Supply Chain Performance Measurement by Combining Criterions of SCOR, Gunasekaran and BSC Models with REGIME Technique

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ABSTRACT

This paper presents a new way for evaluating supply chain performance, through combining criterions of three famous models. Integrated criterions of SCOR, Gunasekaran and BSC models Present a comprehensive view for considers more aspects of a supply chain. Resulted criterions make performance measuring easier and more accurate. For gaining a number for supply chain performance, REGIME technique is used for ranking the importance of criterions. At least, by normalizing number of criterions, comparing different performance aspects is possible. The weakness points of supply chain performance are extracted and crucial areas of concern are presented.

KEY WORD: SCOR, Gunasekaran, BSC, Supply Chain, performance Measurement, REGIME

1. INTRODUCTION

In the area of globalization, competition status has been changed enormously. In order to maintain in today's challenging environment, competition has forced many enterprises to revisit their operations strategy to more competitive status [19, 31]. Quite often, Because of continuous and rapidly changes in the business, enterprises seek competitive advantages to add value for customers; they do that can by increasing the efficiency of supply chain activities. Monitor and understand enterprise performance is a critical element for competing in continuously changing business environment [30]. As a result, successful supply chain is growing in importance and many current manufacturers are focusing on their supply chain management operation [2, 3, 18, 37]. Enterprises should prepare plans to identifying their performance’s weakness point and employing solution for arising them, especially high priority of them.

There are a lot of models and frameworks for measuring supply chain performance in excit business literature. Otherwise, there have been relatively few attempts to assimilate frameworks of supply chains performance measurement systematically [35, 22]. In literature, there are considerable critiques on aforementioned models by famous researchers such as Beamon (1999), Gunasekaran et al. (2001), Chan and Qi (2003), Otto and Kotza, (2003), Huang et al. (2005), Aramyan et al. (2007), Berrah & Cliville (2007), Jammernegg and Reiner (2007), Yeh et al. (2007), Zhu et al. (2008), Chae (2009) and Lin et al. (2010). Each of models and frameworks focuses on some single area of supply chain performance measurement, so other aspects are connived [1, 3, 6, 21, 39, 9, 17; 10; 37, 8]. Based on aforementioned facts, for the purpose of present context, this study aims to integrate criterions of three models - Supply Chain Operations Reference Model, which known as the SCOR model, Gunasekaran model and BSC- for propose a more holistic way for measuring supply chain performance against each dimension. On the other hand, this article integrates some frameworks, tools, and technologies into a cohesive way for supply chain performance measurement. This way is aligned with decision making level, balance approach and process focused, which integrates fact-based feedback with human judgment in the criterion's definition and evaluation.

In this paper, SCOR model is introduced as first model, which was developed by the Supply Chain Council (SCC) for assist firms in increasing effectiveness of their supply chain. SCOR model provides a process-based approach to supply chain measurement [30]. The main purpose of SCOR is facilitating construction of a systematic supply chain performance measurement; so it has been often identified as a systematic approach for identifying, measuring and monitoring supply chain performance by covering core supply chain processes (i.e. Plan Source, Make, Deliver, and Return [3, 8, 32]. There are twelve performance matrices as part of the SCOR model to measure process performance [26]. These twelve performance measures are grouped as (i). Delivery reliability; (ii).Flexibility and responsiveness; (iii).Costs; and (iv).Assets [30, 6].

The second model is BSC, which is a mean to evaluate corporate performance from four different perspectives: the financial, the internal business process, the customer, and the learning and growth [7].

The last model was presented by Gunasekaran for consider the overall SC goals and the metrics to be used, so this model measure supply chain performance in the decision making levels [20, 21]. Both framework of Gunasekaran in 2001 and 2004, represent a balanced approach and should be classified at strategic, tactical and operational levels, also be classified in financial and nonfinancial measures, as well [30].

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In brief, the remaining sections of the paper are structured as follows: Section 2 overviews the existing studies on supply chain performance measurement frameworks and models. Section 3 deals with proposed methodology. The methodology of REGIME and its principle are presented in Section 4 and 4.1. The outcomes of REGIME and prioritizing criterions, with measuring supply chain performance are presented in section 5. Section 6, concludes the paper and presents recommendations for future studies.

2. LITERATURE REVIEW

During the past years, a large amount of publications appeared on supply chain management specifically in the measuring supply chain performance. These researches have been developed following various approaches, different scopes and mathematical techniques [16]. Measuring supply chain performance, has been greatly studied in the literature, the following paragraphs summarizes some of the contribution that are important to this [3, 29, 6, 17, 16, 30, 37,44].

