# Evaluation of the Performance Measures of the Impact of Industry 4.0 on Supply Chain Management in IT Industry

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## Abstract

The rapid growth of IT industry worldwide has created lot of business opportunities but still there is a huge competition in this sector. To be competitive, today's supply chain professionals in the technology sector must optimize every area of their supply and logistics operations. The key to doing both is effective supply chain management. To overcome that competitive stress all the industries are trying to improve the production of their supply chain. Industry 4.0 technologies are emerged as a solution for them to resolve all their issues and get some competitive advantage. The terminology Industry 4.0 was devised to depict the fourth industrial revolution. The implementation of the Industry 4.0 techniques like Internet of Things, Big data etc., to every aspect of the end-to-end supply chain is called as Supply Chain 4.0 (SC 4.0). It places actuators everywhere, create networks all over, automate all the things, and inspect everything to remarkably enhance performance and customer satisfaction. Hence, the purpose of this paper is identifying the key performance measures of the impact of industry 4.0 on SCM in IT industry through literature review. Later we are going to evaluate the performance measures of the SC 4.0 in IT industry by employing Fuzzy AHP technique and there finding the ranking of the performance measures according to their importance.

## Keywords
Internet of Things, Industry 4.0, Fuzzy AHP, Supply Chain 4.0, IT Industry.

## 1. Introduction
Within last three decades, information technology (IT) services have grown rapidly, touching almost all aspects of daily life. The trend away from the internet toward the new gadgets that employ virtualized cloud resources is among the most substantial changes. During this great adventure of the Era Of the internet, which seems determined by incorporating machine automated and porTable computational capabilities, the Internet is indeed interfacing to wireless connections. Such latest innovations have widened practically infinite opportunities for merging individuals and computers in a cyber-physical environment setting employing information from multiple resources and also actual device interconnections. The installation of this network system within the construction and operation setting is referred to as Industry 4.0. Industry 4.0 encompasses 3D printing, industrial automation, CPS and Robotic systems, artificial intelligence, virtual reality, human-machine interfaces, device communication, block chain technology, internet of things, cloud-stored data, digitalization, driver less cars, unmanned aerial vehicles, and more. By integration of industry 4.0 technology in Supply Chain the organizations gets lot of benefits such as improved performance, cost and time reductions, better efficiency, and so on. Industry 4.0 combines smart manufacturing, smart amenities, and the Internet connected objects, with the goal of providing real-time data on production, machinery, and component flow. Even by knowing all this, still most of the organizations still thinking to implement this technology in their supply chain because of the high investment and lack of guidance.

## 1.1 Objectives

The main objective of this work is Identification of the performance aspects and performance measures of the impact of Industry 4.0 on SCM (SC 4.0) on IT industry and then ranking them based on the influence they possess on the supply chain by using FAHP method.

## 2. Literature Review

Fellahi et al. (2021) this paper aims to investigate and assess the effect of Industry 4.0 on the SC industry. The goal of this research is to provide a global perspective on the application of Industry 4.0 tools in the field of SCM. Finally, it concluded that the application of industry 4.0 tools in SCM will help the organization to achieve positive outcomes in terms of productivity, flexibility, and total production time reduction.

Tan et al. (2021) this article intended to introduce the concept of RFID-IoT technology in SCM. RFID is a technology which can detect unique identification from a range of distance via radio signal. With the implementation of RFID-IoT in SCM, it will identify the reliable data automatically and extend the communications through internet to show the status of material, stock, equipment, machine, and manpower also it enables the users can monitor and supervise every process, stage, and product in real time. The implementation of this technology has automated many applications equipped with sensing, identification, processing, communication, and network capabilities.

Abdirad and Krishnan (2020) in this paper they highlighted the trends, accomplishments, and shortcomings in research on industry 4.0 technologies in supply chain management and to provide future research directions. They classified the studies into three categories based on their content: exploratory versus confirmatory, qualitative versus quantitative, and management versus technology levels.

Attaran (2020) the importance of sophisticated technologies in SCM and logistics is highlighted in this article, which analyses their trends and problems in enhancing Digital supply chain effectiveness. Here main focus is digitization. By integrating Digitization in SCM, companies can gather real-time data on where consumers shop, what they buy, and how they buy products, among other things. By integrating with these technologies, it improves supply chain performance with respect to all the parameters.

Wamba and Queiroz (2020) in this paper they described about Block chain adoption in supply chain because virtually all business models have been disrupted in unprecedented ways in this digital age, and they all rely on IT systems. Block chain is a well-known and extremely disruptive technology that is already transforming business paradigms and opening new opportunities across the whole supply chain. Block chain emerged as a technology to perform transactions in the cryptocurrency market. Block chain can lead to major advances in transparency, accountability, and trust, as well as increased security, efficiency, and cost reduction.

