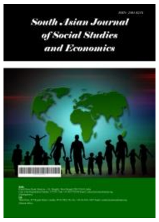

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# Application of Fuzzy DEMATEL Method on the Impact of IT innovation on Supply Chain Management of Food Industry in Nigeria

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***Author's contribution***

*The sole author designed, analyzed, interpreted and prepared the manuscript.*

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## ABSTRACT

Supply chain management can be viewed as an important part of a company's strategic strategy for increasing efficiency, results, and profitability. The aim of this paper is to us the fuzzy DEMATEL method to examine the impact of IT innovation on the operations of supply chain management of food industry in Nigeria. The study obtained sixteen (16) perspectives of impact of IT innovation on food industry SC management as obtain from literature and brain stormy of experts. A fuzzy Linguistic scale was developed and applies it to food manufacturing firms in Nigeria to test the level of the impact of IT innovation on supply chain management. The questionnaire designed for pairwise comparison to evaluate the influence of each score, where scores of 0, 1, 2, 3 and 4 represent: (no influence), (Very low influence), (low influence), (high influence) and (very high influence), respectively. Twelve experts were asked to complete the questionnaire comprises of 6 general managers, 6 Supply Chain managers all of food industry. Then the Fuzzy DEMATEL method was applied to analyze the importance of criteria and the casual relations among the criteria constructed. The result showed that the advanced planning system had the most impact and the strongest link to other criteria. As a result, APS is a key rationale and key criteria that influence other criteria and driving factors to solve problems.

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*Keywords: Information technology innovation; supply chain; DEMATEL; fuzzy; cause and effect relationship.*

## 1. INTRODUCTION

The supply chain (SC) industry is undergoing a phase of rapid and unparalleled change. The future of SC is underpinned by creativity and technology. Today, the industry is progressively implementing these innovations to ensure quicker, cheaper, more efficient and sustainable delivery. The need for real-time tracking and efficient distribution systems means that supply chain management is ripe for technology innovation— and mobile, wireless, portable technology is leading the way across the supply chain and transport industries. Smooth information and material flows blur boundaries between supply chain parties and enable firms to reduce uncertainty in the supply chain created by the bullwhip effect [1]. The Council of Supply Chain Management professionals (SCMP) defines logistics as that part of supply chain management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services, and related information between the point of origin and the point of consumption in order to meet customers' requirements [2]. Simply put, it can be defined as the management of the flow of goods and services that begin with the origin of the products and ends with the consumption of the product this includes exchange processes as well as coordination tactics between supply chain partners [3].

In recent years, most businesses are gradually implementing information technology (IT) systems in the field of Supply Chain Management (SCM) to boost their performance in global competitive markets. [4]. Recent advancements in both information and technology and scientific management have made it possible for various business activities to collect, exchange and use knowledge [5]. Most importantly, in the business atmosphere, information technology (IT) plays a vital role in the firms' performance; it provides knowledge flow that allows the supply chain more stable and durable without destabilizing its performance. There has been increasing literature that either quantifies the value of information in SCM [6] or studies the incentives of information sharing [7,8].

The role of supply chain management in the food processing industry is to facilitate the efficient movement of required materials, information and the transportation of the final product from factories to the markets close to the customers [9]. Supply chain management in the food industry is critical because timing plays a dynamic role in productivity with high quality, low cost and scarce raw material resources because many of the products have a limited shelf life, the track of the intake of raw material and additives must be monitored to ensure the right quantity of products gets to the right place, it is therefore important to get the logistics process right.

Decision making trial and evaluation laboratory (DEMATEL) technique originated from the Geneva research center of Battelle Memorial Institute for capturing the cause and effect relationship by [10]. DEMATEL has been widely used to extract a problem structure of a complex problem [11]. By using DEMATEL, we could quantitatively excerpt interrelationship among multiple factors contained in the problematic. In addition, DEMATEL can confirm interdependence between factors and help in map creation to represent relative connections within them and can be used to investigate and solve complicated and intertwined problems. This method not only converts the interdependency connections into a cause and effect group via matrixes but also finds the critical factors of a complex structure system with the help of an impact relation diagram. Furthermore, we might find the dispatching stimuli that would rather affect the other elements. These receiving variables would be somewhat influenced by the other factors, the central variables that the number of the dispatching and receiving stimuli is of high intensity.

In this study, a better and more practical is adopted to simplify the impact of IT innovation on the supply chain management of food industry. The DEMATEL method is commonly used to obtain a cause-effect diagram of interdependent factors. This method is superior to conventional techniques due to exposing the relationships between criteria, ranking the criteria relating to the type of relationships and revealing intensity of their effects on each criterion. Since a single method is not sufficient to identify the important of IT innovations in supply chain management most especially in the food industry under timeliness and limited shelf life. Therefore, fuzzy linguistic modeling is utilized to represent and handle flexible information [12]. Arising from the above scenario, this study therefore used Fuzzy DEMATEL to answer the research question ‘Does IT innovation has significant effect on supply chain management of the food industry in Nigeria?’

## 2. RESEARCH BACKGROUND

Supply Chain Management is typically motivated by operational parameters. Innovations are often primarily focused on direct consumer requests. However, Supply Chain Service Providers (SCSPs) have started to realize the importance of proactive innovation to improve competitiveness.

In supply chains, the use of information and communication technologies has been shown to exert a great impact on SC operational efficiency [1] and to sustain the network of relationships [13]. Information technologies (IT) used for SCM, including supply chain management systems (SCMS), Internet/Web, electronic data interchange (EDI), advanced planning system (APS), radio frequency identification (RFID), and mobile technologies, allow firms to exchange timely information, carry out plans precisely and perform various SC functions and activities efficiently [14]. For example, EDI technologies, which have been used in supply chain management for many decades, enables the electronic transfer of business information between trading partners (B2B) through a standardized format. Nonetheless, the theoretical and empirical research regarding the role of supply chain IT in facilitating/inhibiting a supply chain’s ability to manage knowledge is scarce [14].

The miniaturization of electronics is a very important technology, which means the engineering of smaller mechanical, optical and electronic items and devices. [15]. It is the key enabler for Automatic Identification and Data Collection (AIDC) and Radio Frequency Identification (RFID) technologies that help to capture, handle and analyze data in transport processes in the supply chain [16]. In reality, AIDC-and RFID-technologies are part of the so-called entrenched structures. These are microprocessor-based systems that are designed into physical products to monitor a feature or a set of functions. [17].

Supply chain optimization greatly depends on the planning process [18]. This process aims to obtain a balance between supply and demand, from primary suppliers to final customers, to deliver superior goods and services through the optimization of supply chain assets. To cope with the complexity of supply chain planning, a set of information technology (IT) tools can be used directly or indirectly. These systems are used for information integration, inventory management, order fulfillment, delivery planning and coordination, just to mention a few [19]. Among the leading IT tools for Supply Chain Management, the Advanced Planning and Scheduling (APS) system is widely discussed today, which may be due to the fact that APS systems focus on a very relevant problem in supply chains, i.e. how to synchronize hundreds of real planning decisions at strategic, tactical and operational levels in a complex environment. This quite challenging objective requires an advanced solution.

Basically, APS are computer supported planning systems that put forward various functions of Supply Chain Management, including procurement, production, distribution and sales, at the strategic, tactical and operational planning levels [20]. These systems stand for a quantitative model-driven perspective on the use of IT in supporting Supply Chain Management, for exploiting advanced analysis and supply chain optimization methods.

The term Smart Factory includes the idea of Smart Logistics, which defines the application of ubiquitous technology to logistics processes for improving the efficiency of transport, warehouse and storage processes [21]. Smart Data, as a similar term, helps to capture, process and analyze data from an increasingly complex investment universe. Big Data, a vast collection and storing of data in real-time, becomes Smart Data when its purpose is understood [22].

The costs of shipping, storing and processing can be minimized by miniaturizing electronics [23]. Based on this miniaturization process, AIDC-and RFID-technologies enable the digitization process of the supply chain and provide on-line real-time information on the current status of the logistics activities. The truck distribution of particular goods may thus be optimized [24]. For example, information on the distribution of transported goods could be updated in real-time and whenever necessary [25]. In this way, a product that is already on its way to the originally targeted customer might be diverted to another nearby customer if the delivery was cancelled. Thus, with the digitalization of all logistic processes through AIDC-and RFID-technologies, even problem management can be carried out both centrally and online. For example, truck drivers can easily interact with other machines (e.g., the loading area of the target delivery location) and notify the company of the expected delivery time [26]. Machine-to-Machine Communication has an effect on the supply chain as it facilitates automated recording and communication of process information in manufacturing facilities and distribution networks. It further supports the repair of machinery, offers alternative payment mechanisms for the sales feature of the organization and new facilities such as fleet management or track and trace systems. Machine-to-machine connectivity problems emerge from the need for structured communication protocols and cyber protection [27]. Technologies and IT-infrastructure components, which come under the term Business Intelligence, would have an effect on supply chain activities through cost-reduction opportunities and enhanced process transparency. In addition, processes would be more digital and technical, where employees of the company are able to access and exchange information using BI technology from anywhere [28].

