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RESEARCH ARTICLE

Industry–Challenge to Pro-Environmental Manufacturing of Goods Replacing Single-Use Plastic by Indian Industry: A Study Toward Failing Ban on Single-Use Plastic Access

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ABSTRACT One important topic that raised concern among researchers and population is the threat posed by the widespread presence of single-use plastic items, which has become a part of day-to-day life. An urgent need is to build a plan by manufacturers/ investors to give a due concern over environmental preservation. A number of challenges are yet to be addressed for implementation of sustainable manufacturing concerned with environment; this is a matter of worry. Prime minister of India on 150th anniversary of Mahatma Gandhi has urged the nation to make India free of single-use plastics. On July 1, 2022, India banned single-use plastic items that have low utility but are frequently littered around, such as plastic straws. Work done in this research is undertaken for finding the prominent challenges which are faced in the eco-friendly sustainable manufacturing practices in single-use plastic industries. It is also a matter of concern that why a ban on certain single-use plastic with low utility is failing in India?. A framework has been made on Triangular Fuzzy Number (TFN) based fuzzy method to identify and rank the associated problems/ challenges. Triangular fuzzy numbers are effective in modelling imprecise and uncertain information, and have been widely applied in decision making. In this work 13 challenges have been identified and ranking is done using TFN to find the most prominent factors. From results it is very clear that Expense on implication, Scantiness in the support received from the government and Lack of environment concern among suppliers are the most influencing factors/ challenges. Works done on identification of challenges will be of help to policy makers and industrialists in identification of core issues.

INDEX TERMS Single-use plastic, challenging factors, environment, fuzzy, triangular fuzzy numbers (TFN).

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NOMENCLATURE

PET	Polyethylene Terephthalate.
GMP	Good Manufacturing Practice.
FICCI	Federation of Indian Chambers of Commerce and Industry.
TFN	Triangular Fuzzy Numbers.
R & D	Research & Development.

I. INTRODUCTION

Many study/ works has been done on the use of plastics and their disposal [1], [2], [3], it is clear that there are negative impacts of plastics on the environment although to some extent, removal of plastics from environment can be done through proper recovery and recycling. Both government and consumer body have put a pressure on the manufacturing industries as there is an increase in depletion of fossil fuels and global warming to adopt practices of sustainable manufacturing for reducing the emission level up to some extent. India has a commitment to reduce the pollution level by approximately 35% to make the world more environmentally sustainable till 2030 [1]. Rise in pollution level over the recent years has made it more difficult to achieve the target of removing or reducing the usage of single-use plastics. Major reason for the usage of plastic in packaging beverages and food is its durability. It is more popular among consumers for its low cost. Increasing in demand of such single-use plastics has increased its production. Thus, it is getting more problematic as the problem of disposal and accumulation in environment has risen. Thus, it has raised a concern for environment due to impacts of plastic pollution [2]. Today one of the essential parts of our day-to-day life is single-use plastic bottles due to number of reasons like it is easy to carry, portable, less cost and also easy to obtain. If PET polymer is used as a base material, it will be recyclable. This kind of single-use plastic material can be preferred, if reused [3]. It is estimated that around approximately 20 % of bottles made of plastics are reused, while the remaining 80 % of them end in landfills [4]. Single-use plastics have become important in the lives of people. None of the other material has been able to replace packaging by single-use plastics, even tin or glass uses are not able to compete. There is a need to educate more people regarding awareness towards plastics pollution and health risk. Plastics accumulation in the environment is another matter of concern as it is a prolonged process [5]. Reasons for contamination of plastics are its degradation and chemical leaching and fragmentation into micro plastics from macro plastics [6]. One of the study presents new multi-jurisdictional legislative interventions to reduce SUPs since 2017 and incorporating emergence of new non-legislative interventions to mitigate other types of SUPs at individual and private-sector levels that complement or influence legislative interventions [7]. A similar work is done by developing an evaluation model based on the fuzzy- Analytic Hierarchy Process (AHP) and the technique for order preference by similarity to ideal solution (TOPSIS) to enable the industry practitioners to perform performance evaluation in a fuzzy environment. The purpose of the study was to determine the best method for recycling plastics among the various plastic recycling processes. Mechanical recycling process is found to be the best plastic recycling process [8]. Government can tax the industries involved with production of single-use plastics to discourage its use by making it little expensive. Plastic waste problem solution in the environment just by cleaning up or by dumping plastic waste are not good choices; while recycling can add up to carbon emissions. Mitigating the pollution increase in plastic wastes needs to be tackled, a study needs to be done in understanding the relation between plastics consumption by people and increase in plastic waste. Another study was conducted in 2019, in a context directly after the European Union (EU) announced its Directive to ban the most commonly used single-use plastic (SUP) items. This study applied the snowball method as a methodological choice to identify relevant stakeholders [9].

Although central government in India has issued the ban, its successful implementation lies with respective state government and state pollution control board. For successful implementation of ban, availability of cheap alternative to cater demands of these banned products is itself a great challenge. Small and medium enterprise industries will be hit hard with economic jolt and loss of jobs. There are more challenges like political resistance in some states and no planned effort by some state authorities to implement the ban. COVID has also hit hard on implementation of ban and deferring people from using single-use plastics.

Work done in this research is as follows: Literature survey is done to find out the challenges faced in sustainable practices of using single-use plastics and also challenges faced by industries related to single-use plastics. A case study is done after the literature survey to figure out the major challenges under different categories. Next part of the work contains the illustration of solution methodology i.e. TFN based fuzzy methodology. Results obtained after doing a case study using the methodology and concerned challenges are highlighted in the subsequent sections. Further, it contains a discussion and conclusion section for proper analysis on the results obtained.