Ben-Daya et al. (2017), this paper focuses on the role of IoT and its impact on SCM. IoT in SCM process have lot of applications like it impacts basic components of SCM i.e. Plan (effective decision making),Source (Real time progress & Inspection, more visibility, improve quality, reduce lead time),Make (Real time quality & Maintenance, increases revenue, product life & customer satisfaction), Deliver (Inventory tracking, information sharing, efficient use of resources, timely delivery), Return (Enhance reverse logistics, more trace-ability, reduce costs & lead, increase customer satisfaction).

## 3. Methods

### 3.1 Gap Identification

First, the adoption of Industry 4.0 in SCM is a new vital topic that requires further investigation. A thorough review of the influence of Industry4.0 on SCM was conducted based on the topic and existing research in this field. Gaps in the literature have been identified as a result of the review. They are as follows:

- Most studies have emphasized the impact of stand-alone technologies such as IoT, Big Data, RFID, and others in SCM; some studies have begun reviewing existing works on Industry 4.0; and a small number of studies have comprehensively examined the impact of Industry 4.0 in SCM, but they are also based on theoretical analysis or conceptual framework.

- The existing work on Industry 4.0 implementation was mostly focused on identifying the Key Performance indicators of the Supply chain 4.0 in different types of industries but no one didn't evaluate in a detailed manner, about those performance measures that how much each performance measure have influence on the supply chain.

### 3.2 Fuzzy Theory

Main objective of this article is Identification of the performance aspects and performance measures of the impact of Industry 4.0 on SCM (SC 4.0) on IT industry and then ranking them based on the influence they possess on the supply chain by using Fuzzy Analytical Hierarchy Process. First we find out all the performance measures of the impact of industry 4.0 on SCM in IT industry and then we made a survey and collects the response from the various IT experts and students in this relative field. Through that survey we going to find out the importance of the performance aspects and their corresponding performance measures.

Initially thought to go with Analytical Hierarchy process, but later find that AHP has had some flaws, according to Kabir and Hasin (2001), but it is mostly applied in crisp detail tasks, as well as its grading may be wrong. On however one extreme, the ambiguity of the selection maker's individual motives is not taken into account, despite whether they have a higher impact on AHP outcomes, yet on the other contrary, individual evaluation of quality parameters might be inaccurate and unclear. The traditional method is unable to portray individual mind - set and preserve key stakeholders' views because these variables have a significant influence on AHP results. Fuzzy sets can be used as an enhancement of AHP to reflect this type of uncertainties. As a result, Fuzzy AHP (FAHP) will give a more realistic picture of the decision-making mechanism.

The AHP technique necessitates the representation of individual assessments, yet policymakers sometimes found it hard to convey their choices or opinions clearly, like in many cases, since individual assessments are inherently unreliable. Several academics question the AHP procedure which employs a 1–9 point system of evaluations and incapacity to address genuine inconsistency and bias in paired comparisons.

Fuzzy set theory and fuzzy logic are popular statistical techniques for representing ambiguous or unpredict Table processes. When addressed to complicated problems that are difficult to analyze using classical statistical approaches, fuzzy sets and fuzzy logic play a major part, primarily whenever the intention is to discover a decent approximate answer.

### 3.3 Linguistic Variable

A linguistic dependent variable whose results are conveyed in natural or artificial language as terms and phrases. The idea of a fuzzy term gives a way to get a quick snapshot of circumstances that are too sophisticated, inadequately, and difficult to articulate in rigorous qualitative measures. Artificial intelligence, semantics, human decision-making, pattern classification, and economics all benefit from the linguistic approach.

### 3.4 Fuzzy AHP Methodology

Fuzzy members come in a variety of shapes and sizes, including trapezoidal, gaussian, and triangular. However, due to its simplicity and widespread application, triangular fuzzy component is used in this thesis. As seen in Figure 1, triangular fuzzy number $\widetilde{A}$ is made up of the triplet (l, m, u). Specifically, the letters l, m, and u denote the lowest, more favorable, and highest potential outcomes for an imprecise occurrence.

A fuzzy set can be visually displayed using membership functions. The x-axis symbolizes the universe of discourse, while the y-axis and membership function reflect the degree of membership in the [0, 1] interval (MF) $\mu_{\widetilde{A}}(x)$ of $\widetilde{A}$ is denoted as follows:

$$\mu_{\widetilde{A}}(x) = \begin{cases} 0 & u < x < l, \\ x - l/m - ll \leq x \leq m, \\ u - x/u - mm \leq x \leq u \end{cases} \qquad (1)$$
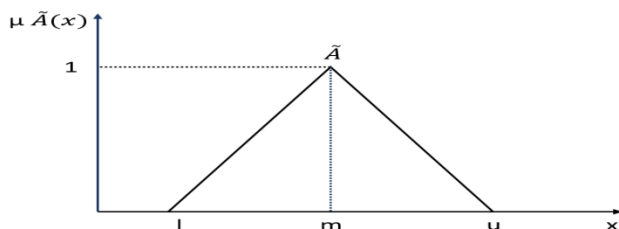
Figure 1. Triangular Fuzzy number $\widetilde{A}$

