Application of Fuzzy Analytic Hierarchy Process (FAHP) to Improve Precision and Certainty on Safety Conformity Evaluation in a Bottling Plant

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ABSTRACT

With the bottling plant facing safety impacts, the commitment toward zero levels of accidents needs to be evaluated. However, the perception and measurement of safety conformity by the safety manager that is subjected to imprecision and uncertainty are hardly evaluated correctly with the present dominant approach of using crisp numeric values. This article presents a fuzzy analytic hierarchy process (FAHP) approach to reduce the imprecision and uncertainty in the safety conformity multicriteria decision-making results. The method establishes and selects the best safety conformity factors in alignment with different criteria within the segments of a Nigerian bottling plant. The fuzzy synthetic extent concerning each alternative, the degree of possibility, prioritizing weights, and the choice of the best criterion were judged based on the maximum weight in the FAHP evaluation process. The average weight criterion was used to distinguish the best from the worst units within each segment. The results reveal the criteria weights as 0.4937 for haulage drillers (warehouse), 0.3038 for palletizers (manufacturing corridor), 0.3333 for syrup mixers/lab technicians for quality assurance, and no choice of the best parameter for the fleet workshop. However, the highest weight for the contractors is 0.3201, which is for contractor 1. To compare the best and worst criteria in the present study and a literature source, the optimal criteria choices of safety conformity conflicted in all the segments. The principal difference between the present method and the analytic hierarchy process approach is integrating fuzzy application to the analytical hierarchy process to provide a more accurate safety conformity assessment, yielding reliable and informative results representing the vagueness of the bottling process decision-making process. This unique approach provides an opportunity for the production workers to work more collaboratively towards attaining new solutions to the uncertainty and imprecision problem in safety conformity for the bottling plant.

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1. INTRODUCTION

The analytic hierarchy process (AHP) is broadly applied in engineering decision-making with the use of expert opinions, trimming down to comply with Saaty's nine-point scale with an eventual outcome of the weights of criteria determined from a prioritizing principle (Sehra et al., 2012). While the AHP method has merits in eliminating subjectivity in decision-making, one of its demerits is its inability to establish ways of handling the influence of uncertainty or imprecision in safety conformity information during the multi-criteria analysis using the AHP (Rajmohan & Srinivasan, 2016; Sharma et al., 2018; Ferrari et al., 2020). To overcome this problem, novel and efficient multi-criteria decision-making (MCDM) model based on Chang's extent analysis model (EAM) has popularly evolved as a fuzzy AHP method. This article aims to implement the EAM in the safety conformity setting to effectively model and reduce the influence of uncertain or imprecise safety conformity information on the resource of safety conformity analysis using the fuzzy AHP MCDM method. The EAM indicates the degree to which the EAM object achieves the set goal of safety conformity. Further, the term "satisfied extent" is applied to describe the means of utilizing fuzzy triangular numbers in this method. A weight vector is established, which can be evaluated by deploying the guidelines to compare fuzzy numbers and extent analysis. Thus, the fuzzy AHP method using extent analysis generously applies for fuzzy triangular numbers as fuzzy quotients whereby preference relations are established with the degree of possibility of weighing each fuzzy triangular number against one another using crisp priority vectors that are synthesized to procedure the final rankings. The fuzzy preference relations are designed to show the differences between the individual preferences, which are established for a particular fuzzy non-strict preference.

The objective of this article is to establish a first contribution to the development of a multi-criteria decision-making structure that reduces the influence of uncertain or imprecise safety conformity information on the fuzzy AHP results. Consequently, a fuzzy-oriented AHP tool that employs fuzzy triangular numbers as fuzzy ratios for producing the fuzzy preference relations and the level of possibility to weigh the fuzzy triangular numbers against one another such that crisp priority vectors are established. These are further synthesized to yield final rankings. Previously, authors have studied the safety conformity problem in manufacturing plants from several perspectives, including control charts (Martins & Oke, 2020a), multi-response optimization (Martins & Oke, 2021), statistical analysis of safety conformance data (Deros et al., 2014) and the role of particular (Subramaniam et al., 2016). However, the establishment of flexible techniques to tackle data for precision was never done previously for the safety conformity problem in the bottling process plant. Thus, a unique method of fuzzy analytic hierarchy process to provide more accurate safety conformity results with the quality of reliability to help decision-making in manufacturing is the novelty of the work. Based on the proposed model, it is possible to establish which of the sub-units within the units of the bottling process plant is complying with the stated goal of safety and which is not. Furthermore, the sub-units are ranked to know the best-performing ones and the least perfuming ones. Finally, the proposed approach was verified by using the data obtained from a bottling process plant where soft drinks are manufactured. The plant comprises five units and multiple sub-units. The units are named manufacturing hallway, beverage testing unit, suppliers, warehouse, and a fleet of vehicle flotillas.

Furthermore, safety conformity in bottling process plants refers to the process used to establish that the human controlling the various process meet specified goals **(**Martins & Oke**,** 2020a; Martins & Oke, 2020b; Martins & Oke, 2021). The goal-setting mechanism of the FAHP method has several benefits. At first, it offers a direction as substantial energy is invested and attempts to intervene in the modeling efforts. Secondly, there is a clear focus on the important safety conformity criteria. Besides, to decide on safety conformity issues, goal setting helps, and it could affect the direction of safety parties in the company. However, the conformity of a unit is dependent on the individual conformity of jobs contained in the unit and often may be detrimental to the system or promote the physical well-being of the individuals within the unit. Although plants sometimes conduct performance evaluations of individual components of the bottling plants, the current knowledge of the process safety personnel is incomplete. For example, in the warehouse, operators may remove some machine guards (or covers) for convenience, but what qualifies as equipment covering removal is a relative process depending on the researcher's perceptions. So the degree to which these covers are removed remains undocumented, considering the uncertainty and imprecision in the judgment of the process safety engineer. Consequently, safety engineers require a better understanding of the degree to which safety procedures are violated to help inform interventions seeking to enhance safety performance outcomes.

Therefore, in this article, a fuzzy analytic hierarchy process (FAHP) method multicriteria decision-making framework is proposed to solve the safety conformity evaluation problem in the context of a bottling production plant where engineering and non-engineering activities are assessed for safety conformity toward enhancing the plant's safety performance.

2. LITERATURE REVIEW

The literature review briefly reviews the relevant literature about safety conformity, FAHP, optimization, decision-making optimization selection of safety processes and units, and fuzzy multicriteria to demonstrate an adequate understanding of the field and establish the research gap pursued in this work with solutions.

Firstly, the discussion starts with process safety optimization. While bottling process plants which is the focus of this research, have been less studied, various process optimization studies regarding safety have been analyzed in the literature. These include industrial gas cleaning plants (Tikadar et al., 2021a), batch chemical reaction processes (Wu et al., 2023), chemical plant process industry (Roy and Gupta (2020) as well as Roy (2022) and industrial acid gas removal process (Al-Ani et al., 2020) a characteristic of these studies is to focus on an aspect of improvement within their process aspect of improvement within the process safety evaluation for instance, Tikadar et al. (2021a) and Tikadar et al. (2021b) focused on environmental and economic dimensions of process safety optimization. The concern of Wu et al. (2023) has been on the economic safety trade-off, while Roy (2022), Roy and Gupta (2020), and Al-Ani et al. (2020) studied safety budget allocation, safety investments, and energy, respectively, on mapped out routes on how the impact the process safety optimization.

Secondly, an interesting set of studies have focused on safety decision-making, but the concern of the bottling process plants has not been tackled. Zhang et al. (2022) focused on safety investment decision-making. They concluded that risk assessment is crucial to the safety of power grids, while safety training investments in organizations and investments in technology follow risk assessment in the order that they are listed. Furthermore, Yazdi et al. (2020) proposed a joint multicriteria decision-making tool method with a Bayesian network framework. The application of the improved DEMATEL method was confirmed as effective in the context the high-tech industry decision-making.

Thirdly, some exciting studies have been conducted on the joint fuzzy multicriteria studies and analytical hierarchy process (Dagdeviren & Yuksel, 2008; Zheng et al., 2012; Rajmohan & Srinivasan, 2016; Sharma et al., 2018; IIbahar et al., 2018). Rajmohan and Srinivasan (2016) examined the various critical criteria in diverse industrial sectors using the fuzzy analytic hierarchy process. It was reported that the principal criterion of "human safety" was assigned a 72.5% weight while other criteria, such as "machine safety" and "work environment safety," had respective weights of 8.920 and 18.49. To further analyze the “human safety” criterion, it exhibited a sub-criterion of mammal lifting, firefighting, drills, eye protection, material handling practices, safety officers, and training. In another study, Dagdeviren and Yuksel (2008) established a fuzzy AHP method for evaluating faulty behavioral risk levels in work organizations, and an application was made in a manufacturing company. The approach adopted weighed the parameters leading to the faulty behavioral risk using the fuzzy triangular numbers in pairwise relationships. It was declared that the approach eliminated faulty behavior before actualization, hereby aiding an improvement in the work system’s safety.