Beamon (1999) presented a framework for selection of performance measurement systems for manufacturing supply chains. Beamon used three types of performance measures –resource, output and flexibility- as necessary components in any supply chain performance measurement [6]. Gunasekaran (2001) developed a framework for measuring the strategic, tactical and operational level performance in a supply chain. Likewise, he presented a list of key performance metrics align and related them to customer satisfaction [21]. Gunasekaran (2004) improved a framework to give a better understanding of the importance of supply chain management performance measurement and the significance of its metrics [20]. SCOR has established itself internationally in research as well in the industrial setting as a cross-industry standard for describing supply chain management processes(Fronia, Wriggers, & Nyhuis, 2008). Huang (2005) summarized SCOR model for one manufacturing company and described a computer-assisted apparatus to configure supply chain[37]. Theeranuphattana and Tang (2008) developed a model which was the combination of Chan and Qi model with SCOR model; so the result model was a practical and efficient measurement model by incorporating the strengths of two models [37]. Thakkar (2009) presented a framework combining the feature of BSC and SCOR model to present a comprehensive performance measurement framework for small and medium scale industries [37]. This framework was inferred using the findings of real life case study research and therefore established a sufficient platform for its application [47]. Bhagwat and Sharma (2007) presented a balance scorecard approach for supply chain management that focused on small and medium size enterprises[16]. Some related work summarized in the next table [3, 5,15,43,34, 41,37].

Table 1: A summary of supply chain performance measurement frameworks

<table>
<thead>
<tr>
<th>Source</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beamon (1999)</td>
<td>Supply chain processes</td>
</tr>
<tr>
<td>Chan and Qi (2003)</td>
<td></td>
</tr>
<tr>
<td>Jammernegg and Reiner (2007)</td>
<td></td>
</tr>
<tr>
<td>Cai et al. (2009)</td>
<td></td>
</tr>
<tr>
<td>Stephens (2001)</td>
<td></td>
</tr>
<tr>
<td>Lambert and Cooper, 2000</td>
<td></td>
</tr>
<tr>
<td>Gunasekaran et al. (2001)</td>
<td>Decision making levels</td>
</tr>
<tr>
<td>Gunasekaran et al. (2004)</td>
<td></td>
</tr>
<tr>
<td>Coyle et al., 2003</td>
<td></td>
</tr>
<tr>
<td>Ge Wang et al. (2003)</td>
<td></td>
</tr>
<tr>
<td>Huang et al. (2005)</td>
<td>Supply chain operations reference (SCOR) model</td>
</tr>
<tr>
<td>Berrah and Civille (2007)</td>
<td></td>
</tr>
<tr>
<td>Ren(2008)</td>
<td></td>
</tr>
<tr>
<td>Chae (2009)</td>
<td></td>
</tr>
<tr>
<td>De Toni &amp; Tornchia (2001)</td>
<td>Financial Versus non-financial</td>
</tr>
<tr>
<td>Aramyan et al. (2007)</td>
<td></td>
</tr>
<tr>
<td>Bhagwat and Sharma (2007a)</td>
<td>Balanced score card perspective</td>
</tr>
<tr>
<td>Chia et al. (2009)</td>
<td></td>
</tr>
<tr>
<td>Rodriguez et al. (2009)</td>
<td></td>
</tr>
<tr>
<td>Biglari and Bottani (2010)</td>
<td></td>
</tr>
<tr>
<td>Dan Swartwood (2003)</td>
<td></td>
</tr>
<tr>
<td>Graeme Knowles et al. (2005)</td>
<td></td>
</tr>
<tr>
<td>Matthew J. Millas (2006)</td>
<td></td>
</tr>
<tr>
<td>Yeh et al. (2007)</td>
<td></td>
</tr>
<tr>
<td>Thakkar et al. (2009)</td>
<td>Integrated balanced score card and SCOR model</td>
</tr>
<tr>
<td>Lin et al. (2010)</td>
<td>Supply chain innovation</td>
</tr>
<tr>
<td>Sony et al., 2010</td>
<td>use performance value analysis (PVA) and strength, weaknesses, opportunities, and threats (SWOT) analysis provided for diagnosis of SCs</td>
</tr>
<tr>
<td>Ashish Agarwal et al. (2006)</td>
<td>market sensitiveness, processintegration, information driver, and flexibility</td>
</tr>
<tr>
<td>Coyle et al., 2003; Keebler et al. 1999</td>
<td>Strategic alignment</td>
</tr>
</tbody>
</table>
According to table 1, some classifications of supply chain performance measurement frameworks are presented. Typically, the categories describe framework base on major scope of supply chain processes, financial versus non-financial, decision making level and combination both of them. As it is seemed, most of framework and models are oriented to SCOR, Gunasekaran and BSC.

3. THE PROPOSED METHOD

Many models and methods have been suggested over the years for evaluation supply chain performance of any organization [7]. By surveying most of supply chain performance measurement frameworks, which mentioned in table 1, three models were selected. The main reason is these models are most comprehensive than others and cover more supply chain aspect. Other models just focus on some especial accepts and other important issue may be neglected. Integrated three selected models’ criterions prepare more confident results because the chance for considering all related issue is arisen.