II. LITERATURE REVIEW

A number of schemes and programs are already functioning to cope with the global warming crisis in the environment by number of countries of the world. A number of programs for protection of environment are already running which proves that a worldwide movement has started for absorbing good sustainable practices. Movements like this also show that sustainable development is arising as an agenda on priority for economies along with economic development. This is now future where economic growth has to run in parallel with environmental conservation. Some of the authors have also stressed to build a healthy relation between environmental aspects and economics [10]. A case is discussed where authors have proved that only emphasizing on the aspects of environment and negligence of economic growth is an undesirable challenge. Without any economic foundation it would be difficult for any industry to invest towards environmental sustainability [11]. A journey has begun towards reducing the global warming; therefore, many challenges remain to be addressed for implementation of sustainable solutions for environment. Sustainable environment is referred as part of green aspects on broader spectrum [12]. Industries challenges differ on region basis [13]. In terms of potential threats to ecosystem and human health, Micro-plastics (MPs) are playing major role and thus drawing attention from the international community. The relationship between their abundance and sizes remains unclear, though in recent years their occurrence and spatial distribution have been extensively studied. It is found that distribution of MPs is not a coincidence but controlled by conditional aging. From different land use settings in Beijing, China applicability of this model is tested. A distinct downsizing phenomenon from fibers, films, and fragments to granules is observed [14]. Microplastics (MPs) and discarded plastics in the environment are considered emerging contaminants and indicators of the Anthropocene epoch. One of the study reports the discovery of plastic rock complexes, a new type of plastic material in the environment, formed when plastic debris irreversibly sorbs onto the parent rock after historical flooding events. These complexes consist of low-density polyethylene (LDPE) or polypropylene (PP) films stuck onto quartz-dominated mineral matrices [15].

There are no proper organizational structures for supporting GMP, deficient R & D due to non-consideration of impact on the environment [16]. Challenges are not same for different kind of industries, as challenges faced by any wind energy industry are different in many terms compared to pharmaceutical industries. It is therefore very important to point out the challenges based on the type of industry and it is not proper to provide a generalized view of all kind of industries. Few challenges faced by industries are domain specific also. Policy makers of sustainable environment practices and ignorant managers are also one of the major challenges faced in the marketing domain [17]. Problems are associated with recycling and recovery area also like proper availability of market for recycled plastics, cost recovery of the recycled plastic products and convenience of use [18]. It is also important to know that challenges are different many times for industrialists and researchers. This may be technical, financial or knowledge based. Authors have presented both kinds of challenges one where industrialist and researcher differ and another where industrialist and researchers view point matches [19]. In India, FICCI had said that imposing ban on plastic industries would lead to a loss of around ₹53000 crores (Indian currency), leading to loss of jobs. In across 10000 firms, 13 lakh personnel would lose their jobs. Industries related to food processing would suffer a loss in revenue of around ₹90000 crores (Indian currency). After such kind of reactions, government would be more cautious in imposing a blanket ban, and may reiterate single-use plastics phase out in India [20]. There is lack of legislature in eco-designing on global perspective [21]. Also, challenges are faced by developing countries in managing electronic wastes [22].

Single-use plastics are not all made only from polyethylene terephthalate: As per the United Nation's definition, any plastic that is made from polymers of high-density polyethylene (HDPE), low-density polyethylene (LDPE), polyethylene terephthalate (PET), polystyrene (PS), polypropylene (PP) or expanded polystyrene (EPS) are single-use plastics - check for example the Plastic factsheet published by the Indian Centre for Science and Environment [23].

III. NOVELTY AND APPROACH

Research concerned with environment has led to many speculations in the world of research and large numbers of factors are considered involved in analysis of factors concerned with clean environment and renewable sources; in such type of studies soft computing and Multi Criteria Decision Making (MCDM) methodologies have been implemented [24], [25], [26]. Soft computing techniques like fuzzy based approach is an easily applicable approach of uncertainty in assigning weights for the given criteria by decision making persons; this reduces the chances of differences from practical solutions by large extent. On various occasions authors have dealt in ranking criteria with traditional approaches of MCDM and fuzzy [27], [28], [29] but implementation of such a mechanism to identify and rank the challenges faced by industries in the replacement of single-use plastics has been novel to the authors as well. Country like India which is in its developing phase, a lot of gap exists in research related to areas which are affecting environment. Lack of knowledge and new technologies sometimes fail to implement, as there exists a lot of research gap in concerned areas affecting environment, due to which at times even desiring states fail to implement advanced systems. This study is thus concerned with developing an environmental concerned sustainable model for replacement of single-use plastics by identifying the core challenges.

The whole work flow of this research paper is illustrated in figure 1. Flow chart briefs the process of work for identifying key challenges. Using of MCDM tools for handling decision-making problems is one of the common practices in the field of research and other practical issues of the field like power system, energy-based applications alike [28], [29], [30], [31].