In the food manufacturing safety area, Sharma et al. (2018) introduced a fuzzy AHP-based approach to evaluating the mine success parameters needed to guarantee sustainable safety practices based on a literature survey and the harvest of expert opinion. The results declared government policies and packaging as the most important parameters associated with safety in the system. Introducing the concepts of Pythagorean fuzzy AHP and fuzzy inference system into occupational safety, IIbahar et al. (2018) assessed occupational safety in a construction yard. The tested method yielded reliable and informative results that represent the vagueness of the construction process decision-making. According to Zheng et al. (2012), humid and hot conditions are prevalent in several industries worldwide and pose risks related to safety problems, specific heat-associated disorders, and productivity decline. To combat these problems, the authors proposed a fuzzy analytic hierarchy process approach to assess occupational safety in humid and hot conditions using a group-based decision process with trapezoidal fuzzy members to capture data imprecision and uncertainty. The results revealed that the method has engineering practicability, and it is effective.

On the fourth account, the central area of this research is the optimal selection of safety conformity recommendations. However, the present authors were able to identify extremely less studies in this area in literature. The fronting study of Cheraghi et al. (2022), with which a benchmark analysis may be made, is unfortunately absent in features particular to the bottling plant process industry. There is no study on optimal process segmental selection of safety conformity that has considered a fuzzy multi-factor decision-making dimension through a deep assessment of the bottling plants segments and the safety conformity problem. Although some interesting studies on safety recommendations have deployed the Delphi method, expert panel, and team members’ perspectives, the suggested idea is in the healthcare industry and is difficult to implement in the bottling industry. However, they have not been tried out for the safety conformity aspect in the process plant. Consequently, this research gap should be explored as the bottling industry is one of the most established processes worldwide, with plants in several countries in the world having multi-billion-dollar investments. So, solving this safety conformity selection problem has implied cost savings and performance efficiency implications for the bottling plant since the selection information is used for budgetary purposes.

The following summarizes the gaps and observations from the review of the safety conformity literature:

1) The influence of uncertain or imprecise safety conformity and how it could be reduced on the multi-criteria decision-making results is omitted.
2) The process segregation into equipment-related and non-equipment-related is not common but is a recent development. This segregation of process is essential because they present a holistic viewpoint of the plant.
3) Most analyses have conceptualized safety conformity to be limited to mechanical moving parts of equipment alone.

Consequently, the important features of this article are as follows:

1) Models the safety conformity process in a bottling process plant by integrating fuzzy application to the analytic hierarchy process by representing the vagueness of the decision maker better and providing a more accurate safety conformity assessment with reliable and informative results.
2) Including the fuzzy information at the comparison matrix evaluation to obtain a fuzzified pairwise comparison matrix from which the fuzzy synthetic extent, Si, the degree of possibility, degree of

possibility, weight vector, and normalized fuzzy weight vector are evaluated.

3. METHODS

In this article, the company-wide data, which comprises engineering (core-business activities of bottling soft drinks) and non-engineering/non-core business-related activities, are distinguished into segments. These segments, namely segments 1, 2, 3, 4, and 5, are the warehouse, manufacturing corridor, quality assurance, fleet workshop, and contractors, respectively. Each segment is a unit that may consist of at least a workstation where different skilled personnel manages, and each group of skilled personnel is accountable for its safety conformity performance at all times. For clarity, the term "segments" means the same as the "divisions" of the bottling plant. It is, however, different from "units and sub-units" as units are further segregations of the segments while sub-units are still an additional scaling of units. Consider the manufacturing corridor as a segment. This segment has a filler operator, for instance, as a unit. However, if a unit such as palletizers/depalletizers is considered, this unit has two sub-units, which are aspects such as the palletizers as well as depalletizers. The safety conformity of the individual skilled groups influences the safety conformity of the segment as a whole. Interestingly, segment 1 comprises eight groups of workers, such as the forklift drivers who are responsible for the movements of creates of drinks both in the empty and filled forms from and to the storage locations within the warehouse aided by the forklifts. Then, the sorters closely watch the moving bottles already in their washed states, leaving the washer that may have applied caustic soda to wash the bottles and water for cleaning. These sorters ought to distinguish confirmed and non-confirmed bottles and remove the bad ones from the moving set out of the washing equipment. The bottles move at a constant speed and need a careful check to distinguish rejects such as bottles with broken tips, those containing dirt although with marks, and bottles with cracks anywhere on their surface. Next is the rescuer, whose position in the bottling line is following the sorters.

Rescuers are responsible for lifting fallen bottles in the course of the movement to the fillers after being certified okay by the sorters. If any bottle falls, the slanting or fully fallen position of the bottle prevents motion as well bottles following the fallen bottles will be prevented from further movement. Notice that as the bottles are passed to the fillers, the prepared syrup is delivered to the fillers through pipes. However, the sugar handlers, the haulage drivers, and the haulage truck mates make syrup production possible. The sugar handlers are responsible for loading the pile of sugar to the forklift that will transport the bags of sugar from the store to the mixing drums. The haulage truck mates need to ensure that the bags of sugar are properly positioned on the forklift for safe delivery to the mixing drums. However, haulage truck drivers are responsible for conveying the bags of sugar to the mixing locations by driving carefully. After mixing the sugar and water, the syrup is obtained, and the filler fills the bottles. However, the corks may be loosely fitted to a damaged bottle during the filling. These bad products are removed by the chip neck removers. Besides, some bottles may not be filled to the specified filling height. They are also removed by the chip neck removers. Furthermore, a specified number of bottles are supposed to be filled in a crate, but the human error of the operator and/or those responsible for filling the crates may fill more than the required number. In this instance, the extra bottle removers do the correction by removing the extra bottles.

Besides, segment 2 contains seven factors, including the sighters. The sighters serve two functions in this second segment, sort, and rescue. Next is the filler operator, who is responsible for controlling the syrup-filling machine. They are conversant with the filling machines' operation speeds and all the technicalities involved in controlling the machine. Next are the palletizers/depalletizers. The pallets upon which the creates are loaded onto the forklift are controlled and positioned in a manner that the forklift could easily carry it by the palletizer. To remove it to the appropriate plate is the function of the depalletizer. Before being filled with syrup, the bottles should be clean as they are brought from the store in the form retrieved from the customers. It is the function of the washer operators to wash the bottles clean. The chick neck removers serve the purpose as described in Segment 1. Furthermore, boilers and other utilities, such as compressors, are required to function before all the engines at the manufacturing corridor can be used. Thus, the technical operators/utilities are responsible for this task. Next, the packer/unpacker serves the purpose of placing and removing packers accordingly from the piles of crates built up by the forklift operation to transport them to the stores.

For the third segment, quality assurance, the components are the sugar lifters, syrup mixers, laboratory technicians, water technicians, Ep technicians, and others. The quality assurance unit carries out all tests on syrup, including its viscosity, to ascertain its measures to standard, and the tests of filling height and color on the filled bottles with samples taken from each batch. In this unit, the sugar lifters are among those responsible for ensuring the quality of the products. Sugars are lifted from the forklift upon arrival at the mixing unit and checked for defects before being poured into the mixing unit by the sugar handlers. Bags of sugar suspected to have spoiled or contaminated with one thing or the other are pointed out to the production manager for inspection. The water technicians are responsible for the various tests of acidity/alkalinity of the water supplied to the production unit. The EP technicians are responsible for maintaining electronic devices in the factory. The laboratory technicians take care of the color checks, filling height checks, and taste, among others, for the bottle products, which are treated in batches. Apart from these staff, other support staff work towards the goal attainment of the quality assurance unit.

Segment 4 is the fleet workshop that comprises three factors, forklift technicians, welders, and battery chargers/technicians. The forklift technician maintains broken-down forklifts. Certain parts of the factory workstations may require welding, and the joining together of these required parts by the different binding methods is the job of the welder. Furthermore, the battery charger/technicians are required to help charge the batteries of all auto vehicles and forklifts. For segments 5 and 6, contractors are considered. These are divided into resident contractors and others. The security that is charged with the protection of lives and properties is part of the resident contractors. Also, the kitchen that prepares food for the workers is classified as a resident contractor. However, there are other contractors whose activities complement that inside. These are called outside contractors.