Specifically, procurement processes can be streamlined as suppliers can be entirely versatile and independently selected by specific software [29]. It will also have an effect on the organisation of supply chain operations from a technical perspective.

The two core processes of e-procurement (electronic procurement) are e-sourcing and e-requisition. E-sourcing uses the Internet to make decisions and form strategies pertaining to how and where to obtain products and services. E-sourcing is more for contractual processes with the tools of e-tendering and e-RFQs (request for quotation and e-auctions) [30]. E-requisition is the web-based application used to process and monitor purchase requisition; it is more transactional with the tool such as e-catalogues. E-requisition may be called as e-ordering.

The main predictor for adoption of e-procurement techniques was perceived drivers. The perceived drivers included better decision making, better inventory management, increasing order accuracy, increasing the visibility of suppliers' products, reducing cycle time for order completion, easy to try or switch to new suppliers, reducing inventory cost, reducing price and reducing transaction cost. Internal and information barriers were significant predictors for e-procurement in the new buying situations.

E-sourcing and e-requisition are the two main e-procurement processes (electronic procurement). E-sourcing uses the Internet to make decisions and develop strategies on how and where to obtain products and services. E-sourcing is more for contractual processes with e-Tendering and e-RFQ tools (request for quotation and e-Actions) [30].

In the future, each employee will be equipped with this type of mobile device, communicate with coworkers, manage time and carry out relevant tasks in the smartphone manufacturing process. Specific systems can be built to increase the efficiency of manufacturing processes, e.g., the monitoring and tracking system of specific product parts, or to assist software for human activities in the business.

Despite the volume of literature on this subject, there is still a shortage of literature on the application of the Fuzzy DEMATEL method to the impact of IT innovation on the supply chain management of the food industry. Most available studies on the impact of IT innovation on supply chain management such as [31] assessed the evaluation of supplier selection criteria by Fuzzy DEMATEL method, [32] used DEMATEL method to analyse the causal relations on technological innovation capability evaluation factors in Thai technology-based firms, [33] did a study on the integrated Fuzzy DEMATEL and intuitionistic Fuzzy TOPSIS method to evaluate sustainable suppliers. None of these studies, however, examined the application of Fuzzy DEMATEL method on the impact of IT innovation on the Supply Chain Management in the food industry in the form of rank of the importance of the elements of the supply chain. A well-designed supply chain strategy, centered on the core elements, will provide managers with a host of benefits, including support for business strategy, improved customer relationships and satisfaction, and efficiency, performance, response, and quality improvement.

## 2.1 The DEMATEL Method

The DEMATEL originated from the Natural Sciences and Humanities Research Plan proposed by the Battelle Institute in 1971 [34].

During the initial stages of development, the DEMATEL was designed to identify intricate problems in the world such as racism, hunger, environmental protection, and energy conservation. In that period, the DEMATEL was employed in 3 major research fields, specifically: world problem structures, analyzing and developing adaptive methods for resolving intricate world problems and reviewing research and methodology data pertaining to world problem [35].

In recent years, the DEMATEL has been employed widely to resolve problems in various fields. [36] worked on Fuzzy DEMATEL-based green supply chain management performance application in cement industry. [37] evaluate the drivers of green supply chain management practices in uncertainty. [38] proposed an intuitionistic fuzzy based DEMATEL method for developing green practices. A case study from automotive industry was used for validation. Sensitivity analysis was performed to check the robustness of the method.

The framework and computation procedures applied in the DEMATEL consist of the following steps [39].

**Step 1: Institute measurement scales and determine the direction and degree of influence between factors**

In this step, various element related to the IT innovations and degree of influence between the various element were identified and defined based on data from literature reviews, brainstorming and expert opinions

**Step 2: Generating the direct-relation matrix**

After the significance of the measurement scales was determined, a coalition of *p* decision makers and *q* variables were used. Every decision-maker (expert) is asked to determine the degree of direct influence between two variables on the basis of a pair-wise comparison. The degree to which the decision-maker interpreted the impact of factor *i* on factor *j* is denoted as $x_{ij}$. Five scales were used to measure the relationship between different criteria: 0 (no influence), 1 (low influence), 2 (medium influence), 3 (high influence), and 4 (very high influence), respectively. For each decision maker, an *n x n* non-negative matrix is constructed as $X^k = x_{ij}^k$ where k is the number of decision maker participating in evaluation process with *1≤ k ≤ p.*

Thus, $X^1, X^2, X^3, \ldots, X^p$ are the matrices from *p* decision makers.

$$X = \begin{bmatrix} 0 & x_{12} & \cdots & x_{1n} \\ x_{21} & 0 & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & 0 \end{bmatrix} \qquad (i)$$

**Step 3: Normalizing the direct-relation matrix**

$$\lambda = \frac{1}{\underset{1 \le i \le n}{Max} \quad (\sum_{=1}^{n} x_{ij})} \, i.j = 1, 2, \ldots, n \qquad (ii)$$

$$N = \lambda X \qquad (iii)$$

**Step 4: Attaining the total-relation matrix**

The total relation matrix can be obtain by using equation (*v*), where I is denoted as the identity matrix

$$T = \lim_{K \to \infty} (N + N^2 + \cdots + N^K) \qquad (iv)$$

$$= \sum_{k=1}^{\infty} N^i$$

*where*

$$\sum_{k=1}^{\infty} N^i = N^1 + N^2 + \cdots + N^k$$

$$= N(I + N^1 + N^2 + \cdots + N^{k-1})$$

$$= N\,(I - N)^{-1}(I - N)(I + N^1 + N^2 + \cdots + N^{k-1})$$

$$= N(I - N)^1\,(I - N^k)$$

$$T \quad = N\,(I - N)^{-1} \qquad (v)$$

**Step 5: Calculate the sum of rows and columns of matrix T**

In the total-relation matrix T, the sum of rows and the sum of columns are represented by vectors D and R respectively.

$$D = [D_i]_{nx1} = (\sum_{j=1}^{n} t_{ij})_{nx1} \qquad (i = 1, 2, \ldots, n) \qquad (vi)$$

$$R = [R_j]_{nx1} = (\sum_{i=1}^{n} t_{ij})_{nx1} \qquad (j = 1, 2, \ldots, n) \qquad (vii)$$

**Step 6: Illustrate the DEMATEL Cause and Effect Diagram**

In this step, (D+R) is classified as Prominence and z = I = j=1, 2, n, illustrating the overall influential direction of the service attribute. This value indicates the core level of service attribute z in question. The parameter (D − R) is defined as the relation, indicating the difference in the influences of this service attribute. This value indicates the magnitude of the impact of the service attribute z in question; a positive value indicates that the attribute is a cause and a negative value indicates that the attribute is an effect. In the cause and effect diagram, the attributes are plotted on the horizontal axis by the value (D + R) and on the vertical axis by the value (D − R). By using pictures, complex causal interactions are condensed into understandable visual constructs.

Based on the coordinate positions of ($D_k + R_k$) and ($D_k - R_k$), attributes can be divided into the following 4 types:

a. ($D_k$ - $R_k$) is positive and ($D_k + R_k$) is large: This indicates that the attributes are causes, which are also driving factors for solving problems.
b. ($D_k$ - $R_k$) is positive and ($D_k + R_k$) is small: This indicates that the attributes are independent and can influence only a few other attributes.
c. ($D_k$ - $R_k$) is negative and ($D_k + R_k$) is large: This indicates that the attributes are the core problems that must be solved; however these are effect-type attributes, which cannot be directly improved.
d. ($D_k$ - $R_k$) is negative and ($D_k + R_k$) is small: This indicates that the attributes are independent and can be influenced by only a few other attributes.

## 2.2 Fuzzy Theory

[40] who believed that people's thought, reasoning, and perceptions of their surroundings are relatively vague, proposed fuzzy set theory. [40] experienced difficulty in allocating a precise percentile or number to these concepts because of individuality and subjectivity and, therefore, contended that conventional extremely precise quantification methods cannot be used to resolve people-centred or complex problems completely. The concepts of fuzzy set theory are essential to accounting for the uncertainty and fuzziness of realistic environments. Research subjects are allocated a value between 0 and 1 to indicate their fuzzy degree [39]. People's subjective judgments are converted into numbers. This conversion compensates the defect of conventional sets in describing events by using binary logic. This method enables research results to comply closely with human thought patterns.

