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Factors Assessment for Encumbering the Implementation of Sustainability Based Lean Six Sigma Practices in Food Supply Chain

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Abstract: Nowadays, there is a makeshift towards the concept of sustainability in the walks of business ventures. Food industries are struggling to cater the exponential population surge, across the globe. Hence to nurture the masses, Food Supply Chains (FSC) needs to relook their operational strategies for ensuring effective and efficient operations. In continuation to the same, various lean, six sigma theory-based fundamentals under aegis of sustainability need to be accumulated in the Food Supply Chain Performance Systems (FSCPS). But adoption of these theories confronts multiple issues which need to be investigated for the smooth adoption of these practices. To tackle the same presented work clusters the various encumbering concerns associated with the smooth adoption of these fundamentals in the dynamics of the FSCPS. Furthermore, to enrich the outcomes of the study, empirical analysis by implying the fundamentals of the neutrosophic theory is exercised. Implications of the presented work can enrich the decisional framework, policymakers to streamline the operating procedurals of FSC in compliance with the sustainability based lean six sigma practices.

Keywords: Sustainable Lean six sigma; Food supply chain;Neutrosophic set; Food industry

1. Introduction

In current times various industrial venues are more shifted their vision towards the successful fulfilment of the consumer demand by rendering the variety of the products. But, to nurture the same and withstand the strong blows of competitiveness, companies are emphasizing more on the production volumes rather than the effective and efficient operations[1)]. Such working scenarios demand embedding the various quality governing and monitoring tools within the working arena of the industries. These tools outlaid the system-based working approach, envisioned to upscale the potencies of system dynamics. Among this deployment of the quality improvement initiatives Lean and Six Sigma (LSS), revamps the operational productivity, serviceability, promptness towards the customer and employees' concerns.

It is remarkable in context of current era need that utilisation of the natural resources should be controlled in order to serve the demands of future generations. Owing to which food processing operations needs to aligned with the fundamentals of triple line bottom approach integrating sustainability in production-consumption procedurals[2)]. As the consumption of food items is directly linked with the societal, economic and environmental perspectives, hence enacting sustainability with its concerned supply chains needs to reinstated. Hence, need arises to revamp the operational approach which maps the quality of products, reduces in process wastage and endures the sustainable perspectives[3)]. In light to same, focus needs to be shifted towards the Sustainability based Lean and Six Sigma (SLSS) approach, where LSS underpins the process improvement protocols and sustainability strengthen the foundation of eco-friendly work approaches. As the wind of globalisation attracted the consumer attention towards the utility of products binding sustainability fundamentals. To cope up with the same in effective and efficient manner, SLSS approach needs to be grounded.

Lean and six sigma deployment streamlines the various procedurals aimed to overcome various anomalies persisting within the various processing industries. Furthermore, integrating lean with six sigma broadens its scope of implementation and enriches its outcomes[4]. LSS is envisioned to enhance the profitability of business establishments and their Supply Chains (SCs), by eradicating the causes behind wastage, delays, and mismanagement[5].This woking approach bears the characteristics of both lean and six-sigma mapped with the horizontal and vertical direction of its implementation. Lean approaches underpin the entities of every working tier, whereas six sigma unites the same notions by considering the whole organization as a single unit. Furthermore, extending sustainability in the pursuit of lean initiatives and for six sigma initiatives distinctly, enriches its intended goals. The enclosure of the SLSS approach in an organisation driving the supply chains is sketched in the figure 1, for ease of visualisation.

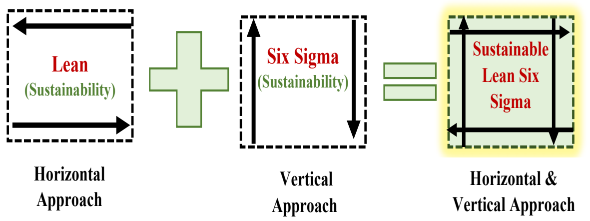

Fig.1: Working approach of the sustainability based lean and six sigma

Deployment of the SLSS based initiatives is unique for every organization and is dependent upon the nature of the product, operation tiers of the supply chain performance system. It is tailored to suit the industrial environment and various service sectors[6]. Implementation of the SLSS based initiatives to the food industries overcomes the issues associated with perishability, seasonal availability, short shelf life, inventory limits, food safety, and security [7]. These attributes make the FSC management cumbersome and capsize the pace of operations allied with it.