$$\widetilde{A} + \widetilde{E} = (l_1, m_1, u_1) + (l_2, m_2, u_2)$$
$$= (l_1 + l_2, m_1 + m_2, u_1 + u_2) \qquad (2)$$

$$\widetilde{A} + \widetilde{E} = (l_1, m_1, u_1) \ (l_2, m_2, u_2)$$
$$= (l_1 - u_2, m_1 - m_2, u_1 - l_2) \qquad (3)$$

$$\widetilde{A} \times \widetilde{E} = (l_1, m_1, u_1) \times (l_2, m_2, u_2)$$
$$= (l_1 \times l_2, m_1 \times m_2, u_1 \times u_2) \qquad (4)$$

$$\widetilde{A} / \widetilde{E} = (l_1, m_1, u_1) / (l_2, m_2, u_2)$$
$$= (l_1 / u_2, m_1 / m_2, u_1 / l_2) \qquad (5)$$

$$k\widetilde{A} = (kl_1, kl_2, kl_3) \qquad (6)$$

$$(\widetilde{A})^{-1} = (1/l_1, 1/l_2, 1/l_3, 1/l_4) \qquad (7)$$

As shown in the grid below, the strand comparison matrix is now made up of triangular fuzzy values (Wang, Luo and Hau, 2006).

$$D = \begin{bmatrix} (1,1,1) & (l_{12}m_{12}n_{12}) & (l_{13}m_{13}n_{13}) & \ldots & (l_{1n}m_{1n}n_{1n}) \\ (l_{21}m_{21}n_{21}) & (1,1,1) & (l_{23}m_{23}n_{23}) & \ldots & (l_{2n}m_{2n}n_{2n}) \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ (l_{n1}m_{n1}n_{n1}) & (l_{n2}m_{n2}n_{n2}) & (l_{n3}m_{n3}n_{n3}) & \ldots & (1,1,1) \end{bmatrix}$$

Due to the ability of fuzzy sets to preserve the ambiguity of decision maker (DM) preferences and evaluations (Huang and Ho, 2013), Saaty's five-point system is turned together into triangular fuzzy numerical measure, as shown in the Table 1.:

Table 1. Fuzzy Triangular scale values with respect to importance

| Scale | Annotation | Fuzzy Triangular scale |
|---|---|---|
| 9 | Absolutely important | (9,9,9) |
| 5 | Fairly important | (4,5,6) |
| 7 | Strongly important | (6,7,8) |
| 3 | Weakly important | (2,3,4) |
| 1 | Equally important | (1,1,1) |

For example, consider two criteria C1 and C2 are the first two letters of the alphabet. If C1 is less essential than C2, the fuzzy triangle magnitude value that corresponds will be (2,3,4). The judgement is not as exact when employing a fuzzy triangle scale as it is when adopting the AHP approach, where the judgement result is only (3). DM's assessment that C1 is weaker than C2 has the flaw of being a minute hazy; the term weakly essential could mean somewhat less and perhaps more unconvincingly significant. As a result, it is given the value (2,3,4) rather than (3), as is the case with the AHP technique, which ignores the fuzziness and inconsistency in spoken interpretability. Due

to the obvious reciprocity aspect stated before, analysis of C2 with regard to C1 in the discriminant correlation matrix of the criterion interprets the fuzzy triangular scale as (1/4, 1/3, 1/2).

### 3.5 Fuzzy AHP Application

Fuzzy AHP is one of the best among the assessment methods and it has been used by many researchers. Standard AHP is combined with Fuzzy Set Theory in FAHP (Wang et al., 2010). In particular, it produces better outcomes than conventional AHP, which would be focused on people who make decisions' preferences and perspective assessments. As just a consequence, numerous academics are interested in Fuzzy AHP instead of the classical approach. Researchers have explored this strategy for several decades in the journals and given many improvements and explanations. Nevertheless, as previously said, the writer chooses Buckley's columnar Geometric mean procedure (1985) to calculate Fuzzy AHP and also to attain the desired outcome (fuzzy weight) because Buckley recommended to use geometric mean, because he wished to utilize such approach that would have been easier to broaden further into fuzzy inverse matrix. Two important characteristics can be highlighted: the FAHP approach is simple to apply to the fuzzy scenario, and it ensures that the correlation matrix has an optimal response (Radionovs et al., 2017). Buckley's technique utilizes peer reviewed articles from Ayhan (2013), Soberi et al. (2016), and Soltani et al. (2013) to produce the final outcome.