Notations

The following are some notations that will appear in the detailed steps to implement the FAHP in this work:

M_i^j An expression for an object x_i is considered in the extent analysis value for goal g_j where i = 1, 2, ..., n and j = 1, 2, …, m. All the M_i^j are fuzzy triangular members.

S_i Fuzzy synthetic extent for the i^{th} object.

$V(S_2 \geq S_i)$ Degree of possibility between two fuzzy synthetic extents the ordinate of the highest intersection point D between Ms_i and Ms_2.

K Convex fu members S_i (1, 2, …, k).

W^i Vector.

W Normalized vector. This is a non-fuzzy member calculated for each comparison matrix.

The steps pursued in solving the formulated problem are as follows:

Step 1: Group the data on factors into levels for convenience. The groupings are best done with the levels expressed in terms of percentage. These are conformity percentages obtained from the field data. Then, the work proceeds to step 2.

Step 2: Develop the comparison matrix: Here, the pair-wise comparison matrix is created with the help of the values for each factor with its corresponding level.

Step 3: Calculate the fuzzified pairwise comparison matrix: Here, the crisp numeric values are translated into fuzzy numbers. In this article, the pairwise comparison method has been deployed to examine the multiple populations' means of the units within segments (parameters) of the bottling plant and to establish whether they are significantly different from one another. However, as the process involves comparing units in pairs, it provides an opportunity to judge which units within the bottling plant segments are preferred. However, the deployment of the pairwise comparison method by the present authors was motivated by the several benefits to be gained from its usage. Firstly, the method offers a consistent and efficient route to prioritize the multiple units within the segments of the bottling plant. Secondly, being a quantitative approach, it disallows bias and gives little room for the emotions of the assessor in the bottling process plant decision-making. The pairwise comparison method permits evaluations to be transformed into numerical values such that when combined with weights, they can be aggregated over the whole range of the safety conformity problem in the bottling plant. Notwithstanding, the fuzzified pairwise comparison is an advancement of the pairwise comparison method in which the ideas of precision and certainty are bought to modify the crisp numerical values provided by the pairwise comparison method.

Step 4: Calculate the fuzzy synthetic extent concerning the i^{th} alternative:

The numbers (estimated synthetics) may be interpreted to provide a clearer idea of the meaning as follows. In synthetics division, the researcher divides one number by another such that the outcome may not have a number. This is a more complex situation in which a direct division of numbers may be challenging.

Step 4.1: To compute this, the first step within this step is the computation of S_i.

Step 4.2: Step 2 in calculating S_i.

Step 4.3: Step 3 in computing S_i (fuzzy synthetic extent): The detail about this for segment 1 (level 1).

Step 4.4: Calculate the degree of possibility. This is aided by the application of the following formula.

Step 4.5: Calculate the degree of possibility for a convex fuzzy number to be greater than the k convex fuzzy number.

Step 4.6: Calculate the weight vector and normalize the non-fuzzy weight vector. In this article, a related weight was assigned to each unit in a segment. However, the weight vector should first be determined. To understand the idea of a weight vector, consider the weight of the units within the segment symbolized as W and occurs in a linear function β in a way that the corresponding weight space is nonzero. Then these entities, which are nonzeros within the weight space, are termed the weight vectors. Viewed differently, a weight vector for the units within segments of a bottling plant is a simultaneous eigenvector considering the action of the elements of V, exhibiting corresponding eigenvalues expressed as β.

4. RESULTS AND DISCUSSION

This article is one of the series obtained from a research endeavor to enhance the safety of a bottling process plant using various techniques, and the data is from a common source as used in other papers such as Martins and Oke (2020a, 2020b, 2021). However, the analysis carried out thereafter is different in the various articles. In this article, the analysis commences with grouping data on factors into levels, Table 1. In this article, one of the authors makes the judgment, and the rating of the segments and their units are given. However, these ratings are carefully considered and analyzed by another author in the group. This makes a second judgment, which corrects the possible bias of an individual. Then, the outcome is used for the analysis involving the fuzzy extent analysis, which potentially reduces uncertainty and imprecision.

The following is a further justification for why one of the authors makes the judgment: Uncertainty in safety conformity is a situation involving imperfect conformity information arising from the on-site (operators) measurements of workers' activities concerning safety conformity in the bottling process plant. However, in tackling uncertainty and imprecision, the fuzzy analytic hierarchy process has been recommended in this study. The method receives inputs from experts on safety conformity issues and then works on the following; First, the combinations of data that yield less variability is pursued to yield the bottling process that will typically produce less measurement uncertainty. Secondly, the literature opinion compares obtained results with the actual values, thus reducing uncertainty. While those uncertainty reduction approaches are effective. The reduced uncertainty threshold is more effective when a group of respondents' assessments are considered. However, in the situation considered, it was challenging to obtain experts in the safety area to fill out a questionnaire on their opinions on uncertainty. Nevertheless, since one of the authors has industrial experience in the working process of the bottling plant, it was resolved to use his expertise in assessing the elements of uncertainty. Then the assessment was cross-checked by other authors of the article. In so doing, the article achieves the same objective of reducing uncertainty as achievable by the group of respondents. Thus, bias reduction and the analysis of data combinations that produce less variability were used as the approaches by the author (assessor) to reduce uncertainty and imprecision in the safety conformity process.

Furthermore, Table 1 shows details of the data obtained from the segments as factors are levels. However, how were these percentage levels determined? At the data collection site, a specified number of data items were collected for each unit within the various segments. Suppose a data set of 50 items. The values are as follows 100.00, 92.31, 100.00, 100.00, 100.00, 92.31, 92.31, …., 100.00. To summarize the data in Table 1, the frequently occurring data are recognized as representative of such dataset. Here, 100.00 as a data item has occurred four times. Therefore 100.00 is picked as the more common item and attached to level 1. Also, 92.31 occurred twice, and only 92.31 will be written as level 2 if numbers are occurring even once such a number represents itself and is taken as a level. However, caution is made not to have many levels as it will be complicated to fix an orthogonal array to the factors and levels.

Step 1: Group the data on factors into levels for convenience, the groupings are best done with the levels expressed in terms of percentage. These are conformity percentages obtained from the field data (Table 1). The method to determine the percentage levels in Table 1 involves focusing on a segment at a time. For this, a period of evaluation is determined, such as one month. Usually, a month contains either thirty or thirty-one days, and all these are working days in the plant. So, daily, samples of activities are taken, say eight times within an 8-hour working period, and an average is obtained to be recorded in Table 1. Considering the forklift driver, the safety conformity tasks are identified, and the most important, which may be a representative of compliance, is noted. Interestingly, some rules governing forklift drivers to avoid accidents are as follows: (1) Keeping the driver's head, legs, feet, and arms inside the forklift while driving. (2) Avoid passing a forklift moving along the same direction as you are driving, especially in dangerous areas, intersections, and blind spots. (3) Avoid driving with the fork up (4) Avoid using the forklift to push other vehicles. So to evaluate each of the forklift drivers within the month, these four rules are considered. Twenty-five percent is given to compliance with each of the four rules. So at an observation point, which may span ten minutes, if the forklift driver violates two rules, he obtains 50% as the score. The averages of the performance are then recorded in Table 1. Similar steps are taken for other units within the segment. Then, the work proceeds to step 2.

Step 2: Develop the comparison matrix: The purpose of the pair-wise comparison matrix in step 2 is to construct comparative judgments in a statistical method, to assess the association between pairs of means when attempting unit element comparison. The method prioritizes the units within the segment. The pairwise comparison is exclusively suitable to inform complicated decisions on safety conformity, which involves the analysis of many units within the segment. Instead of the safety manager ranking all the units at once, from the most to the least preferred, the pair-wise comparison works in a simpler approach: Consider the Forklift drivers against the sorters. This results in establishing the units within the segment. Here, the pair-wise comparison matrix is created with the help of the values for each factor with its corresponding level. Notice that the length of the paired matrix is equal to the number of criteria/factors used in the decision-making process. Furthermore, divide the row elements by the column elements. Then convert the fractions to decimals and calculate the sum of each column. This analysis is obtained for the following: Segment 1 (Level 1), segment 1 (level 2), segment 1 (level 3), segment 3 (level 1), segment 3 (level 2), segment 3 (level 3), segment 4 (level 1), segment 4 (level 1), segment 5 (level 1), segment 5 (level 2), and segment 5 (level 3). However, the analysis will be shown in detail for segment 1 (level 1), while the summarized results for all the other levels are given. Consequently, Table 2 summarizes the comparison matrix for segment 1 (level 1) (Warehouse). The values in the first column of the matrix under "forklift drivers" were extracted from Table 1 at level 1.