Food industries are among of the manufacturing system, which is surrounded by multiple legislative covers and are subjected to the volatile changes related to the demand, production volumes, tasting, and variety of the stuff being served[8]. FSCs encompass multiple operations, uniting the notions from farm to fork. But still, food industries are facing multiple issues to upscale their operating potencies alongwith the enacting sustainability with its dynamics, hence, a need arises to align their supply chain operations with the fundamentals of the sustainability based lean, six, and sigma. Owing to the unique attributes posed by the food industries rendered in figure 2, demand for the adoption of the operational excellence benchmarks like SLSS, which is aimed to coin the term green manufacturing allied with the avenues of FSC performance system.

Furthermore, Indian food industries shares a remarkable contribution in the nation economy and employment proportions. To nurture the spawning population, count of the 135 crores, approximately 39,700 food processing units are registered with the Ministry of food processing industries (MOFPI) undertaking of the Government of India[9]. This contributes 8.3 percent India's gross domestic product (GDP) in the year of 2017-18, employing the 12 percent of total population[7]. Hence, to uplift the operating potencies of the FSCs and food processing industries various qualitative measures needs to be inducted. In continuation to the same, presented work identifies the various perspectives allied with the deployment of SLSS practices in the dynamics of FSC. This is study aimed to handle the following research queries (RQs):

RQ1: What are the various factors widening the gap between the SLSS based practices adoption in the dyanmics of FSCs?

RQ2: What is the mutual interrelationship between the various inhibitors of the SLSS practices enactment in FSCPS?

RQ3 What is the severity allied with the various inhibitors of SLSS practices in the FSC?

Presented work is aimed to extend the SLSS practices with the dynamics of the FSC performance system. For the same various impeding indicators are clustered from the core of the research literature and to enrich its outcomes, empirical investigation is rendered. For the same neutrosophic sets based analysis is exercised to establish the priority of the hurdles, following their severity. This study is dedicated to nurturing the food industries and align FSC with walks of SLSS, competing in the market of emerging economies.

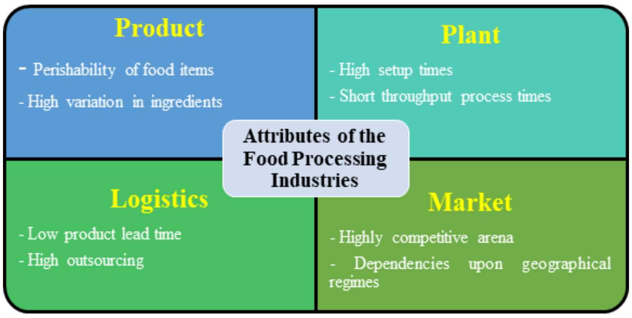

Fig.2: Food industries attributes at a glance

2. Literature review

SLSS based practices adoption tends to make FSC operations quality oriented, reduced wastage also safeguards the environmental perspectives. As production-consumption of the food items is directly linked with the farming-based activities, rooting the utilisation of natural resources. Hence, need arises to extend the sustainability under the aegis of qualitative initiatives like lean and six sigma. Parmar and Desai[2]reviewed the advancements in domain of adoption of SLSS in the manufacturing arena. Erdil et al.[10] explored the avenues of the improvement allied with the deployment of SLSS based practices. Ruben et al.[11]

developed framework seeded by the insights of research literature detailing the adoption of SLSS based initiatives. Fatemi and Franchetti[12]reviewed the scenarios allied with the sustainable lean practices along with the green strategy viability within six sigma protocols in manufacturing environment. Putri and Hartini[13] explored the instances of improvement of sustainable performance in the cattle feed production procedurals. Zahara[14] studied the economic perspectives of sugarcane processing units of Indonesia.Zulkeflyet al.[15]detailed the impact of logistics disruptions within the supply chain on the sustainability. Hamid et al.[16]assessed the scope of implementation of sustainable practices in the service sector subsidiaries. Sabtu et al.[17]encapsulated the environmental and carbon management-based initiatives with the supply chain practices. Tyagi et al.[18] assessed the various barriers allied with measurement of supply chain practices. Gupta and Jayant[19] contemplated the avenues governing selection of low carbon- based suppliers in supply chains. Tyagi et al.[20] detailed the various drivers of the green supply chain performance system.Berawai et al.[21]extended the fuzzy based analysis of determination of the earthquake victims.

It has been rendered by the majority of the studies in the past that SLSS initiatives assure profitability, better serviceability, reduced wastage, enhanced product quality and safeguards environment. Nabhani and Shokri[22] extended the methodology of DMAIC and Pareto charts to resolve the delivery and product issues in the England-based FSC. Scott et al.[23] detailed the various procedurals grounding the deployment of LSS initiatives in Canadian FSC. Upadhye et al.[24] carried a SWOT analysis to assess the LSS practices in the biscuit manufacturing industry. Maheshwar[25] explored the quality issues in the bread industry by extending FMEA analysis. Dora et al.[26] assessed the impact of lean deployment in the food industries by exercising various statistical tools.