The research objective of fuzzy theory, which was developed based on the fuzzy set, is to recognize the phenomenon of vagueness to handle vague and uncertain situations. Fuzzy theory has been employed and it has shown useful results in various fields, such as artificial intelligence, automatic control, image recognition, medical diagnosis, psychology, decision support, management science, weather forecasting, and environmental assessment [39] In the context of fuzzy logic, each number between 0 and 1 is regarded as partially correct. By contrast, crisp set concepts dictate that answers are either 1 or 0. Thus, fuzzy logic enables researchers to process fuzzy, ambiguous, and imprecise mathematical judgments. The most commonly used fuzzy numbers are triangular fuzzy numbers, trapezoidal fuzzy number, and Gaussian fuzzy numbers. A triangular fuzzy number $\bar{A}$ is shown as a triplet (l, m, r) and a membership function $\mu_{\bar{A}}$ Fig. 1.

Defuzzification is to convert a fuzzy quantity (fuzzy number) to a precise quantity (crisp number), which is the positive procedure of fuzzification that is the conversion of a precise quantity to a fuzzy quantity [41]. In other words, defuzzification is to determine the best nonfuzzy score value (BNS) for the corresponding fuzzy number. There are generally three methods to compute the BNS value: mean of maximal (MOM), centre of area (COA), and **λ** - cut [42]. In this paper, the MOM method is used to defuzzify the fuzzy numbers. The method is given by the mathematic expression [41], as follow:

The membership function is defined as:

$$\mu_X(y) = \begin{cases} 0 & y < a \\ \dfrac{(y-a)}{(b-a)} & a \le y \le b \\ \dfrac{(c-y)}{(c-b)} & b \le y \le c \\ 0 & y > c \end{cases}$$

The fuzzy linguistic function entails converting linguistic wording into fuzzy numbers and then defuzzifying these fuzzy numbers to obtain explicit values [39].

The defuzzification solver employed in the present study uses the smallest and largest fuzzy number to determine the left and right threshold values. The overall integral value is determined based on the weighted average of the membership function. The following 4 steps are subsequently conducted [43].

Step 1: Normalization:

$$xr_{ij}^{n} = \frac{\left(r_{ij}^{n} - minl_{ij}^{n}\right)}{\Delta_{min}^{max}} \qquad (vi)$$

$$xm_{ij}^{n} = \frac{\left(m_{ij}^{n} - minl_{ij}^{n}\right)}{\Delta_{min}^{max}} \qquad (vii)$$

$$xl_{ij}^{n} = \frac{\left(l_{ij}^{n} - minl_{ij}^{n}\right)}{\Delta_{min}^{max}} \qquad (viii)$$

Where

$$\Delta_{min}^{max} = maxr_{ij}^{n} - minl_{ij}^{n} \qquad (ix)$$

Step 2: compute right (rs) and left (ls) normalized values:

$$xrs_{ij}^{n} = \frac{xr_{ij}^{n}}{\left(1 + xr_{ij}^{n} - xm_{ij}^{n}\right)} \qquad (x)$$

$$xls_{ij}^{n} = \frac{xm_{ij}^{n}}{\left(1 + xm_{ij}^{n} - xl_{ij}^{n}\right)} \qquad (xi)$$

Step 3: Compute total normalized crisp values:

$$x_{ij}^{n} = \frac{\left[xls_{ij}^{n}\left(1 - xls_{ij}^{n}\right) + xrs_{ij}^{n} \times xrs_{ij}^{n}\right]}{\left[1 - xls_{ij}^{n} + xrs_{ij}^{n}\right]} \qquad (xii)$$

Step 4 – Compute crisp values:

$$z_{ij}^{n} = minl_{ij}^{n} + x_{ij}^{n} \times \Delta_{min}^{max} \qquad (xiii)$$

Step 5 – Integrate crisp value

$$z_{ij} = \frac{1}{p}\left(z_{ij}^{1} + z_{ij}^{2} + \cdots + z_{ij}^{p}\right) \qquad (xiv)$$

## 3. METHODOLOGY

The methodology is divided into five (5) stages: (1) Define the problem, (2) Fuzzy DEMATEL questionnaire design, (3) Application of the Fuzzy DEMATEL Process, (4) Analyzing the degree of central role and relation, (5) The causal diagram.

### Stage 1: Defining the problem

Based on the previous literatures, we focus on (16) variables as IT innovation as impacted supply chain management Table 1. The study develops a fuzzy Linguistic scale and applies it to food manufacturing firms in Nigeria to test the level of the impact of IT innovation on supply chain management. The focus on food manufacturing industries is due to the fact that this sector is one of the major driver of Nigeria economy. The study therefore attempts to answer the research question ‘Does IT innovation has significant effect on supply chain management of the food industry in Nigeria?’

### Stage 2: Fuzzy DEMATEL Questionnaire Design

The study obtained sixteen (16) perspectives of impact of IT innovation on food industry SC management as obtain from literature Table 1. The questionnaire designed for pairwise comparison to evaluate the influence of each score, where scores of 0, 1, 2, 3 and 4 represent: (no influence), (Very low influence), (low influence), (high influence) and (very high influence), respectively.

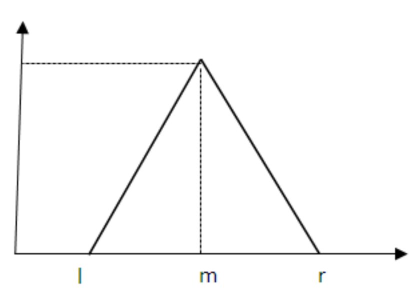


**Fig. 1. A triangle fuzzy numbers A**

## 2.1 Questionnaire Administration

Questionnaires were administered between 20 and 31 January 2020. The questionnaires were primarily administered to a group of experts, who provided their personal opinions regarding the impact of IT innovation on SCM of the food Industry in Lagos State. During the survey, the ambiguity of the experts' subjective judgments was considered. Thus, a linguistic description method was employed to ensure that the evaluation values of the experts' subjective judgments were expressed properly. Subsequently, each judgment value was expressed as a triangular fuzzy number Fig. 1.

Twelve experts were asked to complete the questionnaire comprises of 6 general managers, 6 Supply Chain managers all of food industry. All have more than 8 years of experience in supply chain management. After completion of the questionnaires, the relationships among the 16 criteria of the impact of IT on SCM were assessed, namely, pairwise comparisons of the degree of causal and interactive relationships among the criteria. The researcher personally visit each expert to explain the content of the questionnaire prior administration. A total of 10 valid questionnaires were retrieved, yielding an effective recovery rate of 83.33%.

**Stage 3: The Fuzzy DEMATEL Model**

The fuzzy-DEMATEL model combines the fuzzy linguistic aspect of fuzzy theory with the DEMATEL [39]. The study Apply the DEMATEL in fuzzy which enables the researcher to analyse the causal relationships of fuzzy variables and determine the level of interactive influence between variables.

**A: Develop evaluation standards and design a fuzzy linguistic scale.**

The computation addresses response to the human logic variable, according to the linguistics variable (Li 1999): no influence, very low influence, low influence, high influence and very high influence, and shows positive triangular fuzzy numbers $(l_{ij}^{n}, m_{ij}^{n}, r_{ij}^{n})$ (Table 2).

**Table 1. Information technology innovations in supply chain management**

| Variables | IT Innovations in Supply Chain Management |
|---|---|
| 1 | Inventory Management |
| 2 | Advanced Planning System (APS) |
| 3 | Automated Guided Vehicle System (AGVS) |
| 4 | Order Fulfillment |
| 5 | Automatic Identification and Data Collection (AIDC) |
| 6 | Real time online Tracking |
| 7 | Customer Relationship Management |
| 8 | Delivery Planning & Coordination |
| 9 | Radio Frequency Identification (RFID) |
| 10 | Electronic Data Interchange (EDI) |
| 11 | Material Requirement Planning (MRP) |
| 12 | Voice Technology |
| 13 | E-Sourcing |
| 14 | Internet/Web |
| 15 | Smart Data |
| 16 | E-requisition |

*Source: Author's computation 2020*

**Table 2. The fuzzy linguistic scale**

| Linguistic Terms | Influence Score | Triangular Fuzzy Numbers |
|---|---|---|
| No Influence (No) | 0 | (0, 0, 0.25) |
| Very Low Influence (VL) | 1 | (0, 0.25, 0.50) |
| Low Influence (L) | 2 | (0.25, 0.50, 0.75) |
| High Influence (H) | 3 | (0.50, 0.75, 1.00) |
| Very High Influence (VH) | 4 | (0.75, 1.00, 1.00) |

**B: Initiation of fuzzy/linguistic scale**

Independently, each expert was given a 16 x16 linguistic/fuzzy scale for comparison of impact of IT on SCM. For example, a completed scale from expert1 within a fuzzy linguistic scale assessment among the decision maker on the impact of IT on SCM is shown in Table 3.there are 16 elements.