Some drawbacks are introduced for using supply chain performance measurement frameworks such as SCOR or BSC lonely. Applying many individual measures, unable to being effective in improving overall performance and at least reduce effectiveness and efficiency are more important shortcomings [8].

For the presented paper aims, it was necessary to combine the criterions of three models for selecting the most beneficial of them after eliminating similar criterions. Toward select relevant attributes base on the type of supply chain activity, all the list of criterions should be extracted through a questionnaire by expert's knowledge about supply chain. By using Q-Sort method, appropriate criterion base on the field of supply chain activity are selected. With an efficient technique named REGIME method, criterions are ranked. REGIME method reflects a certain degree of one choice option's dominance with respect to other choice option for the unweighted effects for all judgment criterions. Regarding to the type of this paper’s criterions, REGIME technique help for put all criterions alongside, notwithstanding their various types. At least, because of aforementioned reasons, REGIME is the preferred technique[23, 27]. At least by assigning normalized numbers to every dimension of supply chain, strengths and weaknesses are extracted.

The below list present the resulted criterions of combining three models and eliminating common criterion of them in fifth dimension of supply chain performance.

Criterions of cost and possession dimension of supply chain[38, 34, 4]:
- Level of customer perceived value of product
- Variances against budget
- Order lead time
- Inventory days of supply
- Information processing cost
- Net profit & profit margin
- Total cycle time
- Total cash flow time
- Total cost of supply chain
- Product development cycle time
- Customer query time
- Product development cycle time
- Accuracy of forecasting techniques
- Planning process cycle time
- Order entry methods
- Human resource productivity
- Percentage of defects
- Cost per operation hour
- Capacity utilization
- Utilization of economic order quantity
- Warranty costs
- Growth of market share

Criterions of reliability, flexibility and responsiveness dimension of supply chain[38]:
- On time delivery of goods
- Quality of delivered goods
- Effectiveness of delivery invoice methods
- Number of faultless delivery notes invoiced
- Order fill rate
- Reduce time of market entrance
In respect of supply chain activity field, some criterions aren’t relevant and there isn’t any need for investigating them. Thus, selecting appropriate criterion make the measuring performance more efficiency. One way is distributing a questionnaire between supply chain's experts, after collecting them the final list of criterions is gained. Some approaches such as Q-Sort will be helpful for settle any disagreement between experts' opinions, if any. By Q-sort technique data will be analyzed to specify the greater agreement about the similarity of various descriptions [33, 14, 36, 49, 40]. In this study, because of existence limitations, there isn't a unanimous result and Q-Sort was used for choosing terminal criterions [14, 12].

4. REGIME Technique:

Supply chain performance measurement is a rapidly growing multi-criterion decision making problem owing to the large amount of criterions affecting decision making. Anyway, the better choice of performance measurement factors, the better success in competitiveness of firms in the era of globalization [7, 14]. In literature some methodologies have been used for selecting or sorting criterion, each methodology has certain benefits, follow table presents some of them [43, 34].

<table>
<thead>
<tr>
<th>Methodology</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANP methodology was applied for considering interactions among the parameters of the Model</td>
<td>Agarwal et al., 2006; Isik et al., 2007; Najmi et al., 2010</td>
</tr>
<tr>
<td>maximum, minimum, sum and so on, to integrate their model</td>
<td>Chang et al., 2007; Angerhofer &amp; Angelides, 2006; Berrah &amp; Cliville, 2007</td>
</tr>
<tr>
<td>a combination of methodologies was used for integrating models</td>
<td>Taticchi et al., 2009; Yurdakul &amp; Ie, 2005; Banwet &amp; Deshmukh, 2008</td>
</tr>
<tr>
<td>data envelopment analysis (DEA) methodology</td>
<td>WaiPeng Wong &amp; Kuan Yew Wong, 2007; Sajeev Abraham George et al., 2008</td>
</tr>
</tbody>
</table>

By reviewing applied mathematical techniques, It will be concluded that a good option is REGIME technique. AHP and ANP so repetitive but the REGIME has been not used before for measuring supply chain performance and it is absolutely the first time. Also, REGIME method is able to enrapture a wide variety of qualitative multiple criteria choice problems based on both ordinal and mixed ordinal-cardinal data regarding both the characteristics (and impacts) of a choice option and the weights (or priorities) of a choice maker[33, 34,
Regarding to the type of this paper’s criterions, REGIME technique help for put all criterions alongside, not withstanding their various types. Also, Q-methodology is a technique uniting the advantages of both qualitative and quantitative research. This is a factor is same in both Q-sort technique and REGIME, so applying them together make bolder this trait [16]. At least, because of aforementioned reasons, REGIME is the preferred technique.

4.1. Principles of the Regime Method:

The regimes are + and -signs that each alternative takes after the pairwise comparison with the rest of the alternatives. The advantage of the regime method is that different weighs can be assigned to criteria according to their relative importance and different priorities to them [11, 28, 48, 25, 42].