Besseris[27] utilized the Taguchi method-based outcomes for the optimum product selection underpinning LSS initiatives. Dora et al.[1] grounded the questionnaire-based outcomes, to assess the impact of LSS practices on the FSCs. Borges Lopes et al.[28]developed the spaghetti diagram and analyzed the same for minimizing the batch sizes of the food processing facility. Maleszka et al.[29] explored the Poland-based industry for assessment of the LSS initiatives by regression and FMEA based tools. Shah and Ganji,[30] determined the impact of lean practice by considering the supplier and consumer's perspectives. Costa et al.[31] reviewed the scope of various LSS practices within the dynamics of the FSC. Jain and Lyons[32] explored the England based food and beverage industries to underpin the various notions of Lean approach, based upon the insights of survey based outcomes. Dora et al.[26]clustered the various factors allied with the implementation of the lean practices in the various food processing SMEs by implying the statistical tools.

Corbett[33] focused on the financial gains concerned with the reduced cycle time in New- Zealand based building material manufacturing industry. Kumar and Sampath [34] implied the value stream mapping based strategies to reduce the work in process inventory levels, results showcased the improvement of 15 percent in terms of profitability. Jirasukprasert et al.[35]expedited towards the reduction of the defective rubber based gloves situated in the Thailand, by implying Analysis of the Variance (ANOVA) and developing PARETO Charts.

Swarnakar and Vinodh[36] developed cause and effect plots, to reduce defectives parts percentage as well as non-value timing in the auto-parts manufacturing industry. Adikorley et al.[37]curtailed the metal contamination for the improving the quality of the weaving in the America based apparel industry. Uluskan and Oda[38] implied six sigma strategies for minimisation of the defects incurring in the oven door assembly industry of Turkey. Raval et al.[39]extended the outranking based decisional outcomes of the Analytical Hierarchical Process and Technique of Order Preference By Similarity to the Ideal Solution for underpinning the successful implementation of LSS based practices.Alam et al.[40]implied the multi criteria decision making technique based outcomes to assess the various social and economic perspectives allied with the construction of vertical houses development. Yadav et al.[41]implied the statistical tools for analysis of the projected figures governing the cognizance of COVID-19.Bhatnagar et al.[42] analysed the various trends allied with the projected figures of COVID-19 infection as well as its predicted peak in Indian context.

2.1 Research motivation

It is evident that plethora of the past studies rendered in domain of the lean, six and sigma, reflect, need to expedite towards the operational excellence measures. Owing to the unique attributes posed by the food industries, it can be rendered that pace of the adoption of the various qualitative measures bundling sustainability with the LSS is challenging, which needs to be examined for the various critics'[43,3,44]. Furthermore, avenues allied with the food processing industries are prosperous in context of economy, employment concerns[7] to felicitate the same operational benchmarking approaches focusing on FSC excellence procedurals alongwith the sustainability needs to be ramped up. But, focus on the traditional working approaches, resist deployment of such measures and various challenges counterfeiting the notions needs to be analysed critically, for exploring every miniature of the FSC dynamics, aimed to upscale the efficiency and effectiveness.

2.2 Model development

Based upon the aforementioned insights, it is assessed that adoption of the SLSS practices in the FSCs needs to be investigated for securing the prosperous avenues[45]. Hence, to bridge this FSC are explored for widening the scope of implementation of the various SLSS practices by extending the various decision-making tools. In continuation to same various factors impeding the smooth deployment of SLSS are explored from the core of research literature in table 1.

Table 1. Hurdles in the SLSS practice

Hurdles		Description	Reference
HR1	Perishable nature of food commodities	Deterioration in the chemical and biological properties of the key constituents	Ramos et al.[46]
HR2	Volatile consumer demand	High vulnerabilities allied with the fluctuating demand levels.	Sharma et al.[8]
HR3	High variability in the foodstuff processing.	Owing to the unique attributes posed by every processed food item.	Costa et al.[43]
HR4	Sophisticated working and storage environment	A working environment that is free from external contaminations and susceptibilities.	Adams et al.[47]
HR5	Financial capping	Product costing constraints, due to food safety and security.	Costa et al.[31]
HR6	Complicated food supply chains network	Multiple count of the partners handling the dynamics of the FSC performance system.	Sharma et al.[48]
HR7	Strict quality norms	The end product is subjected to consumption purpose and sustaining life.	Ali et al.[49], Mahmood et al. [50]

3. Research methodology

For the empirical investigating the aforementioned hurdles, a duo approach comprising of the brainstorming, as well as encapsulation of the assessments from the field practitioner, is opted.

