excluded from the list of impactful factors within the beverage testing unit. For the shuttle vehicle flotilla workshop, there is a tie in performance between forklift technicians and battery charger/technicians as the most impactful factors within the workshop segment. But to our surprise, for the previous results, these factors were counted as not significant. For the suppliers, the kitchen with an SS value of 11.83 is the most impactful factor in the group. Interestingly, it was chosen as a significant factor according to our earlier decision.

Another set of results is the optimum factor combination which entails all the segments. For the stockroom, the optimal factor combinations are as follows:

- $FD_1S_3R_3SH_3HD_1HTM_1CNR_1EBR_1$
- $FD_1S_3R_3SH_3HD_1HTM_1CNR_1EBR_2$
- $FD_1S_3R_3SH_3HD_1HTM_1CNR_1EBR_3$
- $FD_1S_3R_3SH_3HD_2HTM_2CNR_2EBR_2$
- $FD_1S_3R_3SH_3HD_2HTM_2CNR_2EBR_3$
- $FD_1S_3R_3SH_3HD_2HTM_2CNR_2EBR_1$
- $FD_1S_3R_3SH_3HD_3HTM_3CNR_3EBR_3$
- $FD_1S_3R_3SH_3HD_3HTM_3CNR_3EBR_2$
- $FD_1S_3R_3SH_3HD_3HTM_3CNR_3EBR_1$

Here, FD is for forklift drivers, S means sorters, R means rescuers, SH means syrup handles, HD stands for transport drivers, HTM is used for transport truck mates, CNR is used for chip neck removers while EBR is the extra bottle removers. For the manufacturing hallway, the optimal factor combination is:

$V_1FO_3PD_3WO_3CNR_3TOU_3PUO_3$

where, viewers, filler operators, palletizers/depalletizers, washer operators, chip neck removers, technical operators, and packers/unpackers are represented by V, FO, PD, WO, CNR, TOU and PUO, respectively. For the beverage testing unit, the optimal factor combination is:

$SL_3SM_1LT_3WT_2ETPT_1O_3$

where, syrup lifters, syrup mixers, laboratory technicians, water technicians, electrical technicians and others are represented as SL, SM, LT, WT, ETPT, O, respectively. For the shuttle vehicle flotilla workshop, the optimal factor combination is:

$FT_2W_1BCT_1$

where, forklift technicians, welders and electric battery technicians are presented as FT, W and BCT, respectively. However, for the suppliers, the optimal factor combination is:

$S_1K_3S1_3S2_3S3_1$

where, security, kitchen, supplier 1, supplier 2 and supplier 3 are represented by S, K, S1, S2 and S3, respectively.

In conclusion, through the optimization using Taguchi method, it was established that some factors such as forklift drivers and transport drivers (segment 1), viewers, filler operator, palletizers/depalletizer, washer operators and chip neck removers (segment 2), syrup lifters and technicians (segment 3), forklift technicians and electric battery technicians (segment 4) and security (segment 5), are more important for the effectiveness for the safety conformity issue. The study has dealt with the bottling process plant however the food industry which is the umbrella under which the bottling plant is will be the aim of forthcoming research.

In Uzor and Oke (2018), the safety conformity was conceived only as of the adherence to guidelines on machine guarding only for the manufacturing hallway. The model breaks down when applied to all segments that are not directly involved with the bottling production activities. To solve this problem, the current paper offered a universal model in the plant. Simple metrics of evaluating the global parametric and the specific parametric values for all the factors in the segments are presented. This research proposes a Taguchi optimization technique by arguing that quantified responses of a bottling process plant are inclusive of activities in warehousing, shuttle vehicle flotilla, beverage testing unit, contracting beyond the manufacturing hallway, which has been considered in research till date. This study, therefore, offers a unique contribution to safety at the workplace by advancing our understanding on how decision-making could be enhanced based on the computed values of optimal parametric setting, specific and global optimized values of safety conformity in a bottling process plant.