Suppose we have a discrete choice problem with I choice options or alternatives i (i=1,2,3,...,I), characterized by J judgment criteria j (j=1,2,...,J ). The basic information we have is composed of qualitative data regarding the ordinal value of all J judgment criteria for all I choice options. In particular we assume a partial ranking of all I choice options for each criterion j, so that the following effect matrix can be constructed:

\[
E = \begin{bmatrix}
e_{11} & \cdots & e_{1J} \\
\vdots & \ddots & \vdots \\
e_{I1} & \cdots & e_{IJ}
\end{bmatrix}
\] (1)

The entry e_{ij} (i=1,...,I; j=1,...,J) represents thus the rank order of alternative i according to judgments criterion j. Without loss of generality, we may assume a rank order characterized by the condition 'the higher, the better', in other words: if e_{ij}>e_{i'j}, then choice option i is preferable to j for judgment criterion j. As there is usually not a single dominating alternative, we need additional information on the relative importance of (some of) the judgment criteria. In case of weighting methods this information is given by means of preference weights attached to the successive criterion. If we deal with ordinal information, the weights are represented by means of rank orders Wj (j=1,...,J) in a weight vector w:

\[
w = (w_1, w_2, \ldots, w_J)^T
\] (2)

\[
w^* = (w_1^*, w_2^*, \ldots, w_J^*)^T
\] (3)

Next, the regime method uses a pairwise comparison of all I choice options, so that the mutual comparison of two choice options is not influenced by the presence and effects of other alternatives.

Consider two alternative choice options i and i’. If for criterion j a certain choice option i is better than i’, it should be noted that in case of ordinal Information, the order of magnitude of i’j is not relevant, but only it’s sign. \(\sigma_{i'i'j} = \text{sign } s_{i'i'j} = +\) and \(\sigma_{i'i'j} = \text{sign } s_{i'i'j} = -\), we may construct a Jx1 regime vector \(r^i\), defined as:

\[
r^i = (\sigma_{i'i_1}, \sigma_{i'i_2}, \ldots, \sigma_{i'i_J})^T
\] (4)

These regime vectors can be included in a Jx(I-1) regime matrix R:

\[
R = \{r_{12} \ r_{13} \ldots \ r_{1I} \ \ldots \ r_{I1} \ r_{I2} \ldots \ r_{I(I-1)}\}
\] (5)

It should be assumed that the weighted dominance of choice option i with regard to i’ can be represented by means of the following stochastic expression based on a weighted summation of cardinal entities.

\[
v_{ii'} = \sum_{j=1}^{I} \alpha_{ij}w^j
\] (6)

Next, a certain probability \(p_{ij}\) for the dominance of i with respect to i’, should be introduced:

\[
p_{ij} = \text{prob } (v_{ij} > 0)
\] (7)

And define as an aggregate probability measure:

\[
P_i = \frac{1}{I-1} \sum_{i' \neq i} p_{ii'}
\] (8)

5. Case Study

This paper is a survey to rank criterions of supply chain performance measurement in meat packing industry in a developing country. There are 80 employees who work in different parts of the factory. The employer wanted to get more understandings about the performance in every dimension of supply chain, which has never been evaluated before. There is scant research on measuring supply chain performance of this type factory. Questionnaires were developed in order to collecting data and they were divided into all sections of supply chain. The factory is initially, criterion for measuring supply chain performance are addressed on the basis of literature, then screening by experts' opinions and through Q-Sort method; In the next step, due to the fact that the data about supply chain is obtained from the connoisseurs of company, experts’ ideas were collected through some questionnaires; questionnaires were constructed for evaluate criterions proportion to three measures, which approves by experts.

Follow tables are Impacted matrix that show the result of characterized criterions with respect to three attributes: Effect on the goal of supply chain performance measurement, Time needed of investigating attribute, Cost of investigating attribute[30, 46]. This paper used SCOR model's five core supply chain performance dimensions: Reliability, Responsiveness, Agility or Flexibility, Costs, and Asset Management. Regard to these 313
attributes makes it possible to detect weakness and strength separately [45]. Impact matrixes are constructed according to Eq. (1) and shown as follow tables.

**Table3: Impact matrix for Efficiency dimension**

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Effect on the goal of supply chain performance</th>
<th>Time needed of investigating alternative</th>
<th>Cost of investigating alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Relative impact between alternatives Mean</td>
<td>Relative impact between alternatives Mean</td>
<td>Relative impact between alternatives Mean</td>
</tr>
<tr>
<td>1. Total cash flow time</td>
<td>6</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>2. Inventory days of supply</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>3. Total cost of supply chain</td>
<td>5</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>4. Net profit &amp; profit margin</td>
<td>3</td>
<td>6</td>
<td>11.6</td>
</tr>
<tr>
<td>5. Growth of market share</td>
<td>4</td>
<td>5</td>
<td>3.8</td>
</tr>
<tr>
<td>6. Variances against budget</td>
<td>1</td>
<td>2.8</td>
<td>2.3</td>
</tr>
</tbody>
</table>