3.1 Neutrosophic based ranking algorithm

The proposed methodology of the neutrosophic-based ranking algorithm, effectively quantifies the vagueness, indeterminacy ad uncertainty allied with the human judgemental scenarios. Neutrosophic sets (*NS)* are derived from the intuitionistic fuzzy set theory[21], comprising of the membership function value pointing towards truthness, indeterminacy and falsity respectively[51].

<u>*Definition 1*</u>[52]: Assume '*Z*' as the universal set comprising of the entities where, z *ε Z.* A typical *ND* comprises of the truth, falsity, and indeterminacy allied with the membership function depicted as $TM_{ND}(z)$, $FM_{ND}(z)$ and $IM_{ND}(z)$ respectively.

<u>*Definition 2*</u>[52]:Let *'Z'* as universal set, presuming the mathematical form $ND = \{z, TM_{ND}(z), IM_{ND}(z), FM_{ND}(z)\}$, where $TM_{ND}(z): Z - [0,1]$, $IM_{ND}(z): Z - [0,1]$ and $FMN_D(z): Z - [0,1]$, subjected to $0 \leq TM_{ND}(z) + IM_{ND}(z) + FM_{ND}(z) \leq 3$, where, z *ε Z.*

<u>*Definition 3*</u>[53]: Assume $\sigma_r, \tau_r, \rho_r \in [0,1]$ and r_1, r_2, r_3, and r_4 ε *R*, where, '*R'* is real line set values allied with the single-valued 'ND' depicted by '*r*'. It is depicted as the, $r = \langle (r_1, r_2, r_3, r_4);\ \sigma_r, \tau_r, \rho_r \rangle$, whose membership, indeterminacy, and falsity membership function values are evaluated as the:

$$TM_{ND}(z) = \begin{cases} \sigma_r \left(\dfrac{x - r_1}{r_2 - r_1}\right) & (r_1 \leq z < r_2) \\ \tau_r & (r_2 \leq z \leq r_3) \\ \gamma_r \left(\dfrac{r_4 - z}{r_4 - r_3}\right) & (r_3 \leq z < r_4) \\ 0 & Otherwise \end{cases} \quad IM_{ND}(z)$$

$$= \begin{cases} \left(\dfrac{r_2 - z + \theta_r(z - r)}{r_2 - r_1}\right) & (r_1 \leq z < r_2) \\ \sigma_t & (r_2 \leq z \leq r) \\ \left(\dfrac{(z - r_3 + \tau_r(r_4 - z)}{r_4 - r_3}\right) & (r_3 \leq z < r_4) \\ 1 & Otherwise \end{cases}$$

$$FM_{ND}(z) = \begin{cases} \left(\dfrac{r_2 - z + \rho_r(z - r_1)}{r_2 - r_1}\right) & (r_1 \leq z < r_2) \\ \sigma_r & (r_2 \leq z \leq r_3) \\ \left(\dfrac{(z - r + \rho_r(r_4 - z)}{r_4 - r_3}\right) & (r_3 \leq z < r_4) \\ 1 & Otherwise \end{cases}$$

<u>*Definition 4*</u>[54]: Suppose $\tilde{a}$ *and* $\tilde{b}$, as two single valued trapezoidal based neutrosophic numbers as: $\tilde{a} = \langle (a_1, a_2, a_3, a_4);\ \sigma_a, \tau_a, \rho_a \rangle$ and $\tilde{b} = \langle (b_1, b_2, b_3, b_4);\ \sigma_b, \tau_b, \rho_b \rangle$, their basic operations of addition, subtraction, multiplication and division is executed as:

Addition: $\tilde{a} + \tilde{b} = \langle (a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b_4);\ \sigma_a \wedge \sigma_b,\ \tau_a \veebar \tau_b,\ \rho_a \vee \rho_b \rangle$

Subtraction: $\tilde{a} - \tilde{b} = \langle (a_1 - b_4,\ a_2 - b_3,\ a_3 - b_2,\ a_4 - b_1);\ \sigma_a \wedge \sigma_b,\ \tau_a \veebar \tau_b,\ \rho_a \vee \rho_b \rangle$

Multiplication:

$a.b =$

$$\begin{cases} \langle (a_1b_1, a_2b_2, a_3b_3, a_4b_4);\ \sigma_a \wedge \sigma_b, \tau_a \vee \tau_b, \rho_a \vee \rho_b \rangle & if\ (a_4 > 0, b_4 > 0) \\ \langle (a_1b_4, a_2b_3, a_3b_2, a_4b_1);\ \sigma_a \wedge \sigma_b, \tau_a \vee \tau_b, \rho_a \vee \rho_b \rangle & if\ (a_4 < 0, b_4 > 0) \\ \langle (a_4b_4, a_3b_3, a_2b_2, a_1b_1);\ \sigma_a \wedge \sigma_b, \tau_a \vee \tau_b, \rho_a \vee \rho_b \rangle & if\ (a_4 < 0, b_4 < 0) \end{cases}$$

Division:

$$a/b = \begin{cases} \langle \frac{a_1}{b_4}, \frac{a_2}{b_3}, \frac{a_3}{b_2}, \frac{a_4}{b_1};\ \sigma_a \wedge \sigma_b, \tau_a \vee \tau_b, \rho_a \vee \rho_b \rangle & if\ (a_4 > 0, b_4 > 0) \\ \langle \frac{a_4}{b_4}, \frac{a_3}{b_3}, \frac{a_2}{b_2}, \frac{a_1}{b_1};\ \sigma_a \wedge \sigma_b, \tau_a \vee \tau_b, \rho_a \vee \rho_b \rangle & if\ (a_4 < 0, b_4 > 0) \\ \langle \frac{a_4}{b_1}, \frac{a_3}{b_2}, \frac{a_2}{b_3}, \frac{a_1}{b_4};\ \sigma_a \wedge \sigma_b, \tau_a \vee \tau_b, \rho_a \vee \rho_b \rangle & if\ (a_4 < 0, b_4 < 0) \end{cases}$$

This method seeds the input rendered from the trapezoidal linguistic rating terms, which yields the development of the pairwise comparison of the terms as shown in equation 1.

$$\left[\begin{pmatrix} 0 & (w_{12}, w_{12}, w_{13}, w_{14};\ \sigma_w, \tau_w, \rho_w) & \cdots & (w_{1mi}, w_{1mj}, w_{1mk}, w_{1ml};\ \sigma_w, \tau_w, \rho_w) \\ (w_{21}, w_{22}, w_{23}, w_{24};\ \sigma_w, \sigma_w, \rho_w) & 0 & \cdots & \vdots \\ \vdots & \vdots & \ddots & \vdots \\ (w_{n1i}, w_{n2j}, w_{n3k}, w_{n4l};\ \sigma_{w_p}, \tau_w, \rho_w) & (w_{n2i}, w_{n2j}, w_{n3k}, w_{n4l};\ \sigma_w, \tau_w, \rho_w) & \cdots & (w_{nmi}, w_{nmj}, w_{nmk}, w_{nml};\ \sigma_w, \tau_w, \rho_w) \end{pmatrix}\right] \quad (1)$$

This pairwise comparison of the trapezoidal *NS*-based assessment is converted into the crisp value $\boldsymbol{D(w_{nm})}$ by following the formulation mentioned in equation 2.

$$\boldsymbol{D(w_{nm})} = \frac{1}{16}\left[w_{1i} + w_{2j} + w_{3k} + w_{4l}\right] * (2 + \sigma_w - \tau_w - \rho_w) (2)$$

The aforementioned crisp values are averaged by considering the row entities, as showcased in equation 3.

$$R_{nm} = \frac{CP_{1n} + CP_{2n} + CP_{3n} \ldots\ldots\ldots + CP_{mn}}{n} \quad (3)$$

Obtained values are depicted as the $Lower\ and\ Upper\ limit(\bar{L})\ ;(\bar{U})$ respectively. Within these limits, trapezoidal *NS* 'p' and 'q' are laid, underpinning the formula mentioned in equation 4.

$$\tilde{Q} = (\bar{L}, p, q, \bar{U});\ using\ \overline{Q_y} = [(\bar{L} + (p - \bar{L})z), (\bar{U} - (\bar{U} - q)z)\ ]$$

$$R(\bar{Q}) = \frac{1}{2}\int_0^1 [\bar{Q}_z^{-L}; \bar{Q}_z^{-U}]dz \text{ and } (\bar{Q}) = \frac{1}{2}\int_0^1 [(\bar{L} + (p - \bar{L})z), (\bar{U} - (\bar{U} - q)z)]dz \text{, where } z = [0,1] (4)$$

Evaluated values of the $R(\bar{Q})$ establishes the priority of the attributes under consideration.