However, the reciprocal was used to obtain the values in the second, third, and eighth columns. Consider the second column sorters". The first element of the matrix is the interaction between forklift drivers and sorters. The question to answer is, "How important are forklift drivers to sorters? For this, the present assessor takes it as the reciprocal of 0.7500, which is 1.333. The next element

Table 1. Group data into segments, factors, and levels

Segment 1 (Warehouse)			
Factors	*Level 1(%)*	*Level 2(%)*	*Level 3(%)*
Forklift Drivers	100.00	92.31	-
Sorters	75.00	-	-
Rescuer	100.00	-	-
Sugar Handlers	100.00	75.00	-
Haulage Drivers	91.30	100.00	86.96
Haulage Truck Mates	95.45	90.91	-
Chip Neck Remover	100.00	80.00	-
Extra Bottle Remover	100.00	66.67	-
Segment 2 (Manufacturing corridor)			
Factors			
Sighters	100.00	87.50	-
Filler Operator	100.00	80.00	-
Palletizers/Depalletizers	83.33	100.00	-
Washer Operators	100.00	50.00	-
Chip Neck Remover	100.00	87.50	-
Technical Operators/Utilities	100.00	-	-
Packer/Unpacker Operators	100.00	-	-
Segment 3 (Quality Assurance)			
Factors			
Sugar Lifters	100.00	-	-
Syrup Mixers	100.00	50.00	62.50
Lab Technicians	83.33	100.00	-
Water Technicians	100.00	50.00	-
Etp Technicians	100.00	50.00	-
Others	94.12	100.00	-
Segment 4 (Fleet workshop)			
Factors			
Forklift Technicians	100.00	-	-
Welders	100.00	0.00	-
Battery Charger/Technicians	100.00	-	-
Segment 5 (Contractors – Resident and others)			
Factors			
Security	100.00	86.36	95.45
Kitchen	100.00	91.67	-
Contractor 1	92.86	100.00	-
Contractor 2	100.00	86.96	-
Contractor 3	100.00	-	-

under the second column is "sorters". The question is, "How important are sorters to sorters? The answer is 1.000 and hence recorded as such at the interaction of sorters to sorters.

The next entry is between rescuers and sorters. So how important are rescuers to sorters? By assessing one of the present investigations, a value of 1.3333 is chosen. So the table filling continues similarly, and a complete Table 2 is produced. Now, the strategy adopted in the computation is to treat only segment 1 (level 1) in full calculations and then present a summary of results for all others mentioned earlier. So the next computation is still for segment 1 (level 1), which is the application for step 3.

Step 3: Calculate the fuzzified pairwise comparison matrix: Here, the crisp numeric values are translated into fuzzy numbers, as shown in Table 3. In Table 3, crisp numeric values of the units of the warehouse segment are transformed from Table 2. In Table 2, the crisp numeric values are converted into fuzzy numbers by first acknowledging the pairwise comparison matrix that was developed from the scale of comparative importance. It is noticed that the constituents of the scale of relative importance are crisp numeric values such as 1, 3, 5, 7, 9, {2, 4, 6, 8}, {1/3, 1/5, 1/7, 1/9}, which represents equal importance of two units within the segment, moderate importance of a unit over the other, strong importance of a unit over the other, very strong importance of a unit over the other, extreme importance of a unit over the other and intermediate values of a unit over the other. However, the values of {1/3, 1/5, 1/7, 1/9} are given as the inverse comparison. However, these stated crisp numeric values are converted to fuzzy numbers in fuzzy. While implementing a fuzzy system for the bottling plant, various terms were used, such as fuzzification, which means converting linguistic terms into membership functions. In this article, the triangular membership function is used as it is effective. Here, the shape of the membership function is triangular.

Table 2. Comparison matrix for Segment 1 (level 1) – Warehouse

	Forklift Drivers	Sorters	Rescuers	Sugar Handlers	Haulage Drivers	Haulage Truck Mates	Chip Neck Removers	Extra Bottle Removers
Forklift Drivers	1.0000	1.3333	1.0000	1.0000	1.0953	1.0477	1.0000	1.0000
Sorters	0.7500	1.0000	0.7500	0.7500	0.8215	0.7858	0.7500	0.7500
Rescuers	1.0000	1.3333	1.0000	1.0000	1.0953	1.0477	1.0000	1.0000
Sugar Handlers	1.0000	1.3333	1.0000	1.0000	1.0953	1.0477	1.0000	1.0000
Haulage Drivers	0.9130	1.2173	0.9130	0.9130	1.0000	0.9565	0.9130	0.9130
Haulage Truck Mates	0.9545	1.2727	0.9545	0.9545	1.0455	1.0000	0.9545	0.9545
Chip Neck Removers	1.0000	1.3333	1.0000	1.0000	1.0953	1.0477	1.0000	1.0000
Extra Bottle Removers	1.0000	1.3333	1.0000	1.0000	1.0953	1.0477	1.0000	1.0000
Sum	7.6175	10.1567	7.6175	7.6175	8.3434	7.9806	7.6175	7.6175

In the approach of the triangular membership function used in this work, the fuzzy value $\mu_A(x)$ is generally represented as A= (1, 2, 3), where 1, 2, and 3 are the fuzzy number, and this number is associated with the triangular membership function. The numbers 1, 2, and 3, which are similar to (0.9, 1, 1.1) for the intersection of the forklift and itself, are the lower, middle, and upper parts of the x-axis for the triangle that may be drawn for the triangular membership functions. On a scale of relative importance, crisp numbers such as 1, 3, 5, 7, and 9 are replaced with fuzzy numbers. The motivation is from the understanding that assigning a single number to any term may not be justified. So, assigning the value of 3 to moderate is replaced with (2, 3, 4), where 2, 3, and 4 are the respective lower, middle, and upper parts of the fuzzy number. So, a triangle for the membership function for moderate is constructed. In general, the crisp numeric values of 1, 3, 5, 7, and 9 are replaced with the fuzzy numbers (1, 1, 1), (2, 3, 4), (4, 5, 6), (6, 7, 8), and (9, 9, 9), respectively. Thus, using the specific numbers from Table 2, the fuzzy numbers are created and displayed in Table 3.

Step 4: Calculate the fuzzy synthetic extent concerning the i^{th} alternative:

Equation (1) helps evaluate the fuzzy synthetic extent concerning the i^{th} alternative:

$$S_i = \sum_{j=1}^{m} M_{g_i}^{j} \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^{j} \right]^{-1} \quad (1)$$

Step 4.1 To compute this, the first step within this step is the computation of S_i, which is shown for—segment 1 (level 1) in Table 4.

Step 4.2. Step 2 in calculating S_i.

The accompanying table is shown in Table 4.

Step 4.3: Step 3 in computing S_i (fuzzy synthetic extent): The details about this for segment 1 (level 1) is shown in Table 5.

Step 4.4: Calculating the degree of possibility. This is aided by the application of the following formula.

$$V\left(S_j \geq S_i\right) - height\left(S_i \cap S_j\right) - \begin{cases} 1, \text{if } m_j \geq m_i \\ 0, \text{if } l_i \geq u_j \\ \dfrac{l_i - u_j}{\left(m_j - u_j\right) - \left(m_i - l_i\right)}, \text{otherwise} \end{cases} \quad (2)$$

The details are as follows:

V ($S_1 \geq S_2$) = 1; *V* ($S_1 \geq S_3$) = 0; *V* ($S_1 \geq S_4$) = 0; *V* ($S_1 \geq S_5$) = 1; *V* ($S_1 \geq S_6$) = 1; *V* ($S_1 \geq S_7$) = 0; and *V* ($S_1 \geq S_8$) = 0.

V ($S_2 \geq S_1$) = 1.1818; *V* ($S_2 \geq S_3$) = 1.1818; *V* ($S_2 \geq S_4$) = 1.1818; *V* ($S_2 \geq S_5$) = -1.3333; *V* ($S_2 \geq S_6$) = -1.5; *V* ($S_2 \geq S_7$) = 1.1818; and *V* ($S_2 \geq S_8$) = 1.1818.