A promising approach of TFN based on fuzzy model is used here for ranking purposes. In this study, for assessment of the challenging factors related to the single-use plastic industry, thirteen challenges are identified which the Indian industries are facing in replacing single-use plastic goods with environmentally sustainable manufacturing practices. Challenging factors considered are Scantiness in the support received from government (C1), Training courses available for workers not properly utilized (C2), No proper structure for implementation in organization (C3), Lack of environment concern among suppliers (C4), Lack of social responsibility among corporate (C5), Awareness among the suppliers regarding environment (C6), Cheap products are always an

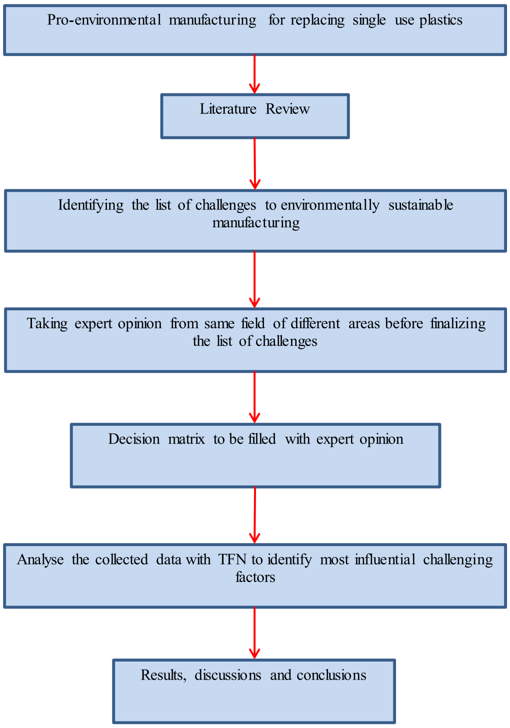

FIGURE 1. Flow chart for identification and analysis of challenges in manufacturing for sustainable environment.

attraction among customers (C7), Adoption of new product by Indians (C8), Investors should have patience and perseverance (C9), Bank should support green products by giving loans at lesser interest rate (C10), Expense on implication (C11), Carbon emission regulations (C12), Lack of industrial infrastructure (C13) as shown in Table 1.

Brief explanation of the identified factors (challenges):

C1: There should be immense support from the government. Some financial assistance in the form of reducing taxes can be provided, if the industries are switching to environmentally friendly products.

C2: Management in industries should carry green and sustainable practices. Workers should be educated and trained to adopt pollution free practices.

C3: A proper organizational structure is missing which can integrate sustainable environmental processes into traditional supply chain.

C4: Sometimes there is lack of interest in suppliers for preserving environment, this also happens due to lack of competition among them.

C5: Every industry must have a concern and should work on it as a social responsibility by encouraging employees to contribute for social responsibility.

C6: Sometimes industries are interested in implementation of environment friendly practices but lack of knowledge and ignorance of suppliers is a major hurdle.

C7: Customers are always attracted towards cheaper products; replacement of single-use plastic can increase the price of goods.

TABLE 1. Considered criteria for evaluation.

Sl. No.	Factor	Criteria	Symbol	Reference
1	Financial problem	Cheap products are always an attraction among customers.	C7	[32]
		Expense on implication	C11	[34], [36] [40], [43] [44]
2	Dormant	Awareness among the suppliers regarding environment.	C6	[35]
		Scantiness in the support received from government.	C1	[32], [33] [34],
		Investors should have patience and perseverance	C9	[33]
		Bank should support green products by giving loans at lesser interest rate.	C10	[33], [36]
3	Industrial and manufacturing technology	Carbon emissions regulations.	C12	[23]
		Lack of industrial infrastructure.	C13	[33], [37] [38], [39] [40]
4	Knowledge with skills	Lack of environment concern among suppliers.	C4	[36]
		Adoption of new product by Indians.	C8	[41], [42]
5	Association and support	Training courses available for workers not properly utilised.	C2	[45]
		No proper structure for implementation in organization.	C3	[36]
		Lack of social responsibility among corporate.	C5	[46]

C8: This is an environmental transition phase and it needs to be adapted by Indians.

C9: Investors who are investing for transition to environment friendly manufacturing should be patient as it may take time in giving good returns.

C10: It needs bank support. Bank should be encouraged and supported for providing loans at cheaper rates to the industries which are pro environmental.

C11: Requirement of recyclable materials for green products is expensive. Also, a technological demand requires heavy investments in research and development (R & D) by industries/ companies.

C12: This is an issue which needs concern as on recycling of plastic products; there are lots of carbon emissions.

C13: There should be proper advertisement discouraging use of single-use plastics, for example: Paper cups can be placed instead of single-use plastic cups near arrangement of drinking water. A proper infrastructure support should be there to support this cause.

IV. METHODOLOGY

The ranking system has been explained under the "Ranking of criteria using TFN" section.

A. RANKING OF CRITERIA USING TFN

Fuzzy Set Theory was first proposed in 1965 [47]. In aiming decisions based on the decision making of criteria or factors, preferential degree of judgement is done using three sets of numbers [48]. This kind of scaling helps in raking in a better way. In absence of concrete data, this kind of ranking is very helpful. Using this scale input is taken from three different experts, this minimizes the chances of error to occur as finally working with the model averaging of the three different inputs from experts will be done.

In a generalised fashion TFN can be represented as I = (b_1, b_2, b_3), where, for judgement's uncertainty b_1 is minimum bound limit, b_2 is median value and b_3 is maximum limit respectively [49].

Membership function in fuzzy can be given as:

$$\mu\left(\frac{s}{R}\right) = \begin{Bmatrix} 0 & s \le b_1 \\ \dfrac{(s-b_1)}{(b_2-b_1)}, & b_1 \le s \le b_2 \\ \dfrac{(b_3-s)}{(b_3-b_2)}, & b_2 \le s \le b_3 \\ 0 & s \ge b_3 \end{Bmatrix} \tag{1}$$

where 's' is a real number.

Two arbitrary TFNs are considered $R_1 = (a_1, b_1, c_1)$ and $R_2 = (a_2, b_2, c_2)$, their elementary properties of addition and division can be showcased as:

$$R_1 + R_2 = (a_1 + a_2, b_1 + b_2, c_1 + c_2) \tag{2}$$

$$R_1/R_2 = (a_1/a_2, b_1/b_2, c_1/c_2) \tag{3}$$

Scale, as shown in Table 2 [49] is an authentic, simple way to assign fuzzy membership values. Data are fed on 10-point scale proposed using TFN shown in Table 2. The beauty of using TFN scale is that it considers vagueness in data. Ranking of fuzzy numbers by total integral value method is a chosen method [49].

