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A Decision Making Model for the Evaluation of Supply Chain Execution and Management Systems

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Abstract

A Supply Chain Execution and Management (SCEM) system is an enterprise application that integrates all of the necessary supply chain functions into a single system. These functions range from common ones such as warehouse and transportation management to less known ones such as demand management. In order to execute and manage the supply chain processes successfully, organisations need a comprehensive evaluation approach to determine the most suitable system. The evaluation of an SCEM system involves numerous decision making criteria. Moreover, it is usually characterised with uncertainty and vagueness since it is very difficult to rate SCEM system alternatives with exact terms. To cope with this problem, a fuzzy logic-based approach is developed in this study. This approach main integrates the Fuzzy Analytic Hierarchy Process to weight the decision criteria and the Fuzzy Technique for Order Preference by Similarity to Ideal Solution to rate alternatives. A real life example is provided to demonstrate the capability of the proposed approach.

Keywords: Supply Chain Execution and Management System, F-MADM, F-AHP, F-TOPSIS.

1. Introduction

The main objective of this paper is to propose a systematic evaluation model to help the members of supply chains for the selection of the most appropriate Supply Chain Execution and Management (SCEM) system among a set of available alternatives. The study considers supply chain modules as criteria while evaluating SCEM systems. These criteria are derived from the literature and an industrial analysis. According to our knowledge, the approach of considering modules as criteria has not been followed before. The best SCEM system selection problem is both a Multi-Attribute Decision Making (MADM) problem where many criteria should be considered in the decision-making, and a problem containing subjectivity, uncertainty and ambiguity in the assessment process. Therefore, this study makes use of a MADM method to determine the importance weights of evaluation criteria, and fuzzy logic to obtain the performance ratings of the feasible alternatives in linguistic values.

Supply chain is a field where structural changes occur frequently. Uncertainty arises and continuous planning is required due to those changes in the processes of the supply chain. Therefore supply chain management (SCM) is coming under scrutiny to try to achieve this competitive advantage as it provides many opportunities for reducing operating costs and improving customer service and satisfaction.[1] Hence, dynamic and integrated management systems are necessary to cope with this continuous change. Managers are required to choose the proper level of integration for particular relationships in the supply chain and the appropriate degree of information sharing.[2] An SCEM system is a business system that integrates a company's internal resources to manage and work with the external supply chain. In this sense, correct decisions would be taken with the right management systems. Based on their organisational structure and business diversity, firms use management systems to not only identify correct investments and reduce costs, but also to increase their efficiency. This organisational nature of supply chain makes systems evaluation, selection, and implementation more complex. The basic reason to use an SCEM system is to support all planning and execution functions required for the supply chain.[3,4] The major aims of SCEM system are to reduce supply chain risk, reduce production costs, maximise revenue, improve customer service, optimise inventory levels, business processes, and cycle times, and result in increased competitiveness, customer satisfaction and profitability.[5,6] These systems also provide platforms for fast and reliable operations between trading partners, regardless of any physical barriers.

The supply chain software market has risen to the challenge of complexity in the supply chain by making its SCM solutions more and more complex, often to the detriment of the very efficiency and cost-effectiveness that supply chain users need. Such system packages cost hundreds of thousands or even millions of dollars, making purchasing a system solution a high expenditure activity that consumes a significant portion of companies' capital budgets.[7] Companies have trouble finding the return on investment for these massive supply chain projects. The evaluation of those systems is a very complicated and costly task, and their inappropriate use may lead the firm to bankruptcy. Consequently, the selection of those management systems involves a complex decision process, and detailed analysis supported with analytical methods is needed. Hence, firms should evaluate their SCEM system with appropriate criteria and implement it properly to increase performance and efficiency. In addition, with new standards, processes, and a continuously developing technology, the evaluation process becomes more elaborative and dynamic.[8]

Selecting the right solution is an exhausting process for companies. Therefore, evaluating a system that meets the requirements needs a full examination of many conflicting factors, which is a difficult task. This has led researchers to investigate better ways of evaluating and selecting those systems. Early studies show us that the selection processes of these systems have been studied many times considering different methodologies and criteria. SCEM systems are relatively related to ERP and SCM systems. Hence, we have to review those system evaluation approaches and criteria to better understand the originality of this paper. A number of methods have been applied to ERP, SCM or other information system selections, including scoring, ranking, mathematical optimisation, and multi-criteria decision analysis.[5,9-16] However, an SCEM system evaluation problem is not considered in a module-based multi-criteria decision making framework in the existing literature. This paper models a MADM method for SCEM system evaluation. The method is an F-AHP & F-TOPSIS integrated decision-making approach. A fuzzy logic approach was adopted due to subjective considerations of human judgments. A multi-stage MADM method was used, including F-AHP to determine the relative weights of evaluation criteria, and F-TOPSIS to rank the alternatives.

The rest of the paper is structured as follows: We present a brief literature review on SCEM system modules in Section 2. In Section 3, we provide the details of our evaluation approach which integrates F-AHP and F-TOPSIS methods. How the proposed approach can be used to evaluate real world examples is discussed in Section 4. Finally, the last section contains some conclusions and suggestions.

2. Literature Review on SCEM Systems Modules

We conducted an extensive review of the current literature on supply chain execution and management system modules. Most of the reviewed articles focus on the different types of measures, such as strategic, tactical and operational, tangible, intangible, financial and non-financial. Some articles focus on the techniques and tools used in evaluating information system projects and investments. The articles that mention the modules that are used in supply chain management are given in Table 1.

