The bullwhip effect: causes, intensity, and mitigation

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ABSTRACT
This research explores the causes and intensity of demand fluctuation and supply shortage of a supply chain (SC) occurred specially at the festival times. Management offers sales incentives & product discounts at festival times that sometimes create a complex situation to supply the demands properly. This complexity restricts SC performance and market possession. Hence, this research aimed to explore the responsible causes behind this complexity & bullwhip occurrence and claimed sales force incentives, number of echelons, price variation, quantity discount, & machine breakdown as the most responsible causes. Intensity of bullwhip effect (BWE) was measured by Fuzzy Inference System (FIS) of MATLAB™ to visualize their severity on SC performance. Few strategies have been proposed to minimize their severity on SC excellence. Finally, this article proposed some managerial applications and guidelines to release the management from the frequently arising problems of distorted demands that will result in proper production & inventory management.

1. Introduction

Though different types of business follow different SC, each has a common function to connect all the stages (supplier, manufacturer, wholesaler, retailer, and at last consumers) of an SC. The manufacturers collect raw materials from the suppliers and then convert them into finished products to provide the wholesalers who combine the products of different manufacturers. Wholesalers then sell them to the retailers who at last sell them to the consumers. This movement of products from a supplier to a retailer can be said as the physical flow of products. According to consumer’s demand, at first, the retailers place an order to the wholesalers and then they place them to the manufacturers which are the basis of the retailer’s demand. Receiving orders, manufacturers purchase raw materials from suppliers to fulfill wholesaler’s demands. This information related to the ordering process moves through the SC stages can be considered as information flow (Mentzer et al., 2001) and disruptions in this flow happen SC demand fluctuation/distortion which nature & magnitude is shown in Figure 1.

Information fluctuation happens due to disorganization and communication gap among the SC stages, thereby this incurs a demand fluctuation among these stages.
This phenomenon is known as the BWE in SC. It was introduced to many operations management academics as Forrester’s work included in a textbook named ‘the classic planning and control’ by Buffa and Taubert (1972). Forrester (1961) indicated huge differences between the variance of customers demand and the variance of perceived demand to the manufacturers. He stated BWE widens at each stage of an SC and he also stated a lack of information sharing or information distortion between two stages is the main cause of BWE. ‘Beer distribution game’ is a classroom game which was described by Sterman (1995) and where an SC consisted of a beer brewery, distributor, wholesaler, and retailer were simulated by the participants. When the game proceeded, a small change of customer demand was converted into a huge change in both the order quantity and inventory level. This game had already been played many times by not only students but also executives of firms who were a part of such an SC and it was found that the result was still the same. This type of results indicated that the total system’s risk & cost increase five to ten times of normal or optimal costs (Pattanayak et al., 2019; Sterman, 1989, 1995). The beer distribution game was used by Senge (2014) and Senge and Sterman (1992) as a prime example and observed managerial behavior that indicated the occurrence of BWE due to a lack of ‘system thinking’ by management. Senge and Sterman (1992) recommended some corrective actions which were costly for solving the BWE. Blackburn (1991) ignored the causes of BWE eliminating time delays between the SC stages and indicated that forecast errors could be reduced while sales increased by compressing time delays among these stages. Buffa and Taubert (1972) claimed two basic reasons for BWE and they are (a) seasonal demand variation and (b) demand variation due to forecasting errors. Lee, Padmanabhan, Whang et al. (1997a, 1997b)) identified demand signal processing, rationing game, order batching, and price variation as the causes of BWE. Again, Michna, Peter, and Izabela (2018) claimed the lead time processing as the fundamental cause of BWE. Hudnurkar et al. (2014) analyzed the role of the information sharing on the effective SC performance. Junhai Ma and Xiaogang Ma (2017) measured BWE under moving average forecasting technique and investigated some effects of lead time, market competition, incidence of forecast, demand uncertainty on the BWE. Cao
et al. (2017) emphasized on lead time as a cause of BWE and they also showed a relationship between supply impact and demand fluctuation for the purpose of finding elimination ways of BWE. Again, Udenio et al. (2017) studied the impact of behavioral causes on BWE and D. Wang et al. (2018) showed BWE for higher quantity goods as well as showed its increasing trend from downstream to upstream stages.

From the above-stated summarization of the previous researches, aggregated causes of BWE are demand variation, imperfect demand forecasting, lead times variations, mistakes in batch ordering, supply shortage, price variation, changing base stock policies, misperceptions of time delay etc. those can be included within behavioral strategies or operational strategies. Demand fluctuation is a common phenomenon that occurs due to the variability of above-listed causes. This phenomenon has become more severe and makes much variance in demand through the SC upward stages of a company especially at the time of festivals. This variance of demand compels the manufacturers for the extra production & supply up to the retailers. Most of the times these supplies are counted as the redundant/unnecessary supply that occurs as a manufacturer’s compensation. Therefore, they face big troubles regarding the created difficulties at festival times which makes troublesome circumstances to regulate the actual causes of this variance. Focusing this frequently generated troubles, this research fixed the two following objectives.