Steps involved in procedural calculations, assuming $R_{ij} = (a_{ij}, b_{ij}, c_{ij})$ to be a TFN are:

Step 1: With the help of three bounded fuzzy numbers, for comparison of all the considered criteria (in this case 13) a pairwise decision matrix is formed with the help of ranking scheme which is illustrated in Table 2.

TABLE 2. Preferential scale for TFN method to rank criteria.

SL. No	Linguistic Scale	Associated TFN	Reciprocal TFN
1	Equal preference	(1,1,1)	(1,1,1)
2	Weak to moderate	(1,2,3)	(1/3, 1/2, 1)
3	Moderate preference	(2,3,4)	(1/4, 1/3, 1/2)
4	Moderate to strong preference	(3,4,5)	(1/5, 1/4, 1/3)
5	Strong preference	(4,5,6)	(1/6, 1/5, 1/4)
6	Strong to very strong preference	(5,6,7)	(1/7, 1/6, 1/5)
7	Very strong preference	(6,7,8)	(1/8, 1/7, 1/6)
8	Very Strong to Extreme Preference	(7,8,9)	(1/9, 1/8, 1/7)
9	Extreme preference	(8,9,9)	(1/9, 1/9, 1/8)

Formation of pairwise decision matrix involves opinions from experts of various field along with the own circumstantial preferences of decision maker. This means that criteria have been chosen after the detail literature review. Input given by the experts are first judged thoroughly by the authors. If any value in the decision matrix created seems odd to authors, then it is enquired with the experts for justification. This is done to avoid any error in result.

Step 2: Next Synthetic Extent Value for the i^{th} object is given as:

$$F_i = \sum\nolimits_{j=1}^{n} L_{ij} \times \frac{1}{\left[\sum\nolimits_{i=1}^{m}\sum\nolimits_{j=1}^{n} L_{ij}\right]} \tag{4}$$

The above equation can be detailed as:

$$\frac{1}{\left[\sum\nolimits_{i=1}^{m}\sum\nolimits_{j=1}^{n} L_{ij}\right]} = \left(\frac{1}{\sum\nolimits_{i=1}^{m}\sum\nolimits_{j=1}^{n} c_{ij}}, \frac{1}{\sum\nolimits_{i=1}^{m}\sum\nolimits_{j=1}^{n} b_{ij}}, \frac{1}{\sum\nolimits_{i=1}^{m}\sum\nolimits_{j=1}^{n} a_{ij}}\right) \tag{5}$$

A re-arranged equation is obtained by doing few modifications and further simplifying the above equation with the help of synthetic extent value as: [49].

$$\frac{1}{\sum\nolimits_{i=1}^{m}\sum\nolimits_{j=1}^{n} L_{ij}} = \left(\frac{1}{\sum\nolimits_{i=1}^{m}\sum\nolimits_{j=1}^{n} b_{ij}}, \frac{1}{\sum\nolimits_{j=1}^{n} cr_{ij} + \sum\nolimits_{i=1}^{m}\sum\nolimits_{j=1}^{n} a_{ij}}\right) \tag{6}$$

Step 3: Using comparison method synthetic extent value is carried by calculating degree of possibility for the said criteria:

$$\begin{aligned} V\left(F_j \ge F_i\right) &= Height\left(F_i \cap F_j\right) \\ &= 0, \quad if\ b_j \ge b_i \\ &= 1, \quad if\ a_i \ge c_j \\ &= \frac{a_i - c_j}{\left(b_j - c_j\right) - \left(b_i - a_i\right)} \quad \text{Otherwise} \end{aligned} \tag{7}$$

TABLE 3. Input from Expert 1.

		C11	C1	C4	C6	C7	C10	C5	C3	C9	C13	C2	C12	C8
C11	E1	1	7	3	3	5	3	7	7	7	5	9	7	9
C1	E1	1/7	1	5	5	7	7	5	5	3	3	7	5	7
C4	E1	1/3	1/5	1	7	5	3	7	5	5	5	5	7	5
C6	E1	1/3	1/5	1/7	1	6	5	3	7	7	5	3	5	5
C7	E1	1/5	1/7	1/5	1/7	1	5	5	5	5	5	5	3	5
C10	E1	1/3	1/7	1/3	1/5	1/5	1	5	5	5	5	5	5	7
C5	E1	1/7	1/5	1/7	1/3	1/5	1/5	1	5	7	7	5	7	5
C3	E1	1/7	1/5	1/5	1/7	1/5	1/5	1/5	1	7	5	5	5	5
C9	E1	1/7	1/3	1/5	1/7	1/5	1/5	1/7	1/7	1	5	7	7	3
C13	E1	1/5	1/3	1/5	1/5	1/5	1/5	1/7	1/5	1/5	1	5	5	5
C2	E1	1/9	1/7	1/5	1/3	1/5	1/5	1/5	1/5	1/7	1/5	1	7	3
C12	E1	1/7	1/5	1/7	1/5	1/3	1/5	1/7	1/5	1/7	1/5	1/7	1	5
C8	E1	1/9	1/7	1/5	1/5	1/5	1/7	1/5	1/5	1/3	1/5	1/3	1/5	1

TABLE 4. Input from Expert 2.