**C: Conversion of fuzzy scale Direct-Relation Matrix**

The fuzzy scale shown in Table 3 was converted into fuzzy numbers Table 4. In this study, the degree of influence can be described using 5 linguistic expressions, specifically, NO- No influence, VL- Very low influence, L- Low influence, H- High influence, and VH – Very high influence, with influence score of 0, 1, 2, 3 and 4 respectively. This then is further converted to triangular Fuzzy Number of (0, 0, 0.25), (0, 0.25, 0.50), (0.25, 0.50, 0.75), (0.50, 0.75, 1.00) and (0.75, 1.00, 1.00) respectively as presented in Table 2, to establish a direct relation fuzzy matrix Table 4.

**Step 4: Transform Triangular fuzzy numbers into the initial direct-relation matrix**

The initial direct relation matrix was computed using equations (vi) to (xii) this is to develop a crisp value direct-relation matrix for each evaluator.

Utilizing Table 4 with the linguistic assessments by expert 1, we exemplify the normalization and crisping for Factor V1 to V2. A fuzzy linguistic scale of (0, 0.25, 0.50) is currently assigned for this comparison by expert1. Essentially, it means that expert1 believes factor V1 has a Very low influence on factor V2.

Since the minimum value for each column *j* ($minl_{ij}^{n}$) is 0 for expert 1 and the maximum value for each column *j* ($maxr_{ij}^{n}$) is 1, our $\Delta_{min}^{max}$ = 1. For our example given that

*From equation (vi)*

$$xr_{12}^{1} = \frac{(r_{12}^{n1} - minl_{12}^{1})}{\Delta_{min}^{max}} = \frac{0.5-0}{1} = 0.5$$

*From equation (vii)*

$$xm_{12}^{1} = \frac{(m_{12}^{1} - minl_{12}^{1})}{\Delta_{min}^{max}} = \frac{0.25-0}{1} = 0.25$$

*From equation (viii)*

$$xl_{12}^{1} = \frac{(l_{12}^{1} - minl_{12}^{1})}{\Delta_{min}^{max}} = \frac{0-0}{1} = 0$$

Where $\Delta_{min}^{max} = maxr_{ij}^{n} - minl_{ij}^{n}$

*From equation (x)*

$$xrs_{12}^{1} = \frac{xr_{12}^{1}}{(1 + xr_{12}^{1} - xm_{12}^{1})} = \frac{0.5}{(1+0.5-0.25)} = 0.4$$

*From equation (xi)*

$$xls_{12}^{1} = \frac{xm_{12}^{1}}{(1 + xm_{12}^{1} - xl_{12}^{1})} = \frac{0.25}{(1+0.25-0)} = 0.2$$

*From equation (xii)*

$$x_{12}^{1} = \frac{[xls_{12}^{1}(1 - xls_{12}^{1}) + xrs_{12}^{1} \times xrs_{12}^{1}]}{[1 - xls_{12}^{1} + xrs_{12}^{1}]} = \frac{[0.2(1-0.2)+(0.4 \, x \, 0.4)]}{[1-0.2+0.4]} = 0.267$$

The computation of the final crisp value is achieved by utilizing equation (xiv)

$$z_{12}^{1} = minl_{12}^{1} + x_{ij}^{n} \times \Delta_{min}^{max} = 0 + 0.267(1) = 0.267$$

From equation *(xv)*

In the same vain, the computation of the response of all the experts for the calculation of the normalization and crisping for factor V1 to V2 was done. Thereafter, computation of the average value of influence was equally done using equation (xvi) as indicated In Table 5 below

$$z_{ij} = \frac{1}{p}\left(z_{ij}^{1} + z_{ij}^{2} + \cdots + z_{ij}^{p}\right)$$

The calculation of other results of the comparisons between the variables obtained from all experts. Table 6 shows the final result.

## 2.2 Set Up the Generalized Direct-Relation Matrix

A generalized direct-relation matrix was obtained using equation (i) in which all principal diagonal elements are between 1 to zero as shown in Table 7

Table 8 shows the total relation matrix M acquired using equation (iv to v) from the generalized direct-relation matrix.

**Table 3. Fuzzy scale from expert 1**

| | Inventory Mgt. | APS | AGVS | Order Fulfillment | AIDC | Real time online Tracking | Customer Relationship Mgt. | Delivery Planning & Coordination | RFID | EDI | MRP | Voice Technology | E-Sourcing | Internet/Web | Smart Data | E-requisition. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Inventory Mgt. | 0 | 3 | 2 | 2 | 4 | 3 | 3 | 1 | 4 | 1 | 2 | 2 | 3 | 1 | 3 | 1 |
| APS | 1 | 0 | 3 | 3 | 3 | 3 | 2 | 3 | 1 | 4 | 3 | 2 | 3 | 1 | 1 | 3 |
| AGVS | 2 | 3 | 0 | 1 | 2 | 4 | 1 | 3 | 4 | 4 | 3 | 3 | 4 | 2 | 2 | 1 |
| Order Fulfillment | 1 | 2 | 3 | 0 | 3 | 3 | 4 | 2 | 2 | 3 | 4 | 4 | 3 | 3 | 1 | 3 |
| AIDC | 2 | 3 | 2 | 3 | 0 | 3 | 3 | 1 | 1 | 3 | 4 | 3 | 4 | 3 | 2 | 3 |
| Real time online Tracking | 3 | 2 | 3 | 3 | 3 | 0 | 3 | 2 | 3 | 1 | 3 | 2 | 3 | 2 | 2 | 4 |
| Customer Relationship Mgt. | 1 | 1 | 1 | 4 | 2 | 3 | 0 | 1 | 2 | 2 | 3 | 4 | 3 | 2 | 2 | 3 |
| Delivery Planning & Coordination | 1 | 1 | 1 | 2 | 1 | 2 | 2 | 0 | 3 | 2 | 2 | 2 | 1 | 1 | 3 | 2 |
| RFID | 1 | 2 | 3 | 2 | 2 | 3 | 2 | 2 | 0 | 1 | 1 | 1 | 2 | 2 | 2 | 2 |
| EDI | 2 | 3 | 2 | 3 | 2 | 2 | 2 | 1 | 1 | 0 | 2 | 1 | 3 | 2 | 1 | 2 |
| MRP | 1 | 3 | 3 | 3 | 2 | 3 | 3 | 1 | 1 | 2 | 0 | 3 | 2 | 2 | 2 | 3 |
| Voice Technology | 2 | 2 | 3 | 4 | 2 | 3 | 4 | 2 | 1 | 3 | 3 | 0 | 2 | 2 | 2 | 3 |
| E-Sourcing | 1 | 2 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 0 | 1 | 1 | 2 |
| Internet/Web | 1 | 2 | 2 | 3 | 3 | 3 | 2 | 1 | 2 | 1 | 3 | 3 | 2 | 0 | 1 | 0 |
| Smart Data | 1 | 1 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 2 | 2 | 1 | 1 | 1 | 0 | 1 |
| E-requisition | 1 | 3 | 1 | 2 | 1 | 3 | 3 | 1 | 1 | 2 | 1 | 3 | 1 | 1 | 1 | 0 |