(a) Aggregation & prioritization of behavioral and operational strategies for the fluctuation/variance of customer demands & supply shortage of a company named PRAN Foods Ltd.

(b) Development of bullwhip intensity measurement techniques and proposal for strategies adoption to intensify SC excellence by mitigating bullwhip severity for a company.

To achieve these objectives this research is organized into five sections and this organization is review of literature in section 2, research methods in section 3, results and discussion in section 4, and conclusions, implications & future research scope in section 5.

2. Review of literature

As the level of competition & its uncertainty changes regularly due to being SC performance competitive & uncertain, this changing scenario should be focused on its strategy formulation and strategy adaptation linking manufacturing firms for a larger company (Rahman & Rahman, 2020). Focusing on controlling the BWE and reducing the inventory propagation throughout the SC layers should be given more priority to enhance its excellence & to reduce its total inventory cost. To accomplish these outcomes this article briefly summarized here some historical premises & definitions for the concept of BWE and showed the significance of BWE in supply chain followed by critical appraisal of various methods.

2.1. Historical premises & definitions for the concept of BWE

Sabbaghnia et al. (2018) developed an optimal controller by the application of optimal control theory considering demand as a control variable to dampen inventory
propagation throughout the SC networks that reveals its dynamic characteristics and provides the perfect interface for the decision-makers (DMs). The impact of BWE & inventory propagation was explored by Hussain and Saber (2012) considering batching & information sharing with multi-echelon SC using simulation and Taguchi experimental design and found non-monotonic relation between batch size & demand amplification. Sabbaghnia et al. (2018), Hussain and Saber (2012) & Hussain and Drake (2011) contributed to control BWE providing practical ways/approaches to the SC operations managers to understand its impact on SC excellence. The subjectivity of DMs was assessed by fuzzy logic and a supplier selection problem was solved by the development of a new ranking method on the basis of a fuzzy inference system (FIS) (Aminidoust et al., 2012). Again, the imprecisionness and uncertainty of supplier selection processes were handled by the proposition of Fuzzy Inference System as an alternative approach (Carrera & Mayorga, 2008). A computational intelligence approach was presented to address BWE in SCs by O’donnell et al. (2006) using genetic algorithms (GA) to determine optimal ordering policy for its members and found the effect of sales promotion on ordering policies. Contributions of SC design parameters and interactions among them was understood through iThink® simulations & Taguchi design of experiments that were concerned with managing & designing SC operations (Hussain & Saber, 2012) and claimed interactions among lead time, batch size, forecasting constants, and inventory are the main causes of BWE. Dealing of management problems under dynamic demand was analyzed by Campuzano-Bolarin et al. (2019) through the proposition of rolling horizon (RH) approach using Campuzano system dynamics (SD) simulation in planning horizons considering lead-time variation. They claimed more sustainable planning & fill rates can be generated through RH simulation approach & lot-sizing techniques and De Sampaio et al. (2017) & Sahin et al. (2013) claimed adoption of a planning horizon with uncertain information considering a flexible planning tool. Safety stock levels were determined to deal SCs demand uncertainty by Boulaksil et al. (2009) whereas the best production planning decision platform was developed by Rafiei et al. (2014) with a periodic preplanning strategy of an RH procedure & various mixed-integer programming models for a wood manufacturing SC. Three different data envelopment analysis (DEA) network models were introduced & an alternative DEA model was constructed by Chen and Yan (2011) to embody the internal structure of SC performance evaluation. A network DEA model of SC efficiency evaluation was obtained determining the relationships between balanced scorecards (BSCs) & employing decision-making trial and evaluation laboratory (DEMATEL) approach (Shafee et al., 2014). Performance of sustainable SCs can be evaluated by a novel hybrid BSC-DEA framework proposed by Haghighi et al. (2016) where qualitative & quantitative indicators can be dealt with by account for desirable and undesirable indicators. Performance measurement framework was developed using two-stage value chain DEA models by Saranga and Moser (2010), Implementation of an integrated Lean Six Sigma (LSS) framework was described by Hill et al. (2018) to identify SC performance factors of an aerospace Maintenance Repair and Overhaul (MRO) facility, a model of SC coordination using an integrated approach of Fuzzy AHP & Fuzzy TOPSIS was proposed by Shukla et al. (2014), comprehensive evaluation tool of SC & decision model was proposed by Jakhar and Barua (2014)
integrating structural equation modeling (SEM) & fuzzy AHP for Indian textile-apparel-retail SC network, SC management performance was measured by Bhagwat and Sharma (2007) using AHP methodology to aid in decision evaluation and to measure performance strategies.