Table 1 Supply Chain Modules

Modules and sub-modules /Authors	Simpson and Erenguc[17]	Berkelaar et al.[18]	Downs[19]	Lee et al.[20]	Meyr et al.[21]	Whitehair and Berg[22]	Boyson et al.[23]	Caputo et al.[24]	Fleischmann and Meyr[25]	Sahay and Gupta[26]	Stadtler[27]	Disney et al.[28]	Arbib and Marinelli[29]	Dellaert and Jeunet[30]	Helo and Szekely[31]	Nilsen and Larsen[32]	Persson and Gothe[33]	Spitter et al.[34]	Lancester et al.[35]	Karkkainen et al.[36]
Accounting standards						•														
Advanced planning system				•		•				•	•	•						•		
Available to promise					•		•		•		•						•			
Bar-coding							•							•					•	
Catalogue management																			•	
Collaboration										•	•	•								•
Customer service										•		•							•	
Decentralisation											•									
Delivery coordination																				•
Demand fulfilment			•		•				•		•						•			
Demand planning					•					•	•							•		
Distribution planning	•			•	•					•				•			•			•
Event-based planning											•									
Finance control															•					
Fleet size								•												
Forecasting												•								
Human resources															•					
Inventory control																•			•	
Inventory management							•			•						•			•	
Lead times		•													•			•		
Logistics Planning								•												
Lot sizing optimisation		•													•					
Marketing																			•	
Master planning	•	•	•		•						•		•				•	•		
Material handling															•					
Material requirement planning					•		•				•			•	•			•		
Transportation control															•					
Order flow															•					
Order promising			•						•	•			•		•		•	•		
Order tracking															•					•
Procurement				•																
Production planning	•				•						•							•		
Purchasing				•			•									•				
Real time information															•					
Route Planning															•					
Scheduling		•		•	•					•	•	•	•				•			
Service demand								•												
Shortage planning													•					•		
Shipment planning													•							
Supplier management										•										
Supply chain planning				•						•									•	•
Supply chain design										•										
Strategic network planning					•															
Transportation planning	•				•			•										•		
Transaction process															•				•	•
Uncertainty											•				•					
Vehicle routing								•												
Vehicle type								•												

3. Methodology of the Research

MADM is a methodology that helps decision-makers when making preference decisions regarding a finite set of available alternatives characterised by multiple potentially conflicting attributes.[37] The typical multi-attribute evaluation problem focuses on a set of feasible alternatives and considers more than one criterion to determine a priority ranking for alternative implementation. MADM involves three phases; firstly, the information about attribute weights and attribute values needs collecting; secondly, weighted aggregation of the attribute values across all attributes for each alternative is performed to obtain an overall value; thirdly, the overall values are ordered to obtain the best alternatives.[38] In MADM, each criterion needs to be compared with other criteria in terms of their relative importance for achieving the overall objective of the problem.[39] However, in many cases, the preference model of the human decision maker is uncertain, and it is relatively difficult to provide exact numerical values for the comparison ratios. To cope with uncertain judgments expressions, the ratios were fuzzy sets, which incorporate the vagueness of human thinking. Linguistic variables are very useful in dealing with uncertain and inaccurate factors involved in complex group decision situations.[40] In fuzzy decision-making, alternatives can be evaluated by using quantitative and/or qualitative variables. As fuzzy models can use both of these types of variable, they are more flexible than other decision-making models.

3.1. *The Fuzzy Logic*

The underlying logic of linguistic approach is that the truth values are fuzzy sets and the rules of inference are approximate rather than exact. Fuzzy logic allows us to make rational decisions in an environment of uncertainty, fuzziness and imprecision without losing the richness of verbal judgment. We consider a triangular type of fuzzy number as a well-known application. The membership function for a triangular fuzzy number (TFN) is the triangular shape, which can be presented by a triplet (*l, m, u*), indicating the lower limit of support, the mode (core) and the upper limit of support. They are the most common fuzzy numbers, and the main reason for using them is that decision makers find them intuitively easy to use.[39] TFN's membership function is defined as:

$$\mu_{\tilde{A}}(x)=\begin{cases}\dfrac{x-l}{m-l}, & l\le x\le m\\ \dfrac{u-x}{u-m}, & m\le x\le u\\ 0, & otherwise\end{cases} \qquad (1)$$

where $l \le m \le u$; l and u stand for the lower and upper value of the support of A, respectively; m is the most possible value of fuzzy number A. When $l = m = u$, it is a non-fuzzy number by convention.[10] We assume that $-\infty < l \le m \le u < \infty$. The operational laws of two TFNs

$\tilde{A}_1=(l_1,m_1,u_1)$ and $\tilde{A}_2=(l_2,m_2,u_2)$ as shown:

Fuzzy number addition and subtraction:

$$\tilde{A}_1 \mp \tilde{A}_2=(l_1,m_1,u_1)\mp(l_2,m_2,u_2)=(l_1\mp l_2, m_1\mp m_2, u_1\mp u_2) \qquad (2)$$

Fuzzy number multiplication:

$$\tilde{A}_1 \otimes \tilde{A}_2=(l_1,m_1,u_1)\otimes(l_2,m_2,u_2)=(l_1\times l_2, m_1\times m_2, u_1\times u_2) \qquad (3)$$

Fuzzy number inversion:

$$\tilde{A}^{-1}=(l,m,u)^{-1}\cong\left(1/u, 1/m, 1/l\right) \text{ for } l,m,u>0 \qquad (4)$$

Overall, the SCEM system evaluation procedure contains subjective judgments including vague and imprecise information. These kinds of processes make fuzzy logic necessary for SCEM system evaluation. Fuzzy MADM methods are used in this paper to compute ratings for vendors.

3.2. *Extended F-AHP and F-TOPSIS Integrated Approach*

The proposed approach incorporates the following elements: it can handle uncertain information, which is gathered in linguistic terms; decision making can be conducted by the decision makers in an integrated hierarchy; and alternatives are evaluated along a hierarchy. The F-AHP phase applies the fuzzy set theory to construct the pair-wise comparisons of the AHP by transforming linguistic judgments into fuzzy numbers to calculate and integrate the weights of the criteria. These weights are then used to rank the alternatives in the F-TOPSIS phase. An AHP and

TOPSIS integrated model has been applied to various decision-making problems.[41-42]

3.2.1. *F-AHP Phase*

The AHP has been widely used for the evaluation of software packages[43], and was first introduced by Saaty[44], making it one of the most used multi-criteria decision making methods. AHP incorporates the evaluations of all decision makers into a final decision by pair-wise comparisons of the alternatives, without having to elicit their utility functions on subjective and objective criteria.[44] Many researchers have studied on software evaluation applications of fuzzy AHP[43] and several models are constructed in relation with the evaluation of supply chain systems. F-AHP has been used to help experts to evaluate a knowledge portal[49], to evaluate IT departments[50], to select a suitable ERP system for the textile industry[11], to classify inventories[51], to estimate the relative importance strategic factors involved in the decision making process of adopting third party e-markets[52], and to develop radio frequency identification technology in logistics and supply chain management.[42]