*Source: Author's computation 2020*

**Table 4. Direct relation fuzzy matrix**

| | V 1 | V 2 | V 3 | V 4 | V 5 | V 6 | V 7 | V 8 | V 9 | V 10 | V 11 | V 12 | V 13 | V 14 | V 15 | V 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| V1 | 0 | 0, 0.25, 0.5 | 0.5, 0.75, 1 | 0.25, 0.5, 0.75 | 0.5, 0.75, 1 | 0.5, 0.75, 1 | 0.75, 1, 1 | 0.25, 0.5, 0.75 | 0.25, 0.5, 0.75 | 0.5, 0.75, 1 | 0.75, 1, 1 | 0.25, 0.5, 0.75 | 0.5, 0.75, 1 | 0, 0, 0.25 | 0, 0.25, 0.5 | 0, 0, 0.25 |
| V2 | 0.25, 0.5, 0.75 | 0 | 0.25, 0.5, 0.75 | 0.25, 0.5, 0.75 | 0.75, 1, 1 | 0.5, 0.75, 1 | 0.75, 1, 1 | 0.25, 0.5, 0.75 | 0, 0.25, 0.5 | 0, 0.25, 0.5 | 0.5, 0.75, 1 | 0.75, 1, 1 | 0.25, 0.5, 0.75 | 0.25, 0.5, 0.75 | 0.25, 0.5, 0.75 | 0.25, 0.5, 0.75 |
| V3 | 0.75, 1, 1 | 0, 0.25, 0.5 | 0 | 0.5, 0.75, 1 | 0.75, 1, 1 | 0.5, 0.75, 1 | 0.5, 0.75, 1 | 0.25, 0.5, 0.75 | 0.25, 0.5, 0.75 | 0.25, 0.5, 0.75 | 0.25, 0.5, 0.75 | 0, 0.25, 0.5 | 0, 0.25, 0.5 | 0, 0.25, 0.5 | 0, 0.25, 0.5 | 0, 0, 0.25 |
| V4 | 0.25, 0.5, 0.75 | 0.25, 0.5, 0.75 | 0.25, 0.5, 0.75 | 0 | 0.25, 0.5, 0.75 | 0.75, 1, 1 | 0.5, 0.75, 1 | 0.25, 0.5, 0.75 | 0.5, 0.75, 1 | 0, 0.25, 0.5 | 0.75, 1, 1 | 0.75, 1, 1 | 0.75, 1, 1 | 0.5, 0.75, 1 | 0.5, 0.75, 1 | 0.75, 1, 1 |
| V5 | 0.5, 0.75, 1 | 0.25, 0.5, 0.75 | 0.5, 0.75, 1 | 0.25, 0.5, 0.75 | 0 | 0.5, 0.75, 1 | 0.5, 0.75, 1 | 0, 0.25, 0.5 | 0.25, 0.5, 0.75 | 0.5, 0.75, 1 | 0.25, 0.5, 0.75 | 0.25, 0.5, 0.75 | 0.25, 0.5, 0.75 | 0, 0.25, 0.5 | 0, 0.25, 0.5 | 0, 0.25, 0.5 |
| V6 | 0.25, 0.5, 0.75 | 0.5, 0.75, 1 | 0.5, 0.75, 1 | 0.75, 1, 1 | 0.5, 0.75, 1 | 0 | 0.5, 0.75, 1 | 0.25, 0.5, 0.75 | 0.5, 0.75, 1 | 0.75, 1, 1 | 0.5, 0.75, 1 | 0.75, 1, 1 | 0.25, 0.5, 0.75 | 0.25, 0.5, 0.75 | 0, 0.25, 0.5 | 0.5, 0.75, 1 |
| V7 | 0.5, 0.75, 1 | 0, 0.25, 0.5 | 0.5, 0.75, 1 | 0.5, 0.75, 1 | 0.75, 1, 1 | 0.5, 0.75, 1 | 0 | 0.25, 0.5, 0.75 | 0.5, 0.75, 1 | 0.5, 0.75, 1 | 0.25, 0.5, 0.75 | 0.25, 0.5, 0.75 | 0.25, 0.5, 0.75 | 0, 0.25, 0.5 | 0.25, 0.5, 0.75 | 0, 0.25, 0.5 |
| V8 | 0, 0.25, 0.5 | 0.75, 1, 1 | 0.25, 0.5, 0.75 | 0.25, 0.5, 0.75 | 0.5, 0.75, 1 | 0.75, 1, 1 | 0.25, 0.5, 0.75 | 0 | 0.25, 0.5, 0.75 | 0, 0, 0.25 | 0.25, 0.5, 0.75 | 0.75, 1, 1 | 0.5, 0.75, 1 | 0.5, 0.75, 1 | 0, 0.25, 0.5 | 0.5, 0.75, 1 |
| V9 | 0.25, 0.5, 0.75 | 0.25, 0.5, 0.75 | 0, 0.25, 0.5 | 0.25, 0.5, 0.75 | 0.25, 0.5, 0.75 | 0.75, 1, 1 | 0.25, 0.5, 0.75 | 0, 0.25, 0.5 | 0 | 0, 0, 0.25 | 0.5, 0.75, 1 | 0.25, 0.5, 0.75 | 0.5, 0.75, 1 | 0, 0.25, 0.5 | 0, 0.25, 0.5 | 0.25, 0.5, 0.75 |
| V10 | 0.25, 0.5, 0.75 | 0.25, 0.5, 0.75 | 0.25, 0.5, 0.75 | 0.25, 0.5, 0.75 | 0.5, 0.75, 1 | 0.75, 1, 1 | 0.25, 0.5, 0.75 | 0.25, 0.5, 0.75 | 0, 0.25, 0.5 | 0 | 0.25, 0.5, 0.75 | 0.5, 0.75, 1 | 0, 0.25, 0.5 | 0, 0.25, 0.5 | 0, 0.25, 0.5 | 0.25, 0.5, 0.75 |
| V11 | 0.25, 0.5, 0.75 | 0.25, 0.5, 0.75 | 0, 0.25, 0.5 | 0.75, 1, 1 | 0.25, 0.5, 0.75 | 0.25, 0.5, 0.75 | 0, 0.25, 0.5 | 0, 0.25, 0.5 | 0, 0.25, 0.5 | 0.25, 0.5, 0.75 | 0 | 0.75, 1, 1 | 0.5, 0.75, 1 | 0.25, 0.5, 0.75 | 0.5, 0.75, 1 | 0.5, 0.75, 1 |

| | V 1 | V 2 | V 3 | V 4 | V 5 | V 6 | V 7 | V 8 | V 9 | V 10 | V 11 | V 12 | V 13 | V 14 | V 15 | V 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| V12 | 0.25, 0.5, 0.75 | 0.25, 0.5, 0.75 | 0.25, 0.5, 0.75 | 0.75, 1, 1 | 0.5, 0.75, 1 | 0.5, 0.75, 1 | 0.5, 0.75, 1 | 0.25, 0.5, 0.75 | 0.25, 0.5, 0.75 | 0.25, 0.5, 0.75 | 0.25, 0.5, 0.75 | 0 | 0, 0.25, 0.5 | 0, 0.25, 0.5 | 0.25, 0.5, 0.75 | 0, 0.25, 0.5 |
| V13 | 0, 0, 0.25 | 0.5, 0.75, 1 | 0.25, 0.5, 0.75 | 0.75, 1, 1 | 0.5, 0.75, 1 | 0, 0.25, 0.5 | 0.25, 0.5, 0.75 | 0.25, 0.5, 0.75 | 0.75, 1, 1 | 0.5, 0.75, 1 | 0.75, 1, 1 | 0.25, 0.5, 0.75 | 0 | 0.25, 0.5, 0.75 | 0.5, 0.75, 1 | 0, 0.25, 0.5 |
| V14 | 0, 0, 0.25 | 0.25, 0.5, 0.75 | 0.25, 0.5, 0.75 | 0.5, 0.75, 1 | 0.25, 0.5, 0.75 | 0.5, 0.75, 1 | 0.25, 0.5, 0.75 | 0.5, 0.75, 1 | 0.25, 0.5, 0.75 | 0, 0.25, 0.5 | 0.25, 0.5, 0.75 | 0, 0.25, 0.5 | 0.25, 0.5, 0.75 | 0 | 0, 0.25, 0.5 | 0.25, 0.5, 0.75 |
| V15 | 0, 0.25, 0.5 | 0.25, 0.5, 0.75 | 0.75, 1, 1 | 0.75, 1, 1 | 0, 0.25, 0.5 | 0.25, 0.5, 0.75 | 0.25, 0.5, 0.75 | 0.5, 0.75, 1 | 0, 0.25, 0.5 | 0, 0.25, 0.5 | 0.25, 0.5, 0.75 | 0.25, 0.5, 0.75 | 0.5, 0.75, 1 | 0.5, 0.75, 1 | 0 | 0.25, 0.5, 0.75 |
| V16 | 0, 0, 0.25 | 0.5, 0.75, 1 | 0.25, 0.5, 0.75 | 0.75, 1, 1 | 0.25, 0.5, 0.75 | 0.5, 0.75, 1 | 0.5, 0.75, 1 | 0.5, 0.75, 1 | 0.25, 0.5, 0.75 | 0, 0.25, 0.5 | 0.5, 0.75, 1 | 0, 0.25, 0.5 | 0.25, 0.5, 0.75 | 0, 0.25, 0.5 | 0.25, 0.5, 0.75 | 0 |

*Note: Inventory mgt. (V1), advanced planning sys. (V2), automated guided vehicle sys. (V3), order fulfillment (V4), automated identification & data collection (V5), Real time online tracking (V6), customer relationship mgt. (V7), delivery planning & coordination (V8), radio frequency identification (RFID) (V9), Electronic Data Interchange (EDI) (V10), Material Requirement Planning (MRP) (V11), Voice Technology (V12), E-Sourcing (V13), Internet/Web (V14), Smart Data (V15), E-requisition (V16); Source: Author's computation 2020*