2.2. Significance of BWE in supply chain

The above critical appraisals described in some historical premises accumulated different methodologies, tools, and software to measure & evaluate SC performance, capabilities, and strategies. These methodologies brought out some noteworthy positive outcomes such as sustainable planning related to bullwhip effect and total cost has been developed by Francisco Campuzano-Bolarin et al. (2019) adopting RH simulation techniques and lot-sizing techniques, a practical approach in controlling BWE has been proposed by Hussain and Saber (2012) using iThink® and Taguchi. Again, Hussain and Drake (2011) showed a relationship between batch size and demand amplification using iThink® that contributed to controlling the bullwhip across multi-echelon supply chains. Loung (2007) developed a way to measure BWE of a simple two-stage SC in an environment where demand forecast was performed through the first-order autoregressive model, AR (1). Analyzing the findings from the above-described articles, this research proceeded to develop BWE intensity measurement techniques to intensify SC excellence considering the current scenario of PRAN Foods Ltd. using Fuzzy Inference System (FIS) of MATLAB®. This measurement technique will add more values in SC excellence since these will enhance its performance capability by formulating strategies to minimize the effect of bullwhip.

3. Research methods

This section represents an adoption of systematic empirical research protocol to accomplish research objectives shown in Figure 2. It summarized step by step procedural actions of the whole research work with a brief description.
3.1. Problems generalization & strategies aggregation

3.1.1. Problems generalization
For the purpose of finding out SC excellence determinant & models generalization of BWE, this article developed its foundation on the basis of real problems occurred frequently in PRAN Foods Ltd. which is one of the extensive food manufacturing companies in Bangladesh. They manufacture more than 350 food items including Beverages, Biscuits and Bakery, Culinary, Dairy, Snacks, Sugar confectionery, Frozen foods and serve the people nationally and internationally. Their continuous services from 1981 gained global reputations through the annexation of national and international awards achievement. To work uninterruptedly conciliating their vision ‘supplying product items spontaneously,’ they repeatedly face some interruptions those hamper people’s servicing continuation temporarily, specifically at festival times. Problems/difficulties are stated below according to the commentary of management from some of the largest foods manufacturing units of Pran Agro Ltd. located in Natore.

(a) Demand forecasting is miscalculated because of miscarrying and misleading information produced at the time of festivals from the SC ground level. This phenomenon occurs mostly when Eid al-Fitr and Eid al-Adha become closer since these are the largest festivals in Bangladesh. During the Wedding Season, this problem also grows up which normally takes place in Bangladesh in the winter season (November to January). Targeting these festivals and wedding programs competitors of PRAN Foods Ltd. change behavioral and operational strategies such as changing base-stock policies, price variations, lead time variations, quantity discounts, order variations, etc., to create a challenging environment and to dominate over one another. To govern over them the management of PRAN Foods Ltd. also changes competitive strategies functioned to operational strategies & behavioral strategies that often lead to a problem of order redundancy and supply shortage.

(b) At discount times such as free jacket for buying culinary products, buy 2 get 1 free for food items and offer from different co-related organizations such as bKash and Rocket offers carbonated soft drinks produced by PRAN Foods Ltd. at one taka, most of the retailers & distributors stock the items more targeting these offers. It was found that almost 80% of products are sold during the offer period and only 20% of products are sold in the regular pricing period. Such pricing variations and discounts lead the management towards pricing & policy obstacles that distort SC excellence & firm performance.

(c) It was also found that a large amount of product is sold by the company when they offer extra incentives for the field level marketing sale teams but meanwhile based on the free return policy a good number product like snakes and dairy items also back to the distributor as the expired date. Besides these, customer’s demand also grows up significantly during incentives periods. This situation leads the management to deviate from the success of the firm performance and SC excellence.

(d) Changes in Government regulation overnight creates an adverse effect on the products that are already in the market. In this circumstance, most of the retailers return their in-hand products based on free return policy that creates a severe
problem on inventory policy & profit earning and hence the management becomes maze due to not having any recovery solution to overcome.

From the above-described problem statements according to the management’s commentary of PRAN Foods Ltd., it can be claimed preliminary that pricing and policy obstacles, salesforce incentives, free return policies, and changing governmental regulations are mostly responsible for supply shortage and order redundancy. To claim more precisely, this research aggregated and categorized all the possible behavioral and operational strategies and found out the responsible strategies extracted from the results got by Fuzzy AHP ranking.