**Step 1:** To build a hierarchy organization, reduce the underlying issue into an objective, requirements, and possibilities. The fusion correlation matrix should then be determined. It is suppressed by $d_{ij}^k$ that specifies the $k^{th}$ choice of the individual who is making decision of $i^{th}$ basis over $j^{th}$ measure, via fuzzy triangular number. The tilde suggests the triangular integer proportions. For example, $\tilde{d}_{12}^1$ shows the foremost choice of the maker selection of first prerequisite above the second one.

$$\tilde{A}^k = \begin{bmatrix} \tilde{d}_{11}^k & \tilde{d}_{12}^k & \cdots & \tilde{d}_{1n}^k \\ \tilde{d}_{21}^k & \cdots & \cdots & \tilde{d}_{2n}^k \\ \cdots & \cdots & \cdots & \cdots \\ \tilde{d}_{n1}^k & \tilde{d}_{n2}^k & \cdots & \tilde{d}_{nn}^k \end{bmatrix}$$

**Step 2:** If there are multiple preference makers, the viewpoints of every choice maker must be considered, $(\tilde{d}_{ij}^k)$ are averaged and $(\tilde{d}_{ij})$ is calculated as in equation (2).

$$\tilde{d}_{ij} = \frac{\sum_{k=1}^K \tilde{d}_{ij}^k}{K}$$

**Step 3:** The pair-wise interrelated matrix from (2) is altered as illustrated in (3).

$$\tilde{A} = \begin{bmatrix} \widetilde{d_{11}} & \cdots & \widetilde{d_{1n}} \\ \vdots & \ddots & \vdots \\ \widetilde{d_{n1}} & \cdots & \widetilde{d_{nn}} \end{bmatrix}$$

**Step 4:** The weighted sum of every criterion's fuzzy correlate value is determined using (4), where $\tilde{r}_i$ still represents triangular values.

$$\tilde{r}_i = \left( \prod_{j=1}^n \tilde{d}_{ij} \right)^{1/n} , i = 1,2, \dots, n$$

**Step 5:** During the further 3 sub-steps, you may find the fuzzy weights of every constraint using (5).
5a. Find the vector summation of each $\tilde{r}_i$.
5b. Compute the cumulative element's inverse (-1 power). Substitute the hazy triangular integer with a more precise one and rearrange it in ascending order.
5c. To find the fuzzy weight of criterion I ($\widetilde{W}_i$), multiply each $\tilde{r}_i$ with this reverse vector.

$$\begin{aligned} \widetilde{w}_i \quad &= \tilde{r}_i \otimes (\tilde{r}_1 \oplus \tilde{r}_2 \oplus \cdots \oplus \tilde{r}_n)^{-1} \\ &= (lw_i, mw_i, uw_i) \end{aligned}$$

**Step 6:** Since $\widetilde{w}_i$ are still fuzzy triangular numbers, it is necessary to de-fuzzified them by applying (6).

$$M_i = \frac{lw_i + mw_i + uw_i}{3}$$

**Step 7:** $M_i$ does not belong to fuzzy integer. But it needs to be normalized by (7).

$$N_i = \frac{M_i}{\sum_{i=1}^{n} M_i}$$

Up to this point, primarily conceptual technique has been explained; so now it's able to go on to observable phenomenon.

## 4. Data Collection

Selection of different performance aspects and performance measures of the impact of Industry 4.0 on supply chain management in IT industry. Identification of the different performance aspects and Key performance indicators in IT industry is conducted in two steps. First, by conducting a systematic literature review which helped in identifying 18 performance measures of Supply Chain 4.0 (which is made by utilization of Industry 4.0 technologies in supply chain). Second the validation of listed performance measures has carried out from decision group inputs. For this, a survey has been conducted on Fuzzy AHP criteria identification for the impact of industry 4.0 on SCM in IT industry and then collected responses from the industrial experts and scholars whoever working on the relevant study about how significant role that a performance aspect and performance measure plays in the IT industry. In that way all the 18 performance measures of Supply Chain 4.0 in IT industry were confirmed for their usage.

Next, these finalized performance measures were grouped under five performance aspects. They are as follows (Table 2):

Table 2. Different Performance aspects with respect to Performance measures

| S.No | Aspects | Performance Measures |
|---|---|---|
| 1 | Industry 4.0 performance (I4.0) | Security and Data safety (SDS) |
| | | Digital performance management (DPM) |
| | | Production planning (PP) |
| 2 | Delivery performance (DYP) | Intelligent transportation system (ITS) |
| | | IoT in logistics (IOTL) |
| | | Perfect order rate (POR) |
| | | Freight bill accuracy (FBA) |
| 3 | Sustainability performance (SUS) | Reducing environmental pollution (REP) |
| | | Resource utilization and recyclability (RUR) |
| | | Improving Employee safety and security |
| 4 | Economical performance (ECO) | Increasing Inventory Turnover (ITO) |
| | | Improving Revenue growth (RG) |
| | | Increasing Return on Assets (ROA) |
| | | Reducing Energy consumption (REC) |
| 5 | Operational performance (OPL) | Flexibility and online Transparency (FOT) |
| | | Cycle time (CT) |
| | | Product quality (PQ) |
| | | Customer satisfaction index (CSI) |