The F-AHP methodology steps:

Step 1. Structure problem hierarchy: The first step of the methodology is to construct a problem into a hierarchy, including a goal, set of criteria, and set of alternatives. The general hierarchy structure of F-AHP is shown as Figure 1. The highest level of the hierarchy (level 1) consists of only one element, an object or a goal, that the decision maker wants to reach. The lower levels (level 2) of the hierarchy contain criteria (attributes), which contribute to the goal. The process may continue down to criteria that are more detailed at level 3. The last level of the hierarchy, level 4, includes decision alternatives, which are to be evaluated in terms of the criteria of the upper level.

Step 2. Construct pair-wise comparisons: It is very difficult to reasonably express those situations that are overtly complex or hard to define with conventional quantification; therefore, the notion of a linguistic variable is necessary in such situations. A linguistic variable is a variable whose values are words or sentences in a natural or artificial language. In this paper, we use the linguistic scales shown in Table 2.

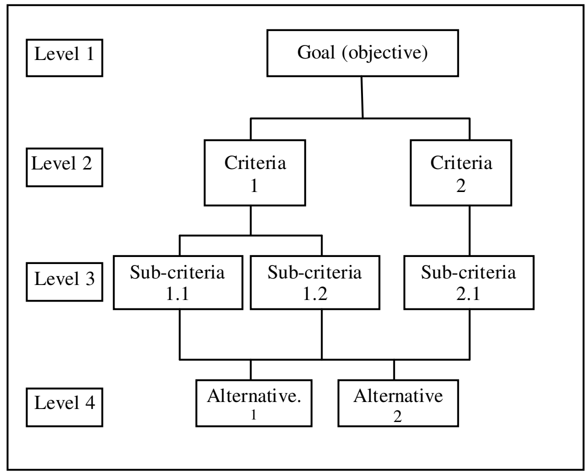

Figure 1 The construct of fuzzy pair-wise comparison matrices

Step 3. Transform Linguistic Judgments into Fuzzy Numbers: After the decision makers complete the assigning of linguistic judgment in the pairwise comparison matrix in step 2, the linguistic judgment is transformed into a fuzzy number. In this paper, the computational technique is based on the fuzzy numbers defined in Table 2. Here, each membership function (scale of fuzzy number) is defined by three parameters of the symmetrical triangular fuzzy number: the left point, middle point and right point of the range over which the function is defined.

Table 2 Membership function of linguistic scale

Fuzzy number	Linguistic scales	Scale of fuzzy number
$\tilde{1}$	Equally important (Eq)	(1, 1, 3)
$\tilde{2}$	Weakly important (Wk)	(1, 3, 5)
$\tilde{3}$	Essentially important (Es)	(3, 5, 7)
$\tilde{4}$	Very strongly important (Vs)	(5, 7, 9)
$\tilde{5}$	Absolutely important (Ab)	(7, 9, 9)

Linguistic terms are assigned to the pairwise comparisons by asking which is the more important of each two criteria, such as:

$$A = \begin{bmatrix} 1 & \tilde{b}_{12} & \cdots & \tilde{b}_{1n} \\ \tilde{b}_{21} & 1 & \cdots & \tilde{b}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{b}_{n1} & \tilde{b}_{n2} & \cdots & 1 \end{bmatrix} \quad (5)$$

$$= \begin{bmatrix} 1 & \tilde{b}_{12} & \cdots & \tilde{b}_{1n} \\ 1/\tilde{b}_{12} & 1 & \cdots & \tilde{b}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/\tilde{b}_{1n} & 1/\tilde{b}_{2n} & \cdots & 1 \end{bmatrix} \quad (6)$$

where

$$\tilde{b}_{ij} = \begin{cases} \tilde{1}, \tilde{3}, \tilde{5}, \tilde{7}, \tilde{9} & \text{criterion } i \text{ is relatively more important than criterion } j, \\ 1 & i = j, \\ \tilde{1}^{-1}, \tilde{3}^{-1}, \tilde{5}^{-1}, \tilde{7}^{-1}, \tilde{9}^{-1} & \text{criterion } i \text{ is relatively less important than criterion } j \end{cases}$$

Triangular fuzzy numbers are substituted into the pair-wise comparison matrix to deal with criteria measurements and determine the fuzzy consensus problem in judgment.[45,46] A geometric mean is used for aggregating the judgments of each group member found in pairwise comparison matrices. This approach is used when individuals are willing to relinquish their own preferences for the good of the organisation.[47]

From each decision maker's questionnaire results, we establish fuzzy weights for control criteria according to the membership functions. The geometric mean of the decision makers' evaluations forms the consensus in this paper, and is established as follows:

$$\tilde{a}_{ij} = \left(l_{ij}, m_{ij}, u_{ij}\right) \quad (7)$$

$l_{ij} \le m_{ij} \le u_{ij}$ and $l_{ij}, m_{ij}, u_{ij} \in [1/9, 1] \cup [1, 9]$.

$$l_{ij} = \left(\prod_{k=1}^{n} B_{ijk}\right)^{1/n}, \quad (8)$$

$$m_{ij} = \left(\prod_{k=1}^{n} B_{ijk}\right)^{1/n}, \quad (9)$$

$$u_{ij} = \left(\prod_{k=1}^{n} B_{ijk}\right)^{1/n}. \quad (10)$$

where B_{ijk} represents a judgment of decision maker k for the relative importance of two criteria, *i-j*.

Step 4. Check the Consistency: Different methods for computing the consistency ratio can be found in the literature; however, the algorithm proposed by Mikhailov[48] is preferred. According to this algorithm, if the eigenvalue computed for pairwise comparison matrices consisting of fuzzy numbers is between 0 and 1, the matrix is assumed to be consistent, and if the eigenvalue is less than 0 the matrix is assumed to be inconsistent.