3.1.2. Strategies aggregation and categorization

Strategies that come from the insights of management psychology in order to merge cognitive and social psychology with strategic management theory and practice are called behavioral strategies. Again, the strategies that are formulated by the management for the effective and efficient use of personnel, resources and work processes to reach their objectives are called operational strategies. Strategies those are changed on the basis of psychological insights and operational perfection targeting festival times were aggregated from the management of several firms of PRAN Foods Ltd. and classified into behavioral & operational category shown in Figure 3. This aggregation was conducted through the collection of management’s commentary and reviewing literature (Bhattacharya & Bandyopadhyay, 2011; Campuzano & Mula, 2011; Croson & Donohue, 2006; Giard & Sali, 2013; Khan et al., 2019; N. Wang et al., 2016) those were considered preliminary as the responsible causes of order redundancy or supply shortage. A hierarchical classification of these causes shown in Figure 3 that was developed to make easy in visualization their prioritization and to open management’s insights.

3.2. Strategies prioritization

3.2.1. Pair-wise comparison data collection

FAHP approach

Fuzzy logic is a suitable method for simulating decision-making procedure. To proceed through Fuzzy AHP professional’s opinions (opinions of production managers & assistant managers, SC managers & assistant managers, and procurement managers & assistant managers of PRAN Foods Ltd.) were collected through a questionnaire using common linguistic terms. To analyze their opinions, it is required to convert qualitative terms into quantitative terms to proceed towards mathematical operations since this operation is not possible directly on linguistic values. That is why the linguistic scales had been converted into a fuzzy scale. The triangular fuzzy conversion scale given in Table 1 was used in the evaluation model of this paper adopted by Chang (1996).

The questionnaire set adopted from the appendix section of Rahman and Rahman (2019) was provided to the management teams to get the pair-wise comparison matrix (Table 3–10) which was the first step of analysis by taking the arithmetic mean of their evaluations.
Figure 3. Hierarchy structure of the considered causes of BWE.

<table>
<thead>
<tr>
<th>Table 1. Triangular fuzzy conversion scale.</th>
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</thead>
<tbody>
<tr>
<td><strong>Linguistic scale</strong></td>
</tr>
<tr>
<td>Just equal</td>
</tr>
<tr>
<td>Equally important</td>
</tr>
<tr>
<td>Weakly more important</td>
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<tr>
<td>Strongly more important</td>
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<tr>
<td>Very strongly more important</td>
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<tr>
<td>Absolutely more important</td>
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</table>

3.2.2. Strategy’s weight calculation

*Step 1: collection of relevant data*

The management team of PRAN Foods Ltd. were the targeted respondents. Signed consent was taken before having data from an individual. All the participants participated voluntarily. The questionnaire set was explained how the scale values (Table 1) define a level of comparison
between two attributes and also among all the sub-attributes of the main strategy (behavioral/operational) and finally provided them for evaluation. This research collected these evaluations and proceeded towards its further calculations.

**Step-2: aggregating the expert’s opinions**

Relative importance $C_i$ and $C_j$ of two strategies can be quantified as $\tilde{T} = (I_{ij}^l, I_{ij}^m, I_{ij}^u)$ where $I_{ij}^l, I_{ij}^m, I_{ij}^u$ are calculated by the following equations:

\[
I_{ij}^l = \min \left\{ O_{ijk}^l \right\} \quad (1) \\
I_{ij}^m = \sqrt[n]{\prod_{i} O_{ijk}^m} \quad (2) \\
I_{ij}^u = \max \left\{ O_{ijk}^u \right\} \quad (3)
\]

where parameters $O_{ijk}^l, O_{ijk}^m$ and $O_{ijk}^u$ represented the integrated opinions provided by the management experts. Comparison matrix between two major strategies (operational and behavioral) adopted from expert integrated opinions had been represented in Table 2 and comparison matrixes among the strategies under operational & behavioral strategies also represented in table 3–10.

**Step-3: defuzzification of the opinion**

This article adopted the defuzzification method developed by Liou and Wang (1992) for the conversion of fuzzy pair-wise comparison matrix $\tilde{F}$ (see equation 4) to crisp pair-wise comparison matrix $P$ (see equation 6). Equation 5 showed this conversion formula.

\[
\tilde{F} = \begin{bmatrix}
1 & \tilde{f}_{12} & \ldots & \tilde{f}_{1n} \\
\frac{1}{\tilde{f}_{12}} & 1 & \ldots & \tilde{f}_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
\frac{1}{\tilde{f}_{1n}} & \frac{1}{\tilde{f}_{2n}} & \ldots & 1
\end{bmatrix} \quad (4)
\]

\[
P = \begin{bmatrix}
P_{ij}
\end{bmatrix} = \begin{cases}
\beta \left( f_{ij}^m - f_{ij}^l \right) + f_{ij}^l, & 0 \leq \alpha, \beta \leq 1, i \leq j. \\
\frac{1}{P_{ij}}, & 0 < \alpha, \beta \leq 1, i > j.
\end{cases} \quad (5)
\]

where $\alpha$ and $\beta$ are known as the preference of decision-maker and risk associated with decision-making, respectively. Usually, the values of $\alpha$ and $\beta$ are considered equal to 0.5.

