International Journal of Industrial Engineering and Engineering Management (IJIEEM), Vol. 8, No. 1, June 2026

e-ISSN: 2685-4090 http://ojs.uajy.ac.id/index.php/IJIEEM

Novel NGT-DEMATEL Method for Interrelationship Management of Safety Conformity in a Bottling Process Plant

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ABSTRACT

The NGT (nominal group technique) is a structured brainstorming decision-making method with the ability to reach a quick consensus and incorporate all voices in safety management. The DEMATEL method is used to establish safety measure influential parameters, their interdependence, and their impacts on each other. This article presents the NGT-DEMATEL method based on the NGT and DEMATEL methods and uses real-time bottling process data to test the proposed method. The results reveal that for segments 1 to 5, the casual groups, having positive (Sr – Sc) values, are sorters (0.3523), rescuers (0.6271), sugar handles (0.4332), haulage drivers (1.0958), and haulage truck mates (0.2442) for segment 1; sighters (0.2981), washer operators (0.7459), and technical operators (utilities) (0.3761) for segment 2; sugar lifters (2.8805) and ETP technicians (1.1935) for segment 3; forklift technician (1.6203) for segment 4; kitchen (0.0399) for segment 5. However, the effect groups are forklift drivers (-0.8338), chip neck removers (-1.5044) and extra bottle removers (-0.4143) for segment 1; filler operators (-0.3078), palletizers/depalletizers (-0.0421), chip neck removers (-0.9615), packers/unpackers (-0.1086) for segment 2; syrup mixers (-2.5812), laboratory technicians (-1.4505) and water technicians (-0.0423) for segment 3; welders (-1.1380) and battery changers/technicians (-0.4823) for segment 4; security (-2.4973), and contractor 2 (safety boot suppliers) (-1.0840) for segment 5. The most important criteria in segments 1 to 5 are forklift drivers, sighters, syrup mixers, welders, and security. The principal novelty of this article is that it introduces a procedure to concurrently incorporate consensus and the voices of workers while establishing the interrelationships of the various workers using the NGT-DEMATEL method. This is the first article to develop and use NGT-DEMATEL for safety conformity in the bottling process plant.

DOI: https://doi.org/10.24002/ijieem.v8i1.11526

Keywords: bottling plant, hazards, performance, safety conformity, workforce, workplace

Research Type: Research Paper

Article History: Received May 7, 2025; Revised May 7, 2026; Accepted July 21, 2026

How to cite: Martins, S.A., Oke, S.A., Ogundare, A.A., Orisaleye, J.I., Aderibigbe, S.B., Rajan, J., Jose, S., & Ahmed, A.F. (2026). Novel NGT-DEMATEL method for interrelationship management of safety conformity in a bottling process plant. *International Journal of Industrial Engineering and Engineering Management, 8*(1), 51-68.

1. INTRODUCTION

A bottling process plant designed to produce beverages such as soft drinks, non-alcoholic syrups, and concentrates (Tireki, 2021; Singh and Awoke, 2023; Tadesse et al., 2024; Martins et al., 2026). However, a significant output of the company studied, whose data is analysed here, produces soft drinks classified into several brand names (Singh and Awoke, 2023; Swain et al., 2024). The facilities in the production plant studied fill beverages into bottles and cans (Singh and Awoke, 2023). The process is essentially the cleaning and sterilization of cans and bottles, filling them with the intended liquid, sealing the labeled cans and bottles, and afterwards packaging them for distribution to customers. However, the equipment used and the production environment where soft drinks are produced are risky for several reasons. Firstly, the requirement for huge production volumes of soft drinks while maintaining precision and safety when conducting the bottle or can-filling and sealing operations poses significant pressure on the operators and risk of accidents and injuries. Other aspects are the exposure of certain workers in the factory to chemicals, such as those involved in the water treatment plant and the sanitation activities in the plant (Alleyne and Steele, 2021). Moreover, there are occasion's explosions when safety guidelines regarding storage and usage of chemicals are violated. Also, the handling of hazardous liquids exposes the workers to the dangers of skin poisoning and burns. In the foregoing, proper safety control measures and metrics for the operation of the plant in all the mentioned aspects are crucial in reducing risks of accidents and ill health consequences in the bottling plant.

Moreover, the risks indicated in the previous paragraphs are shared by manufacturing industries globally, with compelling statistics that make intervention programmes critical and urgent. In the following paragraphs, the statistics shared by Raymohan and Srinivasan (2016) are mentioned. The Bhopal Gas Tragedy in Bhopal, India, during a toxic methyl sol cyanate leakage in 1984, which resulted in 558; 125 worker injuries, is horrifying, pointing to similar risks to gas exposure in bottling plants, which must be controlled. A boiler explosion in a tyre-melting company in Coimbatore, India, inflicted workers with severe body burns cautious workers in the bottling process plant with responsibility for boiler operations and maintenance should be cautious (Rajmohan and Srinivasan, 2016). Furthermore, a fire outbreak in a leather company in Kolkata, India, in 2006 resulted in 10 fatalities and 18 injuries, respectively (Rajmohan and Srinivasan, 2016), which is a tragedy to the manufacturing community. All these activities are reminders of the presence of risks in the bottling process industry. They reinforce the need for more caution on safety and accident prevention in the soft drinks industry.

Also today, the workforce population in bottling process plants has astronomically grown in size, skill requirement and training needs. The diversity of the workforce and shortages of skilled workers in the bottling process industry place a compelling obligation on the plant to absorb and manage workers available in the job market within the industry (Severino et al., 2024). This decision to absorb and train, and the large workforce required to manage the bottling plant, has ushered in significant workplace hazards, accidents, deaths, injuries, and ill health in the bottling process plant studied. To manage and control these undesirable events and happenings, the issue of safety conformity is critical. It is also central to the survival of operations and the sustainability of the company at large. Unfortunately, the literature that specifically addresses the safety conformity problem is scanty and has only recently emerged as a critical mass. To be particular, normal group technique, which aids in assessing decisions and the extent to which safety has been complied with, is completely absent in the critical mass of research on safety conformity. This threatens the survival of the bottling process plant, as failure to account for the safety conformity of the plant leads to ineffectiveness and wasteful spending on safety. Failure to analyse through the decision model of nominal group technique is even more grievous as activities within the plant will run at sub-optimal points, giving room for leakages in man-hours and monetary values. Apart, consider the various decision-making tools used for engineering decision making in engineering literature; the normal group technique has achieved significant interest in various application temerities. The nominal group technique offers a structured group brainstorming opportunity for experts concerning a subject, encouraging individual creativity prior to deciding collectively. Individuals generate ideas, discuss them with other group members, rank them, and vote to prioritize the best solutions for the problems. The normal group technique ensures that every member of the group has his/her voice heard, contributing to a more efficient and informed decision – making process.

Subsequently, the normal group technique has been used in several engineering processes. The nominal group technique has expanded significantly among safety practitioners and decision makers, which is one of the models the authors intend to integrate to form a holistic model used in this work. Moreover, from the methods used for structural modeling, the DEMATEL method is known for its significance in the engineering application domain. The DEMATEL method could examine complex systems by establishing and visualizing the causal relationship between the process parameters, which are represented as sub-segments in this work. Consequently, the DEMATEL method has been used in several engineering procedures. To date, no method is available in the literature on safety conformity, covering the nominal group technique and the DEMATEL method. To this end, this paper presents a new method, called the nominal group techniques-based DEMATEL method, and applies it to a real-life bottling process plant that produces soft drinks, located in Lagos, Nigeria. The current study is different from the application of either the nominal group technique alone or DEMATEL alone in scope and application. The nominal group technique, a structured approach to generating and prioritizing group-oriented ideas, while the nominal group techniqueoriented DEMATEL joins the nominal group technique with the DEMATEL approach, examining and modeling complicated systems such as the bottling process plant and the decision – making situations. Notice that the nominate group technique is founded on idea development and ordering, while DEMATEL centres on establishing and mapping causal associations between various parameters, such as the washer operators, chip neck remover, filler operator, technical operators/utilities, palletizers/depalletizers, sighters, and packer unpacker operators who are members of the manufacturing corridor segment of the bottling process plant. The authors hope to provide a model that offers insights on safety conformity decision-making process in the presence of causal relationships, and the visualizations provide a foundation on which future studies could be built upon.

2. LITERATURE REVIEW

2.1. Safety studies

Safety conformity, within the bottling process plant, has emerged as a new concept in literature and has recently stimulated some studies such as Martins and Oke (2020a, b, 2021), Martins et al. (2021), and Sawyerr et al. (2023). These studies have successfully deviated from the traditional perception of safety conformity that is limited to the regulation of covers for moving machines, where the operator who removes the covers to the rotary parts of machines is categorized as non-conforming to safety rules. However, several issues associated with a comprehensive study into the mutual effect of parameters in an indirect or direct manner remained unresolved. The main reason for this research gap is the lack of a comprehensive scheme to interrogate parameters from an interactive perspective. The following works on safety conformity, which were stated earlier, are revised in detail. Safety conformity for bottling process plants can be evaluated by optimization techniques following single and hybrid techniques, such as the hybrid control chart-Taguchi approach, the multi-response Taguchi approach, and the binomial-oriented Taguchi approach. The hybrid control chart-Taguchi approach used the control chart to monitor the periodic performance of the workers in the sub-segments and establish occasions that it the parametric performance deviates from a predictable condition of stability, stressing the necessity to correct the behaviour (Martins and Oke, 2020a). The data used in the evaluation process reveals the competence of the model to optimize and concurrently control the bottling process parameters, which are the same as those investigated in the present study. The Taguchi method was used by Martins Oke (2021) to optimize the safety conformity process parameters. The multi-response model proposed works by searching for the optimal combination of the parameters, which concurrently achieve safety conformity of workers for each outcome of the process. This opposes an attempt at optimizing individual responses.

