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Investigating Enablers to improve transparency in sustainable food supply chain using F-BWM

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Abstract. Food Supply Chains (FSC) are complex and dynamic in behaviour and prone to increasing risks of unsustainability. Consumers increasingly demand food quality, safety, and sustainability, which are fast becoming issues of great importance in FSC. Lack of real-time information sharing and connectivity among stakeholders make these issues tougher to mitigate. Supply chain transparency (SCT) is thus an essential attribute to manage these supply chain complexities and enhance the sustainability of FSC. The paper identifies and analyses key enablers for SCT in FSC. Several technical, as well as sustainability-related enablers, contribute to the implementation of SCT. The identified enablers are analysed using Fuzzy-best worst methodology (F-BWM), which determine the most critical factors using the decision maker's opinion. Extending BWM with fuzzy logic incorporates the vagueness of human-behaviour into decision-making approach. The results of this research provide decision-makers with the priority of enablers to the decision-maker. Enhancing these enablers will help improve the transparency for better management of FSC. The article expands upon the practical as well as theoretical implications of SCT on sustainability in FSC. It addresses the requirement of including sustainability in the decision-making process. The results demonstrate the effectiveness of the F-BWM for the decision-making process. The study is conducted by considering downstream supply chain activities in the Indian context. It is one of the first studies that analyse SCT enablers using F-BWM method in Indian context. The study contributes towards improving the environmental, economic, and social sustainability of FSC.

Keywords: Supply Chain Transparency, Fuzzy-Best Worst Method, Sustainable Food Supply Chain

1. Introduction

Food supply chain (FSC) in the 21st century is long and complex, with large number of operations, covering large distances. A multitude of complex challenges such as-product perishability, quality issues, poor demand management, poor traceability, and supply chain (SC) visibility, logistics and cold chain performance etc., that make them tough to manage (Kumar et al., 2020). All these issues in FSCs lead to a huge amount of wastage and losses in the FSCs. Almost one-third of the total food produced is wasted/lost globally (Confederation of Indian Industry, 2017). Apart from these challenges, food quality, safety, and security are the essential factors for a sustainable food supply chain (SFSC) (Shankar et al., 2018; Wang and Yue, 2017). Various food scares such as the melamine milk adulteration scandal in China, horsemeat scandal in Ireland, avian influenza outbreak have added to the concerns of customers regarding food quality and safety (Astill et al., 2019). Managing these challenges call for transparency, monitoring, and traceability, in FSC.

While most food companies express their willingness to improve transparency and traceability for an SFSC, the shift in the Indian food industry has been rather slow. One major reason for this could be that the motivators and enablers for improving transparency in an SFSC are not fully understood. This serves as a research gap for us to investigate the enablers for transparency in SFSC using advanced multi-criteria decision-making (MCDM) tools.

A varied range of MCDM tools can be found in literature such as AHP (Kumar et al., 2015), ANP(Saaty and Vargas, 2013), VIKOR (Opricovic and Tzeng, 2004), TOPSIS (Tyagi et al., 2018) etc. Among these AHP is the most popular one, with ANP it's general form, which are both based on pair-wise comparison matrix formulation. However, AHP has also been criticized for inconsistency in decision-making and the requirement of a large number of input comparisons. Owing to these issues, Rezaei (2015) proposes the Best-Worst Method (BWM) for ranking factors, that essentially gave better results than AHP. The BWM uses reference comparisons with respect to the best and worst criterion and essentially remedies the inconsistency issue. Further, to integrate the uncertainty and the vagueness in the decision-makers perspective, we use the fuzzy-BWM to analyse the enablers to improve transparency in SFSC.