**Table4: Impact matrix for Reliability dimension**

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Effect on the goal of supply chain performance</th>
<th>Time needed of investigating alternative</th>
<th>Cost of investigating alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Relative impact between alternatives Mean</td>
<td>Relative impact between alternatives Mean</td>
<td>Relative impact between alternatives Mean</td>
</tr>
<tr>
<td>1. On time delivery</td>
<td>3</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>2. Order fill rate</td>
<td>4</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>3. Number of faultless delivery notes invoiced</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>4. Supplier On-time Delivery</td>
<td>2</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>5. Capability of distribution planning</td>
<td>1</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>6. Quality of delivered goods</td>
<td>2</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

**Table5 - Impact matrix for Flexibility (Agility) dimension**

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Effect on the goal of supply chain performance</th>
<th>Time needed of investigating alternative</th>
<th>Cost of investigating alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Relative impact between alternatives Mean</td>
<td>Relative impact between alternatives Mean</td>
<td>Relative impact between alternatives Mean</td>
</tr>
<tr>
<td>1. Flexibility of Human resource</td>
<td>2</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>2. Innovation in services and products</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>3. Innovation in process</td>
<td>6</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>4. Flexibility of service system to meet customer needs</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>5. Capacity utilization</td>
<td>5</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>6. Reduce time of market entrance</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

**Table6: Impact matrix for Responsiveness dimension**

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Effect on the goal of supply chain performance</th>
<th>Time needed of investigating alternative</th>
<th>Cost of investigating alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Relative impact between alternatives Mean</td>
<td>Relative impact between alternatives Mean</td>
<td>Relative impact between alternatives Mean</td>
</tr>
<tr>
<td>1. Supply Chain Response Time</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>2. Delivery reliability performance</td>
<td>6</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>3. Customer compliances</td>
<td>4</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>4. Responsiveness to urgent deliveries</td>
<td>3</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>5. Responsiveness to order's information</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>6. Supplier ability to respond to quality problems</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>

Furthermore, we assume the following weight vector w:  
\[ W = (4, 2, 1) \]

A pairwise comparison of the information in impact matrixes leads to the following regime matrixes as Eq. (5).
Regime matrix for the efficiency dimension toward first attribute, effect on the goal of supply chain performance measurement, is presented as follows:

\[
R_{11} = \begin{bmatrix}
A_1 & A_2 & A_3 & A_4 & A_5 & A_6 \\
A_1 & + & + & + & + & + \\
A_2 & - & - & - & - & + \\
A_3 & - & + & + & + & + \\
A_4 & - & + & - & - & - \\
A_5 & - & + & - & + & + \\
A_6 & - & - & - & - & - \\
\end{bmatrix}
\]

Regime matrix for the efficiency dimension toward second attribute, time needed for investigating alternatives, is presented as follows:

\[
R_{12} = \begin{bmatrix}
A_1 & A_2 & A_3 & A_4 & A_5 & A_6 \\
A_1 & - & - & + & + & - \\
A_2 & + & - & + & - & - \\
A_3 & + & + & + & + & + \\
A_4 & - & - & + & - & - \\
A_5 & - & - & + & + & - \\
A_6 & + & + & + & + & + \\
\end{bmatrix}
\]

Regime matrix for the efficiency dimension toward third attribute, cost of investigating attributes, is presented as follows:

\[
R_{13} = \begin{bmatrix}
A_1 & A_2 & A_3 & A_4 & A_5 & A_6 \\
A_1 & - & - & + & - & - \\
A_2 & + & - & + & - & - \\
A_3 & + & + & + & + & + \\
A_4 & - & - & + & - & + \\
A_5 & - & - & + & + & - \\
A_6 & + & + & + & + & + \\
\end{bmatrix}
\]

Regime matrix for the reliability dimension toward first attribute, effect on the goal of supply chain performance measurement, is presented as follows:

\[
R_{21} = \begin{bmatrix}
A_1 & A_2 & A_3 & A_4 & A_5 & A_6 \\
A_1 & - & + & + & + & + \\
A_2 & + & + & + & + & + \\
A_3 & - & - & + & + & 0 \\
A_4 & - & - & + & + & 0 \\
A_5 & - & - & 0 & - & - \\
A_6 & - & - & + & 0 & + \\
\end{bmatrix}
\]

Regime matrix for the reliability dimension toward second attribute, time needed for investigating attributes, is presented as follows:

\[
R_{22} = \begin{bmatrix}
A_1 & A_2 & A_3 & A_4 & A_5 & A_6 \\
A_1 & + & - & - & + & + \\
A_2 & - & - & + & + & - \\
A_3 & + & + & - & + & + \\
A_4 & + & + & + & + & + \\
A_5 & - & - & - & - & + \\
A_6 & - & - & - & - & + \\
\end{bmatrix}
\]