**Table 5. Average value of influence**

| EXP | VAR | V1 | V2 | V3 | V4 | V5 | V6 | V7 | V8 | V9 | V10 | V11 | V12 | V13 | V14 | V15 | V16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Exp 1 | V1 | 0.00 | 0.27 | 0.73 | 0.50 | 0.73 | 0.73 | 0.97 | 0.50 | 0.50 | 0.73 | 0.97 | 0.50 | 0.73 | 0.03 | 0.27 | 0.03 |
| Exp 2 | V1 | 0.00 | 0.27 | 0.97 | 0.27 | 0.73 | 0.50 | 0.50 | 0.27 | 0.50 | 0.27 | 0.50 | 0.50 | 0.03 | 0.03 | 0.27 | 0.03 |
| Exp 3 | V1 | 0.00 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.73 | 0.97 | 0.73 | 0.97 | 0.97 | 0.97 | 0.73 |
| Exp 4 | V1 | 0.00 | 0.27 | 0.73 | 0.50 | 0.50 | 0.50 | 0.50 | 0.27 | 0.50 | 0.27 | 0.50 | 0.50 | 0.97 | 0.03 | 0.97 | 0.03 |
| Exp 5 | V1 | 0.00 | 0.27 | 0.73 | 0.50 | 0.50 | 0.50 | 0.50 | 0.27 | 0.27 | 0.27 | 0.50 | 0.50 | 0.03 | 0.03 | 0.27 | 0.03 |
| Exp 6 | V1 | 0.00 | 0.27 | 0.97 | 0.50 | 0.50 | 0.73 | 0.97 | 0.50 | 0.50 | 0.73 | 0.97 | 0.27 | 0.73 | 0.03 | 0.27 | 0.03 |
| Exp 7 | V1 | 0.00 | 0.27 | 0.73 | 0.27 | 0.73 | 0.50 | 0.97 | 0.27 | 0.27 | 0.73 | 0.97 | 0.27 | 0.03 | 0.03 | 0.27 | 0.03 |
| Exp 8 | V1 | 0.00 | 0.27 | 0.97 | 0.97 | 0.97 | 0.97 | 0.50 | 0.97 | 0.97 | 0.27 | 0.50 | 0.73 | 0.03 | 0.03 | 0.27 | 0.03 |
| Exp 9 | V1 | 0.00 | 0.27 | 0.73 | 0.50 | 0.73 | 0.50 | 0.50 | 0.27 | 0.50 | 0.27 | 0.50 | 0.27 | 0.03 | 0.03 | 0.27 | 0.73 |
| Exp 10 | V1 | 0.00 | 0.97 | 0.73 | 0.50 | 0.50 | 0.50 | 0.50 | 0.27 | 0.50 | 0.27 | 0.50 | 0.27 | 0.03 | 0.97 | 0.27 | 0.03 |
| Total | | 0.00 | 4.07 | 8.27 | 5.47 | 6.87 | 6.40 | 6.87 | 4.53 | 5.47 | 4.53 | 6.87 | 4.53 | 3.60 | 1.23 | 4.07 | 1.73 |
| Average | | 0.00 | 0.41 | 0.83 | 0.55 | 0.69 | 0.64 | 0.69 | 0.45 | 0.55 | 0.45 | 0.69 | 0.45 | 0.36 | 0.12 | 0.41 | 0.17 |

*Source: Author's computation 2020*

**Table 6. The initial direct relation matrix**

| | V1 | V2 | V3 | V4 | V5 | V6 | V7 | V8 | V9 | V10 | V11 | V12 | V13 | V14 | V15 | V16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| V1 | 0.00 | 0.41 | 0.83 | 0.55 | 0.69 | 0.64 | 0.69 | 0.45 | 0.55 | 0.45 | 0.69 | 0.45 | 0.36 | 0.22 | 0.41 | 0.17 |
| V2 | 0.50 | 0.00 | 0.41 | 0.45 | 0.69 | 0.78 | 0.50 | 0.87 | 0.45 | 0.55 | 0.64 | 0.50 | 0.69 | 0.45 | 0.59 | 0.69 |
| V3 | 0.55 | 0.27 | 0.00 | 0.59 | 0.83 | 0.69 | 0.69 | 0.59 | 0.41 | 0.50 | 0.50 | 0.31 | 0.45 | 0.45 | 0.78 | 0.50 |
| V4 | 0.69 | 0.45 | 0.59 | 0.00 | 0.69 | 0.83 | 0.64 | 0.41 | 0.41 | 0.50 | 0.83 | 0.92 | 0.83 | 0.64 | 0.78 | 0.97 |
| V5 | 0.43 | 0.57 | 0.78 | 0.52 | 0.00 | 0.45 | 0.57 | 0.47 | 0.33 | 0.54 | 0.40 | 0.50 | 0.24 | 0.29 | 0.24 | 0.47 |
| V6 | 0.50 | 0.69 | 0.69 | 0.92 | 0.64 | 0.00 | 0.73 | 0.83 | 0.83 | 0.92 | 0.55 | 0.64 | 0.41 | 0.69 | 0.55 | 0.59 |
| V7 | 0.64 | 0.78 | 0.69 | 0.64 | 0.59 | 0.59 | 0.00 | 0.50 | 0.55 | 0.55 | 0.36 | 0.64 | 0.45 | 0.45 | 0.59 | 0.50 |
| V8 | 0.55 | 0.73 | 0.55 | 0.59 | 0.50 | 0.69 | 0.50 | 0.00 | 0.50 | 0.50 | 0.36 | 0.73 | 0.59 | 0.55 | 0.59 | 0.73 |
| V9 | 0.45 | 0.45 | 0.31 | 0.59 | 0.45 | 0.83 | 0.69 | 0.45 | 0.00 | 0.31 | 0.41 | 0.55 | 0.83 | 0.41 | 0.36 | 0.45 |
| V10 | 0.31 | 0.41 | 0.41 | 0.55 | 0.69 | 0.87 | 0.69 | 0.27 | 0.22 | 0.00 | 0.45 | 0.59 | 0.59 | 0.36 | 0.36 | 0.41 |
| V11 | 0.87 | 0.59 | 0.45 | 0.83 | 0.31 | 0.64 | 0.50 | 0.50 | 0.64 | 0.50 | 0.00 | 0.59 | 0.87 | 0.55 | 0.59 | 0.64 |
| V12 | 0.43 | 0.52 | 0.34 | 0.92 | 0.59 | 0.78 | 0.59 | 0.82 | 0.59 | 0.45 | 0.82 | 0.00 | 0.45 | 0.39 | 0.75 | 0.29 |
| V13 | 0.55 | 0.45 | 0.27 | 0.73 | 0.45 | 0.45 | 0.55 | 0.55 | 0.73 | 0.50 | 0.83 | 0.36 | 0.00 | 0.55 | 0.78 | 0.50 |
| V14 | 0.22 | 0.45 | 0.45 | 0.69 | 0.31 | 0.59 | 0.41 | 0.69 | 0.41 | 0.36 | 0.50 | 0.41 | 0.45 | 0.00 | 0.64 | 0.45 |
| V15 | 0.41 | 0.36 | 0.50 | 0.73 | 0.27 | 0.31 | 0.55 | 0.41 | 0.41 | 0.41 | 0.55 | 0.41 | 0.83 | 0.45 | 0.00 | 0.45 |
| V16 | 0.17 | 0.50 | 0.22 | 0.83 | 0.36 | 0.73 | 0.31 | 0.69 | 0.50 | 0.41 | 0.59 | 0.27 | 0.27 | 0.36 | 0.50 | 0.00 |