2. Literature Review

Transparency is an essential characteristic of efficiency in SFSC. It may be defined as the timely sharing of accurate, fact-based, reliable, relevant, and readable information, of appropriate quality and quantity, among all the stakeholders (Wognum et al., 2011). It is essentially an SC performance metric, a lack of which can lead to problems related to the business, environment, and social sustainability (Bai and Sarkis, 2020).. Ringsberg (2014) conducting a review of the literature on various perspectives on traceability in FSCs, found transparency and interoperability as an important perspective for risk management in FSCs. Wognum et al. (2011) studying the use of information systems for sustainability in FSCs, identified that most of the systems were focussed on single actors and did not consider the whole FSC. Bastian and Zentes (2013) studied the antecedents and consequences of SC transparency of sustainability in FSC, identifying significant effects on social, ecological, operational, and relational dimensions of sustainability. The majority of the studies on transparency considered traceability as the focal concept affecting SFSC (Bai and Sarkis, 2020; Bosona and Gebresenbet, 2013).

A lot of support can be found in the literature for the use of technology based solutions such as information communication and technology (ICT), internet of thing (IoT), and blockchain (Astill et al., 2019; Zhao et al., 2019).

2.1. Enablers for transparency

Addressing consumer concerns are central to sustainable development in FSC (Cagliano et al., 2016). Gaining trust and confidence from the customer is one of the essential factors in the food industry (Bilyea and Mcinnes, 2016). Research has shown that consumers show a great interest in accessing product-related information such as point of origin, date of manufacturing, expiry date, how they are produced (Astill et al., 2019). A study in 2016 finds that 94% of respondents found transparency an important characteristic of food manufacturers, with 84% finding in-depth information of the product of great value(Insight, 2016).

By enabling traceability and with a seamless flow if information, the governments play a crucial role of avoiding the unforeseeable disasters in FSCs (Faisal, 2015). Government Regulations, through legislations, drive implementation of transparency and traceability in FSC at domestic and international levels (Shankar et al., 2018). Wu et al. (2018) identify a lack of regulatory supervision in links of the dairy supply chain as a contributing factor of the 2008 melamine scandal. Such health hazards make transparency and traceability the cornerstone of food safety. Further, it protects FSC from various malpractices such as, use of hazardous chemicals and additives, adulterations and food frauds, processing malpractices, etc. Adulteration or “food counterfeit” of food products or supply of inferior quality by suppliers is a common complaint in FSC (Gupta and Shankar, 2016). Counterfeits are generally cases of conscious fraud, and are coupled with genuine scientific knowledge(Creydt and Fischer, 2019). This makes the guilty especially tough to pinpoint without a strong transparency-based system. Thus, the detection of counterfeits is a major enabler for supply chain transparency.

Transparency enables auditing of sustainability practices of all the stakeholders in the SC (Venkatesh et al., 2020). It ensures that operations are free from negative consequences such as child labor, waste mismanagement, poor factory conditions, etc. (Bai and Sarkis, 2020). In such a system, governments and NGOs can monitor all the parties involved in the SC in real. Therefore, preventing any social as well as environmental malpractice. From an operational perspective, transparency and traceability help reap many benefits such as quick and easy recalls, swift pin-pointing of the actor-at-fault in case of a product performance issue, improved cooperation among organizations (Wognum et al., 2011). Significant market competition in the globalized world makes it necessary to invest in transparency and coordination based technologies (Shankar et al., 2018).

Thus, a SC transparency-based system with information sharing about the sustainability of participants across multiple tiers of SC is essential. Based on an extant literature review, as shown in Table 1, eight enablers of SC transparency are identified, which are next analysed using Fuzzy-BWM.

Table 1. Enablers for improving transparency in SFSC

S No.	Enablers	Source
1.	Enhance operational efficiency	(Wognum et al., 2011) (Shankar et al., 2018)
2.	Mitigate Food Hazard and enable Safety	(Gupta and Shankar, 2016; Kaur, 2019)
3.	Fulfil regulatory Requirements	(Faisal, 2015; Wu et al., 2018)
4.	Promote sustainability in Supplier practices	(Bai and Sarkis, 2020; Mani and Gunasekaran, 2018)
5.	Expanding e-retail business	(Confederation of Indian Industry, 2017)
6.	Quick and Easy Recall	(Shankar et al., 2018)
7.	Product counterfeit prevention	(Confederation of Indian Industry, 2017; Creydt and Fischer, 2019)
8.	Gain customer Trust and Confidence	(Astill et al., 2019; Cagliano et al., 2016)

3. Research Methodology

The BWM, as proposed by Rezaei (2015), provides a priority vector based on two reference comparison vectors. The extension of BWM using fuzzy set theory, previously used in literature (Guo and Zhao, 2017; Karimi et al., 2020), has been found give preference with better consistency.