V ($S_3 \geq S_1$) = 0; *V* ($S_3 \geq S_2$) = 1; *V* ($S_3 \geq S_4$) = 0; *V* ($S_3 \geq S_5$) = 1; *V* ($S_3 \geq S_6$) = 1; *V* ($S_3 \geq S_7$) = 0; and *V* ($S_3 \geq S_8$) = 0.

V ($S_4 \geq S_1$) = 0; *V* ($S_4 \geq S_2$) = 1; *V* ($S_4 \geq S_3$) = 0; *V* ($S_4 \geq S_5$) = 1; *V* ($S_4 \geq S_6$) = 1; *V* ($S_4 \geq S_7$) = 0; and *V* ($S_4 \geq S_8$) = 0.

V ($S_5 \geq S_1$) = -8.3333; *V* ($S_5 \geq S_2$) = 1; *V* ($S_5 \geq S_3$) = -8.3333; *V* ($S_5 \geq S_4$) = -8.3333; *V* ($S_5 \geq S_6$) = 28; *V* ($S_5 \geq S_7$) = -8.3333; and *V* ($S_5 \geq S_8$) = -8.3333.

V ($S_6 \geq S_1$) = -7.25; *V* ($S_6 \geq S_2$) = 1; *V* ($S_6 \geq S_3$) = -7.25; *V* ($S_6 \geq S_4$) = -7.25; *V* ($S_6 \geq S_5$) = 1.

V ($S_6 \geq S_7$) = -7.25; and *V* ($S_6 \geq S_8$) = -7.25.

V ($S_7 \geq S_1$) = 0; *V* ($S_7 \geq S_2$) = 1; *V* ($S_7 \geq S_3$) = 0; *V* ($S_7 \geq S_4$) = 0; *V* ($S_7 \geq S_5$) = 1; *V* ($S_7 \geq S_6$) = 1; and *V* ($S_7 \geq S_8$) = 0.

V ($S_8 \geq S_1$) = 0; *V* ($S_8 \geq S_2$) = 1; *V* ($S_8 \geq S_3$) = 0; *V* ($S_8 \geq S_4$) = 0; *V* ($S_8 \geq S_5$) = 1; *V* ($S_8 \geq S_6$) = 1; and *V* ($S_8 \geq S_7$) = 0.

However, to understand the formula, its interpretation is given in Figure 1.

Furthermore, the earlier conditional statements are used to illustrate the degree of possibility between two fuzzy members, M1 and M2. Now consider the warehouse segment, and it means that for forklift drivers and sorters, the degree of possibility may be calculated as follows. However, it is essential to establish l_1, m_1, u_1, and l_2, m_2, and u_2 with the fuzzy members. Here for the forklift driver, the S_i is (0.113, 0.131, 0.152) where l_1, m_1, and u_1 are 0.113, 0.131, and 0.152, respectively. Then l_2, m_2, and u_2 from the fuzzy number for sorters give (0.085, 0.098, 0.113), where l_2, m_2, and u_2 are 0.085, 0.098, and 0.113, respectively. Now considering the conditional statements and comparing our values, m_1, which is 0.131, is greater than m_2, which is 0.098. The condition is that it should be assigned *1* where $V (S_1 \geq S_2) = 1$. This means that the degree of possibility of S_1 greater than S_2 is 1. Similarly, if we are considering the quality assurance segment, S_3 is introduced. Here, we define l_3, m_3, and u_3 as 0.113, 0.131, and 0.152, respectively, from the fuzzy synthetic extent of S_3 of (0.113, 0.131, 0.152). If we compare S_1 and S_3, $V (S_1 \geq S_3)$ is known by considering all the conditions of comparison that may result in 1, 0, and otherwise. Here, m_1 and m_3 are the same, which makes $V (S_1 \geq S_3) = 1$. Now, the degree of possibility of S_2 greater than S_1 is obtained as $V (S_2 \geq S_1)$. Nevertheless, the question "is m_2 greater than m_1"? The answer is no. Then, also consider the question: is l_1 greater or equal to u_2? The answer is yes since the value of $l_1 = u_2 = 0.113$. In this case, zero is allocated to it such that $V (S_2 \geq S_1) = 0$. Similarly, other values can be calculated. Next, we calculate the degree of possibility of our convex fuzzy number to be greater than the k convex fuzzy number. Here, the applicable equation is Equation (3):

$$V (S \geq S_1, S_2,..,S_k) = \min V (S \geq S_i),\ i = 1, 2, ..., k \quad (3)$$

The interpretation is that we are looking for the degree of possibility of S_1 greater than S_2, S_3, and others stated as follows:

$V (S_1 \geq S_2, S_3)$
$V (S_2 \geq S_1, S_3)$
$V (S_3 \geq S_1, S_2)$

It is calculated using Equation (3), where the minimum value of the degree of possibility of S greater than S_i is taken. It means that for $V (S_1 \geq S_2, S_3)$, the minimum of $V (S_1 \geq S_2)$ and $V (S_1 \geq S_3)$ is taken. Next, we calculate the weight vector and normalize weight vector. The values of $V (S_1 > S_2, S_3)$, $V (S_2 \geq S_1, S_3)$, and $V (S_3 \geq S_1, S_2)$ are taken as the weight vector, where w is computed as the transpose of the values. Then the weight vector is normalized by adding the element and dividing by the sum. On solving in non-fuzzy weight vector is obtained. These values can be used as the weight of the criteria, and to obtain weights in fuzzy form, a S_i value generated may be used.

Step 4.5. Calculate the degree of possibility for a convex fuzzy number to be greater than the *k* convex fuzzy number.

The results are as follows:

Calculate the degree of possibility for a convex fuzzy number to be greater than k convex fuzzy number.

$V (S_1 \geq S_2 S_3 S_4 S_5 S_6 S_7 S_8) = 0$; $V (S_2 \geq S_1 S_3 S_4 S_5 S_6 S_7 S_8) = -1.5$; $V (S_3 \geq S_1 S_2 S_4 S_5 S_6 S_7 S_8) = 0$;
$V (S_4 \geq S_1 S_2 S_3 S_5 S_6 S_7 S_8) = 0$; $V (S_5 \geq S_1 S_2 S_3 S_4 S_6 S_7 S_8) = -8.333$; $V (S_6 \geq S_1 S_2 S_3 S_4 S_5 S_7 S_8) = -7.25$; $V (S_7 \geq S_1 S_2 S_3 S_4 S_5 S_6 S_8) = 0$; and $V (S_8 \geq S_1 S_2 S_3 S_4 S_5 S_6 S_7) = 0$.

Step 4.6. Calculate the weight vector and normalize the non-fuzzy weight vector.

The results are as follows (see also Table 6):

$W' = (0, -1.5, 0, 0, -8.333, -7.25, 0, 0)^T$

$W' = (-0/17.083, 1.5/17.083, -0/17.083, -0/17.083, 8.333/17.083, 7.25/17.083, -0/17.083, -0/17.083)^T$

$W' = (0, 0.0878, 0, 0, 0.4878, 0.4244, 0, 0)^T$

Now, the summarized results for the weight vector and Si for the manufacturing corridor are given in Table 7. Furthermore, the weight vector and *Si* for quality assurance are shown in Table 8 for the vehicle fleet, and Table 9 for contractors is shown in Table 10. Tables 6 to 10 are the summaries of the weight vectors and S_i for the various segments, emphasizing the weight of criteria and details of S_i per level. This has been extracted from the individual data sets for all levels, and each segment has been considered. The usefulness of these tables is that they reflect the averages of the weights of criteria when all the levels have been considered. This provides information for further managerial customs in the safety domain of the bottling plant. To explain how these tables were obtained, an illustration of Table 6 is given in detail concerning its computational procedure. In the warehouse, the parameters considered range from the forklift drivers to the extra bottle removers. However, the field movements were done at three levels (i.e., 1,2, and 3). Nevertheless, it is essential to represent true figures for each parameter. There, the averages obtained for the forklift drivers account for the first adding 0, 0.1694, and 0, representing levels 1, 2, and 3, respectively, and then dividing by three to obtain 0.0565, 0.0293, 0.0000, 0.1693, 0.4937, 0.1962, 0.0335 and 0.0209 for the respective parameters of forklift drivers, sorters, rescuers, sugar handlers, haulage drivers, haulage truck mates, chip neck removers and extra bottle remover. Although the averages were not extended to the fuzzy synthetic extent values of parameters in work, they may be done for more clarity work. Overall, the averages of parameters for the manufacturing corridor are 0.1091, 0.1180, 0.3038, 0.0267, 0.1091, 0.0000, and 0.0000 for the respective parameters of sighters, filler operator, palletizers/depalletizers, washer operators, chip neck remover, technical operators/utilities and packer/unpacker operators. Next, the averages of parameters for quality assurance are 0.0000, 0.3333, 0.3333, 0.0000, 0.0000, and 0.0000 for the respective parameters of sugar lifters, syrup mixers, lab technicians, welders, battery charger/technicians. The averages of the parameters for contractors are 0.5732, -0.0132, 0.3201, 0.1799, and 0.0000 for the respective parameters of security, kitchen, contractor 1, and contractor 2.