		C11	C1	C4	C6	C7	C10	C5	C3	C9	C13	C2	C12	C8
C11	E2	1	6	3	3	5	4	7	8	7	5	9	8	9
C1	E2	1/6	1	5	6	7	8	5	5	3	3	7	6	7
C4	E2	1/3	1/5	1	7	5	3	7	5	5	5	5	7	5
C6	E2	1/3	1/6	1/7	1	7	5	3	7	7	5	3	5	5
C7	E2	1/5	1/7	1/5	1/7	1	5	6	5	5	5	5	3	5
C10	E2	1/4	1/8	1/3	1/5	1/5	1	5	5	5	5	5	5	7
C5	E2	1/7	1/5	1/7	1/3	1/6	1/5	1	5	8	7	5	7	5
C3	E2	1/8	1/5	1/5	1/7	1/5	1/5	1/5	1	7	5	5	5	5
C9	E2	1/7	1/3	1/5	1/7	1/5	1/5	1/8	1/7	1	5	6	7	3
C13	E2	1/5	1/3	1/5	1/5	1/5	1/5	1/7	1/5	1/5	1	5	5	5
C2	E2	1/9	1/7	1/5	1/3	1/5	1/5	1/5	1/5	1/6	1/5	1	7	3
C12	E2	1/8	1/6	1/7	1/5	1/3	1/5	1/7	1/5	1/7	1/5	1/7	1	4
C8	E2	1/9	1/7	1/5	1/5	1/5	1/7	1/5	1/5	1/3	1/5	1/3	1/4	1

TABLE 5. Input from Expert 3.

		C11	C1	C4	C6	C7	C10	C5	C3	C9	C13	C2	C12	C8
C11	E3	1	7	2	3	5	3	7	6	7	5	9	7	9
C1	E3	1/7	1	5	4	7	7	5	5	3	3	7	5	7
C4	E3	1/2	1/5	1	7	5	3	7	5	5	5	5	7	5
C6	E3	1/3	1/4	1/7	1	7	6	3	7	7	5	3	5	5
C7	E3	1/5	1/7	1/5	1/7	1	5	5	5	5	6	5	3	5
C10	E3	1/3	1/7	1/3	1/6	1/5	1	5	4	6	5	5	5	7
C5	E3	1/7	1/5	1/7	1/3	1/5	1/5	1	5	7	7	5	7	5
C3	E3	1/6	1/5	1/5	1/7	1/5	1/4	1/5	1	7	5	5	5	5
C9	E3	1/8	1/3	1/5	1/7	1/5	1/6	1/7	1/7	1	5	7	7	3
C13	E3	1/5	1/3	1/5	1/5	1/6	1/5	1/7	1/5	1/5	1	5	6	6
C2	E3	1/9	1/7	1/5	1/3	1/5	1/5	1/5	1/5	1/7	1/5	1	7	3
C12	E3	1/7	1/5	1/7	1/5	1/3	1/5	1/7	1/5	1/7	1/6	1/7	1	5
C8	E3	1/9	1/7	1/5	1/5	1/5	1/7	1/5	1/5	1/3	1/6	1/3	1/5	1

Figure 2 reveals the maximum point of interaction present in the marked boundaries of μF_j and μF_i.

Step 4: Assumptions are made:

$$b^{*}(H_i) = \min R\,(F \geq F_i); \quad (i = 1, 2, 3 \ldots k) \tag{8}$$

Weight vector $WV*$ can be obtained as:

$$WV^{*} = \left(b^{*}(H_1), b^{*}(H_2) \ldots, b^{*}(H_n)\right)^{\mathrm{T}} \tag{9}$$

Step 5: Equation (x) is then used for getting the normalized weight vectors for each of the said criteria but thereafter for

TABLE 6. Preferential decision matrix by Expert 1 for TFN method.

		C11	C1	C4	C6	C7	C10	C5	C3	C9	C13	C2	C12	C8
C11	E1	(1,1,1)	(6,7,8)	(2,3,4)	(2,3,4)	(4,5,6)	(2,3,4)	(6,7,8)	(6,7,8)	(6,7,8)	(4,5,6)	(8,9,9)	(6,7,8)	(8,9,9)
C1	E1	(1/8,1/7,1/6)	(1,1,1)	(4,5,6)	(4,5,6)	(6,7,8)	(6,7,8)	(4,5,6)	(4,5,6)	(2,3,4)	(2,3,4)	(6,7,8)	(4,5,6)	(6,7,8)
C4	E1	(1/4,1/3,1/2)	(1/6,1/5,1/4)	(1,1,1)	(6,7,8)	(4,5,6)	(2,3,4)	(6,7,8)	(4,5,6)	(4,5,6)	(4,5,6)	(4,5,6)	(6,7,8)	(4,5,6)
C6	E1	(1/4,1/3,1/2)	(1/6,1/5,1/4)	(1/8,1/7,1/6)	(1,1,1)	(6,7,8)	(4,5,6)	(2,3,4)	(6,7,8)	(6,7,8)	(4,5,6)	(2,3,4)	(4,5,6)	(4,5,6)
C7	E1	(1/6,1/5,1/4)	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/8,1/7,1/6)	(1,1,1)	(4,5,6)	(4,5,6)	(4,5,6)	(4,5,6)	(4,5,6)	(4,5,6)	(2,3,4)	(4,5,6)
C10	E1	(1/4,1/3,1/2)	(1/8,1/7,1/6)	(1/4,1/3,1/2)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1,1,1)	(4,5,6)	(4,5,6)	(4,5,6)	(4,5,6)	(4,5,6)	(4,5,6)	(6,7,8)
C5	E1	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/8,1/7,1/6)	(1/4,1/3,1/2)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1,1,1)	(4,5,6)	(6,7,8)	(6,7,8)	(4,5,6)	(6,7,8)	(4,5,6)
C3	E1	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1,1,1)	(6,7,8)	(4,5,6)	(4,5,6)	(4,5,6)	(4,5,6)
C9	E1	(1/8,1/7,1/6)	(1/4,1/3,1/2)	(1/6,1/5,1/4)	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1/8,1/7,1/6)	(1/8,1/7,1/6)	(1,1,1)	(4,5,6)	(6,7,8)	(6,7,8)	(2,3,4)
C13	E1	(1/6,1/5,1/4)	(1/4,1/3,1/2)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1,1,1)	(4,5,6)	(4,5,6)	(4,5,6)
C2	E1	(1/9,1/9,1/8)	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/4,1/3,1/2)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1,1,1)	(6,7,8)	(2,3,4)
C12	E1	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/4,1/3,1/2)	(1/6,1/5,1/4)	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/8,1/7,1/6)	(1,1,1)	(4,5,6)
C8	E1	(1/9,1/9,1/8)	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1/4,1/3,1/2)	(1/6,1/5,1/4)	(1/4,1/3,1/2)	(1/6,1/5,1/4)	(1,1,1)