This paper is in the area of quantitative studies where it is known that the greater the number of participants engaged in the sample surveyed, the more reliable the results of the study may be for generalization. However, in generalization, it is required to have a sample size and a population, which are often different. So, generalizability needs a previous establishment of the population that will be represented and which restricts the generalization to the particular population. Contrary to the above, the sample size and the population for the team members, representing the parameters/factors as well as the number of factors representing a segment in the practical instance studied is the same. So, the design of the evaluation scheme for the team is such that all the team members are assessed at once. The deficiency in any team member’s performance affects the whole team, considered as factors/parameters of the segment. So, the issue of generalization of the findings does not exist but the model may be generalized since it is a unique work on its own.

The uniqueness of the work is that previous conformity studies were directed by earlier researchers to equipment-related activities such as the use of machine guards for machines in a production-oriented environment. The focus on equipment has been noticed in the literature for more than five decades. However, as a challenger to the conventional approach, this paper presents a variance idea that compels safety managers to evaluate the non-equipment activities in addition to equipment-oriented activities. This is the novelty of the present study.

4. CONCLUSION

This paper deals with how to optimize safety conformity of segments within a bottling process plant in operative and non-operative positions. A framework is implemented for a plant in a developing country to validate the approach. The presented approach outweighs the current approach by Uzor and Oke (2018) by incorporating non-operative aspects of the work. In the mechanical equipment industry, the generally known practice is to monitor the operators of mechanical equipment such as the glass bottle washer in the bottling plant. Hazards are eliminated from the work environment of the bottle washer and the chief concern of the safety engineer is to ensure compliance of the operator to guidelines on the use of personal protective equipment and machining guards. In general, no concern is shown beyond this domain by the safety manager. Accidents happen outside the factory floor when forklift drivers at speed collide with each other or other moving vehicles or persons. It is known that whether accidents happen while working at the factory floor or in non-equipment activities liability costs will be incurred by the company upon any accident occurrence.

So, the novelty of this article is the expanded scope of treatment of safety conformity that exceeds the traditional scope of machine guarding monitoring and compliance with the safety rules to non-equipment activities such as activities in the stockroom, outside the manufacturing hallway. Furthermore, part of the novel elements of the paper is the new measures consisting of global and specific optimal values were evaluated and verified. Positive results were obtained from the optimization process, which means that safety conformity of workers was healthy in the plant. The results of this work may be advantageous to the bottling process plant by potentially raising consciousness among the workers who are not operating production equipment. These workers will be aware that they are evaluated and this could lead to their commendation or reprimand. With continuous negative performance, they should be aware that their services may no more be needed as their performance falls below the required company's standard. Thus, the awareness may result in the enhancement of workplace safety conformity and the prevention of errors and mishaps through the development or enhancement of strategies, guidelines and workers' training in the bottling process plant.

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Appendix 1: Details of Table 3