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<thead>
<tr>
<th>n</th>
<th>1</th>
<th>2</th>
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<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
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<tr>
<td>RI</td>
<td>0</td>
<td>0</td>
<td>0.58</td>
<td>0.9</td>
<td>1.12</td>
<td>1.24</td>
<td>1.32</td>
<td>1.41</td>
<td>1.45</td>
</tr>
</tbody>
</table>

Source: Talapatra and Uddin (2019)
\[ P = [P_{ij}] = \begin{bmatrix} 1 & \frac{P_{12}}{P_{11}} & \ldots & \frac{P_{1n}}{P_{11}} \\ \frac{P_{12}}{P_{11}} & 1 & \ldots & \frac{P_{2n}}{P_{1n}} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{1}{P_{1n}} & \frac{1}{P_{2n}} & \ldots & 1 \end{bmatrix} \] (6)

**Step-4: checking the consistency of pair-wise comparison**

Consistency index (CI) is used to calculate the consistency ratio (CR) that checks the consistency of pair-wise comparisons. CR value less than 0.1 calculated by using the formula 7 & 8 indicates that pair-wise comparison is consistent.

If we have \( P_{ij} = 1/P_{ji} \) \( i \neq j \) in crisp pairwise comparison matrix, then CI can be calculated by Equation 7.

\[ CI = \frac{\lambda_{\text{max}} - n}{n - 1} \] (7)

Where \( n \) and \( \lambda_{\text{max}} \) are known as the total number of factors taken into consideration & the greatest number among the Eigenvalues, respectively.

The following equation can be used to determine Consistency Ratio (CR):

\[ CR = CI/RI \] (8)

Where RI = Random index. Table 2 displays the corresponding RI values in pair-wise relation regarding the number of factors (n) considered.

**Step-5: factor’s weight calculation**

The weight of attributes and sub-attributes was calculated by solving equations 9 & 10 simultaneously adopting Chang’s (1996) extent analysis as it is simple and robust.

\[
\begin{cases}
(P - \lambda_{\text{max}}).W = 0 \\
\sum W = 1
\end{cases}
\] (9)

\[
S_{OS} = \begin{pmatrix} 2.25 & 2.5 & 3 \end{pmatrix} \otimes \begin{pmatrix} 1/4.8 & 1/4.16 & 1/3.75 \end{pmatrix} = \begin{pmatrix} 0.4688 & 0.60 & 0.80 \end{pmatrix}
\]

\[
S_{BS} = \begin{pmatrix} 1.5 & 1.67 & 1.8 \end{pmatrix} \otimes \begin{pmatrix} 1/4.8 & 1/4.16 & 1/3.75 \end{pmatrix} = \begin{pmatrix} 0.3125 & 0.4014 & 0.48 \end{pmatrix}
\]

\[ V(S_{OS} \geq S_{BS}) = 1 \]

\[ V(S_{BS} \geq S_{OS}) = 0.0533 \]

The minimum degree of possibility of superiority (i.e. weight vector of criteria) was obtained and the weight vector, \( W' \) is

\[ W' = \begin{pmatrix} 1 & 0.0533 \end{pmatrix} \]

The normalized value of this vector decides the priority weights of each criterion over another. The normalized weight vector was calculated as

\[ W = \begin{pmatrix} W_{OS} & W_{BS} \end{pmatrix} = \begin{pmatrix} 0.9494 & 0.0506 \end{pmatrix} \]
Table 3–10 showed the pair-wise comparison matrixes regarding attributes & sub-attributes and their weights (see Table 11) based on data provided by the management team. These matrixes took the arithmetic means of their evaluations which is the first step’s inputs for the calculation of attributes normalized weight (W) from pair-wise comparisons. Normalized weight ($W_{OS} = 0.9494$ and $W_{BS} = 0.0506$) got from Table 3 indicates operational strategies are extensively responsible for demand redundancy/supply shortage than behavioral strategies. Similarly, this research also calculated sub-attributes weight belong to two main attributes by using the data of Table 4–10, moreover, it also summarized the attribute’s weight and their ranking represented in Table 11.