*Source: Author’s computation 2020*

**Table 7. The generalized direct relation matrix**

| | V1 | V2 | V3 | V4 | V5 | V6 | V7 | V8 | V9 | V10 | V11 | V12 | V13 | V14 | V15 | V16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| V 1 | 0 | 0.04 | 0.08 | 0.05 | 0.07 | 0.06 | 0.07 | 0.05 | 0.05 | 0.05 | 0.07 | 0.05 | 0.04 | 0.02 | 0.04 | 0.02 |
| V 2 | 0.05 | 0 | 0.04 | 0.05 | 0.07 | 0.08 | 0.05 | 0.09 | 0.05 | 0.05 | 0.06 | 0.05 | 0.07 | 0.05 | 0.06 | 0.07 |
| V 3 | 0.05 | 0.03 | 0 | 0.06 | 0.08 | 0.07 | 0.07 | 0.06 | 0.04 | 0.05 | 0.05 | 0.03 | 0.05 | 0.05 | 0.08 | 0.05 |
| V 4 | 0.07 | 0.05 | 0.06 | 0 | 0.07 | 0.08 | 0.06 | 0.04 | 0.04 | 0.05 | 0.08 | 0.09 | 0.08 | 0.06 | 0.08 | 0.10 |
| V5 | 0.04 | 0.06 | 0.08 | 0.05 | 0 | 0.04 | 0.06 | 0.05 | 0.03 | 0.05 | 0.04 | 0.05 | 0.02 | 0.03 | 0.02 | 0.05 |
| V 6 | 0.05 | 0.07 | 0.07 | 0.09 | 0.06 | 0 | 0.07 | 0.08 | 0.08 | 0.09 | 0.05 | 0.06 | 0.04 | 0.07 | 0.05 | 0.06 |
| V 7 | 0.06 | 0.08 | 0.07 | 0.06 | 0.06 | 0.06 | 0 | 0.05 | 0.05 | 0.05 | 0.04 | 0.06 | 0.05 | 0.05 | 0.06 | 0.05 |
| V 8 | 0.05 | 0.07 | 0.05 | 0.06 | 0.05 | 0.07 | 0.05 | 0 | 0.05 | 0.05 | 0.04 | 0.07 | 0.06 | 0.05 | 0.06 | 0.07 |
| V 9 | 0.05 | 0.05 | 0.03 | 0.06 | 0.05 | 0.08 | 0.07 | 0.05 | 0 | 0.03 | 0.04 | 0.05 | 0.08 | 0.04 | 0.04 | 0.05 |
| V10 | 0.03 | 0.04 | 0.04 | 0.05 | 0.07 | 0.09 | 0.07 | 0.03 | 0.02 | 0 | 0.05 | 0.06 | 0.06 | 0.04 | 0.04 | 0.04 |
| V11 | 0.09 | 0.06 | 0.05 | 0.08 | 0.03 | 0.06 | 0.05 | 0.05 | 0.06 | 0.05 | 0 | 0.06 | 0.09 | 0.05 | 0.06 | 0.06 |
| V12 | 0.04 | 0.05 | 0.03 | 0.09 | 0.06 | 0.08 | 0.06 | 0.08 | 0.06 | 0.05 | 0.08 | 0 | 0.05 | 0.04 | 0.07 | 0.03 |
| V13 | 0.05 | 0.05 | 0.03 | 0.07 | 0.05 | 0.05 | 0.05 | 0.05 | 0.07 | 0.05 | 0.08 | 0.04 | 0 | 0.05 | 0.08 | 0.05 |
| V14 | 0.02 | 0.05 | 0.05 | 0.07 | 0.03 | 0.06 | 0.04 | 0.07 | 0.04 | 0.04 | 0.05 | 0.04 | 0.05 | 0 | 0.06 | 0.05 |
| V15 | 0.04 | 0.04 | 0.05 | 0.07 | 0.03 | 0.03 | 0.05 | 0.04 | 0.04 | 0.04 | 0.05 | 0.04 | 0.08 | 0.05 | 0 | 0.05 |
| V16 | 0.02 | 0.05 | 0.02 | 0.08 | 0.04 | 0.07 | 0.03 | 0.07 | 0.05 | 0.04 | 0.06 | 0.03 | 0.03 | 0.04 | 0.05 | 0 |

*Note: Inventory mgt. (V1), advanced planning sys. (V2), automated guided vehicle sys. (V3), order fulfillment (V4), automated identification & data collection (V5), Real time online tracking (V6), customer relationship mgt. (V7), delivery planning & coordination (V8), radio frequency identification (RFID) (V9), Electronic Data Interchange (EDI) (V10), Material Requirement Planning (MRP) (V11), Voice Technology (V12), E-Sourcing (V13), Internet/Web (V14), Smart Data (V15), E-requisition (V16)*

*Source: Author's computation 2020*

**Table 8. The total relation matrix**

| | V1 | V2 | V3 | V4 | V5 | V6 | V7 | V8 | V9 | V10 | V11 | V12 | V13 | V14 | V15 | V16 | Ri |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| V1 | 0.18 | 0.22 | 0.25 | 0.28 | 0.25 | 0.28 | 0.27 | 0.24 | 0.23 | 0.22 | 0.26 | 0.23 | 0.24 | 0.19 | 0.24 | 0.21 | 3.77 |
| V2 | 0.26 | 0.22 | 0.25 | 0.33 | 0.29 | 0.34 | 0.29 | 0.32 | 0.26 | 0.27 | 0.30 | 0.27 | 0.30 | 0.24 | 0.30 | 0.29 | 4.50 |
| V3 | 0.24 | 0.23 | 0.20 | 0.32 | 0.28 | 0.32 | 0.29 | 0.27 | 0.24 | 0.24 | 0.27 | 0.24 | 0.26 | 0.22 | 0.29 | 0.25 | 4.16 |
| V4 | 0.30 | 0.29 | 0.30 | 0.32 | 0.32 | 0.38 | 0.33 | 0.31 | 0.28 | 0.29 | 0.35 | 0.34 | 0.34 | 0.28 | 0.34 | 0.34 | 5.11 |
| V5 | 0.23 | 0.25 | 0.27 | 0.30 | 0.20 | 0.29 | 0.27 | 0.26 | 0.22 | 0.24 | 0.25 | 0.25 | 0.23 | 0.20 | 0.24 | 0.25 | 3.96 |
| V6 | 0.29 | 0.31 | 0.31 | 0.41 | 0.32 | 0.32 | 0.34 | 0.35 | 0.32 | 0.33 | 0.32 | 0.32 | 0.31 | 0.29 | 0.33 | 0.31 | 5.16 |
| V7 | 0.26 | 0.28 | 0.27 | 0.34 | 0.28 | 0.32 | 0.24 | 0.28 | 0.26 | 0.26 | 0.27 | 0.28 | 0.27 | 0.24 | 0.29 | 0.27 | 4.41 |
| V8 | 0.25 | 0.27 | 0.25 | 0.32 | 0.26 | 0.32 | 0.29 | 0.23 | 0.25 | 0.25 | 0.27 | 0.28 | 0.28 | 0.24 | 0.29 | 0.28 | 4.32 |
| V9 | 0.23 | 0.24 | 0.22 | 0.31 | 0.25 | 0.32 | 0.28 | 0.26 | 0.19 | 0.22 | 0.25 | 0.25 | 0.28 | 0.21 | 0.25 | 0.24 | 3.99 |
| V10 | 0.21 | 0.22 | 0.22 | 0.29 | 0.26 | 0.31 | 0.27 | 0.23 | 0.20 | 0.18 | 0.25 | 0.25 | 0.25 | 0.20 | 0.24 | 0.23 | 3.78 |
| V11 | 0.30 | 0.28 | 0.26 | 0.37 | 0.27 | 0.35 | 0.30 | 0.30 | 0.28 | 0.27 | 0.25 | 0.29 | 0.32 | 0.26 | 0.31 | 0.29 | 4.69 |
| V12 | 0.26 | 0.27 | 0.25 | 0.37 | 0.29 | 0.35 | 0.30 | 0.32 | 0.27 | 0.26 | 0.32 | 0.23 | 0.29 | 0.24 | 0.31 | 0.26 | 4.59 |
| V13 | 0.25 | 0.25 | 0.23 | 0.33 | 0.26 | 0.30 | 0.28 | 0.28 | 0.27 | 0.25 | 0.30 | 0.25 | 0.22 | 0.24 | 0.30 | 0.26 | 4.25 |
| V14 | 0.19 | 0.22 | 0.22 | 0.30 | 0.22 | 0.28 | 0.24 | 0.26 | 0.22 | 0.21 | 0.25 | 0.23 | 0.24 | 0.16 | 0.26 | 0.23 | 3.72 |
| V15 | 0.21 | 0.21 | 0.22 | 0.30 | 0.21 | 0.26 | 0.25 | 0.23 | 0.22 | 0.21 | 0.25 | 0.22 | 0.27 | 0.20 | 0.20 | 0.23 | 3.69 |
| V16 | 0.18 | 0.22 | 0.19 | 0.30 | 0.21 | 0.29 | 0.22 | 0.25 | 0.22 | 0.21 | 0.25 | 0.21 | 0.22 | 0.19 | 0.24 | 0.18 | 3.59 |
| Ci | 3.82 | 3.98 | 3.90 | 5.19 | 4.16 | 5.02 | 4.45 | 4.37 | 3.93 | 3.90 | 4.39 | 4.13 | 4.32 | 3.60 | 4.42 | 4.12 | |

*Note: Inventory mgt. (V1), advanced planning sys. (V2), automated guided vehicle sys. (V3), order fulfillment (V4), automated identification & data collection (V5), Real time online tracking (V6), customer relationship mgt. (V7), delivery planning & coordination (V8), radio frequency identification (RFID) (V9), Electronic Data Interchange (EDI) (V10), Material Requirement Planning (MRP) (V11), Voice Technology (V12), E-Sourcing (V13), Internet/Web (V14), Smart Data (V15), E-requisition (V16)*

*Source: Author's computation 2020*

The sums of rows and columns of matrix T were calculated by using Eq. (vi) to Eq. (vii) as shown in Table 9.