Step 5. Calculate the Fuzzy Weight Vectors: We define the fuzzy geometric mean and fuzzy weights of each criterion as follows:

$$\tilde{r}_i = \left(\tilde{a}_{i1} \otimes \tilde{a}_{i2} \otimes \ldots \otimes \tilde{a}_{in}\right)^{1/n}, \quad (11)$$

$$\tilde{w}_i = \tilde{r}_i \otimes \left(\tilde{r}_1 \oplus \ldots \oplus \tilde{r}_n\right)^{-1}, \quad (12)$$

where $\tilde{a}_{in}$ is fuzzy comparison value of criterion i to criterion n; thus, $\tilde{r}_i$ is geometric mean of fuzzy comparison value of criterion i to each criterion;, $\tilde{w}_i$ is the fuzzy weight of the i^{th} criterion, and can be indicated by a TFN, $\tilde{w}_i = \left(lw_i, mw_i, uw_i\right)$. Here lw_i, mw_i and uw_i stand for the lower, middle and upper values of the fuzzy weight of the i^{th} criterion. Calculations are performed for each criterion (for both the main and secondary criteria), then the global weights are found by multiplying the main criterion fuzzy weight to each secondary-criterion weight that is connected to the main criterion fuzzy weight. The fuzzy weights of alternatives derived from the F-AHP process are used as parameters for goal constraints in the F-TOPSIS.

3.2.2. *F-TOPSIS Phase*

The basic principle of this approach is that the chosen alternative should have the shortest distance from the ideal solution and farthest distance from the negative-ideal solution.[53] TOPSIS views a MADM problem with t alternatives as a geometric system, with t points in the n-dimensional space.[54] The implementation of an enhanced TOPSIS model is based on the concept that the chosen SCEM system alternatives should be the shortest distance from the ideal solution and the farthest from the negative-ideal solution. The advantages of using the F-TOPSIS concept have been highlighted by its intuitively appealing logic, its simplicity and comprehensibility, its computational efficiency, its ability to measure the relative performance of the alternatives with respect to individual or all evaluation criteria in a simple mathematical form, and its applicability in solving various practical MADM problems.[55,56]

F-TOPSIS methodology steps:

Step 1. Determine the weights of the evaluation criteria: the overall weights of various criteria have been considered with the F-AHP method to conduct the F-TOPSIS phase.

Step 2. Choose the appropriate linguistic variables for the alternatives with respect to criteria: The linguistic variables are described by TFNs, such as $\tilde{x}_{ij} = \left(a_{ij}, b_{ij}, c_{ij}\right)$ in Table 3.

Table 3 Linguistic variables for the preference rating of alternatives

Linguistic variable	Corresponding triangular fuzzy numbers
Very poor (VP)	(0.0, 0.0, 0.2)
Poor (P)	(0.0, 0.2, 0.4)
Fair (F)	(0.3, 0.5, 0.7)
Good (G)	(0.6, 0.8, 1.0)
Very Good (VG)	(0.8, 1.0, 1.0)

Then, the fuzzy calculations are performed in a fuzzy decision matrix as follows:

$$\tilde{D} = \begin{matrix} & \begin{matrix} C_1 & C_2 & \dots & C_n \end{matrix} \\ \begin{matrix} A_1 \\ A_2 \\ \vdots \\ A_m \end{matrix} & \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{bmatrix} \end{matrix}, \; i = 1, 2, ..., m; \; j = 1, 2, ..., n \quad (13)$$

$$\tilde{x}_{ij} = \frac{1}{k} \left(\tilde{x}_{ij}^1 + \tilde{x}_{ij}^2 + \dots + \tilde{x}_{ij}^k \right) \quad (14)$$

where $\tilde{x}_{ij}^k$ is the rating of alternative A_i with respect to criteria C_j evaluated by decision maker *k*,
and $\tilde{x}_{ij}^k = \left(a_{ij}^k, b_{ij}^k, c_{ij}^k\right)$.

Step 3. Construct the fuzzy decision matrix and the normalised fuzzy decision matrix: The aim here is to transform the various criteria scales into a comparable scale. Therefore, we can obtain the normalised fuzzy decision matrix denoted by $\tilde{R}$:

$$\tilde{R} = \left[\tilde{r}_{ij} \right]_{m \times n} \; i = 1, 2, \dots, m; \; j = 1, 2, \dots, n. \quad (15)$$

The normalisation process can then be performed using the following formula:

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*} \right), \quad (16)$$

$$c_j^* = \max_i c_{ij}. \quad (17)$$

The normalised $\tilde{r}_{ij}$ are still triangular fuzzy numbers.

Step 4. Construct the weighted normalised fuzzy decision matrix: The normalisation method mentioned above is used to preserve the property to which the ranges of normalised TFNs belong [0,1]. Considering the different importance of each criterion, we can construct the weighted normalised fuzzy decision matrix as:

$$\tilde{V} = \left[\tilde{v}_{ij} \right]_{m \times n}, \; i = 1, 2, \dots, m; \; j = 1, 2, \dots, n \quad (18)$$

and

$$\tilde{v}_{ij} = \tilde{r}_{ij} \times \tilde{w}_j \quad (19)$$

as well as $\tilde{w}_j$ global TFN weights, as defined in Eq. (12) that are calculated in F-AHP phase.