Segment 1 (Stockroom) L54(3**7) Orthogonal Array

S/N	Forklift drivers	Organizers	Rescuers	Syrup handlers	Transport drivers	Transport truck mates	Chip neck removers	Extra bottle removers	1/Y^2	MSRD	S/N(η)
1	100.00	75.00	100.00	100.00	91.30	95.45	100.00	100.00	0.000908	1.13E-04	39.45
2	100.00	75.00	100.00	100.00	91.30	95.45	100.00	100.00	0.000908	1.13E-04	39.45
3	100.00	75.00	100.00	100.00	91.30	95.45	100.00	100.00	0.000908	1.13E-04	39.45
4	100.00	75.00	-	75.00	100.00	90.91	80.00	66.67	0.001058	1.32E-04	38.79
5	100.00	75.00	-	75.00	100.00	90.91	80.00	66.67	0.001058	1.32E-04	38.79
6	100.00	75.00	-	75.00	100.00	90.91	80.00	66.67	0.001058	1.32E-04	38.79
7	100.00	75.00	-	-	86.96	-	-	-	0.00041	5.13E-05	42.90
8	100.00	75.00	-	-	86.96	-	-	-	0.00041	5.13E-05	42.90
9	100.00	75.00	-	-	86.96	-	-	-	0.00041	5.13E-05	42.90
10	100.00	-	100.00	100.00	100.00	90.91	-	-	0.000521	6.51E-05	41.86
11	100.00	-	100.00	100.00	100.00	90.91	-	-	0.000521	6.51E-05	41.86
12	100.00	-	100.00	100.00	100.00	90.91	-	-	0.000521	6.51E-05	41.86
13	100.00	-	-	75.00	86.96	-	100.00	100.00	0.00061	7.63E-05	41.18
14	100.00	-	-	75.00	86.96	-	100.00	100.00	0.00061	7.63E-05	41.18
15	100.00	-	-	75.00	86.96	-	100.00	100.00	0.00061	7.63E-05	41.18
16	100.00	-	-	-	91.30	95.45	80.00	66.67	0.000711	8.89E-05	40.51
17	100.00	-	-	-	91.30	95.45	80.00	66.67	0.000711	8.89E-05	40.51
18	100.00	-	-	-	91.30	95.45	80.00	66.67	0.000711	8.89E-05	40.51
19	100.00	-	100.00	75.00	91.30	-	80.00	-	0.000654	8.17E-05	40.88
20	100.00	-	100.00	75.00	91.30	-	80.00	-	0.000654	8.17E-05	40.88
21	100.00	-	100.00	75.00	91.30	-	80.00	-	0.000654	8.17E-05	40.88
22	100.00	-	-	-	100.00	95.45	-	100.00	0.00041	5.12E-05	42.91
23	100.00	-	-	-	100.00	95.45	-	100.00	0.00041	5.12E-05	42.91
24	100.00	-	-	-	100.00	95.45	-	100.00	0.00041	5.12E-05	42.91
25	100.00	-	-	100.00	86.96	90.91	100.00	66.67	0.000778	9.73E-05	40.12
26	100.00	-	-	100.00	86.96	90.91	100.00	66.67	0.000778	9.73E-05	40.12
27	100.00	-	-	100.00	86.96	90.91	100.00	66.67	0.000778	9.73E-05	40.12
28	92.31	75.00	100.00	-	86.96	90.91	80.00	100.00	0.000905	1.13E-04	39.47
29	92.31	75.00	100.00	-	86.96	90.91	80.00	100.00	0.000905	1.13E-04	39.47
30	92.31	75.00	100.00	-	86.96	90.91	80.00	100.00	0.000905	1.13E-04	39.47
31	92.31	75.00	-	100.00	91.30	-	-	66.67	0.00074	9.25E-05	40.34
32	92.31	75.00	-	100.00	91.30	-	-	66.67	0.00074	9.25E-05	40.34
33	92.31	75.00	-	100.00	91.30	-	-	66.67	0.00074	9.25E-05	40.34
34	92.31	75.00	-	75.00	100.00	95.45	100.00	-	0.000783	9.78E-05	40.10
35	92.31	75.00	-	75.00	100.00	95.45	100.00	-	0.000783	9.78E-05	40.10
36	92.31	75.00	-	75.00	100.00	95.45	100.00	-	0.000783	9.78E-05	40.10
37	92.31	-	100.00	75.00	86.96	95.45	-	66.67	0.000862	1.08E-04	39.68
38	92.31	-	100.00	75.00	86.96	95.45	-	66.67	0.000862	1.08E-04	39.68
39	92.31	-	100.00	75.00	86.96	95.45	-	66.67	0.000862	1.08E-04	39.68
40	92.31	-	-	-	91.30	90.91	100.00	-	0.000458	5.73E-05	42.42
41	92.31	-	-	-	91.30	90.91	100.00	-	0.000458	5.73E-05	42.42
42	92.31	-	-	-	91.30	90.91	100.00	-	0.000458	5.73E-05	42.42
43	92.31	-	-	100.00	100.00	-	80.00	100.00	0.000574	7.17E-05	41.44
44	92.31	-	-	100.00	100.00	-	80.00	100.00	0.000574	7.17E-05	41.44
45	92.31	-	-	100.00	100.00	-	80.00	100.00	0.000574	7.17E-05	41.44
46	92.31	-	100.00	-	100.00	-	100.00	66.67	0.000642	8.03E-05	40.95
47	92.31	-	100.00	-	100.00	-	100.00	66.67	0.000642	8.03E-05	40.95
48	92.31	-	100.00	-	100.00	-	100.00	66.67	0.000642	8.03E-05	40.95
49	92.31	-	-	100.00	86.96	95.45	80.00	-	0.000616	7.70E-05	41.14
50	92.31	-	-	100.00	86.96	95.45	80.00	-	0.000616	7.70E-05	41.14
51	92.31	-	-	100.00	86.96	95.45	80.00	-	0.000616	7.70E-05	41.14
52	92.31	-	-	75.00	91.30	90.91	-	100.00	0.000636	7.95E-05	41.00
53	92.31	-	-	75.00	91.30	90.91	-	100.00	0.000636	7.95E-05	41.00
54	92.31	-	-	75.00	91.30	90.91	-	100.00	0.000636	7.95E-05	41.00