## 3. RESULTS AND DISCUSSION

This study combines Fuzzy System Theory and DEMATEL method to develop a systematic analytical impact of IT innovation on the supply chain management of food industry. The degree of central role (D*i* + R*i*) in DEMATEL represents the strength of influences of IT innovation on Supply Chain Management of Food Industry. On the other hand, if (D*i* - R*i*) is positive, then the IT innovation *i* dispatches the influence to other IT innovation on supply chain more than it impact. If (D*i* - R*i*) is negative, the IT innovation *i* receives the influence from other IT innovations more on supply chain.

However, in this paper sixteen (16) variables were characterized and presented according to prominence (D + R) and relation (D – R), as presented in Table and figure the essence is to understand their directions and degrees of interactive influence.

The assessment criteria Advanced planning system (v2), Automated guided vehicle system (V3), Real time online tracking (V6), RFID (V9), MRP (V11), Voice technology (V12), and Internet/Web (V14) are classified into the cause criteria group, while effect criteria group includes Inventory Management (V1), Order fulfillment (V4), AIDC (V5), Customer relationship management (V7), Delivery Planning & Coordination (V8), EDI (V10), E-Sourcing (V13), Smart Data (V15) and E-requisition (V16) which need to be improved. Since cause factors influence the effect group criteria, they should be the focus. The cause group criteria refer to the implication of the influencing criteria, while the effect group criteria refer to the implication of the influenced criteria. Considering the interdependence among factors, much attention should be paid to the cause group criteria related to their influence on the effect group criteria (Gabus and Fontela, 1976).

However, advanced planning system (V2), real time online tracking (V6), customer relationship management (V7), MRP (V11) and Voice Technology (V12) are variables with high prominence and high relation these variables are characterised as reason variables, are the core variables influencing other variables, and are the driving factors for resolving problems. While, order fulfillment (V4), Delivery Planning & Coordination (V8) and E-Sourcing (V13) are variables with high prominence and low relation. These variables influence a minority of the other variables and the degree of influence is low. Whereas, variables with low prominence and high relation are characterized as result variables, are influenced by other variables and cannot be directly improved this category comprised Internet/Web (V14), RFID (V9) and automated guided vehicle system (V3). Variables with low relation and low prominence: comprises of Inventory Management (V1), EDI (V10), E-requisition (V16), reduction in operational costs (V5) and Smart Data (V15). These variables are influenced by other variables; however, the degree of influence is extremely low, suggesting that they are relatively independent.

Graphic representation (prominence-causal diagram) and diagram relations are now being constructed. This stage will allow a better visualization of the structure and relationships amongst the IT innovation and Supply Chain Management of Food Industry. One of the first task of this sub-step is to plot the various IT innovation variables on a two-axes the prominence horizontal axis (R+D) and the net cause/effect vertical axis (R-D). We do this to help us observe general patterns and relationships amongst all the innovations simultaneously and in pairs. For instance, we see that V16 have very little influence/effect on the other programs, and is more of an effect or influenced by others.

The development of the digraphs in Fig. 2 shows the interrelationships amongst each of the individual supplier selection criteria. We can also observe general clusters into cause and effect groups. Generally the IT innovation criteria that are part of the effect cluster include V1, V4, V5, V7, V8, V10, V13, V15 and V16; the cause cluster includes V2, V3, V6, V9, V11, V12 and V14.The causal relationships among IT innovation criteria can be depicted as the causal diagram (Fig. 2). This figure showed that Advanced Planning System is the most influence and the strongest connection to other criteria.

The outcome of this research in effect corroborated similar findings of [44] they concluded in there research that It is possible for businesses to improve their treatment of delivery deadlines, fines and special freights reduction, raw materials, WIP, and finished goods stocks reduction, reduction in production lead times,

**Table 9. The degree of central role (D + R)**

| Variables | Ri | Ci | Ri + Ci | Ri - Ci | Identify |
|---|---|---|---|---|---|
| V1 | 3.77 | 3.82 | 7.59 | -0.05 | effect |
| V2 | 4.5 | 3.98 | 8.48 | 0.52 | cause |
| V3 | 4.16 | 3.9 | 8.06 | 0.25 | cause |
| V4 | 5.11 | 5.19 | 10.3 | -0.07 | effect |
| V5 | 3.96 | 4.16 | 8.12 | -0.2 | effect |
| V6 | 5.16 | 5.02 | 10.18 | 0.13 | cause |
| V7 | 4.41 | 4.45 | 8.86 | -0.04 | effect |
| V8 | 4.32 | 4.37 | 8.69 | -0.05 | effect |
| V9 | 3.99 | 3.93 | 7.92 | 0.06 | cause |
| V10 | 3.78 | 3.9 | 7.69 | -0.12 | effect |
| V11 | 4.69 | 4.39 | 9.07 | 0.3 | cause |
| V12 | 4.59 | 4.13 | 8.72 | 0.47 | cause |
| V13 | 4.25 | 4.32 | 8.57 | -0.06 | effect |
| V14 | 3.72 | 3.6 | 7.32 | 0.11 | cause |
| V15 | 3.69 | 4.42 | 8.11 | -0.72 | effect |
| V16 | 3.59 | 4.12 | 7.71 | -0.54 | effect |

*Source: Author's computation 2020*

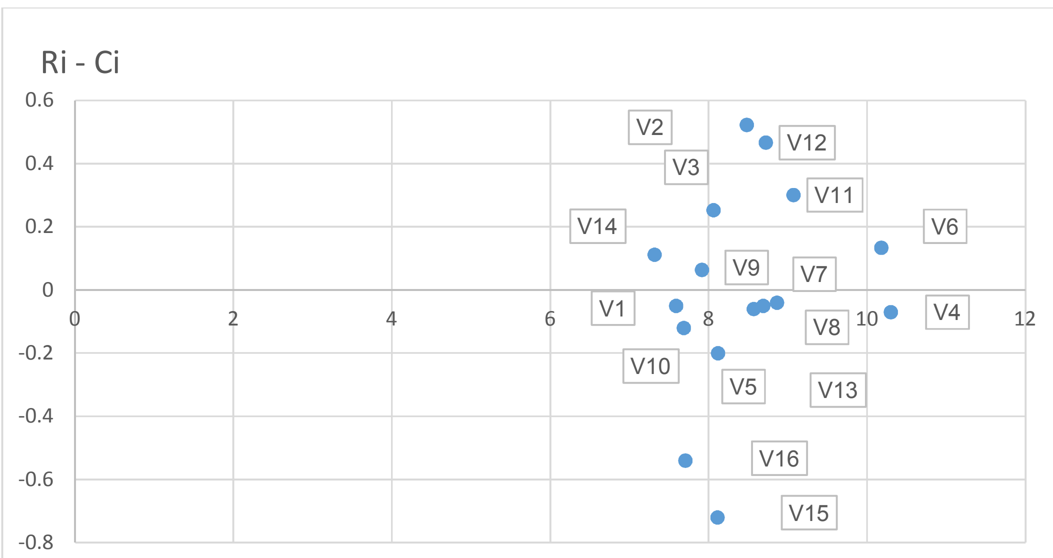


**Fig. 2. Cause and effect diagram**

better customer service, productivity and overall efficiency of productive resources, purchases and hiring of outsourced resources through implementing APS.

## 4. CONCLUSION

This study applied DEMATEL method not only to analyse the impact of IT innovation on supply chain management, consisting of sixteen criteria for food industry but also describe the cause and effect relationship among them. Technology has the potential to boost profitability and productivity by enhancing supply chains. More competition is growing between supply chains than between individual businesses, and technology has undoubtedly played an integral role. Firms in the food industry must weigh the cause and the effect before deciding if a certain technology is appropriate for their given business model. From the fuzzy DEMATEL results, we can understand that Advanced Planning System could directly or indirectly influence many other characteristics such as packaging, fleet delivery management, inventory control system, transportation and delivery scheduling. APS therefore, constitute crucial reason criteria, and core criteria influencing other criteria, and the driving factors for resolving problems.

The time and effort taken to evaluate these strategies is a major limitation. Each expert had to complete over 250 comparisons for this report. Fatigue is a real possibility, and it can lead to some reliability issues. Other multiple attribute decision-making strategies that could be used to rate the importance of supply chain variables include PROMETHEE, VIKOUR, ELECTRE, and TOPSIS.

Further research may be the application of these methods to other manufacturing sectors such as brewery, conglomerate etc. and comparing the SC management operations of each of these companies with each other. Finally, adding more alternative variables in the SC may serve another avenue for future research, though it may increase computational difficulties. In a decision-making process, the use of linguistic variables in decision problems is highly beneficial when performance values cannot be expressed by means of crisp values. In this paper, we present Fuzzy DEMATEL as a generalized method to identify the most important variables under a fuzzy environment

## CONSENT

As per international standard or university standard, respondents' written consent has been collected and preserved by the author(s).

## COMPETING INTERESTS

Author has declared that no competing interests exist.

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