TABLE 7. Decision matrix by Expert 2 for TFN method.

		C11	C1	C4	C6	C7	C10	C5	C3	C9	C13	C2	C12	C8
C11	E2	(1,1,1)	(5,6,7)	(2,3,4)	(2,3,4)	(4,5,6)	(3,4,5)	(6,7,8)	(7,8,9)	(6,7,8)	(4,5,6)	(8,9,9)	(7,8,9)	(8,9,9)
C1	E2	(1/7, 1/6, 1/5)	(1,1,1)	(4,5,6)	(5,6,7)	(6,7,8)	(7,8,9))	(4,5,6)	(4,5,6)	(2,3,4)	(2,3,4)	(6,7,8)	(5,6,7)	(6,7,8)
C4	E2	(1/4,1/3,1/2)	(1/6,1/5,1/4)	(1,1,1)	(6,7,8)	(4,5,6)	(2,3,4)	(6,7,8)	(4,5,6)	(4,5,6)	(4,5,6)	(4,5,6)	(6,7,8)	(4,5,6)
C6	E2	(1/4,1/3,1/2)	(1/7,1/6,1/5)	(1/8,1/7,1/6)	(1,1,1)	(6,7,8)	(4,5,6)	(2,3,4)	(6,7,8)	(6,7,8)	(4,5,6)	(2,3,4)	(4,5,6)	(4,5,6)
C7	E2	(1/6,1/5,1/4)	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/8,1/7,1/6)	(1,1,1)	(4,5,6)	(5,6,7)	(4,5,6)	(4,5,6)	(4,5,6)	(4,5,6)	(2,3,4)	(4,5,6)
C10	E2	(1/5,1/4,1/3)	(1/9,1/8,1/7)	(1/4,1/3,1/2)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1,1,1)	(4,5,6)	(4,5,6)	(4,5,6)	(4,5,6)	(4,5,6)	(4,5,6)	(6,7,8)
C5	E2	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/8,1/7,1/6)	(1/4,1/3,1/2)	(1/7,1/6,1/5)	(1/6,1/5,1/4)	(1,1,1)	(4,5,6)	(7,8,9)	(6,7,8)	(4,5,6)	(6,7,8)	(4,5,6)
C3	E2	(1/9,1/8,1/7)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1,1,1)	(6,7,8)	(4,5,6)	(4,5,6)	(4,5,6)	(4,5,6)
C9	E2	(1/8,1/7,1/6)	(1/4,1/3,1/2)	(1/6,1/5,1/4)	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1/9,1/8,1/7)	(1/8,1/7,1/6)	(1,1,1)	(4,5,6)	(5,6,7)	(6,7,8)	(2,3,4)
C13	E2	(1/6,1/5,1/4)	(1/4,1/3,1/2)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1,1,1)	(4,5,6)	(4,5,6)	(4,5,6)
C2	E2	(1/9,1/9,1/8)	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/4,1/3,1/2)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1/7,1/6,1/5)	(1/6,1/5,1/4)	(1,1,1)	(6,7,8)	(2,3,4)
C12	E2	(1/9,1/8,1/7)	(1/7,1/6,1/5)	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/4,1/3,1/2)	(1/6,1/5,1/4)	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/8,1/7,1/6)	(1,1,1)	(3,4,5)
C8	E2	(1/9,1/9,1/8)	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1/4,1/3,1/2)	(1/6,1/5,1/4)	(1/4,1/3,1/2)	(1/5,1/4,1/3)	(1,1,1)

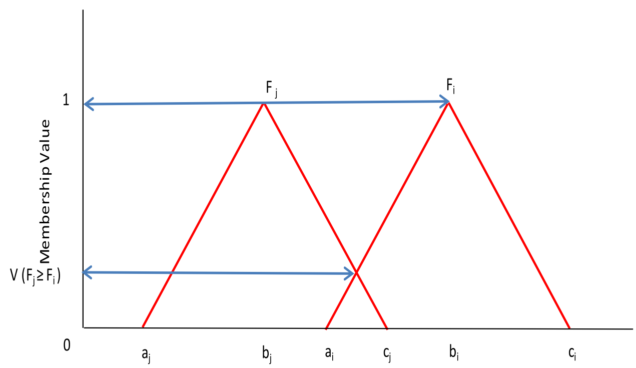

FIGURE 2. Highest point of interaction between F_j and F_i.

modifications, integral value system is used [49] by resolving it into equation (xi) as shown here under:

$$WV = (b(H_1), b(H_2)\ldots, b(H_n))^{\mathrm{T}} \quad (10)$$

$$J_T^{\beta}(F_j) = \frac{1}{2}\beta\left(b_j + c_j\right) + \frac{1}{2}(1-\beta)\left(a_j + b_j\right) = \frac{1}{2}\left[\beta c_j + b_j + (1-\beta)\, a_j\right] \quad (11)$$

where $0 \leq \beta \geq 1$ represents an optimism degree of decision maker's perspective. 0.5 is the value assigned here [49].