Regime matrix for the reliability dimension toward third attribute, cost of investigating attributes, is presented as follows:

\[
R_{23} = \begin{bmatrix}
A_1 & A_2 & A_3 & A_4 & A_5 & A_6 \\
A_1 & - & - & - & - & + \\
A_2 & + & 0 & - & - & + \\
A_3 & + & 0 & - & + & + \\
A_4 & + & + & + & + & + \\
A_5 & + & + & + & + & + \\
A_6 & - & - & - & - & - \\
\end{bmatrix}
\]
Regime matrix for the flexibility dimension toward first attribute, effect on the goal of supply chain performance measurement, is presented as follows:

\[
R_{31} = \begin{bmatrix}
A_1 & A_2 & A_3 & A_4 & A_5 & A_6 \\
A_1 & - & - & - & - & + \\
A_2 & + & - & - & - & - \\
A_3 & + & + & + & + & + \\
A_4 & + & + & - & - & + \\
A_5 & + & + & - & + & + \\
A_6 & - & - & - & - & - \\
\end{bmatrix}
\]

Regime matrix for the flexibility dimension toward second attribute, time needed for investigating attributes, is presented as follows:

\[
R_{32} = \begin{bmatrix}
A_1 & A_2 & A_3 & A_4 & A_5 & A_6 \\
A_1 & - & - & - & - & - \\
A_2 & + & - & - & - & - \\
A_3 & + & + & + & + & + \\
A_4 & + & + & - & - & 0 \\
A_5 & + & + & 0 & + & + \\
A_6 & + & + & - & 0 & - \\
\end{bmatrix}
\]

Regime matrix for the flexibility dimension toward third attribute, cost of investigating attributes, is presented as follows:

\[
R_{33} = \begin{bmatrix}
A_1 & A_2 & A_3 & A_4 & A_5 & A_6 \\
A_1 & - & - & - & - & - \\
A_2 & + & - & - & - & - \\
A_3 & + & + & + & 0 & + \\
A_4 & + & + & - & - & 0 \\
A_5 & + & + & 0 & + & + \\
A_6 & + & + & - & 0 & - \\
\end{bmatrix}
\]

Regime matrix for the responsiveness dimension toward first attribute, effect on the goal of supply chain performance measurement, is presented as follows:

\[
R_{41} = \begin{bmatrix}
A_1 & A_2 & A_3 & A_4 & A_5 & A_6 \\
A_1 & - & + & + & + & + \\
A_2 & + & + & + & + & + \\
A_3 & - & - & + & + & + \\
A_4 & - & - & - & - & + \\
A_5 & - & - & - & - & + \\
A_6 & - & - & - & - & + \\
\end{bmatrix}
\]

Regime matrix for the responsiveness dimension toward second attribute, time needed for investigating attributes, is presented as follows:

\[
R_{42} = \begin{bmatrix}
A_1 & A_2 & A_3 & A_4 & A_5 & A_6 \\
A_1 & - & + & + & - & + \\
A_2 & + & + & - & - & + \\
A_3 & - & - & - & - & + \\
A_4 & - & - & - & - & + \\
A_5 & + & + & + & + & + \\
A_6 & - & - & - & + & - \\
\end{bmatrix}
\]

Regime matrix for the Responsiveness dimension toward third attribute, cost of investigating attributes, is presented as follows:

\[
R_{43} = \begin{bmatrix}
A_1 & A_2 & A_3 & A_4 & A_5 & A_6 \\
A_1 & - & + & - & - & + \\
A_2 & + & + & - & - & + \\
A_3 & - & - & - & - & - \\
A_4 & + & + & + & + & + \\
A_5 & + & + & - & - & + \\
A_6 & - & - & + & - & - \\
\end{bmatrix}
\]

We can easily derive \( V^* \) by means as Eq. (6)
For the efficiency dimension $V_1$ table is as follow:

| $V_{11} = 1$ | $V_{12} = 1$ | $V_{13} = 7$ | $V_{14} = 5$ | $V_{15} = 1$ |
| $V_{21} = -1$ | $V_{22} = -7$ | $V_{23} = -1$ | $V_{24} = -5$ | $V_{25} = -1$ |
| $V_{31} = -1$ | $V_{32} = 7$ | $V_{33} = 7$ | $V_{34} = 5$ | $V_{35} = 5$ |
| $V_{41} = -7$ | $V_{42} = 1$ | $V_{43} = -7$ | $V_{44} = -5$ | $V_{45} = -1$ |
| $V_{51} = -5$ | $V_{52} = 3$ | $V_{53} = -7$ | $V_{54} = 7$ | $V_{55} = 1$ |
| $V_{61} = -1$ | $V_{62} = -1$ | $V_{63} = -5$ | $V_{64} = -1$ | $V_{65} = -1$ |