The results showed that safety conformity leads to a healthy operation within the plant. The binomial-based Taguchi approach by Martins et al. (2021) optimized safety conformity for operations within the bottling process plant using the binomial-oriented Taguchi method. The best confirming parameter, within the 5 segments studied, is the liberators (segment 1), syrup lifters, forklift technicians, and suppliers 3 in segments 2, 3, 4, and 5, respectively. Moreover, all the above reviews are optimization-based, but other studies, effective in implementation, have been implemented but not in the optimization terrain. These studies are as follows: Martins and Oke (2020b) used historical data on safety conformity to predict the single outcome variable that depends on each parameter in the sub- segment studied. The parameters used are the same as those analysed in the present study. The results of the study indicated the most significant variables measured at $p < 0.05$. Sawyer et al. (2023) apply the fuzzy analytic hierarchy process to minimize the imprecision and uncertainty observed during the evaluation of safety conformity in a bottling process plant. The above literature discussion has revealed the dependence of authors on the evaluation of safety conformity using optimization and numerical analysis techniques, including multicriteria analysis. This is only one perspective of the safety conformity literature. Hon et al. (2025) qualitatively assessed the viewpoint of occupational safety and health within an Ontario-based manufacturing sector using focus group discussions involving managers and workers disjointedly. The key outcomes of the study include an understanding that language barriers and technical expressions hinder effective communication in safety and health issues. Also, multiple delivery routes of communication and their tones are important considerations for safety and health effectiveness.

However, before the reviews above, earlier studies have entirely placed the safety conformity issue as the problem of machine guard usage alone. For instance, Uzor and Oke (2020) analysed a machine guard usage conformity approach using a multiple regression model combined with the Taguchi method. It was reported that the efficient predictive ability of the approach, using the coefficient of determination, was R2 = 0.997. The number of functional guards and damaged guards were the significant variable of the bottling process. It was also reported that the highest operator compliance using machine guard exhibited a mean of 269.28 and a signal-to-noise ratio of 48.60. These two views are limited, and studies have attempted to look closely at the interactions among the parameters of the bottling process. Yet interactions reveal significant details about parameters, informing the researcher on how important parameters are to one another. This information is critical and useful for resource planning, but no studies have shed light on these hidden details on safety conformity parameters in the literature. Given this understanding, there is a state of emergence in research on research of interaction among the parameters of the bottling process plant. Moreover, all these literature insights suggest that it is essential to study the safety process in the bottling plant, involving the safety conformity issue. It points out that a comprehensive procedure where the mutual effects of parameters, either in an indirect or direct manner, with a deep causal-effect understanding, while taking decisions in a complex bottling process environment in necessary. Such a study would offer the essential information to visualize the causal associations between parameters in the bottling plant. The method proposed would also provide insights on the principal drivers, possible solutions, and crucial parameters yielding more informed strategic decision making, which is the choice of decision options that will influence the safety performance of the bottling plant and its long–term goals.

2.2. Nominal group technique

Riley-Bennet et al. (2024) introduced a novel format of the Nominal Group Technique (NGT), which innovatively excludes face-to-face discussion and referred to it as the virtual Nominal Group Technique (vNGT). The vNGT was applied to clinical prioritisation and in the generation of guidelines in healthcare. The differences between this reviewed paper and the current work are that while it tackles a healthcare scenario, the present study is focused on the bottling process plant with a manufacturing inclination. However, the innovativeness of the virtual implementation of the NGT is borrowed for use in the present work. Notwithstanding, to date, it remains unclear how the technique could be integrated with the DEMATEL method. McMillan et al. (2016) presented an overview of the NGT and Delphi methods. The authors elaborated on the stages of the NGT method to contain four principal phases, namely, idea generation, round robin, clarification of ideas, and ranking (voting). Smith et al. (2024) represent how nominal groups were facilitated virtually using Microsoft Teams. The effect was introduced, prioritising content for a theory-oriented characteristic adjustment intervention to enhance responses in clinically deteriorated patients. This study is similar to the current study in utilising virtual NGT. Although Microsoft Teams is used while Google Meet is applied here, the characteristics in terms of avoiding the physical presence of respondents in the same place are the consensus methods, the application areas such as the health care in the reviewed work, and the bottling process plant are different.

3. METHODOLOGY

An overview of the concerns treated in this study is produced in Figure 1. Moreover, the idea of the NGT-DEMATEL method shares some resemblance with the work in Martins et al. (2026), being part of a larger project conducted by the authors.

3.1. Principal parameters used during the operational study

In this article, novel interrelationship management of safety conformity parameters are discussed for the carbonated beverage bottling plant where precision and expertise coupled with a safe environment are required at every stage of the production stage of the production stage. However, chosen representative parameters that influence the working operations during the operational studies are crucial. These parameters are discussed here for direct and indirect beverage production activities. Thus, the essential parameters considered in Martins and Oke 2020a, 2020b; Martins et al. (2021) were adapted in the present since it is part of a larger project considered by the author. In all, five segments were considered: notably, warehouse, manufacturing corridor, quality assurance, fleet workshops, and contractors. The detailed explanations of this segment are as follows: Segment 1 is the warehouse that contains 8 inputs: Forklift drivers, sorters, rescuers, chip neck removers, haulage drivers, haulage truck mates, and extra bottle removers. The convener explained the function of each of the sub-units, which are personnel in the warehouse. The forklift drivers are those who drive the forklifts for the carriage of creates and heavy items that may be challenging for manual lifting. It includes raw materials and finished goods. The movement of the forklift drivers is often within the factory. Sorters are responsible for arranging and separating different bottle brands. Often, customers may mix different brands of bottles in a crate. Washing and feeding these brands with the same content is not appropriate. Hence, sorters are responsible for correcting this anomaly. Rescuers are those who watch the moving bottles on the conveyor belt and ensure that they flow well without interrupting the flow and also without disturbing other bottles from standing upright in the flow. They ensure that there is no obstruction. If they discover potential obstruction damage on the bottles in their flow, they intervene by arranging them. Sugar handlers see to the carriage of sugar bags, which are one of the raw materials. Haulage drivers are those who drive the trucks that bring in empty bottles to the plant. They also bring in raw materials and transport the product from the warehouse to the consumers. Haulage truck mates are those who assist in the loading and offloading of haulage trucks. Chip neck removers observe the necks of the bottles, discover those whose necks are cracked or broken, and remove them from the flow as they perceive that they could further break during filling and constitutes an hazard to the consumer. Extra bottle removers are meant to discover excess bottles along the line and remove them from the flow of bottles. These descriptions are for segment 1. However, segment 2 has the following components and descriptions.

Segment 2 is the manufacturing corridor, which has the following items, inputs, or operators: sighters are those who watch all over the whole process. Next is the filler operation, which operates the syrup filling machines: palletizers and depalletizers are those who remove bottles from the wooden carriages that carries creates. They also put the products on the wooden carriages. Washer operators are those who operate the bottle washing machine. Chip neck removers carry out the functions as explained under the warehouse segments. Technical operators (utilities) are those who work on maintenance activities on the different machines within the plant. Packer and unpacker operators are those who operate the packing machine and also the unpacking activities. Segment 3 is the quality assurance, which has the following members: sugar mixers, who carry sugar bags from point to point, within the quality control unit. They

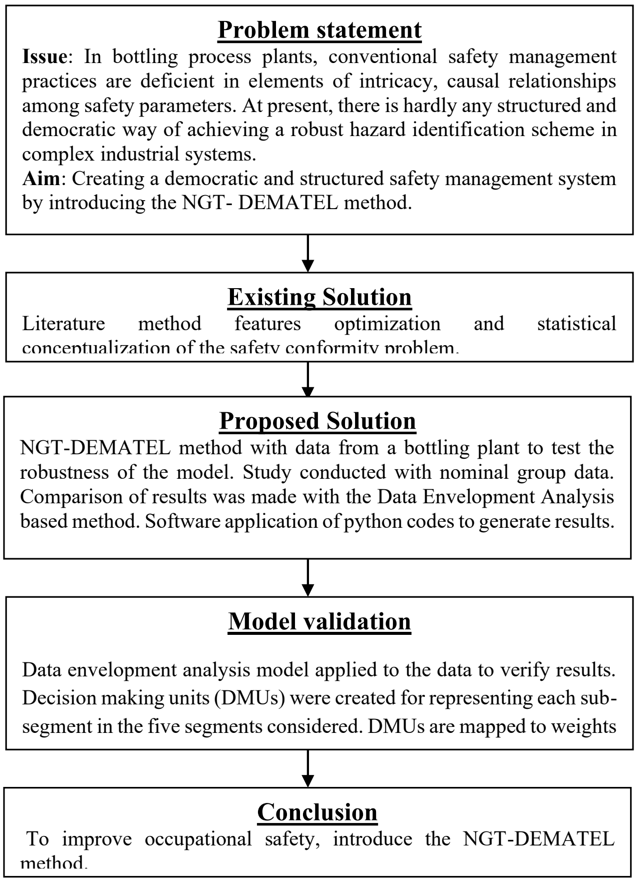

Figure 1. An overview of the concerns addressed in this research

move the sugar bags from the warehouse to where they will be mixed. They also carry sugar bags from any point in the plant where the forklifts have dropped them. Syrup mixers are those with oversight functions on the mixing of syrup. They introduce a mixing ratio between water concentrates and sugar. Laboratory technicians are quality control personnel who work in the laboratory to measure the properties of the bottled daunts as well as their quality characteristics such as taste and filling height, as well as colour and smell. Water technicians are those working on water. The Etp are technicians who engage in other electrical works. Others are the category that encompasses industrial attachment students and other support staff, and technicians. Segment 4 is the fleet workshops, which has three members: forklift technicians, are those that maintain the forklift. Welders are those who engage in welding work. Battery chargers/technicians are those that works on the batteries, especially the batteries of the forklifts. They change the batteries. The last segment is segment 5, which is contractors, which comprises residents and others. Under segment 5, there are five participants: security, who are those who attend to the security of the factory premises. Kitchens are people who work in the kitchen, contractors I, II, and III. These contractors handle different aspects of materials required for the operation. Contractor I is tailors that saw uniforms for the factory workers. Contractor II is responsible for the supplies of safety boots. Contractor III is the chemical supplier for the plant.