**4.1 Survey report of Fuzzy AHP criteria identification for the impact of industry 4.0 on SCM in IT industry:**

By doing the survey and collecting the response from the scholars and experts. We got the result which is shown below:
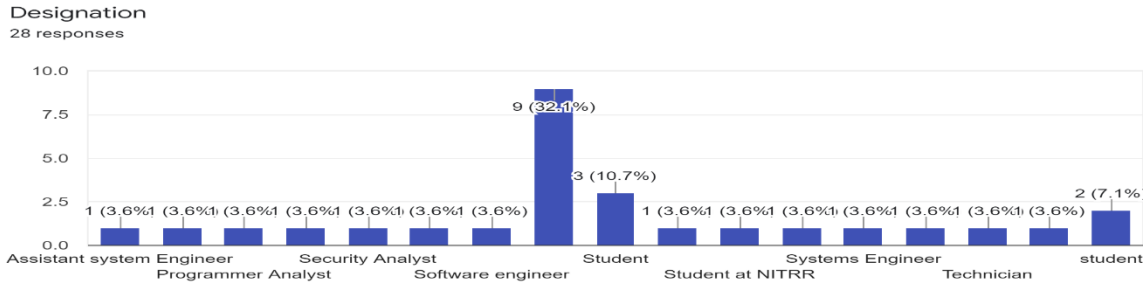
Figure 2. Survey responses collected from different kind of experts and students

In the above Figure 2, which shows that different kind of industrial persons and students who are studying and possess knowledge on this study. They have given response on the basis of how much significant role a performance aspect and performance measure play in the IT industry.
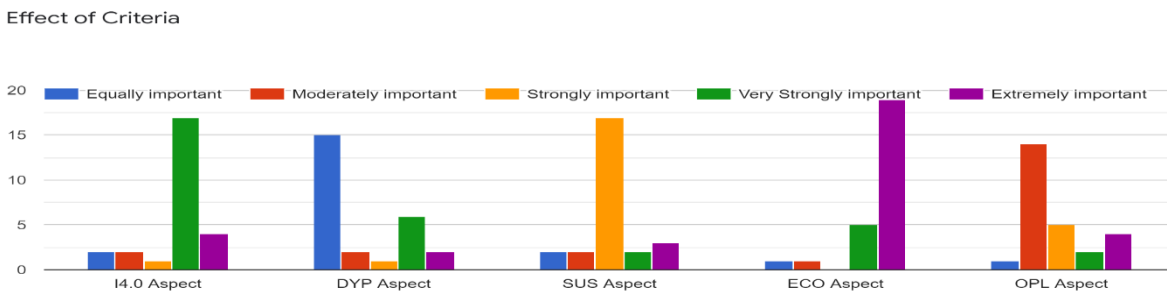


Figure 3. Survey responses for the different Performance aspects

From the above Figure 3 we can say that Economical aspects (ECO) are very extremely important in IT industry, followed by Industry 4.0 aspects (I4.0), Sustainability aspects (SUS), Delivery performance aspect (DYP), Operational aspects (OPL).

Similarly, we took responses for all the performance measures with respect to the individual performance aspects. Based on these responses, we carried out the Fuzzy AHP process and there I found the ranking of those performance measures (Figure 4).

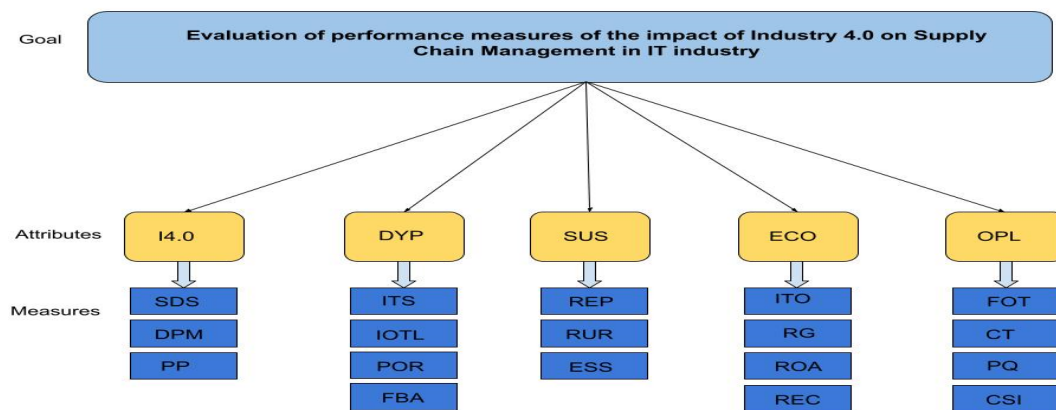## 4.2 Construct the hierarchy structure for performance measurement:



Figure 4. The hierarchy structure for the performance aspects and performance measures