**Table 3. Pair-wise comparisons between operational strategies (OS) and behavioral strategies (BS).**

<table>
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<tr>
<th></th>
<th>OS</th>
<th>BS</th>
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<tbody>
<tr>
<td>OS</td>
<td>(1, 1, 1)</td>
<td>(1.25, 1.5, 2)</td>
</tr>
<tr>
<td>BS</td>
<td>(1, 1, 1)</td>
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</table>

**Table 4. Pair-wise comparisons for the attributes of behavioral strategies (BS).**

<table>
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<th>A12</th>
<th>A13</th>
<th>A14</th>
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<tr>
<td>A11</td>
<td>(1, 1, 1)</td>
<td>(0.5, 1.0, 1.5)</td>
<td>(0.97, 1.33, 1.72)</td>
<td>(1.25, 1.75, 2.25)</td>
<td>(1.0, 1.39, 1.83)</td>
<td>(0.8, 1.06, 1.39)</td>
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<td>(1.25, 1.75, 2.25)</td>
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<td>A12</td>
<td>(1, 1, 1)</td>
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<td>(0.81, 1.13, 1.63)</td>
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<td>(0.95, 1.28, 1.63)</td>
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<td>(0.58, 0.89, 1.25)</td>
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<td>A15</td>
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<td>(0.41, 0.52, 0.72)</td>
<td>(1.38, 1.88, 2.38)</td>
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**Table 5. Pair-wise comparisons for the attributes of operational strategies (OS).**

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<td>(1.15, 2)</td>
<td>(0.5, 1.5)</td>
<td>(1.5, 2.25)</td>
<td>(1.5, 2.25)</td>
<td>(0.75, 1.25, 1.75)</td>
<td></td>
</tr>
<tr>
<td>B24</td>
<td>(1, 1, 1)</td>
<td>(0.5, 1.5)</td>
<td>(1.5, 2.25)</td>
<td>(1.5, 2.25)</td>
<td>(2.25, 3.25)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B25</td>
<td>(1, 1, 1)</td>
<td>(0.33, 0.40, 0.5)</td>
<td>(1, 1, 1)</td>
<td>(0.40, 0.5, 0.67)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B26</td>
<td>(1, 1, 1)</td>
<td>(0.67, 1.2)</td>
<td>(1, 1, 1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B27</td>
<td>(1, 1, 1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 6. Pair-wise comparisons for the attributes of changing pricing policy (B21).**

<table>
<thead>
<tr>
<th></th>
<th>B21-1</th>
<th>B21-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>B21-1</td>
<td>(1, 1, 1)</td>
<td>(8, 1.3, 1.8)</td>
</tr>
<tr>
<td>B21-2</td>
<td>(1, 1, 1)</td>
<td></td>
</tr>
</tbody>
</table>
3.2.3. Prioritization of strategies

Table 11 is the summarization of local weights (normalized weights) prioritized the sub-attributes belong to a particular attribute and global weights prioritized all the sub-attributes including all attributes which are the attribute’s ranking. Highest global weight of sales force incentives indicates it as the most severe strategy of order redundancy/supply shortage of PRAN Foods Ltd. Now, this prioritization claims the operational strategies as the most responsible causes since top five responsible sub-attributes are involved only in operational strategies those result in troublesome demand quantity, order quantity, and base-stock quantity of this company. This article extended its contribution by the development of bullwhip intensity measurement technique & SC excellence model generalization for a company to measure bullwhip considering seasonal variability caused by troublesome quantities.

### 3.3. BWE intensity measurement and mitigating strategies formulation

Aiding the research of SC management & production management in the dynamic environment when objectives, constraints & measurements limit its specification, Fuzzy
logic has become an attractive tool. FIS was proposed alternatively to handle supplier selection for new product development by Carrera and Mayorga (2008). Again, the assessment of subjectivity handling of decision-makers & supplier selection problems was developed by Amindoust et al. (2012). Efficient, timely, & cost-effective purchasing of goods maximize SC performance and actual pictures of supply & demand issues assist in computing actual measurement of SC performance by Fuzzy logic. The methodology used for modeling & analyzing decisions systems by Fuzzy logic clarifies the inherent vagueness & imprecision of SC decision-maker’s mental model of the problem under study. Fuzzy logic–Fuzzy Inference System (FIS) of MATLAB™ is the platform where one can define the severity (low, medium, severe) & put the calculated weight of an attribute. Relationship between two attributes & their impact on performance can be viewed by surface view paradigm setting their rules & putting weights as shown in Figures 5–7. Among the changed strategies by PRAN Foods Ltd., sales force incentive policies and variation in echelons showed a tremendous bullwhip increasing nature which intensity was measured by the surface view and quiver view paradigm (see Figure 7) by setting various possible rules. For an example, the moderate severity & equal weight (1:1) of sales force incentives & number of echelons showed moderate intensity of BWE and their gradual increasing severity turns it into more acute as shown in Figures 4, 7. Similar phenomenon caused by price variation can also be predicted as it also propagates demand forecasting and finally results in severe bullwhip when it embeds with sales force incentive policies which are supported by Cao et al. (2017) & Wang et al. (2016).