The discussion in this section of the paper encourages the adoption of the NGT DEMATEL method in a soft drinks bottling plant and using the method to evaluate the safety conformity of the various sub-segments, which are termed parameters in this work. Moreover, the effectiveness of the safety programme and the need to establish areas of improvement push the present investigations to seek a method that would show the interactions among the parameters of the bottling process plant. In this section, the nominal group technique methodology and how it was applied are discussed.

3.2. Nominal group technique-DEMATEL application

There are three accounts on which the norminal group technique was developed. While some scholars declared the late 1960s, others mentioned 1971 and 1975 as the years of emergence of the nominal group technique. Although there is controversy about when the structured technique was created, there is consensus on the preponents of the technique as Andre Delbeq and Andrew Van de Ven. They were both acknowledged to have first implemented the technique for organisational planning. Besides, there is an agreement that the nominal group technique works on consensus planning, where participants are assembled to discuss an issue that will be coordinated by a moderator.

Summary: Nominal group discussions were held in two Google Meet meeting sessions held on Saturday, December 30, 2023(6.05 pm) and Tuesday, January 2, 2024(11.18 am). Overall, 10 participant nominal group members conducted the meeting with the researcher serving as the coordinator of the meeting. The chosen participants include those who work in the manufacturing sector in positions such as engineers on the factory floor. The participant includes human resource professionals as well as those who graduated from universities but have experience at work in the manufacturing plant. Experience and knowledge of the operations of a manufacturing plant were considered important to qualify as a member of the nominal group for the present study.

Details of the meeting: The highlight of the group discussion on the methodology of the nominal group technique and its application is revealed in this section of the paper. The group discussion was held using a Google Meet facility, which allows teams to meet and discuss issues that are relevant to them. The meeting started at about 6.05 pm on the 30th December 2023. In attendance were 10 participants. The convener started the meeting and introduced himself. He asked all the participants to introduce themselves, mentioning their names, backgrounds, and the area of work. Then the convener introduced the topic of the research and what was expected of the participants. Afterwards, the convener ran through the work, which involves the use of the DEMATEL method by the group, referred to as the nominal group members. It was emphasized that the nominal group technique will be adopted.

Specifically, the research is on the bottling process plant, focusing on the safety conformity in operations and other units within the plant. The segment is divided into five, namely warehouse (segment 1), manufacturing corridor (segment 2), quality assurance (segment 3), fleet workshop (segment 4), and contractors (residents and others) (segment 5). The focus on these segments is all about the safety and logistics, i.e., internal logistics, involving the movement of raw materials and finished goods. Another is the safety of the operators and the interdependence of the whole operation. The convene runs through the segments one after the other, explaining the components (parameters) of each of the segments. The sub – segments, such as the forklift driver for segment 1, are taken as the parameter in this case. Earlier, the convener explained the comparative scale of importance for the DEMATEL method. It was stated that the parameters would be compared on a scale basis, which is between 0 and 4. The definition of the scale ranges from. “No influence”, which is 0, to “very high influence”, which is 4. In between these extreme classifications are intermediate groupings of 1, implying “No influence”, 2 is “Medium influence”, and 3 is “High influence”. The convener explained each of the items in the five segments worked on by the members of the nominal group. Then the convener asked all the participants to fill in a form based on the explanations given earlier and their understanding of the interdependence of different parameters from segments 1 to 5. The convener ran through the form for the members to fill, some of the participants raised observation which were responded to A. total of 10 to 15 minutes was given to the participants to fill out the forms from segments 1 to 5 and send them through e-mail to the convener. It was agreed to have a group meeting three days after this first meeting for further discussions. A summary of the steps in implementing the NGT-DEMATEL method is as follows.

Step 1- Pre-NGT activities:

Participants were asked to prepare the materials needed. These include paper, pen, or pencils for each expert at the various locations. Additional materials needed are flipcharts, marking pens, and read-aloud phones. Since a platform such as Google Meet is earmarked for online calls, the participant requires a computer system with a functional and reliable internet connection, a microphone, webcam, and necessary software such as Google installations for the online course. More importantly, adequate lighting and a chair for the expert are needed to allow enjoyable call sections by the experts.

Step 2- Generating ideas:

Experts were encouraged to quietly and independently brainstorm ideas, specifically weighing two subsegments of a particular segment at a time, for their relationship in terms of how related they are. The five measuring parameters to be kept in mind are; “no inference”, “low inference”, “medium inference”, high inference”, and “very high inference”, which are assigned values of 0, 1, 2, 3, and 4, respectively. This nominal group is unlike the traditional brainstorming group that entails creating ideas openly in a group. For these methods, experts are encouraged to only share their ideas when the coordinator calls for them.

Step 3 - Recording ideas:

At each location where the participants are, they are encouraged to record their ideas on a large paper, such as an A3 paper, using a pen or pencil.

Step 4 - Discussion and ranking of ideas:

Through the coordinators, the group members (experts) share ideas on their agreement or disagreements on their value rating for each interaction assessment between any two subsegment members in any of the five segments considered in this study. A consensus is reached where only one value is picked for each interaction assessment by all the group members. The coordinator ensures that a justification for the choice that differs from the proposal of other members is made. A rank is finally given to each conflicting ranking choice by members of the group.

Step 5 - Establishing a direct relation matrix:

A square matrix is created where two parts of the matrix are filled with numbers for each cell. The first part should consist of all the entries of the group members that must have been dictated during the call by the expert who assigned that number to the cell. In the particular being considered there, where eight members of the norminal group are used, eight entries are written. For example, by considering sorters, along the row, while the forklift drivers are along the column in the warehouse segment, values of 3,3,0,0,3,2,3,2 are obtained. The second part of the cell is where the consensus number is written in a larger font than those written earlier. In this particular case, a bold value “3” is written under those 8 numbers written earlier. This indicates that the consensus number of all the numbers in the group is 3. The direct relation matrix is the pairwise association between the two subsegments (parameters) of the segment.

Step 6 - Calculating the normalised direct relation matrix:

The idea of normalisation is introduced such that the consensus values from the groups are organised to reduce redundancy and to enhance the safety data integrity. An effort is made to reduce all the entries in the matrix (consensus values) to a range between 0 and 1. This is achieved by summing all the values along the row, picking the highest among them, and using this value as a denominator in the division effort.

Equation (1) provides information in the evaluation of the normalized direct relation matrix (Maduekwe and Oke, 2021). The starting expression is

$$X = K \times A \tag{1}$$

where,

$$K = \frac{1}{\max\limits_{1 \le i \le n} \sum_{j=1}^{n} a_{ij}}; \; i, j = 1, 2, \ldots, n \tag{2}$$

Step 7 - Calculating the total relation matrix:

These shapes show the cumulative impacts of both indirect and direct effects between the parameters of the bottling process plants being considered. This is obtained where the normalised direct relation matrix is transformed, through its elemental modification, by matrix multiplication of the normalised matrix (Y) to obtain a total influence matrix.

Equation (2) leads to the computation of the total relation matrix (Maduekwe and Oke, 2021).

$$T = X(I - X)^{-1} \tag{3}$$

where I means the identity matrix.

Step 8 - Analysis of results - for insight into the effect of each parameter on others:

The principal numerical indicators in this case are Sc, Sr, (Sr+Sc), and (Sr-Sc). The (Sr-Sc) is watched for its negative values, which means that the parameters that have such negative values greatly influence other parameters and are called a causal factor. If (Sr-Sc) is positive, it means that the parameter concerned is of the effect group and influenced by other parameters. This step is where the interpretation of the results is given in this section.

4. RESULTS AND DISCUSSIONS

In this section, the analysis of safety conformity in a bottling process plant is considered. The nominal group technique (NGT)-DEMATEL method is employed. The bottling plant is divided into five compartments, called segments, namely the warehouse (segment 1), manufacturing corridor (segment 2), quality assurance (segment 3), fleet workshop segment 4), and contractors, residents, and others (segment 5). Each segment has its data on how many times each of the subsequent members has complied with safety conformity or not. To measure this data, data sheets were designed with two important guidelines. The following marks were used:

⊗ When the worker is observed adhering to safety rules for the activity studied. When the worker studied fails to adhere to the key safety rule for the activity observed.