Segment 2 (Manufacturing hallway) L32(2**7) Orthogonal Array

S/N	Viewers	Filler operators	Palletizers/Depalletizers	Washer operators	Chip neck removers	Technical operators	Packers/unpackers	1/Y^2	MSRD	S/N(η)
1	100.00	100.00	83.33	100.00	100.00	100.00	100.00	0.000744	1.06E-04	39.74
2	100.00	100.00	83.33	100.00	87.50	100.00	-	0.000675	9.64E-05	40.16
3	100.00	100.00	83.33	50.00	100.00	-	100.00	0.000944	1.35E-04	38.70
4	100.00	100.00	83.33	50.00	87.50	-	-	0.000875	1.25E-04	39.03
5	100.00	100.00	100.00	100.00	100.00	-	-	0.0005	7.14E-05	41.46
6	100.00	100.00	100.00	100.00	87.50	-	100.00	0.000531	7.58E-05	41.20
7	100.00	100.00	100.00	50.00	100.00	100.00	-	0.0009	1.29E-04	38.91
8	100.00	100.00	100.00	50.00	87.50	100.00	100.00	0.001031	1.47E-04	38.32
9	100.00	80.00	83.33	100.00	100.00	-	-	0.0006	8.58E-05	40.67
10	100.00	80.00	83.33	100.00	87.50	-	100.00	0.000731	1.04E-04	39.81
11	100.00	80.00	83.33	50.00	100.00	100.00	-	0.001	1.43E-04	38.45
12	100.00	80.00	83.33	50.00	87.50	100.00	100.00	0.001131	1.62E-04	37.92
13	100.00	80.00	100.00	100.00	100.00	100.00	100.00	0.000756	1.08E-04	39.66
14	100.00	80.00	100.00	100.00	87.50	100.00	-	0.000687	9.81E-05	40.08
15	100.00	80.00	100.00	50.00	100.00	-	100.00	0.000956	1.37E-04	38.65
16	100.00	80.00	100.00	50.00	87.50	-	-	0.000887	1.27E-04	38.97
17	87.50	100.00	83.33	100.00	100.00	-	-	0.000575	8.21E-05	40.86
18	87.50	100.00	83.33	100.00	87.50	-	100.00	0.000705	1.01E-04	39.97
19	87.50	100.00	83.33	50.00	100.00	100.00	-	0.000975	1.39E-04	38.56
20	87.50	100.00	83.33	50.00	87.50	100.00	100.00	0.001105	1.58E-04	38.02
21	87.50	100.00	100.00	100.00	100.00	100.00	100.00	0.000731	1.04E-04	39.81
22	87.50	100.00	100.00	100.00	87.50	100.00	-	0.000661	9.45E-05	40.25
23	87.50	100.00	100.00	50.00	100.00	-	100.00	0.000931	1.33E-04	38.76
24	87.50	100.00	100.00	50.00	87.50	-	-	0.000861	1.23E-04	39.10
25	87.50	80.00	83.33	100.00	100.00	100.00	100.00	0.000831	1.19E-04	39.26
26	87.50	80.00	83.33	100.00	87.50	100.00	-	0.000761	1.09E-04	39.63
27	87.50	80.00	83.33	50.00	100.00	-	100.00	0.001031	1.47E-04	38.32
28	87.50	80.00	83.33	50.00	87.50	-	-	0.000961	1.37E-04	38.62
29	87.50	80.00	100.00	100.00	100.00	-	-	0.000587	8.38E-05	40.77
30	87.50	80.00	100.00	100.00	87.50	-	100.00	0.000717	1.02E-04	39.89
31	87.50	80.00	100.00	50.00	100.00	100.00	-	0.000987	1.41E-04	38.51
32	87.50	80.00	100.00	50.00	87.50	100.00	100.00	0.001117	1.60E-04	37.97