### 3.3.1. Strategies to mitigate bullwhip

To be adjusted with these adverse situations created by unnecessary or redundant supply & demand, the management can find a solution that will reduce the bullwhip intensity by

<table>
<thead>
<tr>
<th>Main strategies</th>
<th>Local weight</th>
<th>Sub attributes</th>
<th>Local weight</th>
<th>Sub-sub attributes</th>
<th>Local weight</th>
<th>Global weight</th>
<th>Rank</th>
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</thead>
<tbody>
<tr>
<td>Behavioral strategies</td>
<td>0.0506</td>
<td>A11 0.1495</td>
<td></td>
<td></td>
<td>0.00757</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>A12 0.1492</td>
<td></td>
<td></td>
<td>0.00755</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>A13 0.1587</td>
<td></td>
<td></td>
<td>0.00803</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>A14 0.1163</td>
<td></td>
<td></td>
<td>0.00589</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>A15 0.1087</td>
<td></td>
<td></td>
<td>0.00550</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>A16 0.0826</td>
<td></td>
<td></td>
<td>0.00418</td>
<td>22</td>
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<tr>
<td></td>
<td></td>
<td>A17 0.1480</td>
<td></td>
<td></td>
<td>0.00749</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>A18 0.0427</td>
<td></td>
<td></td>
<td>0.00216</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>A19 0.0443</td>
<td></td>
<td></td>
<td>0.00224</td>
<td>23</td>
<td></td>
</tr>
</tbody>
</table>

| Operational strategies | 0.9494       | B21 0.1925     | B21-1 0.5860 |                    | 0.10709      | 3             |      |
|                        |              | B21-2 0.4140   |              |                    | 0.07567      | 4             |      |
|                        |              | B22 0.2313     | B22-1 0.7509 |                    | 0.16490      | 1             |      |
|                        |              | B22-2 0.2491   |              |                    | 0.05472      | 8             |      |
|                        |              | B23 0.1712     |              |                    | 0.16254      | 2             |      |
|                        |              | B24 0.1434     | B24-1 0.5389 |                    | 0.07339      | 5             |      |
|                        |              | B24-2 0.4611   |              |                    | 0.06279      | 7             |      |
|                        |              | B25 0.0927     | B25-1 0.3999 |                    | 0.03522      | 10            |      |
|                        |              | B25-2 0.1684   |              |                    | 0.01483      | 14            |      |
|                        |              | B25-3 0.2161   |              |                    | 0.01903      | 13            |      |
|                        |              | B25-4 0.2165   |              |                    | 0.01907      | 12            |      |
|                        |              | B26 0.0754     |              |                    | 0.07159      | 6             |      |
|                        |              | B27 0.0933     | B27-1 0.1343 |                    | 0.01190      | 15            |      |
|                        |              | B27-2 0.5835   |              |                    | 0.05170      | 9             |      |
|                        |              | B27-3 0.2822   |              |                    | 0.02500      | 11            |      |
dropping out these strategies. Another strategy can be adopted not dropping out strategies rather changing policies simultaneously on one or more strategies that will reduce its overall intensity. For example, the changing nature of sales force incentives or number of echelons should be eliminated or modified for PRAN Foods Ltd. as they intensify BWE at festival times. Paradigm Figure 7 demonstrates the fluctuating behavior generated by
changing one or more strategies simultaneously or individually. Dropping out or modifying strategies, prediction on its intensity or adjusting on supplying schedule & quantity is possible to maintain.

4. Results and discussion

Causes of order redundancy or supply shortage of PRAN Foods Ltd. have been investigated through this article to provide strategy formulation for SC excellence and it claimed
sales force incentives, number of echelons, price variation, quantity discount, and machine breakdown as the most severe responsible causes. Previous researches (Li et al., 2006; Ma et al., 2013 & Ouyang, 2007) also found a lack of information sharing among SC partners was the main cause of BWE. Again, Michna et al. (2018) claimed time delay was the main cause of BWE while Cao et al. (2017) claimed another two basic reasons: the seasonal demand & the variation in demand due to forecasting errors. Ma et al. (2013) found the transfer of order information tends to be distorted and misguided the inventory and production planning & control decisions to upstream partners. They further claimed demand signal processing, rationing game, order batching, and price variation can distort information sharing and happen variance of order than sales. Sales force incentive policies & the number of echelons are frequently changed by the management of a company targeting festivals or demand increasing times that generates more enthusiasm & motivation among salesmen as drastic shifts in sales volumes happens at distributor & retailer levels. Such kind of raising motivation and inspiration created by the management increase bullwhip intensity represented in Figure 7 illustrations verified by Udenio et al. (2015).