To illustrate what was done, suppose the worker works on the filling machine, and the three important aspects of the machine are the power cut-off devices, fencing of the revolving filling member of the machine, and fire-fighting kits. The assessor asks the following questions:

- Does the worker assure that the power cut-off devices are in good order? ⊗ or O (mark one).
- Does the worker allow the fencing of the revolving filling member to be in a good and proper place? ⊗ or O (mark one)
- Does the worker allow the firefighting kits to be properly placed and ready for use? ⊗ or O (mark one).

Now, all these questions are for only one person in a workstation, and all other questions are asked for other workers in other situations. The results obtained for each worker are added, and the average is obtained. This represents the safety conformity of a subsection of the segment, which is summarized in a table and evaluated. Applying the normal group technique allows the members to be in the position of the evaluator. However, as opposed to observing the situation in which each operator or member of the segment is assessed for conformance to safety regulation, the focus of the members of the group is to evaluate how important each workstation is compared with another? This will provide information on the most important workstations in the plant. This idea will help in directing decisions on budgeting allocations. It will inform the safety officer which of the units in a segment should have the utmost financial, training, and other attention more than others since they are key in ensuring a risk –free work environment. Tables 1 to 5 represent the five segments, namely segments 1 to 5, respectively. Table 1 shows the raw data given by the nominal group, consisting of experts who have experience in the area of bottling plant operation and manufacturing process operations.

Each evaluates from his/her perception how important the sub-segment being evaluated is by its components. For example, eight participants look part in the assessments of all the tables. Consider the first assessment of the group, which is for the first row but the first column, where the importance of the forklift driver is evaluated against itself. The evaluation of this cell follows a general rule, which states that comparing a member of a sub-segment, such as the forklift driver, to itself yields 0. Thus, each of the nominal group members assigns a value of 0 for this activity, which is the eight different zeros placed at the top part of the box where the forklift driver intersects with it. After the assignment, an average is obtained, which is zero, and it is written below the values given by the individual assessor. Compared with the literature, Martins and Oke (2020b), in a study on the application of multiple regressions to evaluate the safety conformity of the bottling company, using the same data, ignored the interrelationship among the sub-segmental parameters but only focused on how responsive each of the parameters is to safety conformity. Moreover, this methodology could be applied to a smaller bottling plant with a sourced maintenance service system for its vehicles and one that does not have an elaborate warehouse. In that instance, the parameters will be limited to the manufacturing corridor, quality assurance, and the contractors. Notice that the eight parameters of segment 1 are the forklift drivers, sorters, extra bottle removers, rescuers, sugar handlers, haulage drivers, haulage truck mates, and clip neck removers, which are represented by the abbreviations, namely, FDR, SOR, EBR, RER, SHR, HDR, HTM, and

CRN.

Table 2 is the second segment called the manufacturing corridor, consisting of 7 parameters, namely sighters (SGR), filler operator (FOR), palletizer/depalletizer (PDR), washer operators (WOR), clip neck remove (CNR), technical operator/utilities (TOU), packer/unpacker operators (PUO) Table 2.

The third segment, quality assurance, is divided into the following parameters: sugar lifter (SLR), syrup mixers (SMR), laboratory technicians (LTN), water technicians (WTN), ETP technicians (ETN), and others (OTR), Table 3.

The fourth segment, fleet worship, is classified into forklift technician (FTN), welders (WLR), and battery charger /technicians (BCT), Table 4.

Table 5 is the component that reveals the component of the contractors, majorly the residents and others. They are detailed as security (STY), kitchen (KTN), contractor 1 (tailors) (CTR), contractor 2 (safety boot supplier) (CSS), and contractor 3 (chemical suppliers) (CCS), Table 5. Having stated the various segments and the parameters that they contain, the step of the DEMATEL method, which advices the research to specify the parameters, has been satisfied. Now, it is useful to refer to a comparative scale, which states that the lens used by each member of the nominal group to evaluate one parameter relative to the other. Specifically, the scale members indicate the degree of influence of a parameter over the other. Here, analysis is performed on segment 1, and after its completion, segments 2 to 5 are analysed and reported.

Under the first analysis, the authors are considering only segment 1. Thus, the results presented in Table 6 show the aggregated nominal group results. Here, the forklift driver matched against the forklift driver results in a value of 0. This result of 0 is also obtained for all other parameters matched against themselves, such as sorters against sorters. These matches continue until all the diagonal elements result in zero values. Now, implementing step 1 of the DEMATEL procedure is the parametric denotation, Table 6. Then the direct relation matrix X is computed as shown in Table 6. Notice that from the point-of-view of analyses, the forklift driver is denoted by FOR, sorters are denoted by SOR, while RER, SHR, HDR, HTM, CNR, and EBR are rescuers, sugar landlers, haulage drivers, haulage truck makes, chip neck removers, and extra bottle removers, respectively.

Then the data in Table 6 is normalized, while the results are shown in Table 7. Thus was obtained by finding the horizontal summation of the parameters. Thus, for FDR, considering the first row, the total is 13, while for SOR, RER, SHR, HDR, HTM, CNR, and EBR, the summations are 13, 14, 2, 14, 12, 6, and 6, respectively, as presented in the last column of Table 6. Now, step 3 is implemented, where the normalization of the direct relation matrix (Y) is obtained. Notice that thus is the result obtained from normalizing the direct relation matrix (X). It was done by dividing all the elements by the highest summation in the normalized direct relation matrix (X). Notice that the highest value is 14, and this is used to divide all the parameters (elements) (Table 7).

Table 1. Segment 1 (Warehouse) - Aggregated Nominal Group Result

	FDR	SOR	RER	SHR	HDR	HTM	CNR	EBR
FDR	0,0,0,0, 0,0,0,0 **0**	3,1,0,0, 1,2,2,2 **2**	4,1,1,1, 2,2,0,1 **1**	0,3,0,2, 3,2,0,1 **0**	4,3,4,2, 3,4,4,2 **4**	1,4,4,3, 4,4,4,2 **4**	1,1,1,0, 2,2,0,1 **1**	1,2,3,0, 1,2,0,1 **1**
SOR	3,3,0,0, 3,2,3,2 **3**	0,0,0,0, 0,0,0,0 **0**	4,2,1,1, 2,1,1,2 **1**	0,3,1,2, 3,0,0,1 **0**	1,3,2,1, 2,3,0,2 **2**	1,2,4,0, 3,3,0,2 **2**	4,4,4,4, 2,1,2,1 **4**	4,3,2,4, 0,1,1,1 **1**
RER	4,2,4,3, 4,2,0,1 **4**	4,2,2,2, 3,1,1,2 **2**	0,0,0,0, 0,0,0,0 **0**	4,1,3,2, 3,0,0,1 **0**	4,3,2,3, 0,1,0,1 **0**	4,3,2,3, 1,1,0,2 **1**	4,3,4,4, 2,0,1,1 **4**	4,3,3,4, 3,2,1,1 **3**
SHR	0,3,0,1, 0,2,0,1 **0**	0,3,0,3, 0,0,0,1 **0**	4,2,2,2, 1,0,0,1 **2**	0,0,0,0, 0,0,0,0 **0**	0,0,1,0, 2,0,0,1 **0**	0,3,1,1, 2,0,0,1 **0**	0,3,2,2, 2,0,0,1 **0**	0,0,1,3, 0,0,0,1 **0**
HDR	4,2,4,4, 2,4,4,2 **4**	1,2,3,3, 2,3,0,2 **2**	4,1,3,2, 2,1,0,2 **2**	0,1,1,1, 1,0,0,1 **1**	0,0,0,0, 0,0,0,0 **0**	4,4,4,3, 4,4,4,2 **4**	0,2,0,2, 1,0,0,1 **0**	0,1,2,1, 1,0,0,1 **1**
HTM	1,3,4,1, 2,4,4,2 **4**	1,3,3,0, 1,3,0,2 **3**	4,3,3,1, 1,1,0,2 **1**	0,2,1,2, 2,0,0,1 **0**	4,3,4,3, 4,4,4,2 **4**	0,0,0,0, 0,0,0,0 **0**	0,3,1,1, 2,0,0,1 **0**	0,3,2,2, 1,0,0,1 **0**
CNR	1,3,0,0, 1,2,0,1 **0**	4,4,4,4, 1,1,1,1 **1**	4,3,4,3, 3,0,1,1 **3**	0,2,1,2, 1,0,0,1 **0**	0,1,1,0, 2,0,0,1 **0**	0,2,1,1, 1,0,0,1 **1**	0,0,0,0, 0,0,0,0 **0**	4,3,1,3, 0,1,1,1 **1**
EBR	1,3,3,1, 0,2,0,1 **1**	4,4,0,2, 2,1,1,1 **1**	4,3,3,3, 1,2,1,1 **3**	0,0,0,2, 1,0,0,1 **0**	0,1,1,2, 2,0,0,1 **0**	0,0,4,2, 2,0,0,1 **0**	4,3,1,4, 1,1,1,1 **1**	0,0,0,0, 0,0,0,0 **0**

Key: Forklift Drivers – FDR; Sorters – SOR; Rescuer – RER; Sugar Handlers – SHR; Haulage Drivers – HDR; Haulage Truck Mates – HTM; Chip Neck Remover –CNR; Extra Bottle Remover - EBR