For the reliability dimension $V_2$ table is as follow:

| $V_{11} = -3$ | $V_{12} = 1$ | $V_{13} = 1$ | $V_{14} = 5$ | $V_{15} = 7$ |
| $V_{21} = 7$ | $V_{22} = 6$ | $V_{23} = 1$ | $V_{24} = 7$ | $V_{25} = 7$ |
| $V_{31} = -1$ | $V_{32} = 2$ | $V_{33} = -7$ | $V_{34} = 3$ | $V_{35} = -1$ |
| $V_{41} = -1$ | $V_{42} = -1$ | $V_{43} = 7$ | $V_{44} = 5$ | $V_{45} = 7$ |
| $V_{51} = -5$ | $V_{52} = -7$ | $V_{53} = -3$ | $V_{54} = -7$ | $V_{55} = -5$ |
| $V_{61} = -7$ | $V_{62} = -7$ | $V_{63} = 1$ | $V_{64} = -4$ | $V_{65} = -1$ |

For the flexibility dimension $V_3$ table is as follow:

| $V_{11} = -7$ | $V_{12} = -7$ | $V_{13} = -7$ | $V_{14} = -7$ | $V_{15} = 1$ |
| $V_{21} = 7$ | $V_{22} = -7$ | $V_{23} = -7$ | $V_{24} = -7$ | $V_{25} = 1$ |
| $V_{31} = 7$ | $V_{32} = 7$ | $V_{33} = 6$ | $V_{34} = 7$ | $V_{35} = 7$ |
| $V_{41} = 7$ | $V_{42} = 7$ | $V_{43} = -7$ | $V_{44} = -7$ | $V_{45} = 4$ |
| $V_{51} = 7$ | $V_{52} = 7$ | $V_{53} = -6$ | $V_{54} = 7$ | $V_{55} = 7$ |
| $V_{61} = -7$ | $V_{62} = -7$ | $V_{63} = -1$ | $V_{64} = -7$ | $V_{65} = 1$ |

For the responsiveness dimension $V_4$ table is as follow:

| $V_{11} = -7$ | $V_{12} = 7$ | $V_{13} = 5$ | $V_{14} = 7$ | $V_{15} = 7$ |
| $V_{21} = 7$ | $V_{22} = 7$ | $V_{23} = 5$ | $V_{24} = 2$ | $V_{25} = 7$ |
| $V_{31} = -7$ | $V_{32} = -7$ | $V_{33} = 1$ | $V_{34} = 1$ | $V_{35} = 1$ |
| $V_{41} = -7$ | $V_{42} = -5$ | $V_{43} = -1$ | $V_{44} = 3$ | $V_{45} = 7$ |
| $V_{51} = -7$ | $V_{52} = -3$ | $V_{53} = -1$ | $V_{54} = -3$ | $V_{55} = -1$ |
| $V_{61} = -7$ | $V_{62} = -7$ | $V_{63} = -1$ | $V_{64} = -7$ | $V_{65} = 1$ |

By using Eq. (7) and (8) it’s directly derived $P_i$ that shown the total dominance of each choice option; via $P_i$ values it’s possible that compare supply chain performance measurement criterion. The following final ranking of alternatives results are demonstrated in table 7.

### Table 7: Ranking supply chain performance measures

<table>
<thead>
<tr>
<th>Aspect of supply chain</th>
<th>No</th>
<th>Alternative</th>
<th>Impact of alternative $i$</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency</td>
<td></td>
<td>1 Total cash flow time</td>
<td>$P_1 = \frac{123}{150}$</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 Inventory days of supply</td>
<td>$P_2 = \frac{56}{150}$</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 Total cost of supply chain</td>
<td>$P_3 = \frac{36}{150}$</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 Net profit &amp; profit margin</td>
<td>$P_4 = \frac{24}{150}$</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 Growth of market share</td>
<td>$P_5 = \frac{78}{150}$</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6 Variances against budget</td>
<td>$P_6 = \frac{40}{150}$</td>
<td>6</td>
</tr>
<tr>
<td>Reliability</td>
<td></td>
<td>1 On time delivery</td>
<td>$P_1 = \frac{123}{150}$</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 Order fill rate</td>
<td>$P_2 = \frac{123}{150}$</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 Number of faultless delivery notes invoiced</td>
<td>$P_3 = \frac{109}{150}$</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 Supplier On-time Delivery</td>
<td>$P_4 = \frac{103}{150}$</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 Capability of distribution planning</td>
<td>$P_5 = \frac{24}{150}$</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6 Quality of delivered goods</td>
<td>$P_6 = \frac{67}{150}$</td>
<td>4</td>
</tr>
<tr>
<td>Flexibility</td>
<td></td>
<td>1 Flexibility of Human resource</td>
<td>$P_1 = \frac{127}{150}$</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 Innovation in services and products</td>
<td>$P_2 = \frac{129}{150}$</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 Innovation in process</td>
<td>$P_3 = \frac{130}{150}$</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 Flexibility of service system to meet customer needs</td>
<td>$P_4 = \frac{120}{150}$</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 Capacity utilization</td>
<td>$P_5 = \frac{170}{150}$</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6 Reduce time of market entrance</td>
<td>$P_6 = \frac{36}{150}$</td>
<td>5</td>
</tr>
<tr>
<td>Responsiveness</td>
<td></td>
<td>1 Supply Chain Response Time</td>
<td>$P_1 = \frac{128}{150}$</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 Delivery reliability performance</td>
<td>$P_2 = \frac{120}{150}$</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 Customer compliances</td>
<td>$P_3 = \frac{24}{150}$</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 Responsiveness to urgent deliveries</td>
<td>$P_4 = \frac{78}{150}$</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 Responsiveness to order's information</td>
<td>$P_5 = \frac{52}{150}$</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6 Supplier ability to respond to quality problems</td>
<td>$P_6 = \frac{28}{150}$</td>
<td>6</td>
</tr>
</tbody>
</table>