Step 5. Determine the fuzzy positive-ideal solution (FPIS) and fuzzy negative-ideal solution (FNIS): According to the weighted normalised fuzzy decision matrix, we know that the elements $\tilde{v}_{ij}$ are normalised positive TFNs and their ranges belong to the closed interval [0,1]. Therefore, we can define the FPIS A^* and A^- using the following formulae:

$$A^* = \left(\tilde{v}_1^*, \tilde{v}_2^*, \dots, \tilde{v}_n^* \right) \quad (20)$$

and

$$A^- = \left(\tilde{v}_1^-, \tilde{v}_2^-, \dots, \tilde{v}_n^- \right) \quad (21)$$

where $\tilde{v}_j^* = w_j \times (1,1,1)$ and $\tilde{v}_j^- = w_j \times (0,0,0)$ for all *j* = 1, 2, …, *n*. (22)

Step 6. Calculate the distance of each alternative from FPIS and FNIS: The distances (d_i^* and d_i^-) of each alternative from A^* and A^- can be currently calculated by the vertex method, which is calculated as follows:
Let $\tilde{a} = (a_1, a_2, a_3)$ and $\tilde{b} = (b_1, b_2, b_3)$ be two triangular fuzzy numbers,

$$d\left(\tilde{a}, \tilde{b}\right) = \sqrt{\frac{1}{3} \left[(a_1 - b_1)^2 + (a_2 - b_2)^2 + (a_3 - b_3)^2 \right]} \quad (23)$$

then,

$$d_i^* = \sum_{j=1}^{n} d\left(\tilde{v}_{ij}, \tilde{v}_j^* \right), \; i = 1, 2, \dots, m \quad (24)$$

and

$$d_i^- = \sum_{j=1}^{n} d\left(\tilde{v}_{ij}, \tilde{v}_j^- \right), i = 1, 2, \ldots, m \qquad (25)$$

where $d(\cdot,\cdot)$ is the distance measurement between two fuzzy numbers.

Step 7. Calculate the closeness coefficient (*CC*) of each alternative, A: *CC* is defined to determine the ranking order of all alternatives once the d_i^* and d_i^- of each alternative A_i $(i = 1, 2, \ldots, m)$ has been calculated. The *CC* of each alternative is calculated as

$$CC = \frac{d_i^-}{d_i^* + d_i^-}, i = 1, 2, \ldots, m. \qquad (26)$$

Step 8. According to the *CC*s, the ranking order of alternatives can be determined: Obviously, an alternative A_i that is closer to the FPIS (A^*) and farther from (A^-) is the best. Therefore, we can determine the ranking order of all alternatives and select the best one from a set of feasible alternatives based on the closeness coefficient.

4. Evaluating SCEM Systems

This application is realised for a manufacturing and distribution company. The company produces heavy construction equipment and is the distributor of one of the global Japanese brands with an important domestic market share in Turkey. The company is planning to purchase an SCEM system and identifying the most appropriate system is important due to the limited budget. According to the initial step in our methodology, a group of decision makers is gathered for the evaluation process. The group is composed of two industrial engineers, one supply chain executive, and a supply chain consultant. Those decision makers are capable of making decisions on SCEM systems due to their previous work experience and expertise in such systems.

The first activity of the decision makers is to identify SCEM system alternatives and the decision criteria. Among the SCEM system alternatives in the market, the decision makers have to choose system alternatives by examining vendors' capabilities. After a careful study, the group limited the list to seven alternatives (S_1, … S_7), by considering the market share of the vendors, the past records of the systems and the company needs.

Once the system alternatives are selected, decision makers have to decide on the criteria that will be used in the evaluation phase. With the contribution of the authors, a broad industry analysis and a careful inspection on the existing supply chain execution and management systems are carried by the group. Finally, the group gathers the most important and widely used criteria and secondary criteria together. The list consists of ten main criteria and sixty secondary criteria. The main criteria are Demand Management (DM), Supply Chain Optimisation (SCO), Warehouse Management System (WMS), Production and Supply Planning (PSP), Service Parts Planning (SPP), Transportation Management System (TMS), International Trade Logistics (ITL), Order Management, Supply Chain Event Management (SCE), and Supplier Relationship Management (SRM).The sixty secondary criteria are given in Appendix A together with their definitions. We refer to the SCEM system module and sub-module as the criterion and secondary criterion, respectively.

4.1.*Application of the Integrated Method*

According to our integrated decision making technique, criteria priority weights are identified with the F-AHP model and alternatives are ranked with F-TOPSIS. After the approval of the decision criteria hierarchy, weights are assigned to each criterion in SCEM system selection with F-AHP in the second stage. In this phase, pairwise comparison matrices are formed to determine the criteria weights. The decision makers made individual evaluations using the scale provided in Table 2. There are four levels in the decision hierarchy structured for SCEM system evaluation. The overall goal of the decision process is determined as the selection of the best SCEM system, and it forms the first level of the hierarchy. Criteria and secondary-criteria are second and third level and the alternative systems are on the fourth level of the hierarchy, which is given in Figure 3.

Once the pairwise comparison matrices are formed and their consistency checked, the weight of each criterion is calculated with Eq. (11) and (12). The results of this calculation or the global weights are given in Table 4. The next stage involves the decision makers evaluating the selected system alternatives. The decision makers were asked to evaluate each alternative system performance according to each criterion by using the linguistic terms given in Table 3. After this phase, we applied F-TOPSIS methodology for ranking alternative systems given the system's scores and the F-AHP weights.

As the last step, SCEM system alternatives are ranked according to their relative closeness to the ideal solution. The distances to ideal and negative-ideal solution together with *CC* values are provided in Table 5. Based on the *CC* values, the ranking of the alternatives in descending order is given in Table 6. It can be remarked that *CC* values are close to each other, but System 3 has the highest value among all of the systems. System 4 has the lowest value of 0.2520.