Table 2. Segment 2 (Manufacturing corridor) - Aggregated Nominal Group Result

	SGR	FOR	PDR	WOR	CNR	TOU	PUO
SGR	0,0,0,0, 0,0,0,0 **0**	4,3,4,1, 3,4,3,1 **4**	4,3,4,2, 4,4,0,1 **4**	4,0,4,3, 4,4,2,1 **12**	4,3,3,3, 3,4,2,1 **4***	4,1,3,4, 3,4,0,1 **4**	4,4,2,2, 4,4,1,1 **4**
FOR	4,3,2,1, 2,4,3,1 **4**	0,0,0,0, 0,0,0,0 **0**	3,3,3,0, 3,4,0,1 **3**	3,2,1,2, 4,4,1,1 **1**	4,1,2,3, 2,2,1,2 **2**	4,4,2,4, 4,3,0,1 **4**	4,4,2,1, 4,4,1,1 **4**
PDR	4,3,3,1, 3,4,2,1 **3**	3,3,2,0, 4,4,0,1 **4**	0,0,0,0, 0,0,0,0 **0**	3,2,0,0, 4,4,0,1 **0**	3,3,2,0, 2,1,0,1 **3**	4,2,3,0, 3,1,1,1 **1**	3,4,4,4, 3,4,2,1 **4**
WOR	4,0,2,3, 2,4,2,1 **2**	3,2,3,2, 3,4,0,1 **3**	3,2,2,0, 3,4,0,1 **3**	0,0,0,0, 0,0,0,0 **0**	3,2,4,1, 3,2,0,1 **2**	4,4,2,1, 4,3,0,1 **4**	0,3,2,2, 3,4,0,1 **3**
CNR	4,3,3,4, 2,4,1,1 **4**	4,1,3,2, 4,2,1,2 **2**	3,3,1,1, 2,1,0,1 **1**	3,2,4,1, 3,2,1,1 **1**	0,0,0,0, 0,0,0,0 **0**	4,0,2,1, 3,0,0,1 **0**	0,3,1,2, 2,1,0,1 **1**
TOU	4,1,2,4, 3,4,0,1 **4**	4,4,4,3, 3,3,2,1 **4**	4,2,1,1, 2,1,0,1 **1**	4,4,3,2, 3,3,1,1 **3**	4,1,4,2, 2,0,0,1 **4**	0,0,0,0, 0,0,0,0 **0**	4,4,3,1, 2,3,1,1 **1**
PUO	4,4,4,3, 1,4,1,1 **4**	4,4,2,1, 3,4,0,1 **4**	3,4,1,3, 3,4,2,1 **3**	0,3,2,2, 2,4,1,1 **2**	0,3,2,2, 2,1,1,1 **2**	4,4,2,2, 1,3,1,1 **1**	0,0,0,0, 0,0,0,0 **0**

Table 3. Segment 3 (Quality Assurance) - Aggregated Nominal Group Result

	SLR	SMR	LTN	WTN	ETN	OTR
SLR	0,0,0,0, 0,0,0,0 **0**	2,4,2,4, 2,4,1,1 **4**	2,1,1,2, 3,0,1,1 **1**	2,4,1,2, 2,0,0,1 **2**	2,1,0,1, 2,0,0,1 **0**	2,2,3,1, 3,0,0,1 **2**
SMR	2,4,1,4, 3,4,1,1 **1**	0,0,0,0, 0,0,0,0 **0**	4,3,4,3, 3,4,3,1 **3**	4,4,2,3, 2,3,3,1 **3**	4,3,2,3, 1,0,2,1 **3**	2,2,2,1, 2,0,1,1 **2**
LTN	2,1,0,1, 2,0,0,1 **0**	4,1,4,2, 4,4,3,1 **4**	0,0,0,0, 0,0,0,0 **0**	4,3,1,3, 3,3,3,1 **3**	4,4,3,3, 2,2,2,1 **2**	2,2,2,2, 2,2,1,1 **2**
WTN	2,1,1,1, 2,0,0,1 **1**	4,4,4,2, 3,3,3,1 **4**	4,3,3,2, 3,3,3,1 **3**	0,0,0,0, 0,0,0,0 **0**	4,4,3,3, 2,1,2,1 **3**	2,2,3,2, 3,1,1,1 **2**
ETN	2,1,1,1, 3,0,1,1 **1**	4,3,3,2, 3,0,2,1 **3**	4,3,3,4, 4,2,2,1 **4**	4,3,3,4, 3,1,2,1 **3**	0,0,0,0, 0,0,0,0 **0**	2,2,3,2, 3,4,1,1 **2**
OTR	2,2,2,1, 2,0,1,1 **2**	2,2,2,1, 2,0,2,1 **2**	2,2,2,0, 2,2,2,1 **2**	2,2,2,0, 2,1,2,1 **2**	2,2,2,0, 2,4,2,1 **2**	0,0,0,0, 0,0,0,0 **0**

Table 4. Segment 4 (Fleet workshop) - Aggregated Nominal Group Result

	FTN	WLR	BCT
FTN	0,0,0,0,0,0,0,0 **0**	4,4,1,3,2,1,3,1 **1**	4,4,1,2,3,4,3,1 **4**
WLR	4,4,2,2,4,1,2,1 **2**	0,0,0,0,0,0,0,0 **0**	4,4,1,2,3,0,0,1 **1**
BCT	4,4,3,4,3,4,3,1 **4**	4,4,1,3,2,0,0,1 **1**	0,0,0,0,0,0,0,0 **0**

Table 5. Segment 5 (Contractors – Resident and others) aggregated Nominal Group Result

	STY	KTN	CTR	CSS	CCS
STY	0,0,0,0,0,0,0,0	4,3,3,3,2,4,2,1	4,2,3,1,2,4,3,1	4,2,3,2,1,4,3,1	4,2,3,4,2,4,3,1
	0	**3**	**2**	**2**	**2**
KTN	4,3,4,1,4,4,2,1	0,0,0,0,0,0,0,0	4,2,2,1,2,1,0,1	1,2,0,0,2,1,0,1	1,2,0,1,3,1,0,1
	4	**0**	**1**	**1**	**1**
CTR	4,2,3,1,4,4,3,1	4,2,3,1,3,1,0,1	0,0,0,0,0,0,0,0	2,2,1,1,1,0,1,1	0,2,2,2,2,0,1,1
	4	**1**	**0**	**1**	**2**
CSS	4,2,4,2,4,4,3,1	1,2,4,1,0,1,0,1	2,2,4,1,1,0,1,1	0,0,0,0,0,0,0,0	0,2,4,4,4,0,1,1
	4	**1**	**1**	**0**	**4**
	4,2,4,1,0,4,3,1	1,2,1,0,0,1,0,1	0,2,0,0,1,0,1,1	0,2,1,2,1,0,1,1	0,0,0,0,0,0,0,0
	4	**1**	**0**	**1**	**0**

Table 6. Parameters Denotations- Direct-Relation Matrix (X)

Parameters	FDR	SOR	RER	SHR	HDR	HTM	CNR	EBR	Total
FDR	0	2	1	0	4	4	1	1	13
SOR	3	0	1	0	2	2	4	1	13
RER	4	2	0	0	0	1	4	3	14
SHR	0	0	2	0	0	0	0	0	2
HDR	4	2	2	1	0	4	0	1	14
HTM	4	3	1	0	4	0	0	0	12
CNR	0	1	3	0	0	1	0	1	6
EBR	1	1	3	0	0	0	1	0	6

Table 7. Normalized Direct-Relation Matrix (Y)

Parameters	FDR	SOR	RER	SHR	HDR	HTM	CNR	EBR
FDR	0.0000	0.1429	0.0714	0.0000	0.2857	0.2857	0.0714	0.0714
SOR	0.2143	0.0000	0.0714	0.0000	0.1429	0.1429	0.2857	0.0714
RER	0.2857	0.1429	0.0000	0.0000	0.0000	0.0714	0.2857	0.2143
SHR	0.0000	0.0000	0.1429	0.0000	0.0000	0.0000	0.0000	0.0000
HDR	0.2857	0.1429	0.1429	0.0714	0.0000	0.2857	0.0000	0.0714
HTM	0.2857	0.2143	0.0714	0.0000	0.2857	0.0000	0.0000	0.0000
CNR	0.0000	0.0714	0.2143	0.0000	0.0000	0.0714	0.0000	0.0714
EBR	0.0714	0.0714	0.2143	0.0000	0.0000	0.0000	0.0714	0.0000

Then step 4 is implemented, which is to calculate the total relation matrix T as indicated in the formula for DEMATEL's evaluation procedure. Notice that I is the identity matrix used in the computation. Notice that step 4 was divided into four steps, indicating the identity matrix (I), an 8 x 8 matrix, is in line with the number of parameters under consideration. The second sub – step under step 4 entrants subtracting the matrix (Y) from the identity matrix (I). The third step of step 4 is to find the inverse matrix of (I) – (Y). Furthermore, the last step and step 4 are to find the Total Relation Matrix (T). Notice that the Total Relation Matrix (I) obtains the product of the inverse matrix and the 8 x 8 matrix earlier stated, Table 8, where the vertical and horizontal sums are indicated, denoted by Sc and Sr, respectively (Table 8). By implementing step 5 of the DEMATEL method, the causal and effect groups are determined, which is an interpretation of the results from Table 8 in Table 9. Thus, Sr, Sc, Sr – Sc, Sr + Sc are in the 2nd, 3rd, 4th, and 5th columns of Table 9, respectively. Then the interpretation of the results is contained in the last two columns of Table 9. Notice that (Sr – Sc), which is negative, implies that the parameter is a receiver, which indicates that the criterion is influenced by other criteria, whereas (Sr – Sc), which is positive, is a causal parameter, implying that such a criterion influences other criteria. For the summation, (Sr + Sc), the value that gives the highest dimension is the most important criterion, which has maximum influence or relationship with other criteria. The criterion with the least value of (Sr + Sc) is the least important criterion, which has the minimum relationship with other criteria, Table 9.