4. Problem assessment

Presented work has secured the seven hurdles allied with the adoption of the SLSS initiatives within the dynamics of the FSC performance system. These seven hurdles are analyzed by extending the fundamentals of neutrosophic set theory, establishing the priority of the severity allied with these initiatives. In continuation to the same, initially, a decision matrix is developed based upon the linguistic rating scale developed in table 2, comprising of the pairwise comparison of these hurdles, indicated by the trapezoidal *NS* linguistics. The same is developed in table 3.

Table 2.Linguistic rating terms based upon the trapezoidal neutrosophic set values [51)]

Linguistic term	Neutrosophic trapezoidal number
Highly low	$\langle (0.1,0.1,0.1,0.1); 0.5, 0.3, 0.3 \rangle$
Slightly low	$\langle (0.3,0.4,0.5,0.6); 0.7, 0.1, 0.1 \rangle$
Fairly low	$\langle (0.4,0.5,0.6,0.7); 0.8, 0.0, 0.1 \rangle$
Neutral	$\langle (0.5,0.6,0.7,0.8); 0.7, 0.3, 0.3 \rangle$
Fairly strong	$\langle (0.7,0.8,0.9,1.0); 0.9, 0.1, 0.1 \rangle$
Highly strong	$\langle (0.8,0.9,1.0,1.0); 0.9, 0.0, 0.1 \rangle$
Very strong	$\langle (1.0,1.0,1.0,1.0); 1.0, 0.0, 0.0 \rangle$

Table 3.Pairwise comparison of assessments

	HR1	HR2	HR3	HR4	HR5	HR6	HR7
R1	<(0.4,0.5,0.6,0.7);0.8,0,1>	<(0.5,0.5,0.5,0.5);0.5,0.5,0.5>	<(0.4,0.5,0.6,0.7);0.8,0,0.1>	<(0.3,0.4,0.5,0.6);0.7,0.1,0.1>	<(0.4,0.5,0.6,0.7);0.8,0,1>	<(0.5,0.6,0.7,0.8);0.7,0.3,0.3>	<(0.3,0.4,0.5,0.6);0.7,0.1,0.1>
R2	<(0.1,0.1,0.1,0.1);0.5,0.3,0.3>	<(0.4,0.5,0.6,0.7);0.8,0,0.1>	<(0.3,0.4,0.5,0.6);0.7,0.1,0.1>	<(0.5,0.5,0.5,0.5);0.5,0.5,0.5>	<(0.2,0.3,0.4,0.5);0.6,0.2,0.2>	<(0.2,0.3,0.4,0.5);0.6,0.2,0.2>	<(0.4,0.5,0.6,0.7);0.8,0,1>
R3	<(0.4,0.5,0.6,0.7);0.8,0,0.1>	<(0.3,0.4,0.5,0.6);0.7,0.1,0.1>	<(0.3,0.4,0.5,0.6);0.7,0.1,0.1>	<(0.4,0.5,0.6,0.7);0.8,0,1>	<(0.3,0.4,0.5,0.6);0.7,0.1,0.1>	<(0.4,0.5,0.6,0.7);0.8,0,1>	<(0.2,0.3,0.4,0.5);0.6,0.2,0.2>
R4	<(0.3,0.4,0.5,0.6);0.7,0.1,0.1>	<(0.1,0.1,0.1,0.1);0.5,0.3,0.3>	<(0.2,0.3,0.4,0.5);0.6,0.2,0.2>	<(0.2,0.3,0.4,0.5);0.6,0.2,0.2>	<(0.4,0.5,0.6,0.7);0.8,0,1>	<(0.1,0.1,0.1,0.1);0.5,0.3,0.3>	<(0.5,0.6,0.7,0.8);0.7,0.3,0.3>
R5	<(0.1,0.1,0.1,0.1);0.5,0.3,0.3>	<(0.4,0.5,0.6,0.7);0.8,0,0.1>	<(0.2,0.3,0.4,0.5);0.6,0.2,0.2>	<(0.3,0.4,0.5,0.6);0.7,0.1,0.1>	<(0.5,0.5,0.5,0.5);0.5,0.5,0.5>	<(0.3,0.4,0.5,0.6);0.7,0.1,0.1>	<(0.1,0.1,0.1,0.1);0.5,0.3,0.3>
R6	<(0.4,0.5,0.6,0.7);0.8,0,0.1>	<(0.4,0.5,0.6,0.7);0.8,0,0.1>	<(0.5,0.5,0.5,0.5);0.5,0.5,0.5>	<(0.5,0.6,0.7,0.8);0.7,0.3,0.3>	<(0.2,0.3,0.4,0.5);0.6,0.2,0.2>	<(0.4,0.5,0.6,0.7);0.8,0,1>	<(0.3,0.4,0.5,0.6);0.7,0.1,0.1>