Table 4 Fuzzy Weights of the 60 evaluation criteria

Criteria	Local weights (TFNs)	Global weights (TFNs)	Criteria	Local weights (TFNs)	Global weights (TFNs)
DM	*(0.019, 0.045, 0.164)*		*ITL*	*(0.018, 0.046, 0.156)*	
DM1	(0.222, 0.414, 0.722)	(0.004, 0,019, 0.118)	ITL1	(0.156, 0.277, 0.451)	(0.003, 0.013, 0.070)
DM2	(0.132, 0.258, 0.501)	(0.003, 0,012, 0.082)	ITL2	(0.092, 0.150, 0.278)	(0.002, 0.007, 0.043)
DM3	(0.055, 0.088, 0.161)	(0.001, 0.004, 0.026)	ITL3	(0.152, 0.238, 0.398)	(0.003, 0.011, 0.062)
DM4	(0.055, 0.101, 0.201)	(0.001, 0.005, 0.033)	ITL4	(0.155, 0.274, 0.449)	(0.003, 0.013, 0.070)
DM5	(0.076, 0.153, 0.312)	(0.001, 0,007, 0.051)	ITL5	(0.038, 0.059, 0.103)	(0.001, 0.003, 0.016)
SCO	*(0.034, 0.076, 0.264)*		*OM*	*(0.031, 0.114, 0.270)*	
SCO1	(0.312, 0.515, 0.817)	(0.011, 0.039, 0.216)	OM1	(0.183, 0.348, 0.598)	(0.006, 0.040, 0.162)
SCO2	(0.119, 0.190, 0.302)	(0.004, 0.014, 0.080)	OM2	(0.050, 0.082, 0.157)	(0.002, 0.009, 0.042)
SCO3	(0.119, 0.226, 0.398)	(0.004, 0.017, 0.105)	OM3	(0.060, 0.092, 0.181)	(0.002, 0.010, 0.049)
SCO4	(0.065, 0.105, 0.208)	(0.002, 0.008, 0.055)	OM4	(0.076, 0.124, 0.212	(0.002, 0.014, 0.057)
WMS	*(0.064, 0.184, 0.538)*		OM5	(0.068, 0.110, 0.198)	(0.002, 0.013, 0.053)
WMS1	(0.092, 0.188, 0.367)	(0.006, 0.035, 0.197)	OM6	(0.096, 0.211, 0.411)	(0.003, 0.024, 0.111)
WMS2	(0.077, 0.168, 0.367)	(0.005, 0.031, 0.197)	*SCE*	*(0.018, 0.056, 0.165)*	
WMS3	(0.061, 0.099, 0.189)	(0.004, 0.018, 0.102)	SCE1	(0.104, 0.178, 0.284)	(0.002, 0.010, 0.047)
WMS4	(0.051, 0.088, 0.194)	(0.003, 0.016, 0.104)	SCE2	(0.044, 0.067, 0.109)	(0.001, 0.004, 0.018)
WMS5	(0.042, 0.078, 0.188)	(0.003, 0.014, 0.101)	SCE3	(0.041, 0.061, 0.096)	(0.001, 0.003, 0.016)
WMS6	(0.157, 0.326, 0.611)	(0.010, 0.060, 0,329)	SCE4	(0.016, 0.025, 0.044)	(0.000, 0.001, 0.007)
PSP	*(0.027, 0.071, 0.236)*		SCE5	(0.037, 0.055, 0.090)	(0.001, 0.003, 0.015)
PSP1	(0.194, 0.306, 0.461)	(0.005, 0.022, 0.109)	SCE6	(0.088, 0.144, 0.227)	(0.002, 0.008, 0.037)
PSP2	(0.194, 0.273, 0.384)	(0.005, 0.019, 0.091)	SCE7	(0.040, 0.059, 0.090)	(0.001, 0.003, 0.015)
PSP3	(0.113, 0.191, 0.348)	(0.003, 0.014, 0.082)	SCE8	(0.104, 0.178, 0.248)	(0.002, 0.010, 0.047)
PSP4	(0.053, 0.080, 0.126)	(0.001, 0.006, 0.030)	SCE9	(0.051, 0.109, 0.216)	(0.001, 0.006, 0.036)
PSP5	(0.050, 0.077, 0.122)	(0.001, 0.005, 0.029)	SCE10	(0.040, 0.056, 0.094)	(0.001, 0.003, 0.016)
PSP6	(0.025, 0.037, 0.060)	(0.001, 0.003, 0.014)	*SRM*	*(0.019, 0.064, 0.161)*	
SPP	*(0.060, 0.178, 0.511)*		SRM1	(0.029, 0.048, 0.093)	(0.001, 0.003, 0.015)
SPP1	(0.075, 0.123, 0.248)	(0.004, 0.022, 0.127)	SRM2	(0.029, 0.052, 0.105)	(0.001, 0.003, 0.017)
SPP2	(0.145, 0.245, 0.385)	(0.009, 0.044, 0.197)	SRM3	(0.045, 0.085, 0.158)	(0.001, 0.005, 0.025)
SPP3	(0.077, 0,181, 0.516)	(0.004, 0.025, 0.158)	SRM4	(0.049, 0.088, 0.163)	(0.001, 0.006, 0.026)
SPP4	(0.139, 0.239, 0.379)	(0.008, 0.043, 0.194)	SRM5	(0.074, 0.151, 0.303)	(0.001, 0.010, 0.049)
SPP5	(0.148, 0.251, 0.396)	(0.009, 0.045, 0.202)	SRM6	(0.029, 0.048, 0.093)	(0.001, 0.003, 0.015)
TMS	*(0.054, 0.167, 0.450)*		SRM7	(0.127, 0.229, 0.393)	(0.002, 0.015, 0.063)
TMS1	(0.278, 0.540, 0.959)	(0.015, 0.090, 0,432)	SRM8	(0.127, 0.248, 0.444)	(0.002, 0.016, 0.071)
TMS2	(0.153, 0.297, 0.604)	(0.008, 0.050, 0.272)	SRM9	(0.045, 0.085, 0.158)	(0.001, 0.005, 0.025)
TMS3	(0.096, 0.163, 0.333)	(0.005, 0.027, 0.150)			

Table 5 The distances of alternatives to positive / negative ideal solutions, the related closeness coefficients

Alternatives	d_i^*	d_i^-	*CC*
System 1	0.7369	0.2767	0.2720
System 2	0.8016	0.2882	0.2640
System 3	0.7338	0.2758	0.2732
System 4	0.8426	0.2832	0.2520
System 5	0.7291	0.2699	0.2700
System 6	0.7278	0.2652	0.2670
System 7	0.7456	0.2684	0.2647

Table 6 Ranking of alternatives

Rank	Alternatives	*CC*
1	System 3	0.2732
2	System 1	0.2720
3	System 5	0.2700
4	System 6	0.2670
5	System 7	0.2647
6	System 2	0.2640
7	System 4	0.2520

4.2. *Results of the integrated method and validation of the model*

Four decision makers made an evaluation with the F-AHP approach to determine criteria weights at the first phase. At the second phase, a set of seven alternatives were rated and most appropriate solution was identified with the F-TOPSIS approach. According to the F-AHP results, we are able to find the most important and the least important criteria for the selected group of experts: due to the results we can say that the most important criteria are WMS (0.064, 0.184, 0.538), SPP (0.060, 0.178, 0.511), and TMS (0.054, 0.167, 0.450) and that the least important criteria are SRM (0.019, 0.064, 0.161), DM (0.019, 0.045, 0.164), and SCE (0.018, 0.056, 0.165). While the main criteria involved ranking, secondary criteria global weights can be ranked according to importance: TMS1 (0.015, 0.090, 0.432), TMS2 (0.008, 0.050, 0.272), and SCO1 (0.011, 0.039, 0.216) and the least important secondary criteria are SCE4 (0.001, 0.003, 0.0079) and PSP6 (0.001, 0.003, 0.014) (see Table 4). The most desirable alternative corresponds to that with the highest score; System 3 (0.2732) would be declared as the most preferable and considered a possible SCEM system. Nevertheless, the alternative System 4 is the worst choice with a score of 0.2520 (Table 6).