Thus, from Table 8, the criteria with negative (Sr – Sc) are FDR, CNR, and EBR, while the criteria with positive (Sr – Sc) are SOR, RER, SHR, HDR, and HTM. The criterion with the highest value is FDR, while the one with the lowest value is SHR. Thus, the most important criterion is forklift driver, FDR, because it has the highest value of (Sc + Sr), and the least important criterion is sugar handler, SHR, since it has the lowest value of (Sc + Sr). The casual group is sorters, rescuers, sugar handlers, haulage drivers, and haulage truck mates. The effect/receiver group is forklift drivers, chip neck removers, and extra bottle removers. The above results

Table 8. The Total-Relation Matrix $T=Y(1-Y)^{-1}$

Parameters	FDR	SOR	RER	SHR	HDR	HTM	CNR	EBR	S_r
FDR	0.9676	0.8107	0.6447	0.0698	0.9766	1.0451	0.5884	0.4484	5.5513
SOR	0.9876	0.5897	0.6012	0.0530	0.7425	0.8162	0.7264	0.4178	4.9346
RER	1.0013	0.6936	0.5403	0.0422	0.5901	0.7173	0.7488	0.5468	4.8803
SHR	0.1430	0.0991	0.2200	0.0060	0.0843	0.1025	0.1070	0.0781	0.8400
HDR	1.2310	0.8354	0.7175	0.1269	0.7769	1.0703	0.5651	0.4686	5.7918
HTM	1.1970	0.8605	0.6281	0.0706	0.9880	0.8306	0.5387	0.3906	5.5040
CNR	0.4031	0.3483	0.4501	0.0192	0.2692	0.3651	0.2755	0.2605	2.3910
EBR	0.4544	0.3450	0.4512	0.0192	0.2685	0.3127	0.3455	0.1976	2.3941
S_c	6.3851	4.5823	4.2532	0.4069	4.6960	5.2598	3.8954	2.8085	

Table 9. Causal and Effect Groups Table (Segment 1)

	S_r	S_c	S_r-S_c	S_r+S_c	S_r-S_c	S_r+S_c
FDR	5.5513	6.3851	-0.8338	11.9364	-ve (Receiver/influenced by other criteria)	Highest (Most important criterion- maximum relationship with other criteria)
SOR	4.9346	4.5823	0.3523	9.51683	+ve (Cause/influence other criteria)	
RER	4.8803	4.2532	0.6271	9.13349	+ve (Cause/influence other criteria)	
SHR	0.8400	0.4069	0.4332	1.24690	+ve (Cause/influence other criteria)	Least (Least important criterion- minimum relationship with other criteria)
HDR	5.7918	4.6960	1.0958	10.4878	+ve (Cause/influence other criteria)	
HTM	5.5040	5.2598	0.2442	10.7638	+ve (Cause/influence other criteria)	
CNR	2.3910	3.8954	-1.5044	6.28636	-ve (Receiver/influenced by other criteria)	
EBR	2.3941	2.8085	-0.4143	5.20258	-ve (Receiver/influenced by other criteria)	

and analysis are for the first segment. (Warehouse) using the DEMATEL method. However, for segments 2 to 5, only the results of the causal and effect groups are given in Tables 10 to 13, with the summaries shown in the respective tables. To summarize the results for segment 2, which is the manufacturing corridor, Table 10 shows the criteria results presented in a 7 x 4 matrix. The interpretation of Table 10 is as follows: The (Sr – Sc) which gives positive results belong to the causal group and include SGR, 0.298 (sighters), WOR, 0.7459 (washer operators), and TOU, 0.3761(technical operators/utilities). The (Sr – Sc) with negative values show that criteria are in the effect/receiving group and include the following: FOR, -0.3078 (filler operator), PDR, -0.0421 (palletizers/depalletizers), CNR, -0.9615 (chip neck removers), and PUO, - 0.1086 (packer/unpacker operators). The interpretation for (Sr + Sc) is to determine the highest value for the summation, which is SGR, 6.045 (sighters), and is the most important criterion in segment 2. It is a criterion that has the maximum relationship with other criteria. However, CNR, 3.7521 (chip neck removers), is the least important criterion in segment 2. It has the minimum relationship with other criteria.

Considering segment 3, the causal and effect group Table 11 interprets the results of the previous analysis from the computation of the Total Relation Matrix, determination of columns for Sc and Sr, which are row-column summation differences and row-column summation addition. For (Sr – Sc), the parameters with positive results in segment 3 are the causal group, which causes influences on other parameters (Table 11). They are, namely, SLR, 2.8805 (sugar lifters) and ETN, 1.1935 (ETP technicians). The parameters whose (Sr – Sc) yields negative results are the effect /receiver group, namely SMR, - 25812 (syrup mixers), LTN, -114505 (laboratory technicians and WTN, - 0.0423 (water technicians). The parameter whose difference gives zero where Sr – Sc is zero is the other, which is also called the neutral group. The parameter "others" is not affected by other parameters and does not affect other parameters.

Table 10. Causal and Effect Groups Table (Segment 2)

Parameters	S_r	S_c	S_r-S_c	S_r+S_c	S_r-S_c	S_r+S_c
SGR	3.1719	2.8738	0.2981	6.0457	+ve (Cause/influence other criteria)	Highest (Most important criterion- maximum relationship with other criteria)
FOR	2.5314	2.8392	-0.3078	5.3705	-ve (Receiver/influenced by other criteria)	
PDR	2.0981	2.1402	-0.0421	4.2384	-ve (Receiver/influenced by other criteria)	
WOR	2.3485	1.6027	0.7459	3.9512	+ve (Cause/influence other criteria)	
CNR	1.3953	2.3568	-0.9615	3.7521	-ve (Receiver/influenced by other criteria)	Least (Least important criterion- minimum relationship with other criteria)
TOU	2.3678	1.9917	0.3761	4.3596	+ve (Cause/influence other criteria)	
PUO	2.2901	2.3987	-0.1086	4.6888	-ve (Receiver/influenced by other criteria)	

Table 11. Causal and Effect Groups Table (Segment 3)

Parameters	S_r	S_c	S_r-S_c	S_r+S_c	S_r-S_c	S_r+S_c
SLR	6.6357	3.7552	2.8805	10.3909	+ve (Cause/influence other criteria)	
SMR	8.8396	11.4209	-2.5812	20.2605	-ve (Receiver/influenced by other criteria)	Highest (Most important criterion- maximum relationship with other criteria)
LTN	8.3260	9.77652	-1.4505	18.1025	-ve (Receiver/influenced by other criteria)	
WTN	9.4546	9.4969	-0.0423	18.9515	-ve (Receiver/influenced by other criteria)	
ETN	9.4225	8.2290	1.1935	17.6515	+ve (Cause/influence other criteria)	
OTR	7.3351	7.3351	0	14.6703	zero (Neutral criteria)	Least (Least important criterion- minimum relationship with other criteria)

To interpret (Sr + Sc), the highest value is the SMR, 20.2605 (syrup mixers), which is the most important criterion in segment 3. It has the maximum relationship with other criteria. However, OTR, O (others is the parameter that gives the least summation of (Sr + Sc). This is the least important criterion that has the minimum relationship with other criteria. Now, considering segment 4, which is the fleet workshop, produces the causal and effect table with a 4 x 3 matrix (Table 12). The results for (Sr – Sc) and (Sr + Sc) are shown in Table 12. First, the (Sr – Sc) shows the parameters that give positive results, belonging to the casual group is the FTN, 1.7037 (forklift technician), which influences other criteria. However, the parameters WLR, - 1.1380 (welders,), BCT,

Table 12. Causal and Effect Groups Table (Segment 4)

Parameters	S_r	S_c	S_r-S_c	S_r+S_c	S_r-S_c	S_r+S_c
FTN	3.3239	1.7037	1.6203	5.0276	+ve (Cause/influence other criteria)	Least (Least important criterion- minimum relationship with other criteria)
WLR	4.2802	5.4181	-1.1380	9.6983	-ve (Receiver/influenced by other criteria)	Highest (Most important criterion- maximum relationship with other criteria)
BCT	4.0410	4.5233	-0.4823	8.5643	-ve (Receiver/influenced by other criteria)	

Table 13. Causal and Effect Groups Table (Segment 5)

Parameters	S_r	S_c	S_r-S_c	S_r+S_c	S_r-S_c	S_r+S_c
STY	4.4336	6.9308	-2.4973	11.3644	-ve (Receiver/influenced by other criteria)	Highest (Most important criterion- maximum relationship with other criteria)
KTN	3.6872	3.6472	0.0399	7.3344	+ve (Cause/influence other criteria)	
CTR	4.0714	2.4435	1.6278	6.5149	+ve (Cause/influence other criteria)	Least (Least important criterion- minimum relationship with other criteria)
CSS	4.8397	2.9263	1.9135	7.7660	+ve (Cause/influence other criteria)	
CCS	3.2261	4.3101	-1.0840	7.5362	-ve (Receiver/influenced by other criteria)	

- 0.4823 (Battery charger/technicians) give negative results, and belong to the effect group. For the (Sr + Sc) column, the parameter that yields the highest value is WLR, 9.6983 (welders). The parameter FTN, 5.0276 (forklift technicians), gives the lowest value. While the earlier-mentioned parameters are the most important in segment 4, the latter-mentioned parameter is the least important in the same segment 4. Table 13 summarizes the causal and effect group for segment 5. The most important criterion is STY, 11.3644 (security), which has the highest (Sr + Sc) value, while CTR, 6.5149 (contractor 1, tailor), is the least important criterion in segment 5. In addition, considering (Sr – Sc), the parameters with the negative value, called the effect group, include STY, - 2.4973 (security), CCS - 1.0840 (contractor 3, chemical supplier). They are influenced by other parameters. The (Sr – Sc) for KTN, 0.0399 (Kitchen), CTR, 1.6278 (Contractor 1, Tailors), and CSS, 1.9135 (Contractor 2, Safety Boot Suppliers) are positive, implying that they are the causal group. The casual group parameters influence other parameters.