In all, since the optimal parameters are desired, they are identified as follows, according to the highest figures in Tables 6 to 10. They are 0.4937 for haulage drillers (warehouse), 0.3038 for palletizers (manufacturing corridor), 0.3333 for syrup mixers/lab technicians for quality assurance, and no choice of the best parameter for the fleet workshop. However, the highest weight for the contractors is 0.3201, which is for contractor 1.

In this article, the synthetic control concept has been applied to estimate the influence of vagueness and imprecision on the safety conformity of a process plant. The potential control units are the warehouse, manufacturing corridor, quality assurance, fleet of vehicle flotilla, and contractors. The outcome variable was safety conformity. The attributes that were chosen to match on are different for each potential control unit. For the potential warehouse control unit, the chosen attributes to match are the forklift drivers, sorters, rescuers, sugar handlers, haulage drivers, haulage truck mates, chip neck removers, and extra bottle removers.

The potential control unit named manufacturing corridor has the following chosen attributes to march on,

Table 3. Fuzzified pairwise comparison matrix for Segment 1 (level 1) – Warehouse

	Forklift Drivers	Sorters	Rescuers	Sugar Handlers	Haulage Drivers	Haulage Truck Mates	Chip Neck Removers	Extra Bottle Removers
Forklift Drivers	(0.9,1.0,1.1)	(1.3,1.3,1.4)	(0.9,1.0,1.1)	(0.9,1.0,1.1)	(1,1.1.0,1.1)	(1.0,1.0,1.1)	(0.9,1.0,1.1)	(0.9,1.0,1.1)
Sorters	(0.7,0.8,0.8)	(0.9,1.0,1.1)	(0.7,0.8,0.8)	(0.7,0.8,0.8)	(0.8,0.8,0.9)	(0.7,0.8,0.8)	(0.7,0.8,0.8)	(0.7,0.8,0.8)
Rescuers	(0.9,1.0,1.1)	(1.3,1.3,1.4)	(0.9,1.0,1.1)	(0.9,1.0,1.1)	(1.0,1.1,1.1)	(1.0,1.0,1.1)	(0.9,1.0,1.1)	(0.9,1.0,1.1)
Sugar Handlers	(0.9,1.0,1.1)	(1.3,1.3,1.4)	(0.9,1.0,1.1)	(0.9,1.0,1.1)	(1.0,1.1,1.1)	(1.0,1.0,1.1)	(0.9,1.0,1.1)	(0.9,1.0,1.1)
Haulage Drivers	(0.9,0.9,1.0)	(1.2,1.2,1.3)	(0.9,0.9,1.0)	(0.9,0.9,1.0)	(0.9,1.0,1.1)	(0.9,0.9,1.0)	(0.9,0.9,1.0)	(0.9,0.9,1.0)
Haulage Truck Mates	(0.9,0.9,1.0)	(1.2,1.3,1.3)	(0.9,0.9,1.0)	(0.9,0.9,1.0)	(1.0,1.0,1.1)	(0.9,1.0,1.1)	(0.9,0.9,1.0)	(0.9,0.9,1.0)
Chip Neck Removers	(0.9,1.0,1.1)	(1.3,1.3,1.4)	(0.9,1.0,1.1)	(0.9,1.0,1.1)	(1.0,1.1,1.1)	(1.0,1.0,1.1)	(0.9,1.0,1.1)	(0.9,1.0,1.1)
Extra Bottle Removers	(0.9,1.0,1.1)	(1.3,1.3,1.4)	(0.9,1.0,1.1)	(0.9,1.0,1.1)	(1.0,1.1,1.1)	(1.0,1.0,1.1)	(0.9,1.0,1.1)	(0.9,1.0,1.1)

Table 4. Steps 1 and 2 in computing S_i for Segment 1 (level 1) – Warehouse

	Forklift Drivers	Sorters	Rescuers	Sugar Handlers	Haulage Drivers	Haulage Truck Mates	Chip Neck Removers	Extra Bottle Removers	Sum
Forklift Drivers	(0.9,1.0,1.1)	(1.3,1.3,1.4)	(0.9,1.0,1.1)	(0.9,1.0,1.1)	(1.0,1.1,1.1)	(1.0,1.0,1.1)	(0.9,1.0,1.1)	(0.9,1.0,1.1)	(7.8,8.5,9.1)
Sorters	(0.7,0.8,0.8)	(0.9,1.0,1.1)	(0.7,0.8,0.8)	(0.7,0.8,0.8)	(0.8,0.8,0.9)	(0.7,0.8,0.8)	(0.7,0.8,0.8)	(0.7,0.8,0.8)	(5.9,6.4,6.8)
Rescuers	(0.9,1.0,1.1)	(1.3,1.3,1.4)	(0.9,1.0,1.1)	(0.9,1.0,1.1)	(1.0,1.1,1.1)	(1.0,1.0,1.1)	(0.9,1.0,1.1)	(0.9,1.0,1.1)	(7.8,8.5,9.1)
Sugar Handlers	(0.9,1.0,1.1)	(1.3,1.3,1.4)	(0.9,1.0,1.1)	(0.9,1.0,1.1)	(1.0,1.1,1.1)	(1.0,1.0,1.1)	(0.9,1.0,1.1)	(0.9,1.0,1.1)	(7.8,8.5,9.1)
Haulage Drivers	(0.9,0.9,1.0)	(1.2,1.2,1.3)	(0.9,0.9,1.0)	(0.9,0.9,1.0)	(0.9,1.0,1.1)	(0.9,0.9,1.0)	(0.9,0.9,1.0)	(0.9,0.9,1.0)	(7.5,7.8,8.3)
Haulage Truck Mates	(0.9,0.9,1.0)	(1.2,1.3,1.3)	(0.9,0.9,1.0)	(0.9,0.9,1.0)	(1.0,1.0,1.1)	(0.9,1.0,1.1)	(0.9,0.9,1.0)	(0.9,0.9,1.0)	(7.6,8.1,8.5)
Chip Neck Removers	(0.9,1.0,1.1)	(1.3,1.3,1.4)	(0.9,1.0,1.1)	(0.9,1.0,1.1)	(1.0,1.1,1.1)	(1.0,1.0,1.1)	(0.9,1.0,1.1)	(0.9,1.0,1.1)	(7.8,8.5,9.1)
Extra Bottle Removers	(0.9,1.0,1.1)	(1.3,1.3,1.4)	(0.9,1.0,1.1)	(0.9,1.0,1.1)	(1.0,1.1,1.1)	(1.0,1.0,1.1)	(0.9,1.0,1.1)	(0.9,1.0,1.1)	(7.8,8.5,9.1)
Sum									(60.0,64.6,69.1)

Table 5. Step 3 in computing S_i for Segment 1 (level 1) – Warehouse

S/No.	Factor	Sum	Reciprocal of the sum total	*Si* (Fuzzy synthetic extent)
1	Forklift Drivers	(7.8,8.472,9.1)	(1/69.1,1/64.561,1/60)	(0.113,0.131,0.152)
2	Sorters	(5.9,6.348,6.8)	(1/69.1,1/64.561,1/60)	(0.085,0.098,0.113)
3	Rescuers	(7.8,8.472,9.1)	(1/69.1,1/64.561,1/60)	(0.113,0.131,0.152)
4	Sugar Handlers	(7.8,8.472,9.1)	(1/69.1,1/64.561,1/60)	(0.113,0.131,0.152)
5	Haulage Drivers	(7.5,7.759,8.3)	(1/69.1,1/64.561,1/60)	(0.109,0.120,0.138)
6	Haulage Truck Mates	(7.6,8.094,8.5)	(1/69.1,1/64.561,1/60)	(0.110,0.125,0.142)
7	Chip Neck Removers	(7.8,8.472,9.1)	(1/69.1,1/64.561,1/60)	(0.113,0.131,0.152)
8	Extra Bottle Removers	(7.8,8.472,9.1)	(1/69.1,1/64.561,1/60)	(0.113,0.131,0.152)