When testing the validity of the model, it is important that the model has not been analysed using past data, due to the unavailability of past data for the particular management case under study. This problem, however, should not be viewed as a significant shortcoming when evaluating the validity of the model. The comparison matrices that are the inputs to the suggested model are defined under known conditions. Thus, it is possible to achieve different results since different pairwise comparison matrices may be obtained at different points in time.

5. Conclusion

In this study, we have proposed an effective method to rate supply chain execution and management systems by integrating F-AHP and F-TOPSIS with a comprehensive set of decision criteria. A decision making group is formed by including different managerial levels with the intention of providing a more accurate and mutually acceptable solution for the company. The importance weights of criteria and the ratings of alternatives are assessed in linguistic terms. As the integrated method gives the capacity to consider the vagueness in the evaluation process of the pairwise comparison matrices, it can provide more useful and adaptable solutions. Using this fuzzified structure also gives to the decision makers the flexibility to express their opinion more openly. Our proposed method can handle the effects of dependences; it is relatively useful and makes the evaluation result more certain. As a conclusion, comprehensive research on supply chains with an integrated fuzzy method renders this method better than other fuzzy methods. F-AHP and F-TOPSIS integrated model is preferred due to the consideration of inner dependences between secondary criteria, but effectiveness of the criteria to each other should not be ignored.

The analytical model illustrated in this paper does have a few limitations. For example, the outcome of the model is dependent on the inputs provided by the decision-makers. The possibility of bias of the decision-maker towards any particular alternative should not be ruled out while applying this model. For further research, the results of this study may be compared with the results of other fuzzy MADM methods like ORESTE, MAUT, SAW, VIKOR, ELECTRE, or PROMETHEE.

References

1. E.A. Williamson, D.K. Harrison, and M. Jordan, Information systems development within supply chain management, *International Journal of Information Management*, **24**(5) (2004).
2. R.A. Lancioni, M.F. Smith, and H.J. Schau, Strategic Internet application trends in supply chain management, *Industrial marketing Management*, **32**(3) (2003).
3. K.K. Hong and Y.G. Kim, The critical success factors for ERP implementation: An organizational fit perspective, *Information & Management*, **40** (2002).
4. C.C. Wei, C. Chien, and M.J. Wang, An AHP-based approach to ERP system selection, *International Journal of Production Economics*, **96** (2005).
5. S.Y. Chou and Y.H. Chang, A decision support system for supplier selection based on a strategy aligned fuzzy SMART approach, *Expert System with applications*, **34** (2008).
6. S.H. Ha and R. Krishnan, A hybrid approach to supplier selection for the maintenance of a competitive supply chain, *Expert Systems with Applications*, **34**(2) (2008).