4.1. Model Validation

In this section, an understanding is provided of how well the NGT-DEMATEL method performs in a particular instance. Recall that the model is newly built and tested in a safety process evaluation environment involving a bottling process plant. Here, an attempt is made to determine whether the NGT–DEMATEL method is effective or not. Can other researchers rely on the NGT-DEMATEL model for safety performance evaluation to help the safety manager make good decisions? Thus, a validation process is created such that the error metric is computed. The principal metric used in this work is the mean absolute error. In following the validation process, the NGT-DEMATEL model is applied to the data. This gives the predictions to which actual data results from the Data Envelopment Analysis (DEA) could be compared. Thus, the error is how well the NGT-DEMATEL model is predicting the results of the DEA model. The mean absolute error is based on the safety conformity objective of the process, which is to ascertain that workers are protected from equipment dangers and accidents in the bottling process plant. The first thing to do is to load the data set, which was given in the previous section of this article. Then the DEA model is used on the data, which is run on the codes of the Python programming language. Details of the codes are given in the appendix. The detailed explanation is as follows: The Python programme displayed in the appendix has a syntax referred to as SciPy, which is a library import syntax. SciPy solves linear programming problems. Importing the spicy from where it is saved is indicated in the first two lines of the code. Then the constraints in the linear programme are imported. For segment 1, with eight parameters, there will be eight equivalent decision-making units. This also implies that there are eight constraints in the linear programming formulation for segment 1. Also, there are three levels in the problem, consisting of two outputs and one input. These will be transferred from the equations in an array (matrix form), in Python code. Here, the vector normalisation is attempted, where the square root of certain values is obtained, and further processing is coordinated on them. The equations are defined in the Python code. After the ranges of values are specified, note whether the stoppage is at J1 or J2. The number of variables considered is known, which is three, prompting the researcher to stop at J2. Notice that Python starts counting from zero, i.e., 0, 1, 2. The array is then built up. Then the linprog code is called up to solve the linear programming. The array to solve over time is defined while it is solved. As the problem is solved, the efficiency value is obtained. It solves the problem with RESS, which is the weighted minimum, g. The efficiency is defined as the reciprocal of g, which is hr. Then the results are printed, indicating the weights of the parameters as defined in the array. This is the syntax with which the code works. In sum, it calls from the linprog module, which has been specified, an inbuilt module. By extending the procedure described above to segments 2 to 5, the efficiency of DMUs in the various segments is calculated. Notice that the adjustment based on the number of constraints in each segment is done. Moreover, the results for each of the segments are given in Tables 14 to 18.

To conduct the validation exercise, segment 1 is first analysed for results. There are multiple outputs of segment 1, which are in terms of Sr, Sc, Sr – Sc, Sr + Sc (Table 9). Although each of these output terms is critical, Sr + Sc is used throughout the analysis for computational convenience and as a strategy to achieve the goal of this safety project quickly (Tables 9 to 13). Thus, the values of the Sr + Sc corresponding to FDR, SOR, RER, SHR, HDR, HTM, CNR, and EBR, which are 11.9364, 9.51683, 9.13349, 1.24690, 10.4878, 10.7638, 6.28636, and 5.202558, are matched against their counterparts produced by the DEA method. These are the efficiency values of the mentioned parameters, which are 1.0000, 0.7568, 1.0000, 1.0000, 1.0000. 0.9714, 1.0000, and 1.0000, respectively, according to the order of listing the parameters previously. The values from the Sr + Sc index of the NGT-DEMATEL method are the observed values, while those of the efficiency results units of parameters 1 to 8, i.e., from FDR (representing DMU1) to EBR (representing DMU8) for the DEA model, are the predicted values. A mean absolute error calculator was used to evaluate the mean absolute error, which produced 7.10575 as the value. The prediction of efficiency, where typical values are from 0 to 1 unit, producing an error of 7.10575, is quite high. For segments 2, 3, 4, and 5, the mean absolute errors are 3.62947, 15.67120, 6.76340, and 7.10318, respectively. These results obtained from other segments are also very high. These high values do not indicate that the model developed is not good, but could be attributed to the following.

The NGT-DEMATEL method and the data envelopment analysis measure fundamentally different ideas with varying scales. This makes them incommensurable. The technical efficiency, which serves as the predictor in this analysis, measures from 0 to 1, based on boundary outputs. However, Sr + Sc, which is called the prominence measure from the NGT-DEMATEL model, evaluates the total influence or the relative importance of a parameter compared to another, rooted in the subjective opinion of the nominal group, which results in values greater than 1. In conclusion, despite the obtained high values of mean absolute errors in the validation exercise, the NGT-DEMATEL method is recommended for use by the research community, and it is open to further improvements.

4.2. Implications of the study

One of the critical aspects of this article, which makes the development and application of the NGT-DEMATEL method in the safety aspect of the bottling plant operation, is its significant impact on the wider society. Applying the method improves occupational health in bottling plants. Apart from the regular employees who conduct daily activities, stakeholders who visit the company are protected from occupational hazards as the model is anchored on their reduction. Improved bottled product safety (soft drinks) and social stability, which is a condition where the burden on local healthcare systems is reduced, is created. Besides, the model proposed encourages economic and structural benefits. These arise from the perspectives of enhanced safety culture, economic stability, and enhanced supply chain practices. The NGT-DEMATEL model creates an understanding that consciousness and compliance with safety culture are not enough, but a proactive approach to safety is the compelling need of the hour. Economic stability may be achieved through the adoption of the NGT-DEMATEL method, as it reduces plant costs, which comprises downtime, worker compensation due to accidents, and absenteeism. The supply chain quality is in demand to improve, as the coverage of the NGT-DEMATEL model includes suppliers and contractors to the bottling plant. This is achieved as the model promotes safety practices in the bottling supply chain. A major aspect of the impact of the NGT-DEMATEL model on the company is that it offers technical and strategic impacts in the aspects of enhanced decision-making and knowledge transfer. In the first instance, the NGT-DEMATEL model eases the intervention of the management to control unwarranted activities since it establishes causal relationships in the plant hazards. Secondly, ideas from one bottling plant could be transformed to others for improved safety performance through the use of the NGT-DEMATEL method.

4.3. Contributions of the NGT-DEMATEL method

This study contributes to the literature of safety conformity parametric interaction by offering quantitative solutions to the identification of the most and least important parameters, the establishment of the causal and effect factors with parameters known to influence others,

Table 14. DEA computations for segment 1 (warehouse)

S/No.	Parameters/Factors	Minimum Weighted Input	Efficiency	Weights
1.	Forklift Drivers (DMU 1)	1.0000	1.0000	(u1, u2, u3, V) = [2.7041, 0.0000, 0.0000, 1.0000]
2.	Sorters (DMU 2)	1.0000	1.0000	(u1, u2, u3, V) = [3.5732, 0.0000, 0.0000, 1.3214]
3.	Rescuer (DMU 3)	1.0000	1.0000	(u1, u2, u3, V) = [2.7041, 0.0000, 0.0000, 1.0000]
4.	Sugar Handlers (DMU 4)	1.0000	1.0000	(u1, u2, u3, V) = [2.7041, 0.0000, 0.0000, 1.0000]
5.	Haulage Drivers (DMU 5)	1.0000	1.0000	(u1, u2, u3, V) = [0.0000, 0.0000, 1.0000, 1.0000]
6.	Haulage Truck Mates (DMU 6)	1.0000	1.0000	(u1, u2, u3, V) = [1.4713, 1.0996, 0.0000, 1.0294]
7.	Chip Neck Remover (DMU 7)	1.0000	1.0000	(u1, u2, u3, V) = [2.7041, 0.0000, 0.0000, 1.0000]
8.	Extra Bottle Remover (DMU 8)	1.0000	1.0000	(u1, u2, u3, V) = [2.7041, 0.0000, 0.0000, 1.0000]

Table 15. DEA computations for segment 2 (manufacturing corridor)