Segment 3 (Beverage testing unit) L27(3**6) Orthogonal Array

S/N	Syrup Lifters	Syrup Mixers	Lab Technicians	Water Technicians	ETP Technicians	Others	1/Y^2	MSRD	S/N(η)
1	100.00	100.00	83.33	100.00	100.00	94.12	0.000657	1.09E-04	39.61
2	100.00	100.00	83.33	100.00	50.00	100.00	0.000944	1.57E-04	38.03
3	100.00	100.00	83.33	100.00	-	-	0.000444	7.40E-05	41.31
4	100.00	50.00	100.00	50.00	100.00	94.12	0.001213	2.02E-04	36.94
5	100.00	50.00	100.00	50.00	50.00	100.00	0.0015	2.50E-04	36.02
6	100.00	50.00	100.00	50.00	-	-	0.001	1.67E-04	37.78
7	100.00	62.50	-	-	100.00	94.12	0.000569	9.48E-05	40.23
8	100.00	62.50	-	-	50.00	100.00	0.000856	1.43E-04	38.46
9	100.00	62.50	-	-	-	-	0.000356	5.93E-05	42.27
10	-	100.00	100.00	-	100.00	100.00	0.0004	6.67E-05	41.76
11	-	100.00	100.00	-	50.00	-	0.0006	1.00E-04	40.00
12	-	100.00	100.00	-	-	94.12	0.000313	5.21E-05	42.83
13	-	50.00	-	100.00	100.00	100.00	0.0007	1.17E-04	39.33
14	-	50.00	-	100.00	50.00	-	0.0009	1.50E-04	38.24
15	-	50.00	-	100.00	-	94.12	0.000613	1.02E-04	39.91
16	-	62.50	83.33	50.00	100.00	100.00	0.001	1.67E-04	37.78
17	-	62.50	83.33	50.00	50.00	-	0.0012	2.00E-04	36.99
18	-	62.50	83.33	50.00	-	94.12	0.000913	1.52E-04	38.18
19	-	100.00	-	50.00	100.00	-	0.0006	1.00E-04	40.00
20	-	100.00	-	50.00	50.00	94.12	0.001013	1.69E-04	37.73
21	-	100.00	-	50.00	-	100.00	0.0006	1.00E-04	40.00
22	-	50.00	83.33	-	100.00	-	0.000644	1.07E-04	39.69
23	-	50.00	83.33	-	50.00	94.12	0.001057	1.76E-04	37.54
24	-	50.00	83.33	-	-	100.00	0.000644	1.07E-04	39.69
25	-	62.50	100.00	100.00	100.00	-	0.000556	9.27E-05	40.33
26	-	62.50	100.00	100.00	50.00	94.12	0.000969	1.61E-04	37.92
27	-	62.50	100.00	100.00	-	100.00	0.000556	9.27E-05	40.33