A triangular fuzzy number (TFN) $\bar{A}$ on the set R, with its membership function $\mu_{\bar{A}}(x): R \rightarrow [0,1]$, is defined as (Kumar et al., 2015)-

$$\mu_{\bar{A}}(x) = \begin{Bmatrix} \frac{x-a}{b-a} x \in [a,b] \\ \frac{x-c}{b-c} x \in [b,c] \\ 0, Otherwise \end{Bmatrix}$$

Where, $a \leq b \leq c$, a is the lower, b the modal, and c the upper boundary of the TFN. We use the Graded-Mean-Integration representation (GMIR), R($\bar{A}_j$) to rank the TFN, and de-fuzzify the solutions.

$$R(\bar{A}_j) = \frac{a_i + 4b_i + c_i}{6}$$

The steps for the Fuzzy-BWM are as follows:

Step 1: Identification of decision factors

On the basis of literature, finalize a set of factors, F = $\{f_1, f_2 \ldots f_n\}$.

Step 2: Identification of best and worst factors based on discussion with experts.

Step 3: Provide the fuzzy preference vomparisons of "Best over other" and "others over Worst".

Using the linguistic comparisons, shown in Table 2, conduct pairwise comparisons to get the "Best over others" Vector, labelled X_B, and "Others over Worst" vector labelled X_W.

$$\overline{X_B} = (\bar{x}_{B1}, \bar{x}_{B2}, \ldots\ldots\ldots \bar{x}_{Bn}), \text{ and } \overline{X_W} = (\bar{x}_{1W}, \bar{x}_{2W}, \ldots\ldots\ldots \bar{x}_{nW})$$

Table 2. Linguistic terms for reference comparison

Linguistic Terms	Fuzzy Numbers
Absolutely more significant	(7/2, 4, 9/2)
Strongly more significant	(5/2, 3, 7/2)
Fairly more significant	(3/2, 2, 5/2)
Weakly more significant	(2/3, 1, 3/2)
Equally significant	(1, 1, 1)

Step 4: Compute the fuzzy weights of the factors.

The fuzzy weights of the factors (W_j) are computed using the BWM programming formulation proposed by (Guo and Zhao, 2017). The optimal weights for the factors are such that $\frac{\overline{W}_B}{\overline{W}_j} = \overline{x}_{Bj}$ and $\frac{\overline{W}_j}{\overline{W}_W} = \overline{x}_{jW}$. To achieve this, we try to minimize the gaps $\left|\frac{\overline{W}_B}{\overline{W}_j} - \overline{x}_{Bj}\right|$ and $\left|\frac{\overline{W}_j}{\overline{W}_W} - \overline{x}_{jW}\right|$, which is done by solving the following constrained optimization problem.

$$\min \overline{\xi}$$

such that

$$\left|\frac{\overline{W}_B}{\overline{W}_j} - \overline{x}_{Bj}\right| \le \overline{\xi}, \quad \left|\frac{\overline{W}_j}{\overline{W}_W} - \overline{x}_{jW}\right| \le \overline{\xi}$$

$$\sum_{j=1}^{n} R(W_j) = 1 \qquad \text{eq 1.}$$

$$a_j^W \ge 0; \quad a_j^W \le b_j^W \le c_j^W; \quad j = 1, 2, \ldots, n$$

, where $\overline{W}_B$, $\overline{W}_j$, $\overline{W}_W$, are fuzzy numbers. The fuzzy weights of the factor f_j is given by $\overline{W}_j = (a_j^W, b_j^W, c_j^W)$, and $\overline{\xi} = (k, k, k)$

Step 5: Check the consistency ration of the solution.