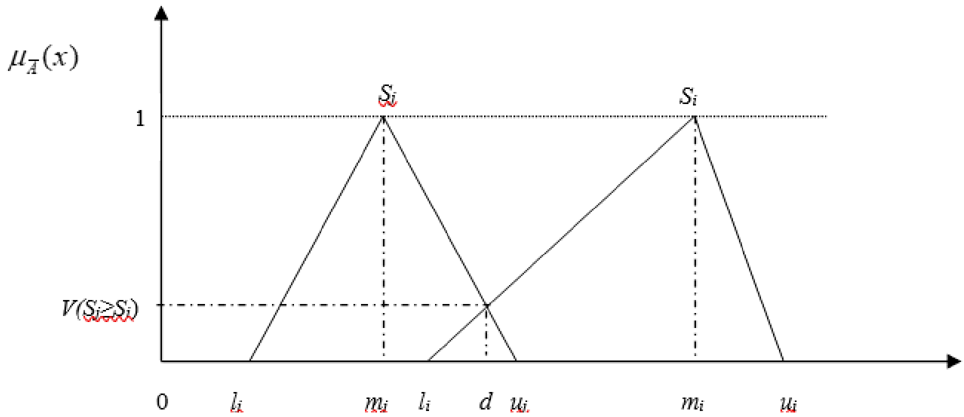

Figure 1. Evaluation of the degree of possibility

namely, chip neck removers, technical operators/utilities, and packer/unpacker operators. The estimated synthetic for the warehouse was 0.1694 for forklift drivers, 0 for sorters, 0 for rescuers, 0.5098 for sugar handlers, -6.7077 E-3 for haulage drivers, 0.1643 for haulage truck mates, 0.1006 for chip neck removers, and 0.0626 for extra bottle removers. For the estimated synthetic for the manufacturing corridor, we have 0.3272 for sighters, 0.3541 for filler operator, -0.0885 for palletizers/depalletizers, and 0.0801 for washer operator, 0.3272 for chip neck remover, 0 for technical operator/utilities and 0 for packer/unpacker operators. Concerning the estimated synthetic for quality assurance, we have zero for all the chosen attributes to match, including sugar lifters, syrup mixers, laboratory technicians, water technicians, etp technicians, and others. Regarding the estimated synthetic for a fleet of vehicle flotilla, we the following weights for the chosen attributes to match zero for forklift technicians, zero for welders, and zero for battery chargers/technicians. Regarding the estimated synthetic for contractors (residuals/others), we have the following values, which are 0.5398 for security, -0.0397 for kitchen, -0.0397 for contractor 1, 0.5397 for contractor 2, and 0 for contractor 3.

To compare the results of the present article with those in the literature, work in the domain of safety conformity regarding the use of Taguchi was considered. To make the comparison, additional information may be calculated on ranking, which was absent in Martins and Oke (2021). In Table 4a of the article, the additional information provided by us is the delta values, which were obtained as 0.23, 40.17, 40.38, 0.46, 0.26, 0.02, 0.25, and 0.85, respectively, for forklift drivers, organizers, rescuers, syrup handlers, transport drivers, transport truck rates, chip neck removers, and extra bottle removers.

However, for this range of values, the rescuers having a value of 40.38, which will be ranked 1st, is the best, while transport truck mates are the worst unit within the conflict with haulage drivers that was obtained as the best in the present article. Furthermore, the data analyzed from Table 4b in Martins and Oke (2021) can be compared in ranking with the results obtained in the present article; hence, the delta values of the various units of segment 2 are established from which the ranks of the units of segment 2 are proposed. The delta values for organizers, filler operators, palletizers/ depalletizers, washer operators, chip neck removers, technical operators/ utilities, and packer/ unpacker operators are 0.21, 0.35, 1.75, 0.13, 39.08, and 39.12, respectively by ranking these delta values, packer/ unpacker operators emerged as the 1st position with a value of 39.12. In contrast, the washer operators took the 7th position. Now, from the present study, the best result obtained is the palletizers and depalletizers, which is at variance with the literature results of Martins and Oke (2021). However, the washer operators concurred with the literature results, thereby affirming the effectiveness of the present method. By computing this optional solution, which is the best value (i.e., the weight of criterion results from palletizers/depalletizers), it could be used for further analysis in other multicriteria methods, such as the EDAS method. It could also be used as the final results for budgetary planning of safety activities.

Here, the focus area in the manufacturing corridor is the palletizer/ unpalletizers. At the same time, careful maintenance of the operations staff is done such that the

Table 6. Weight vector and S_i for segment 1 (warehouse) – (levels 1, 2, and 3)

Factors	Weight of criteria			S_i (fuzzy synthetic extent)		
	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
Forklift Drivers	0.0000	0.1694	0	(0.113,0.131,0.152)	(0.148,0.183,0.237)	(-0.143, 0, -0.143)
Sorters	0.0878	0.0000	0	(0.085,0.098,0.113)	(-0.019,0.000,0.026)	(-0.143, 0, -0.143)
Rescuers	0.0000	0.0000	0	(0.113,0.131,0.152)	(-0.019,0.000,0.026)	(-0.143, 0, -0.143)
Sugar Handlers	0.0000	0.5098	0	(0.113,0.131,0.152)	(0.119,0.149,0.198)	(-0.143, 0, -0.143)
Haulage Drivers	0.4878	-6.7077E-3	1	(0.109,0.120,0.138)	(0.136,0.198,0.256)	(-0.143, 0, -0.143)
Haulage Truck Mates	0.4244	0.1643	0	(0.110,0.125,0.142)	(0.146,0.180,0.234)	(-0.143, 0, -0.143)
Chip Neck Remover	0.0000	0.1006	0	(0.113,0.131,0.152)	(0.122,0.158,0.208)	(-0.143, 0, -0.143)
Extra Bottle Remover	0.0000	0.0626	0	(0.113,0.131,0.152)	(0.103,0.132,0.175)	(-0.108, 0, -0.148)

Table 7. Weight vector and S_i for segment 2 (manufacturing corridor) – (levels 1, 2, and 3)

Factors	Weight of criteria			S_i (fuzzy synthetic extent)		
	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
Sighters	0	0.3272	0	(0.121,0.146,0.177)	(0.165,0.216,0.279)	(-0.143, 0, -0.143)
Filler Operator	0	0.3541	0	(0.121,0.146,0.177)	(0.152,0.198,0.266)	(-0.143, 0, -0.143)
Palletizers/Depalletizer	1	-0.0885	0	(0.106,0.122,0.145)	(0.194,0.247,0.333)	(-0.143, 0, -0.143)
Washer Operators	0	0.0801	0	(0.121,0.146,0.177)	(0.087,0.124,0.171)	(-0.143, 0, -0.143)
Chip Neck Remover	0	0.3272	0	(0.121,0.146,0.177)	(0.165,0.216,0.279)	(-0.143, 0, -0.143)
Technical Operators/Utilities	0	0.000	0	(0.121,0.146,0.177)	(-0.023,0.000,0.032)	(-0.143, 0, -0.143)
Packer/Unpacker Operators	0	0.000	0	(0.121,0.146,0.177)	(-0.023,0.000,0.032)	(-0.143, 0, -0.143)

Table 8. Weight vector and S_i for segment 3 (quality assurance) – (levels 1, 2, and 3)

Factors	Weight of criteria			S_i (fuzzy synthetic extent)		
	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
Sugar Lifters	0	0	0	(0.146,0.173,0.204)	(-0.019,0.000,0.025)	(-0.130, 0.000, -0.231)
Syrup Mixers	0	0	1	(0.146,0.173,0.204)	(0.108,0.143,0.189)	(0.087, 1.000, -0.615)
Lab Technicians	1	0	0	(0.126,0.144,0.165)	(0.234,0.286,0.352)	(-0.130, 0.000, -0.231)
Water Technicians	0	0	0	(0.146,0.173,0.204)	(0.108,0.143,0.189)	(-0.130, 0.000, -0.231)
Etp Technicians	0	0	0	(0.146,0.173,0.204)	(0.108,0.143,0.189)	(-0.130, 0.000, -0.231)
Others	0	0	0	(0.146,0.173,0.204)	(0.234,0.286,0.352)	(-0.130, 0.000, -0.231)

Table 9. Weight vector and S_i for segment 4 (fleet workshop) – (levels 1, 2, and 3)