R7	<(0.5,0.5,0.5,0.5);0.5,0.5,0.5>	<(0.2,0.3,0.4,0.5);0.6,0.2,0.2>	<(0.1,0.1,0.1,0.1);0.5,0.3,0.3>	<(0.1,0.1,0.1,0.1);0.5,0.3,0.3>	<(0.5,0.6,0.7,0.8);0.7,0.3,0.3>	<(0.4,0.5,0.6,0.7);0.8,0,1>	<(0.3,0.4,0.5,0.6);0.7,0.1,0.1>

The developed pairwise comparison matrix comprises of the neutrosophic linguistic ratings which are converted into the crisp values by implying the formulisation rendered in the equation 2 and 3. Obtained values are showcased in the table 4.

Table 4. Equivalent crisp values

	HR1	**HR2**	**HR3**	**HR4**	**HR5**	**HR6**	**HR7**	**Row Average**
HR1	0.2475	0.1875	0.3713	0.2813	0.2475	0.3413	0.2813	0.2796
HR2	0.0475	0.3713	0.2813	0.1875	0.1925	0.1925	0.2475	0.2171
HR3	0.3713	0.2813	0.2813	0.2475	0.2813	0.2475	0.1925	0.2718
HR4	0.2813	0.0475	0.1925	0.1925	0.2475	0.0475	0.3413	0.1929
HR5	0.0475	0.3713	0.1925	0.2813	0.1875	0.2813	0.0475	0.2013
HR6	0.3713	0.3713	0.1875	0.3413	0.1925	0.2475	0.2813	0.2846
HR7	0.1875	0.1925	0.0475	0.0475	0.3413	0.2475	0.2813	0.1921

Based upon the crisp values outranking values are grounded, underpinning formulation mentioned in the set of equations 4. Values are clustered in table 5.

Table 5.Upper and lower bound values

	Lower Integral After Solved	**Upper Integral After Solved**	**Sum Lower & Upper integral**	**Ranking according to sum**
HR1	0.22	0.265	0.485	**3**
HR2	0.225	0.235	0.46	**4**
HR3	0.245	0.265	0.51	**1**
HR4	0.206	0.245	0.451	**5**
HR5	0.21	0.235	0.445	**6**
HR6	0.231	0.275	0.506	**2**
HR7	0.175	0.185	0.36	**7**

5. Results and discussion

Presented work, analyses the various hurdles allied with the adoption of the SLSS initiatives in the dynamics of the FSC performance system. For the assessment of the same neutrosophic set-based outranking methodology is opted. Presented approach of the analysis comprise of the encapsulation of the dimension of truthfulness, indeterminacy and falsity allied with the linguistic ratings, establishing the more secured priorities of the decisional entities. Outcomes of the proposed methodology grounds the outranking as High variability in the foodstuff processing *(HR3)* >Complicated food supply chains network *(HR6)*>Perishable nature of food commodities *(HR1)*>Volatile consumer demand *(HR2)*>Sophisticated working and storage environment *(HR4)*>Financial capping *(HR5)*>Strict quality norms *(HR7)*, showcasing the descending order of the severity allied with the notion under consideration. Furthermore, for the ease of visualisation of the results, as a one-sight view figure 3 is developed.

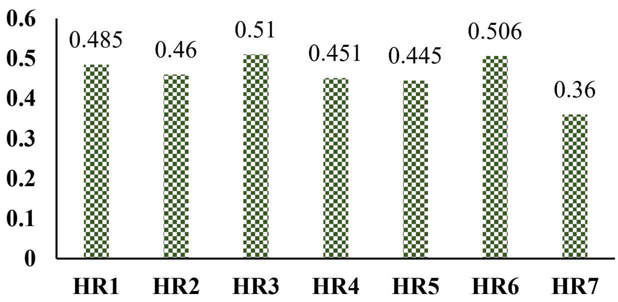

Fig.3: Neutrosophic outranking methodology outcomes plots

It can be understood from figure 2 that among all the hurdles, '*High variability in the foodstuff processing*' (*HR3*) outranks highly among the others with a value of 0.51. It can be well understood that food industries and their FSCs have been subjected to a high degree of variability in terms of ingredients, processing times, operating procedurals, etc. Every processed food item follows its channels and mode of processing, which is having its attribute of storage and distribution protocols.

Such instances render the delays in the dynamics of the FSC and blurs the avenues of the standardization. Furthermore, complicacies allied with the flow of commodities through the tributaries of the FSC also poses challenges in the adoption of operation excellence practices like SLSS.