## 5. Results and Discussion

To examine most of the possibilities for every characteristic, a collection of fuzzy levels is necessary. Such ambiguous phrases were granted by stakeholders and are used to compare choices based on different requirements. The experts were asked to make pair-wise comparisons by Scale and Fuzzy triangular number (Table 3 and Table 4).
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Table 3. Scale and corresponding Fuzzy Triangular number

| Scale | Fuzzy Triangular Scale | Definition: Factor A is […] than Factor B |
|---|---|---|
| 1 | (1/9,1/9,1/9) | Extremely less important |
| 2 | (1/8,1/7,1/6) | Strongly less important |
| 3 | (1/6,1/5,1/4) | Fairly less important |
| 4 | (1/4,1/3,1/2) | Weakly less important |
| 5 | (1,1,1) | Equally important |
| 6 | (2,3,4) | Weakly more important |
| 7 | (4,5,6) | Fairly more important |
| 8 | (6,7,8) | Strongly more important |
| 9 | (9,9,9) | Extremely more important |

**Develop the pair-wise comparison matrix for Level 1 effects**
In this step of pair-wise correlation matrix for effects of Level 1 is developed by using Scale and corresponding Fuzzy Triangular number Table.

Table 4. Pair-wise comparison matrix of different aspects of SC 4.0 in IT industry

| Level 1 effects | I4.0 | DYP | SUS | ECO | OPL |
|---|---|---|---|---|---|
| I4.0 | (1, 1, 1) | (6,7,8) | (2,3,4) | (1/4,1/3,1/2) | (4,5,6) |
| DYP | (1/8,1/7,1/6) | (1, 1, 1) | (1/6,1/5,1/4) | (1/9,1/9,1/9) | (1/4,1/3,1/2) |
| SUS | (1/4,1/3,1/2) | (4,5,6) | (1, 1, 1) | (1/6,1/5,1/4) | (2,3,4) |
| ECO | (2,3,4) | (9,9,9) | (4,5,6) | (1, 1, 1) | (6,7,8) |
| OPL | (1/6,1/5,1/4) | (2,3,4) | (1/4,1/3,1/2) | (1/8,1/7,1/6) | (1, 1, 1) |

Fuzzy Geometric mean value of I4.0,
$\tilde{r}_1 = [(1 * 6 * 2 * 1/4 * 4)^{1/5},(1 * 7 * 3 * 1/3 * 5)^{1/5},(1 * 8 * 4 * 1/2 * 6)^{1/5}]$
$\tilde{r}_1 = (1.643, 2.036, 2.491)$

By doing the first step, we find out the geometric mean, from there we get the sum and at that moment we evaluate the similar stagnations for altogether five effects, add the column numbers and take their reciprocal (which is inverse of the numbers) and lastly arrange the calculated values in the ascending sequence just as below Table 5:

Table 5. Geometric mean of different aspects of SC 4.0

| | Geometric Mean | | |
|---|---|---|---|
| I4.0 | 1.643 | 2.036 | 2.491 |
| DYP | 0.225 | 0.254 | 0.297 |
| SUS | 0.803 | 1.000 | 1.246 |
| ECO | 3.366 | 3.936 | 4.441 |
| OPL | 0.401 | 0.491 | 0.608 |
| Sum | 6.438 | 7.717 | 9.083 |
| Inverse | 0.155 | 0.129 | 0.110 |
| In Increasing order | 0.11 | 0.13 | 0.16 |

Compute the fuzzy weights for each effect, $\widetilde{W}_1$, for example,

For I4.0: $\widetilde{W}_1 = [(1.643 * 0.11), (2.036 * 0.13), (2.491 * 0.16)] = (0.180, 0.264, 0.398)$

The final two stages include, on just one side, calculating the non-fuzzy relative weights ($M_i$) by averaging fuzzy values for every consequence, while at another extreme, normalizing them. For instance,

For I4.0: De-fuzzified crisp values, $M_1 = \frac{l+m+u}{3} = \frac{0.180+0.264+0.398}{3} = 0.278$ and the entire column summation of $M_i$ got as 1.05 which is bigger than 1, so we need to normalize those values to make the sum as 1.

Normalization $N_1 = \frac{0.278}{1.05} = 0.26476$, where 1.05 is the column summation of $M_i$

After that we going to find out the normalized values '$N_i$' which denotes the effectiveness of that particular aspect. Depending on those $N_i$ values we going to assign the ranking as the highest will be considered as rank 1, and second highest is 2 and so on.