Factors	Weight of criteria			S_i (fuzzy synthetic extent)		
	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
Forklift Technicians	0	0	0	(0.273,0.333,0.407)	(-0.333,0,0.333)	(-0.333,0,0.333)
Welders	0	0	0	(0.273,0.333,0.407)	(-0.333,0,0.333)	(-0.333,0,0.333)
Battery Charger/Technicians	0	0	0	(0.273,0.333,0.407)	(-0.333,0,0.333)	(-0.333,0,0.333)

Table 10. Weight vector and S_i for segment 5 (contractors (residents/others)) – (levels 1, 2, and 3)

Factors	Weight of criteria			S_i (fuzzy synthetic extent)		
	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
Security	0	0.5397	1	(0.170,0.203,0.240)	(0.19,0.237,0.291)	(0.143, 1.000, -1.000)
Kitchen	0	-0.0397	0	(0.170,0.203,0.240)	(0.207,0.251,0.312)	(-0.143, 0.000, -0.333)
Contractor 1	1	-0.0397	0	(0.166,0.188,0.223)	(0.223,0.274,0.333)	(-0.143, 0.000, -0.333)
Contractor 2	0	0.5397	0	(0.170,0.203,0.240)	(0.196,0.238,0.298)	(-0.143, 0.000, -0.333)
Contractor 3	0	0	0	(0.170,0.203,0.240)	(-0.028,0.000,0.035)	(-0.143, 0.000, -0.333)

best-skilled workers are transferred to the unit. When such a staff is known to have reasons to be absent from work in the future, paired staff could be made such that skills are transferred from the experienced staff to the less experienced worker for the unit.

Next is the computation of the delta values and ranks of the units within segment 3 (quality assurance, from Table 4 c of Martins and Oke (2021), the delta values of syrup lifters, syrup mixers, laboratory technicians, electrical technicians, and others are 38.96, 1.79, 0.56, 1.50, 1.64 and 0.06, respectively. To introduce ranks to these units of segment 3, syrup lifters rank first and the best while within segment 3. By comparing these results with those of the present study, there is a conflict of opinion. At the same time, a tie involving syrup mixers and laboratory technicians were obtained as the best criteria in the recommendations of the present study, and a complete deviation of choice as syrup lifters was recommended as the best criterion in the literature by Martins and Oke (2021). The recommendation that the unit termed others in segment 3 is the worst concurred in both situations of the present study and the literature study of Martins and Oke (2021).

Moving on to the comparison of results in segment 4, Table 4d is first analyzed, where the forklift technicians, welders, and electric technicians are examined for their delta values and ranks. There are, respectively, 45.08, 10.00, and 45.08 in the order of names of units mentioned above. However, the forklift technicians and electric technicians are placed 1st in ranking while welders are placed 2nd (worst) in ranking by considering the delta values mentioned above. Nevertheless, the present results place no unit as the best or the worst, which conflicts with the literature results of Martins and Oke (2021). Moving forward, the delta value of segment 5 and the corresponding ranks are evaluated.

Finally, segment 5 is analyzed from the literature using the data from Martins and Oke (2021), where security, kitchen, supplier 1, supplier 2, and supplier 3 are concluded to have the respective delta values of 1.09, 0.20, 0.21, 0.35 and 41.52. This implies that supplier 3 is the best unit while the kitchen is the worst unit. On comparing these results, there is a conflict in the outcome of the best results because our results suggest security and contactor 2 as the best. There is also a conflict in the worst results because, as opposed to the kitchen being chosen as the worst result in the literature (Martins & Oke, 2021), the present study declared contractor 3 as the worst result.

Furthermore, once the important unit within a segment of the bottling plant is given to this unit assigning the most experienced and careful workers to this unit. This guarantees that the best outputs will emanate from this unit within the segment. If the best employees had been assigned to a different unit within the segment, corrective actions are taken such that a re-assignment of the task of safety compliance is made by order of scores of the units within the segments of the bottling plant. Also, at the beginning of the planning period, the resources assigned to each segment unit will be made according to the importance declared by the weighted scores of the units. Furthermore, in this work, the term "parameter" has the same meaning as the term "segment" For instance, in the five segments considered in this work, namely the warehouse, manufacturing corridor, quality assurance, a fleet of vehicles, and contractors, they are also referred to as parameters. However, units and sub-units are different from parameters in that they are, respectively, divisions and subdivisions of the segments.

5. CONCLUSIONS

The principal objective of this research, notably to apply a fuzzy analytic hierarchy process (extent analysis method) as an instrument to rank the chief parameters of the segment of a bottling process plant, was attained. To evaluate the safety conformity process, a research process was instituted in which one of the authors used his experience and expertise in the safety system to evaluate the relative importance of one segmental part to another. The results were cross-checked and cross-checked by another member of the author's team.

Furthermore, several parameters were considered, which shows the diversity and importance of an essential safety conformity scheme that can effectively contemplate and select the largely appropriate parameters and order the largely crucial ones (Ferrari et al., 2020). As declared by Ferrari et al. (2020), standardization of safety parameters could hardly be observed in the literature. The observation was confirmed in the present article, with some research limited to the declaration of parametric titles and other variants focused on equations. Unfortunately, the differences observed in the safety literature pose a restriction to researchers and practitioners in understanding how to treat the respective bottling processes plants such as soft drinks and bottled pharmaceutical drug production. Consequently, the systemization of the whole bottling process plant into five segments, notably the warehouse, manufacturing corridor, quality assurance, fleet of vehicles, flotilla, and contractors, was made in this work as a strategic attempt to formalize the findings, combining alike characteristics of the bottling process and directing efforts at the practical use of the parameters this promoting the understanding of the concept of fuzzy AHP method.

The application of the fuzzy AHP method in the context of the bottling process plant attained satisfactory results, thus confirming the method’s effectiveness in revealing and analyzing vagueness and imprecision in safety assessment. The study attained an extremely clear outcome when evaluated from the expert's judgments who are the authors of this research. The results indicated the categories within each segment that were considered the most and least important parameters. The parameter filler operator was considered the most important (i.e., the weight of 0.3541), while the least important parameter was a tie between technical operators/utilities and packer/unpacker operators when the category named manufacturing corridor was considered. For the warehouse category, forklift drivers (i.e., the weight of 0.1694) are the most important parameter, while the least important parameters are sorters and rescuers, with each weighting zero. Considering the quality assurance category, all the criteria are equally important, namely sugar lifters, syrup mixers, laboratory technicians, water technicians, etc. technicians, and others. For the fleet of vehicles, flotilla, all the parameters, notably forklift technicians, welders, and battery chargers/technicians. Now, for the contractors, the security parameter and contractor 2 have the most importance with an equal weight of 0.5397, while the least importance was attached to contractor 3 with a weight of zero. These results obtained in the present study are at variance with the outcome of Ferrari et al. (2020), which presented occupational health and safety management as the most important. Despite attaining a satisfactory outcome, it should be noted that the priority hierarchy used in the article is based on the authors' judgment. However, the results are subject to changes if different assessors were used and considering a different company setup, such as the drug bottling process. As a future outlook, the present authors' advice on the replication of the research with experienced experts in the field. Also, the bottling plant studied could change from soft drinks to a drug bottling process.

In this work, the terms "parameter" and "units/subunits" are used interchangeably to mean the same. However, parameters allow the safety researcher and the engineer to gain an insight into how the safety conformity data behaves under various situations and in the context of how they best fit the bottling plant being considered. Furthermore, the researchers are concerned with determining which parameters (units and sub-units) within each segment exhibit the greatest impact on the conformance behavior of workers in the soft drinks company. To reduce uncertainty and imprecision in measuring safety conformity data, the most important parameter is the one with the greatest impact on the system objective. Identifying the best parameter helps the safety engineers, among other things, decide on the training scale necessary for the workforce in a particular segment by eliminating the best parameter with which more intensive training would help further optimize their performance. Safety engineers could utilize members of the best units as leaders where poor performance is achieved. These members are also potential candidates for international training that the international headquarters of the bottling plant may organize outside the country. This could also be used as leaders in the implementation of performance-enhancing programs such as lean safety processes within the plant.

Besides, from the literature, it is understood that qualitative analysis of subjective judgment examines the prospect of developing the safety conformity issue based on the results of an exercise. Thus, one area where the results of the selection of the best parameter in a segment will be useful from the qualitative dimension is safety training. It is envisaged that the demands by the headquarters of the bottling plant to send personnel for international training from the plant to the headquarters outside the country may be met by choosing the members of the units that perform best in each segment for training abroad. This guarantees that probably the most disciplined and knowledgeable from the units are those selected, and the transfer of knowledge from the training may best be guaranteed from the trainees to potential trainees from this choice.

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