V. CALCULATIONS

Decision matrix is made using TFN of fuzzy logic method after consulting an expert team of the same field. First questionnaires were rigorously prepared by authors for marking by a panel of three experts:

1) Official from ministry of environment and forests, Government of India (E1); Deals with waste management.
2) Engineer from plastic industry (E2); expert on both single-use plastics and recyclable plastics.
3) Fellow researcher (E3); working on environment protection.

Decision matrix was made based on the inputs received by the experts (as shown in Table 3-5) and converted into triangular numbers as shown in Table 6, 7 and 8. After deciding matrix using TFN concept of fuzzy logic, by using equations (iv) to (xi), weights assigned for each of the criteria were found out by following steps described earlier. To avoid any kind of discrepancy in the results, authors are not dependent on any one expert input but authors have taken input from three different experts. The fuzzy numbers are defined in uncertainty situation and then applied to real world problems of engineering. Earlier, there was no concrete mathematical concept to define vagueness. Thus, the model is self-sustainable to produce reliable results.

TFN values of all the thirteen criteria or challenges are obtained as follows:

TABLE 8. Decision matrix by Expert 3 for TFN method.

		C11	C1	C4	C6	C7	C10	C5	C3	C9	C13	C2	C12	C8
C11	E3	(1,1,1)	(6,7,8)	(1,2,3)	(2,3,4)	(4,5,6)	(2,3,4)	(6,7,8)	(5,6,7)	(7,8,9)	(4,5,6)	(8,9,9)	(6,7,8)	(8,9,9)
C1	E3	(1/8,1/7,1/6)	(1,1,1)	(4,5,6)	(3,4,5)	(6,7,8)	(6,7,8)	(4,5,6)	(4,5,6)	(2,3,4)	(2,3,4)	(6,7,8)	(4,5,6)	(6,7,8)
C4	E3	(1/3,1/2,1)	(1/6,1/5,1/4)	(1,1,1)	(6,7,8)	(4,5,6)	(2,3,4)	(6,7,8)	(4,5,6)	(4,5,6)	(4,5,6)	(4,5,6)	(6,7,8)	(4,5,6)
C6	E3	(1/4,1/3,1/2)	(1/5,1/4,1/3)	(1/8,1/7,1/6)	(1,1,1)	(6,7,8)	(5,6,7)	(2,3,4)	(6,7,8)	(6,7,8)	(4,5,6)	(2,3,4)	(4,5,6)	(4,5,6)
C7	E3	(1/6,1/5,1/4)	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/8,1/7,1/6)	(1,1,1)	(4,5,6)	(4,5,6)	(4,5,6)	(4,5,6)	(5,6,7)	(4,5,6)	(2,3,4)	(4,5,6)
C10	E3	(1/4,1/3,1/2)	(1/8,1/7,1/6)	(1/4,1/3,1/2)	(1/7,1/6,1/5)	(1/6,1/5,1/4)	(1,1,1)	(4,5,6)	(3,4,5)	(5,6,7)	(4,5,6)	(4,5,6)	(4,5,6)	(6,7,8)
C5	E3	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/8,1/7,1/6)	(1/4,1/3,1/2)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1,1,1)	(4,5,6)	(6,7,8)	(6,7,8)	(4,5,6)	(6,7,8)	(4,5,6)
C3	E3	(1/7,1/6,1/5)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/5,1/4,1/3)	(1/6,1/5,1/4)	(1,1,1)	(6,7,8)	(4,5,6)	(4,5,6)	(4,5,6)	(4,5,6)
C9	E3	(1/9,1/8,1/7)	(1/4,1/3,1/2)	(1/6,1/5,1/4)	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/7,1/6,1/5)	(1/8,1/7,1/6)	(1/8,1/7,1/6)	(1,1,1)	(4,5,6)	(6,7,8)	(6,7,8)	(2,3,4)
C13	E3	(1/6,1/5,1/4)	(1/4,1/3,1/2)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1/7,1/6,1/5)	(1/6,1/5,1/4)	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1,1,1)	(4,5,6)	(5,6,7)	(5,6,7)
C2	E3	(1/9,1/9,1/8)	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/4,1/3,1/2)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1,1,1)	(6,7,8)	(2,3,4)
C12	E3	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/4,1/3,1/2)	(1/6,1/5,1/4)	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/8,1/7,1/6)	(1/7,1/6,1/5)	(1/8,1/7,1/6)	(1,1,1)	(4,5,6)
C8	E3	(1/9,1/9,1/8)	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1/4,1/3,1/2)	(1/7,1/6,1/5)	(1/4,1/3,1/2)	(1/6,1/5,1/4)	(1,1,1)

TABLE 9. Integral values of factors/ challenges considered.