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Toward recognizing weakness and strength of supply chain performance, actual performance is appraised by normalized impact of measures and actual score of alternatives. Experts determine the actual score through real experience and final score is a mean of their opinion. Tables 8 to 11 indicate the total score of every performance dimension. By positioning criterions in organizational level, measuring performance is more drastically. Through a questionnaire and literature review, criterions are laid in decision making levels, even certain criterions can be laid in to level, for example capacity utilization can be in both positions of tactical and operational level.

Table 8: supply chain performance measurement of Efficiency cost & asset dimension

<table>
<thead>
<tr>
<th>Efficiency in cost &amp; asset</th>
<th>Normalized Impact of alternatives</th>
<th>Total score of dimension's performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Score of alternative</td>
<td>4.5</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>0.18</td>
</tr>
<tr>
<td></td>
<td>5.8</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>0.18</td>
</tr>
<tr>
<td></td>
<td>5.5</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td>1.4</td>
<td>0.12</td>
</tr>
</tbody>
</table>

Table 9: supply chain performance measurement of Reliability dimension

<table>
<thead>
<tr>
<th>Reliability</th>
<th>Normalized Impact of alternatives</th>
<th>Total score of dimension's performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Score of alternative</td>
<td>9</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td>8.3</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td>6.5</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>7.5</td>
<td>0.13</td>
</tr>
</tbody>
</table>

Table 10: supply chain performance measurement of Flexibility dimension

<table>
<thead>
<tr>
<th>Flexibility</th>
<th>Normalized Impact of alternatives</th>
<th>Total score of dimension's performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Score of alternative</td>
<td>3</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>0.27</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>0.29</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>0.22</td>
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<tr>
<td></td>
<td>2</td>
<td>0.27</td>
</tr>
<tr>
<td></td>
<td>6.3</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Table 11: supply chain performance measurement of Responsiveness dimension

<table>
<thead>
<tr>
<th>Responsiveness</th>
<th>Normalized Impact of alternatives</th>
<th>Total score of dimension's performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Score of alternative</td>
<td>3</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>0.23</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>0.30</td>
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<td>3.7</td>
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<td>0.12</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>0.06</td>
</tr>
</tbody>
</table>

In addition, figure 1 displays the comparison between terminal scores of supply chain performance in four dimensions.

Figure 1: Comparison between dimensions of supply chain performance

It's obviously that reliability of performance has the highest score and flexibility of that has the lowest score; taking into account the above results, management should focus more on flexibility dimension of supply chain performance. The results assist the supply chain managers to both make crucial decisions related with the main operations. Plans for improving flexibility should be created.

6. Conclusion

The proposed method of this paper provides a decent implementation way for measuring supply chain performance in a dynamic environment. This paper tries to gaining a comprehensive measurement of supply chain, replace to focuses on some single area of supply chain performance, which few of prior research works have addressed this. To bring about improved supply chain performance, performance evaluation and improvement studies should be done throughout the supply chain [20].
This offers to integrate criterions of three models with human judgment in order to get a holistic view of supply chain performance. For using the strengths of not only one model, criterions are selected from SCOR, Gunasekaran and BSC. Regime technique is used for sorting performance number of every criterion base on its importance on supply chain performance measurement. Results address areas of improvement and corrective action should be defined for enhance supply chain performance. There are some limitations and unsolved problems, especially for applications of proposed method. Hence, the results can be different in various supply chain.

Clearly tremendous opportunity exists to promote modals and frameworks for more effective measuring supply chain performance. Thus, future research includes accomplish proposed method in other industries with different supply chains, because the differences may exist between various supply chain. In order to validating the proposed way with industry experts, using bigger population and sample size to get more information; the reasons is the more connoisseurs the more accurate conclusion. Apply fuzzy approach with a mathematical model make it more facilitate to convert the complex problem into a more quantitative exercise. Especially in sorting supply chain criterion’s importance, fuzzy logic is recommended.

7. REFERENCES