Segment 4 (Shuttle vehicle flotilla workshop) L32(2**3) Orthogonal Array

S/N	Forklift Technicians	Welders	Battery Charger/ Technicians	1/Y^2	MSRD	S/N(η)
1	100.00	100.00	100.00	0.0003	5.00E-05	43.01
2	100.00	100.00	100.00	0.0003	5.00E-05	43.01
3	100.00	100.00	100.00	0.0003	5.00E-05	43.01
4	100.00	100.00	100.00	0.0003	5.00E-05	43.01
5	100.00	100.00	-	0.0002	3.33E-05	44.77
6	100.00	100.00	-	0.0002	3.33E-05	44.77
7	100.00	100.00	-	0.0002	3.33E-05	44.77
8	100.00	100.00	-	0.0002	3.33E-05	44.77
9	100.00	0.00	100.00	0.0002	3.33E-05	44.77
10	100.00	0.00	100.00	0.0002	3.33E-05	44.77
11	100.00	0.00	100.00	0.0002	3.33E-05	44.77
12	100.00	0.00	100.00	0.0002	3.33E-05	44.77
13	100.00	0.00	-	0.0001	1.67E-05	47.78
14	100.00	0.00	-	0.0001	1.67E-05	47.78
15	100.00	0.00	-	0.0001	1.67E-05	47.78
16	100.00	0.00	-	0.0001	1.67E-05	47.78
17	-	100.00	100.00	0.0002	3.33E-05	44.77
18	-	100.00	100.00	0.0002	3.33E-05	44.77
19	-	100.00	100.00	0.0002	3.33E-05	44.77
20	-	100.00	100.00	0.0002	3.33E-05	44.77
21	-	100.00	-	0.0001	1.67E-05	47.78
22	-	100.00	-	0.0001	1.67E-05	47.78
23	-	100.00	-	0.0001	1.67E-05	47.78
24	-	100.00	-	0.0001	1.67E-05	47.78
25	-	0.00	100.00	0.0001	1.67E-05	47.78
26	-	0.00	100.00	0.0001	1.67E-05	47.78
27	-	0.00	100.00	0.0001	1.67E-05	47.78
28	-	0.00	100.00	0.0001	1.67E-05	47.78
29	-	0.00	-	0	0.00E+00	0.00
30	-	0.00	-	0	0.00E+00	0.00
31	-	0.00	-	0	0.00E+00	0.00
32	-	0.00	-	0	0.00E+00	0.00

Segment 5 (Suppliers) L27(3**5) Orthogonal Array

S/N	Security	Kitchen	Supplier 1	Supplier 2	Supplier 3	1/Y^2	MSRD	S/N(η)
1	100	100	92.86	100	100	0.000516	8.60E-05	40.66
2	100	100	92.86	100	-	0.000416	6.93E-05	41.59
3	100	100	92.86	100	-	0.000416	6.93E-05	41.59
4	100	91.67	100	86.96	100	0.000551	9.19E-05	40.37
5	100	91.67	100	86.96	-	0.000451	7.52E-05	41.24
6	100	91.67	100	86.96	-	0.000451	7.52E-05	41.24
7	100	-	-	-	100	0.0002	3.33E-05	44.77
8	100	-	-	-	-	0.0001	1.67E-05	47.78
9	100	-	-	-	-	0.0001	1.67E-05	47.78
10	86.36	100	100	-	100	0.000434	7.23E-05	41.41
11	86.36	100	100	-	-	0.000334	5.57E-05	42.54
12	86.36	100	100	-	-	0.000334	5.57E-05	42.54
13	86.36	91.67	-	100	100	0.000453	7.55E-05	41.22
14	86.36	91.67	-	100	-	0.000353	5.88E-05	42.30
15	86.36	91.67	-	100	-	0.000353	5.88E-05	42.30
16	86.36	-	92.86	86.96	100	0.000482	8.04E-05	40.95
17	86.36	-	92.86	86.96	-	0.000382	6.37E-05	41.96
18	86.36	-	92.86	86.96	-	0.000382	6.37E-05	41.96
19	95.45	100		86.96	100	0.000442	7.37E-05	41.33
20	95.45	100	-	86.96	-	0.000342	5.70E-05	42.44
21	95.45	100	-	86.96	-	0.000342	5.70E-05	42.44
22	95.45	91.67	92.86	-	100	0.000445	7.41E-05	41.30
23	95.45	91.67	92.86	-	-	0.000345	5.75E-05	42.41
24	95.45	91.67	92.86	-	-	0.000345	5.75E-05	42.41
25	95.45	-	100	100	100	0.00041	6.83E-05	41.66
26	95.45	-	100	100	-	0.00031	5.16E-05	42.87
27	95.45	-	100	100	-	0.00031	5.16E-05	42.87