Table 6. Normalized matrix and ranking for different aspects of SC 4.0

| Aspects | Fuzzy weight | | | | $M_i$ (Crisp values) | $N_i$ (Normalized values) | Rank |
|---|---|---|---|---|---|---|---|
| I4.0 | 0.180 | 0.264 | 0.398 | | 0.278 | 0.26476 | 2 |
| DYP | 0.024 | 0.033 | 0.047 | | 0.034 | 0.03238 | 5 |
| SUS | 0.088 | 0.130 | 0.200 | | 0.140 | 0.13333 | 3 |
| ECO | 0.370 | 0.511 | 0.710 | | 0.530 | 0.50476 | 1 |
| OPL | 0.044 | 0.063 | 0.097 | | 0.068 | 0.06476 | 4 |
| Sum | | | | | 1.05 | | |

Based on the obtained result from the above Table 6, 'Economic performance aspect' (ECO) (0.50476) is the most important aspect, next followed by 'Industry 4.0 performance aspect' (I4.0) (0.26476), 'Sustainability performance aspect' (SUS) (0.13333), 'Operational performance aspect' (OPL) (0.06476), and 'Delivery performance aspect' (DYP) (0.03238) which is the least important.

If we calculate the effect of each individual by using their respective normalized values, we can observe that ECO is contributed with 51% which is the highest among all the others and DYP is contributed with least of 3%.

Now we are going to apply Fuzzy AHP method to different field of effects and will get to know that which one having highest impact and which one having least.

We are going to start with the **Industry 4.0 performance (I4.0)** perspective:

Table 7. Pair-wise comparison matrix for performance measures of I4.0 aspect

| I4.0 | SDS | DPM | PP |
|---|---|---|---|
| SDS | (1,1,1) | (4,5,6) | (2,3,4) |
| DPM | (1/6,1/5,1/4) | (1,1,1) | (1/4,1/3,1/2) |
| PP | (1/4,1/3,1/2) | (2,3,4) | (1,1,1) |

Next, we going to find out the geometric mean and ranking of the performance measures of I4.0 aspect, just we like we did on above for different performance aspects (Table 7 and Table 8).

By applying the Fuzzy AHP method to I4.0 performance measures, we can conclude that SDS is more important measure and had more effect when compared with other measures, next followed by PP and DPM has the least effect.

Now we are going to do the same process for **Delivery performance aspect (DYP)** and its measures:

Table 8. Pair-wise comparison matrix for performance measures of DYP aspect

| DYP | ITS | IOTL | POR | FBA |
|---|---|---|---|---|

| ITS | (1,1,1) | (1/4,1/3,1/2) | (1/6,1/5,1/4) | (2,3,4) |
|---|---|---|---|---|
| IOTL | (2,3,4) | (1,1,1) | (1/4,1/3,1/2) | (4,5,6) |
| POR | (4,5,6) | (2,3,4) | (1,1,1) | (6,7,8) |
| FBA | (1/4,1/3,1/2) | (1/6,1/5,1/4) | (1/8,1/7,1/6) | (1,1,1) |

Next, we going to find out the geometric mean and ranking of the performance measures of DYP aspect, just we like we did on above for performance aspects.

By applying the Fuzzy AHP method to DYP performance measures, we can conclude that POR is more important measure and had more effect when compared with other measures, next followed by IOTL, ITS and FBA has the least effect.

Now evaluating the performance measures of **Sustainability performance (SUS) aspect (Table 9)**:

Table 9.Pair-wise comparison matrix for performance measures of SUS aspect

| SUS | REP | RUR | ESS |
|---|---|---|---|
| REP | (1,1,1) | (1/4,1/3,1/2) | (2,3,4) |
| RUR | (2,3,4) | (1,1,1) | (4,5,6) |
| ESS | (1/4,1/3,1/2) | (1/6,1/5,1/4) | (1,1,1) |

Next, we going to find out the geometric mean and ranking of the performance measures of SUS aspect, just we like we did on above for performance aspects.

By applying the Fuzzy AHP method to SUS performance measures, we can conclude that RUR is more important measure and had more effect when compared with other measures, next followed by REP and ESS has the least effect.

Now evaluating the performance measures of **Economical performance (ECO) aspec**t:

Table 10. Pair-wise comparison matrix for performance measures of ECO aspect

| ECO | ITO | RG | ROA | REC |
|---|---|---|---|---|
| ITO | (1,1,1) | (1/4,1/3,1/2) | (1/6,1/5,1/4) | (2,3,4) |
| RG | (2,3,4) | (1,1,1) | (1/4,1/3,1/2) | (4,5,6) |
| ROA | (4,5,6) | (2,3,4) | (1,1,1) | (6,7,8) |
| REC | (1/4,1/3,1/2) | (1/6,1/5,1/4) | (1/8,1/7,1/6) | (1,1,1) |

Next we going to find out the geometric mean and ranking of the performance measures of ECO aspect, just we like we did on above for performance aspects.

By applying the Fuzzy AHP method to ECO performance measures, we can conclude that ROA is more important measure and had more effect when compared with other measures, next followed by RG, ITO and REC has the least effect.