Failure to maintain information flow during the rapid growth of sales disrupts the management to predict the required consumer’s demand that results in disruptions in inventory management and firm performance. Moreover, the management brings variations in product items and pricing & sales policies changing their regular pattern of marketing system focusing festival times or offering periods. This is responsible for misleading and misguiding of information through upward streams and this ultimately distorts SC performance. Its excellence and stability enhance better business practices & flexibility through a cross-industry collaboration of a company which was emphasized by Arzu Akyuz & Erman Erkan, 2010; Burnard & Bhamra, 2011 & Morali & Searcy, 2013. Frequent machine breakdown happens a severe breakthrough which generates an acute crisis in supply as a result of increasing customer demands simultaneously. Leech and Scott (2008) & Sánchez and Pérez (2005) found an impact on SC performance & firm performance due to implementation of new machinery in manufacturing units and hence they claimed it as another main cause of demand fluctuation or supply shortage. Time consumption due to new machinery set up distorts regular supply to downward members. Again, the availability of more time than required production time due to new machinery can be a cause of demand redundancy. Besides these top five responsible strategies, the role of changing organization structure and machine reliability can’t be neglected as they hold their ranks immediately below them. Findings of this research highlighted the responsible causes of demand redundancy or supply shortage of a food and beverage manufacturing company and generalized the terms related to SC excellence. Alignment of order quantity to customer demands brings superior SC performance & flexible inventory management. To ensure this SC performance, this article showed a methodology to measure bullwhip intensity and the fluctuation of order quantity & demand quantity considering seasonal variability & strategies responsible for it. Factors (demand process characteristics, finite capacity, and batch orders etc.) separation becomes easy for econometric analysis through the formula of multiplicative form that can be used as a reference model for future empirical research studies. The linkage between bullwhip measurement & SC performance predicts an appropriate measurement on its parameters to be adaptive with the resources of a company.
Strategies proposition along with the development of a methodology of BWE intensity measurement will guide the SC managers & operational managers to handle regular demand quantity. Alignment of SC functions with operational functions will also enhance the manufacturing capability of a company along with the SC excellence. The findings of this article will contribute to increasing the manager’s skills on SC functions as this provides a concept of BWE nature and its intensity at festival times.

5. Conclusions, implications and future research scope

This article satisfied its objectives by the (a) aggregation and prioritization of bullwhip causes at festival times for PRAN Foods Ltd. and (b) development of BWE intensity measurement techniques & proposition of strategies adoption for a company. Findings of this research suggested the manufacturer on the following SC perspective issues to restrict its disruptions. Firstly, the manufacturer should emphasize on sales force incentive policies as it generates the maximum mismatch between actual demand quantity & supply quantity among the stages. Secondly, they should focus on the authenticity of information flow as it declines & losses its importance due to increasing the number of echelons. Thirdly, they have to understand the simultaneous impact of quality discount & price variation on demand quantity as they are interlinked and have a mysterious impact on customer’s choices and product sales. Fourthly, the managers have to play the most effective roles by forecasting on posterior sales due to bringing up the variation in prices and quantity discount as they frequently faced loss/penalty due to their managerial deficiency. Competitors grab the opportunity to highlight their item’s quality outracing one when its production suddenly falls due to an unexpected occurrence like machine breakdown. This occurrence at an exclusively demanded period creates an acute supply crisis and makes the management maze because new machine installation or replacement is troublesome and time-consuming. To be safe from this adverse situation, sometimes management has not any instant preventive solution but timely updates from technician experts or maintenance managers can assist to generate alternative solutions previously. Changing the organizational structure and machine reliability are another two crucial potential causes of supply deficiency and order abundance of PRAN Foods Ltd. as they placed immediately below top-five and hence shifting focus from them shouldn’t be a sparkle of management. Information’s authenticity and virginity are also ascertained by the organizational structures. Hence, management focus should be on information switching or distortion due to changing in organizational structures as they do to enhance their managerial capability and performance.

5.1. Managerial implications

Through the ranking of SC disruption attributes (changed strategies) of PRAN Foods Ltd. and the measurement of BWE intensity, this article reached to a solution that will assist the manufacturers of a company to be more precious in operational and managerial decisions to resist unexpected supply shortage or demand redundancy. This article’s findings will contribute to open management insights to smoothen SC performance & enhance the excellence of a company. Through the finding out of SC excellence strategies of PRAN Foods Ltd., this article proposed strategies to be adjusted
with fluctuating SC characteristics measuring order quantity, demand quantity, optimal base stock level etc. To make the management flexible & competitive with SC variability, this article suggested to the management to raise more fitted capability in their operational performance by maintaining SC planning & control. Bullwhip dispelling & seasonal variability removal is possible through the adoption of proposed strategies by the organizational managers where the above bullwhip measurement technique will act as a supportive solution. SC managers will find a reflection of SC excellence by the adjustment of competitive capabilities with SC strategies & its accomplishment as this article aligned the proposed SC excellence strategies with the company’s competitive strategies.

However, further studies on forecasting analysis and a correlation between BWE & price variations or sales force-incentives will enhance more values to develop SC excellence. Again, solutions can be developed through statistical analysis developing hypotheses that will more validate and strengthen these findings also.

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