Factors/ Challenges	Integral Values
C1	0.128
C2	0.047
C3	0.064
C4	0.12
C5	0.083
C6	0.105
C7	0.085
C8	0.007
C9	0.053
C10	0.085
C11	0.151
C12	0.016
C13	0.040

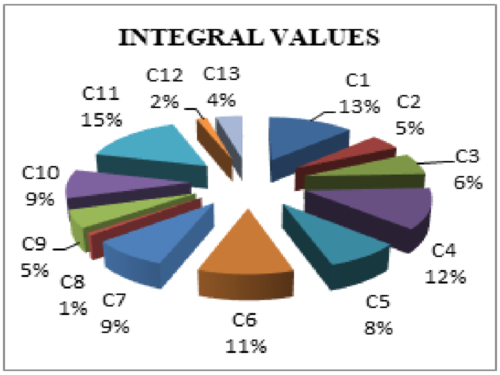

FIGURE 3. Figure depicting the influence of challenges in terms of percentage.

SE1 (C1) = (47.62, 60.81, 71.83) ⊗ ((1/ (47.62 + 532.008), 1/ 452.649, 1/ (71.83 + 368.416)) = (0.082, 0.134, 0.163)

SE2 (C2) = (10.611, 12.932, 16.461) ⊗ ((1/ (10.611 + 532.008), 1/ 452.649, 1/ (16.461 + 368.416)) = (0.019, 0.028, 0.042)

SE3 (C3) = (24.079, 29.292, 34.596) ⊗ ((1/ (24.079 + 532.008), 1/ 452.649, 1/ (34.596 + 368.416)) = (0.043, 0.064, 0.085)

SE4 (C4) = (48.443, 55.588, 66.91) ⊗ ((1/ (48.443 + 532.008), 1/ 452.649, 1/ (66.91 + 368.416)) = (0.083, 0.122, 0.153)

SE5 (C5) = (32.312, 38.524, 44.792) ⊗ ((1/ (32.312 + 532.008), 1/ 452.649, 1/ (44.792 + 368.416)) = (0.057, 0.085, 0.108)

SE6 (C6) = (39.86, 49, 58.25) ⊗ ((1/ (39.86 + 532.008), 1/ 452.649, 1/ (58.25 + 368.416)) = (0.069, 0.108, 0.136)

SE7 (C7) = (27.88, 40.34, 48.48) ⊗ ((1/ (27.88 + 532.008), 1/ 452.649, 1/ (48.48 + 368.416)) = (0.049, 0.089, 0.116)

SE8 (C8) = (3.01, 3.444, 4.227) ⊗ ((1/ (3.01 + 532.008), 1/ 452.649, 1/ (4.227 + 368.416)) = (0.005, 0.007, 0.011)

SE9 (C9) = (19.882, 24.114, 28.522) ⊗ ((1/ (19.882 + 532.008), 1/ 452.649, 1/ (28.522 + 368.416)) = (0.036, 0.053, 0.071)

SE10 (C10) = (31.9, 39.135, 46.56) ⊗ ((1/ (31.9 + 532.008), 1/ 452.649, 1/ (46.56 + 368.416)) = (0.056, 0.086, 0.112)

SE11 (C11) = (61.31, 73.31, 81.14) ⊗ ((1/ (61.31 + 532.008), 1/ 452.649, 1/ (81.14 + 368.416)) = (0.103, 0.161, 0.180)

SE12 (C12) = (6.328, 7.648, 8.184) ⊗ ((1/ (6.328 + 532.008), 1/ 452.649, 1/ (8.184 + 368.416)) = (0.011, 0.016, 0.021)

SE13 (C13) = (15.181, 18.512, 22.056) ⊗ ((1/ (15.181 + 532.008), 1/ 452.649, 1/ (22.056 + 368.416)) = (0.027, 0.04, 0.056)

Further by taking integral value system and then considering degree of optimism as 0.5, integral values are then calculated as shown in Table 9 and Figure 3.

From results it is very clear that "Expense on implication (C11), Scantiness in the support received from the government (C1) and Lack of environment concern among suppliers (C4) are the most influencing factors/ challenges".

VI. DISCUSSION AND CONCLUSION

Establishment and usage of environment friendly product is an effort which involves the usage of both vast investments by investors and efforts put by capable people to rank thirteen different challenges identified, which single-use plastic industries are facing for switching to environment friendly products. Calculation done by using fuzzy logic methodology provides a large space for assumption by the input of advice to experts where there is no concrete data available; it gives room for flexibility by increasing the stability of obtained solution. It is utmost necessary at the same time that analysis is also done in detail by taking the expert's opinion in relevant field, so that wherever applicable weights could be assigned. If any mistake or negligence is done in assigning weights, it may deviate the results. Using TFN, it allows more relaxation in selecting appropriate challenges faced by industries, in absence of rigid corresponding data values and just by involvement of sole opinion of expertise. Results obtained are shown in the form of graph in figure 3 depicting the influence of challenges in terms of percentage. Though, it is a known thing that economic strength influences the role in any social or industrialized grounds. Lack of proper research, many a times put a noteworthy abstinence in the implementation of environment friendly products. Huge involvement of investments both financially and physically is also one of the reasons for not getting proper track towards removal of single-use plastics. This research is a step towards adopting feasible approaches in selection of challenges faced by industries in replacement of single-use plastic products to environmentally friendly products. Few similar researches regarding analysing of challenges can be found in literature [10], [16], [18] but analysis of challenges related to single use plastics is novel to authors themselves.

A detailed study was done in this research to challenges which are blocking the path for implementation of sustainable manufacturing favourable to environment for decreasing single-use plastic consumptions. A case study is done to first identify the major challenges and then finding out the priority for the challenges by using TFN application of fuzzy methodology. Cost and government support are the most prominent challenges as identified from the results obtained. Although it is time taking process, authors have an expectation that the result outcome will help planners and investors in replacement of single-use plastics. Authors have minutely selected the challenges with help of experts so that all the considerations are involved leaving none but it may happen that in future that if any other challenge is involved as one of the criteria then it may lead for a new explicit, stable and applied output on such grounds.

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