High variability in processing of foodstuffs results in customisation of the specific food entity, which wrecks the environmental concerns allied with the production procedurals as well as deployment of qualitative measures. In order to take produce to the consumer commodities have to surpass through the dense network of multiple count of the FSC partners and stakeholders, which further add woes to the production and consumption patterns. This also hurdles the transparency of the chain dynamics and staggers pace of SLSS deployment which is aimed to encompass all the operational tiers of FSCs, impeding its adoption pace. Furthermore, complex FSC network results in the overflowing inventory levels, which account in enhanced share of wastage owing to the perishable nature of the food commodities. Perishability slowly degrades the biological and chemical properties allied with the commodities and makes it unfit for the consumption purposes. Hence, perishability constraints the inventory and procurement volume of the commodities, in the food processing industry. Many a times instances come into light, when due to seasonal availability of the key ingredients, high volume of the procurement is made, resulting in the blockage of working capital and soared inventory holding cost, staggering the profitability in the FSCs. Hence, deployment of SLSS based qualitative initiatives tends to reduce the food wastage and account for the reduced emission rates allied with the FSC dynamics.

Foodstuff's in the supply chain and processing by the industries, face consistently varying consumer demand *(HR2)*. Such, fluctuations, weaken the foundation of the various quality improvement initiatives as well as chokes the profitability. It is very prominent in the Indian market scenario that demand of the particular food items, gains momentum during the festive season, seasonal changes etc. To cherish the same, whole of the standardised protocols of the operations and operational excellence measures gets violated and to capture the market often, gap between the supply and demand widens. Such instances, often demand for the highly sophisticated storage environment to prevent thermal and environmental abuse of the processed commodities, adding up in the product costing and initial investment. It becomes cumbersome for the processing industries which are working on the small scale to extract out a hefty share of the finance for such sophisticated working and storage environment. To ground the deployment of LSS measures stringent quality norms needs to be ramped up, which ensures the quality procurement, production and consumption.

6. Conclusion and implication

Presented work is persuaded with the notion to align the dynamics of the Indian processed FSC performance system with the fundamentals of the various operation excellence practices like lean and six sigma. To explore the various miniatures allied with the same, various challenges which are hurdling its adoption, in lieu to the current operation practices are clustered from the core of the research literature. Identified challenges are further analysed empirically by extending the fundamentals of the neutrosophic set theory, which empower to encapsulate the truthfulness, indeterminacy and falsity allied with the decision maker's perception. Stepping ahead in the same, trapezoidal neutrosophic set based linguistic ratings are incorporated. Outcomes of the proposed methodology, results in the establishment of the severity allied with the challenges under consideration, owing to the complicated mutual interrelationship between them. Results render that high variability in the processing procedurals of food industries as the biggest challenge to standardise the protocols of the lean, six and sigma based practices. Furthermore, tangled FSC network and multiple count of the partners allied with the chain dynamics in journey from farm to fork, further delays the adoption of LSS practices. Lack of transparency within the FSC network, often leads to the communication gaps, resulting in the wastage of the items meant for consumption purpose. Perishability takes up the biological and chemical properties of the food items, due to the temperature, storage environment abuses and results in the broadening of gap between the supply and demand patterns. Due to such unique attributes of the food commodities, and curtail the wastage it becomes necessary to extract out a hefty amount of the working capital for establishing the state of art storage facilities during the transition of food items within tier of FSC and maintain the quality perspectives.

Outcomes of the presented work can be implied in the various multi-disciplinary domains, collaborating the working spirits of the chain practitioners, top management of food processing industries, people from academia and concerned governmental bodies. Industry managers can utilise the outcomes, which are arranged in the order of their severity to move close towards the lean, six and sigma practices. Often, due to high mutual interrelationship and dependencies between the challenges it becomes cumbersome for the practitioner to select a particular challenge which can be most effective and efficient towards the goal. Hence, securing the priorities, makes easy for the management and their managers to develop he robust framework underpinning the various notions to overcome the challenges in more precise manner. For the same, various decisional roadmaps, strategic and tactical measures can be ramped up to align the functioning with the walks of the various SLSS practices. Furthermore, collaborating with the people from academic from government bodies background can aid the managers to work in collaboration with the industries to secure the cost-effective adoption of the various feasible technological solution to streamline and make the hassle-free flow of commodities through the network of the supply chains. Concerned governmental bodies should ramp up the various regulatory, infrastructural and technological support taking the industries closer towards the avenues of the lean, six and sigma.

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