Consistency ration = $\frac{k}{\text{Consistency Index}}$, where consistency index is as given in Table 3, which are the solutions of the eq 2.

$$\xi^2 - (1+2\overline{x}_{BW})\xi + (\overline{x}_{BW}^2 - \overline{x}_{BW}) = 0, \qquad \text{eq 2.}$$

which can be transformed to,

$$\xi^2 - (1+2c_{BW})\xi + (c_{BW}^2 - c_{BW}) = 0 \qquad \text{eq 3.}$$

Table 3. Consistency Index for Fuzzy BWM

Linguistic terms	Abs. more Sig.	Strongly more Sig.	Fairly more Sig.	Weakly more Sig.	Equally Sig.
$\bar{a}_{BW}$	(7/2,4,9/2)	(5/2,3,7/2)	(3/2,2,5/2)	(2/3,1,3/2)	(1,1,1)
Cons. index	8.04	6.69	5.29	3.80	3

4. Results and Discussion

The eight identified enablers were discussed with the industry experts. Based on the discussion, the following reference comparison inputs were provided.

$\overline{X_B}$ = (7/2, 4, 9/2); (0.67,1,1.5); (1,1,1);(2/3, 1, 3/2); (3/2, 2, 5/2); (3/2, 2, 5/2); (2/3, 1, 3/2); (2/3, 1, 3/2), and $\overline{X_W}$ = (1,1,1); (5/2, 3, 7/2); (7/2, 4, 9/2); (3/2, 2, 5/2); (2/3, 1, 3/2); (3/2, 2, 5/2); (3/2, 2, 5/2); (2/3, 1, 3/2).

The formulation in eq. 1 was coded in LINGO 18.0 and solved, we get an ξ = 0.7912, with the preference as shown in Table 4.

Table 4. Preference Ranking of the Enablers to Teansparency in SFSC

Enabler	Fuzzy Weight	Crisp Wight	Preference
Enhance operational efficiency	(.064, .064, .076)	0.066	8th
Mitigate food hazard and enable safety	(.143, .173, .173)	0.168	2th
Fulfil regulatory Requirements	(.206, .206, .237)	0.211	1st
Promote sustainability in supplier practices	(.114, .124, .140)	0.125	3nd
Expanding e-retail business	(.083, .085, .096)	0.086	7th
Quick and easy recall	(.086, .098, .116)	0.099	6th
Product counterfeit prevention	(.114, .124, .140)	0.125	4rd
Gain customer trust and confidence	(.106, .115, .143)	0.118	5th

Consistency Ratio = $\xi / \mathrm{CI} = 0.7912/8.04 = 0.098$, which is very good. Thus we get regulatory requirements as the most significant enabler of improving transparency in FSCs, followed by food hazards, supplier malpractices, and counterfeit prevention, and customer trust. Operations focused enablers such as quick and easy recall, expanding e-retail, and operational efficiency, which is in concurrence with the previous literature (Bastian and Zentes, 2013; Confederation of Indian Industry, 2017). Further, we infer that raising issues related to food safety and security among customers can certain motivate businesses to be more transparent regarding sustainability in their FSCs.

5. Conclusion

The concept of sustainability is fast gaining acceptance in FSCs across the globe as well as in India. From this perspective, it is imperative that we businesses have a clear view of the key factors that are of importance in SFSC. The current paper serves this purpose by identifying key enablers from a social, environmental as well as economical perspective, to improve transparency in SFSC. The identified enablers are analysed using the fuzzy-BEM, which still rather new and has been found to be of great use in this decision-making problems.

The research in this direction can be further extended by validating the results empirically while considering more factors and wider industrial perspective. From the methodological perspective, the results can also be compared with the results of other methodologies such as VIKOR, ELECTRE, etc.

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