S/No.	Parameters/Factors	Minimum Weighted Input	Efficiency	Weights
1.	Sighters (DMU 1)	1.0000	1.0000	(u1, u2, V) = [2.5833, 0.0000, 1.0000]
2.	Filler Operator (DMU 2)	1.0000	1.0000	(u1, u2, V) = [2.5833, 0.0000, 1.0000]
3.	Palletizers/Depalletizer (DMU 3)	1.0000	1.0000	(u1, u2, V) = [0.0000, 1.8437, 1.0000]
4.	Washer Operators (DMU 4)	1.0000	1.0000	-(u1, u2, V) = [2.5833, 0.0000, 1.0000]
5.	Chip Neck Remover (DMU 5)	1.0000	1.0000	(u1, u2, V) = [2.5833, 0.0000, 1.0000]
6.	Technical Operators/Utilities (DMU 6)	1.0000	1.0000	(u1, u2, V) = [2.5833, 0.0000, 1.0000]
7.	Packer/Unpacker Operators (DMU 7)	1.0000	1.0000	(u1, u2, V) = [2.5833, 0.0000, 1.0000]

Table 16. DEA computations for segment 3 (quality assurance)

S/No.	Parameters/Factors	Minimum Weighted Input	Efficiency	Weights
1.	Sugar Lifters (DMU 1)	1.0000	1.0000	(u1, u2, u3, V) = [2.3667, 0.0000, 0.0000, 1.0000]
2.	Syrup Mixers (DMU 2)	1.0000	1.0000	(u1, u2, u3, V) = [0.0000, 0.0000, 1.0000, 1.0000]
3.	Lab Technicians (DMU 3)	1.0000	1.0000	(u1, u2, u3, V) = [0.0000, 1.6583, 0.0000, 1.0000]
4.	Water Technicians (DMU 4)	1.0000	1.0000	(u1, u2, u3, V) = [2.3667, 0.0000, 0.0000, 1.0000]
5.	Etp Technicians (DMU 5)	1.0000	1.0000	(u1, u2, u3, V) = [2.3667, 0.0000, 0.0000, 1.0000]
6.	Others (DMU 6)	1.0000	1.0000	(u1, u2, u3, V) = [0.0000, 1.6583, 0.0000, 1.0000]

Table 17. DEA computations for segment 4 (fleet workshop)

S/No.	Parameters/Factors	Minimum Weighted Input	Efficiency	Weights
1.	Forklift Technicians	1.0000	1.0000	(u1, u2, u3, V) = [1.7321, 0.0000, 0.0000, 1.0000]

Table 17. (Cont.')

S/No.	Parameters/Factors	Minimum Weighted Input	Efficiency	Weights
2.	Welders	1.0000	1.0000	(u1, u2, u3, V) = [1.7321, 0.0000, 0.0000, 1.0000]
3.	Battery Charger/Technicians	1.0000	1.0000	(u1, u2, u3, V) = [1.7321, 0.0000, 0.0000, 1.0000]

Table 18. DEA computations for segment 5 (contractors)

S/No.	Parameters/Factors	Minimum Weighted Input	Efficiency	Weights
1.	Security	1.0000	1.0000	(u1, u2, u3, V) = [0.0000, 0.0000, 1.0000, 1.0000]
2.	Kitchen	1.0000	1.0000	(u1, u2, u3, V) = [2.2071, 0.0000, 0.0000, 1.0000]
3.	Contractor 1	1.0000	1.0000	(u1, u2, u3, V) = [0.0000, 0.0000, 1.0000, 1.0000]
4.	Contractor 2	1.0000	1.0000	(u1, u2, u3, V) = [2.2071, 0.0000, 0.0000, 1.0000]
5.	Contractor 3	1.0000	1.0000	(u1, u2, u3, V) = [2.2071, 0.0000, 0.0000, 1.0000]
6.	Haulage Truck Mates (DMU 6)	1.0000	1.0000	(u1, u2, u3, V) = [1.4713, 1.0996, 0.0000, 1.0294]
7.	Chip Neck Remover (DMU 7)	1.0000	1.0000	(u1, u2, u3, V) = [2.7041, 0.0000, 0.0000, 1.0000]
8.	Extra Bottle Remover (DMU 8)	1.0000	1.0000	(u1, u2, u3, V) = [2.7041, 0.0000, 0.0000, 1.0000]

and those that are being influenced. A case study in the bottling process plant was used to establish the validity of the new approach proposed. The solution outlined in this work reduces the risk in the bottling plant by promoting unbiased, sound, measured safety decision-making through a structured idea-development process, involving group discussion. It further improves safety by examining parameters for their mutual influences directly or indirectly) to bring about superior insights into the cause and effects of parameters in a complex bottling process safety decision-making challenge. This research has extended safety knowledge by also prioritizing the most important safety parameters to improve safety outcomes while helping to visualize the complicated safety issues to establish parameters which require interventions and where such interventions will be largely effective.

4.4. Limitations of the NGT-DEMATEL method

Although the NGT-DEMATEL method seems promising, it faces some limitations. The NGT aspect of the method is time-consuming when large groups are considered. In this work, only 10 participants are mentioned. But as the threshold of the number of members extends beyond 30 participants, substantial time will be required for the whole NGT implementation of the method. Associated with this limitation of the NGT method is that interactions during the initial brainstorming sessions will be restricted. Nonetheless, these limitations could be mitigated using different approaches. For the time-consuming issue in NGT implementation, digital collaborative policies could be introduced to ease each stage of the NGT implementation and efficiently run the system. Moreover, the DEMATEL approach in the NGT-DEMATEL combination may not be effective in the context of operating with several parameters. Furthermore, to tackle this problem, introducing the hierarchical decomposition method will work. Here, the safety conformity process is broken down into smaller subsystems along the vertical and horizontal dimensions, such that the results are then integrated to provide an overall feedback from the system.

5. CONCLUSIONS

In this paper, the safety conformity of a bottling process plant was evaluated for the interaction of factors within the plant based on the DEMATEL method when the nominal group technique is used as the basis for comparing the parameters. The nominal group, involving ten participants, was used to collect data fed into the DEMATEL method, which responds to the sum of columns, the sum of rows, and individual values of columns and rows generated from the parameters. These data provided information on the most and least important parameters in the segments analysed, the causal and effect group of parameters. In all, five segments consisting of eight, seven, six, three, and five sub-segments were analysed, and decisions on the desirables were made. Some conclusions are drawn from the study as follows:

- With five segments analysed, the most important parameters are forklift driver (11.9364), sighters (6.0457), syrup mixers (10.3909), welders (9.6983), and security (11.3644) for segments 1 to 5, respectively. Meanwhile, forklift drivers in group 1 are the most important for the whole bottling process plant. It implies that to achieve the utmost result in the bottling process plant, there should be a focus on the forklift drivers in terms of giving the best training and motivating them.

- For the five segments 1 to 5, sugar handlers (1.2469), chip neck removers (3.7521), others (14.6703), forklift technicians (5.0276), and contractor 1 (tailors) (6.5149) are the respective least important criteria. It implies that minimum attention should be given to them to achieve the utmost in the system.
- This is the first time that the nominal group technique and DEMATEL method were combined for multicriteria decision making in the safety conformity process.
- The ranges for the parameters in segments 1 to 5 are 10.6895, 2.2936, 9.8697, 4.6707, and 4.8496, respectively. This indicates that segment 1, the warehouse, has the best interaction among the workers, while the manufacturing corridor has the worst level of interaction. This result concerning the manufacturing corridor is disturbing, as it is supposed to be the lifeline of the plant. Thus, training is urgently required among the members of the manufacturing corridor to upgrade their interactions among the group members.
- The causal group, which are members who have the greatest effects on others are diverse. Sorters, rescuers, sugar handlers, haulage drivers, and haulage truck mates represent the warehouse. Sighters, washer operators, and technical operators/utilities are for the manufacturing corridor. Sugar lifters and ETP technical's are representatives of the quality assurance group. Forklift technicians are for the fleet of vehicles group. The segment on contractors includes kitchen, contractor 1 (tailor), and contractor 2 (safety boot supplier).
- The effect group, which are members who are influenced by others are as follows: the warehouse contains forklift drivers, chip neck removers, and extra bottle removers. Manufacturing corridor has filler operators, palletizers/depalletizers, chip neck removers, and packer/unpacker operators. Quality assurance has syrup, mixers, laboratory technicians, and water technicians. The fleet of vehicles has welders, battery changers/ technicians, while the segment for contractors has security and contractor 3 (chemical suppliers) as members of the effect group.
- Overall, only one group, others, in quality assurance has a neutral status. It means that they do not affect others, while they are not affected by others.

To continue this research, studies should be conducted by replacing the nominal group technique with other structural group brainstorming approaches as a basis upon which DEMATEL could be applied. Interesting substitute method includes mind mapping, brain writing, starbursting, SWOT analysis, and rapid ideation. Thus, methods such as mind mapping-based-DEMATEL, SWOT analysis-based-DEMATEL may yield alternative results that could advance the conformity literature. The mind mapping approach, for instance, may represent and reveal an understanding of the Complex information in the safety system of the bottling process plant, particularly to established relationship between the various parameters of the subsegments and prioritising risks. This serves as a tool to communicate and collaborate on safety issues among the workers of the sub-segments of the bottling process plant. Furthermore, future studies should include plans to undertake more detailed structural modelling studies by substituting the DEMATEL method with alternative candidates such as system dynamics, partial least squares-based, and covariance-based structural equation modelling. For these studies, earlier suggested methods such as mind mapping and SWOT analysis could be the foundation, which replace nominal group technique, while the new replacement to the DEMATEL method is integrated to this foundational methods. The integrated methods are expected to make specific recommendations to improve insight into the analysis into the complex safety conformity issue in the bottling plant and establish relationships among the sub-segment parametric members of the process.

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