Now we are going to do the evaluation of performance measures of Operational (OPL) aspect (Table 11):

Table 11. Pair-wise comparison matrix for performance measures of OPL aspect

| OPL | FOT | CT | PQ | CSI |
|---|---|---|---|---|
| FOT | (1,1,1) | (1/8,1/7,1/6) | (1/8,1/7,1/6) | (1/4,1/3,1/2) |
| CT | (6,7,8) | (1,1,1) | (1/4,1/3,1/2) | (2,3,4) |
| PQ | (6,7,8) | (2,3,4) | (1,1,1) | (4,5,6) |
| CSI | (2,3,4) | (1/4,1/3,1/2) | (1/6,1/5,1/4) | (1,1,1) |

Next, we going to find out the geometric mean and ranking of the performance measures of OPL aspect, just we like we did on above for performance aspects.

By applying the Fuzzy AHP method to OPL performance measures, we can conclude PQ is more important measure and had more effect when compared with other measures, next followed by CT, CSI and FOT has the least effect.

### 5.1 Validation

Finally, now for all the 18 performance measures we will be using Fuzzy AHP method for finding Global Criteria weights (Table 12):

Table 12. Global criteria weights and ranking of all the 18 performance measures

| Criteria | Average Criteria weight | Sub criteria | Avg. Sub criteria weight | Global criteria weights | Rank |
|----------|-------------------------|--------------|--------------------------|-------------------------|------|
| I4.0 | 0.26476 | SDS | 0.6296 | 0.16669 | 2 |
| | | DPM | 0.1071 | 0.02835 | 9 |
| | | PP | 0.2630 | 0.06963 | 5 |
| DYP | 0.03238 | ITS | 0.1202 | 0.00389 | 16 |
| | | IOTL | 0.2667 | 0.00863 | 14 |
| | | POR | 0.5571 | 0.01803 | 12 |
| | | FBA | 0.0560 | 0.00181 | 18 |
| SUS | 0.13333 | REP | 0.2630 | 0.03506 | 8 |
| | | RUR | 0.6296 | 0.08394 | 4 |
| | | ESS | 0.1073 | 0.01430 | 13 |
| ECO | 0.50476 | ITO | 0.1201 | 0.06062 | 6 |
| | | RG | 0.2667 | 0.13462 | 3 |
| | | ROA | 0.5571 | 0.28120 | 1 |
| | | REC | 0.0560 | 0.02826 | 10 |
| OPL | 0.06476 | FOT | 0.0503 | 0.00325 | 17 |
| | | CT | 0.2843 | 0.01841 | 11 |
| | | PQ | 0.5473 | 0.03544 | 7 |
| | | CSI | 0.1180 | 0.00764 | 15 |

By applying the Fuzzy AHP method to all the 18 performance measures, we can conclude that based on the above Table (12), ROA is more important measure and had more effect when compared with other measures, next followed by SDS, RG, RUR. so on and FBA has the least effect. We can observe that in all the performance measures, ROA is contributed with 28% which is the highest, followed by SDS which is 17% and so on, FBA is the least contributed performance measure which is almost negligible.

## 6. Conclusion and Future scope

Initially we understood the importance of digitized supply chain in this competitive world, but transforming the traditional supply chain into digitized supply chain is not a easy task. It takes lot of time and initial setup cost is also high. We must go through lot of challenges while implementing it. Although some risk is there but still it's worthy to go with that. Our objective is Evaluation of the performance measures of the impact of industry 4.0 on supply chain management in IT industry by using the Fuzzy AHP methodology. Triangular fuzzy numbers were used with the conventional AHP in turn to improve the degree of decisions of decision makers. In this first we identified 18 key performance measures by conducting literature review and then joined those 18 measures which having similarity and kept under 5 performance aspects. After that we conducted a survey on Fuzzy AHP criteria identification for the impact of Industry 4.0 on supply chain management in IT industry and collected the responses from the industrial experts and the students whoever in the relevant field. Based on that survey report we have calculated the weights of all performance aspects of SC 4.0 for the selection of performance measures. In that we found that economical performance aspect is the most important aspect, then followed by industry 4.0, sustainability, operational and delivery performance aspects.

After that we find out the weights of the performance measures in the individual performance aspects. Finally, we find out the global criteria weights of all the 18 performance measures which are responsible for the considerable performance measurement. Further the ranking order of all the performance measures is determined by using Fuzzy AHP approach. In that return on assets is found to be most important performance measure followed by security and data safety, revenue growth and so on and freight bill accuracy is considered to be the least.

The results found in this provides direction to IT industries in determining and seeking the best guidance for transforming their supply chain by using industry 4.0 techniques.

Further research is required to investigate on the potential challenges occurring while transforming the supply chain with industry 4.0 technologies. An expansion of the scope of the interviews with industrial experts might be more helpful to look more detailed in this. If those interviews from different types of industries as well as different geographical areas then it helps to create more generalizable findings. Next research should be undertaken to find the new methods, structures, processes, management flows in the SC4.0.

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