7. A. Gunasekaran, E.W.T. Ngai, and R.E. Mc Gaughey, Information technology and systems justification: A review for research and applications, *European Journal of Operational Research* **173** (2006).
8. J. Sarkis and S. Talluri, Evaluating and selecting e-commerce software and communication systems for a supply chain, *European Journal of Operational Research*, **159** (2004).
9. H.A. Akkermans, P.E. Yucesan, and L.N. Van Wassenhove, The impact of ERP on supply chain management: exploratory findings from a European Delphi study, *European Journal of Operational Research* **146**(2) (2003).
10. G. Buyukozkan, C. Kahraman, and D. Ruan, A fuzzy multi-criteria decision approach for software development strategy selection, *International Journal Gen. Systems*, **33** (2004).
11. U. Cebeci, Fuzzy AHP based decision support system for selecting ERP systems in textile industry by using balanced scorecard, *Expert Systems with Applications*, **36**(5) (2009).
12. A. Hakim, and H. Hakim, A practical model on controlling the ERP implementation risks, *Information Systems*, **35** (2010).
13. E.E. Karsak and C.O. Ozogul, An integrated decision making approach for ERP selection, *Expert Systems with Applications*, 36 (2009).
14. X. Liao, Y. Li, and B. Lu, A model for selecting an ERP system based on linguistic information processing, *Information Systems*, **32** (2007).
15. F. Su and C. Yang, Why are enterprise resource planning systems indispensable to supply chain management?, *European Journal of Operational Research*, **203** (2010).
16. H.R. Yazgan, S. Boran, and K. Goztepe, An ERP software selection process with using artificial neural network based on analytic network process approach, *Expert Systems with Applications*, **36**(5) (2009).
17. N.C. Simpson and S.S. Erenguc, Modeling the order picking function in supply chain systems: Formulation, experimentation, and insights, *IIE Transactions*, **33** (2001) 119–130.
18. A. Berkelaar, C. Deert, B. Oldenkanp and S. Zhang, A primal-dual decomposition-based interior point approach to two-stage stochastic linear programming, *Operations Research*, **50** (2002) 904 – 915.
19. B. Downs, An LP-based capable-to promise system for beef production at ConGra foods, Paper presented at the *INFORMS Annual Meeting* (San Jose, CA, November) (2002) 17–20.
20. Y.H. Lee, M. Gen and D.S. Hochbaum, A focused issue on supply chain management", *Computers & Industrial Engineering,* **43** (2002) 1-3.
21. H. Meyr, M. Wagner and J. Rohde, Structure of advanced planning systems. In: Stadtler, H., Kilger, C. (Eds.), (*Supply Chain Management and Advanced Planning–Concepts, Models Software and Case Studies, Berlin),* (2002) 99–104.
22. R.C. Whitehair and A.J. Berg, Leveraging knowledge: Solving the, (problem is no longer enough. *Supplement to OR/MS today* 2002).
23. S. Boyson, T. Corsi and A. Verbraeck, The e-supply chain portal: a core business model, *Transportation Research Part E,* **39** (2003) 175-192.
24. A.C. Caputo, P.M. Pelagagge and F. Scacchia, Integrating transport systems in supply chain management software tools, *Industrial Management & Data Systems,* **103**(7) (2003) 503-515.
25. B. Fleischmann and H. Meyr, Customer orientation in advanced planning systems, In: Dyckhoff, H., Lackes, R., Reese, J. (Eds.), *Supply Chain Management and Reverse Logistics*, Berlin, (2003) 297–321.
26. B.S. Sahay and A.K. Gupta, Development of software selection criteria for supply chain solutions", *Industrial Management & Data Systems,* 103(2) (2003) 97-110.
27. H. Stadtler, Supply chain management and advanced planning – basics, overview and challenges, *European Journal of Operational Research*, **163** (2004) 575-588.
28. S.M. Disney, M.M. Naim and A. Potter, Assessing the impact of e-business on supply chain dynamics, *International Journal of Production Economics*, **89**(2) (2004) 109 -118.
29. C. Arbib and F. Marinelli, Integrating process optimization and inventory planning in cutting-stock with skiving option: An optimization model and its application, *European Journal of Operational Research*, **163**(3) (2003) 617 – 630.
30. N. Dellaert and J. Jeunet, An alternative to safety stock policies for multi-level rolling schedule MRP problems, *European Journal of Operational Research*, **163**(3) (2005) 751 – 768.
31. P. Helo and B. Szekely, An analysis of software solutions for supply chain co-ordination", *Industrial Management & Data Systems*, **105**(1) (2005) 5-18.
32. C. Nilsen and C. Larsen, An analytical study of the Q(s,S) policy applied to the joint replenishment problem, *European Journal of Operational Research*, 163(3) (2005) 721 - 732.
33. J.A. Persson and M. Göthe-Lundgren, Shipment planning at oil refineries using column generation and valid inequalities", *European Journal of Operational Research*, **163**(3) (2005) 631 - 652.
34. J.M. Spitter, C.A.J. Hurkens, A.G. Kok, J.K. Lenstra and E.G. Negenman, Linear programming models with planned lead times for supply chain operations planning, *European Journal of Operational Research*, **163**(3) (2005) 706 - 720.
35. S. Lancester, D.C. Yen, and C.Y. Ku, E-supply chain management: an evaluation of current web initiatives, *Information Management & Computer Security*, **14**(2) (2006) 167-184.
36. M. Karkkainen, S. Laukkanen, S. Sarpola and K. Kemppainen, Roles of interfirm information systems in supply chain management", *International Journal of*

Physical Distribution & Logistics Management, 37(4) (2007) 264-286.
37. C.W. Chang, C.R. Wu, C.T., Lin, and H.L. Lin, Evaluating digital video recorder using analytic hierarchy and analytic network process, *Information Sciences*, 177(16) (2007).
38. X. Xu, A note on the subjective and objective integrated approach to determine attribute weights, *European Journal of Operation Research*, **156** (2004).
39. C.H. Yeh and Y.H. Chang, Modeling subjective evaluation for fuzzy group multi criteria decision making, *European Journal of Operational Research* **194** (2)(2009).
40. J. Lu, G. Zhang, and D. Ruan, Intelligent multi-criteria fuzzy group decision-making for situation assessments, Soft Computing **12** (2008).
41. I. Ertugrul and N. Karakasoglu, Performance evaluation of Turkish cement firms with fuzzy analytic hierarchy process and TOPSIS methods, *Expert Systems and Applications*, **36**(1) (2009).
42. H.Y. Lin, P.Y. Hsu, and G.J. Sheen, A fuzzy based decision making procedure for data warehouse system selection, *Expert Systems with Applications*, **44** (2006).
43. A.S. Jadhav and R.M. Sonar, Evaluating and selecting software packages: A review, *Information and Software Technology*, **51** (2009).
44. T. L. Saaty, The analytic hierarchy process, McGraw-Hill Company (New York, 1980).
45. F.T. Bozbura, A. Beskese, and C. Kahraman, Prioritization of human capital measurement indicators using fuzzy AHP, *Expert Systems with Applications*, **32**(4) (2007).
46. C.W. Chang, C.R. Wu, and H.C. Chen, Using expert technology to select unstable slicing machine to control wafer slicing quality via fuzzy AHP, *Expert Systems with Applications*, **34**(3) (2008).
47. R. Aull-Hyde, S. Erdogan, and J.M. Duke, An experiment on the consistency of aggregated comparison matrices in AHP, *European Journal of Operational Research*, 171(1) (2006).
48. L. Mikhailov, A fuzzy approach to deriving priorities from interval pairwise comparison judgments, *European Journal of Operational Research*, **159** (2004).
49. V.B. Kreng and C.Y. Wu, Evaluation of knowledge portal development tools using a fuzzy AHP approach: The case of Taiwanese stone industry, *European Journal of Operational Research*, **176** (2007).
50. A.H.I. Lee, W.C. Chen, and C.J. Chang, A fuzzy AHP and BSC approach for evaluating performance of IT department in the manufacturing industry in Taiwan, *Expert Systems with Applications*, **34** (2008).
51. O. Cakir and M.S. Canbolat, A web-based decision support system for multi-criteria inventory classification using fuzzy AHP methodology, *Expert Systems with Applications*, **35**(3) (2008).
52. H.P. Fu, P. Chao, T.H. Chang, and Y.S. Chang, The impact of market freedom on the adoption of third-party electronic marketplaces: A fuzzy AHP analysis, *Industrial Marketing Management*, **37**(6) (2008).
53. S. Opricovic and G.H. Tzeng, Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS, *European Journal of Operational Research*, **156**(2) (2004).
54. C. Kahraman, G. Buyukozkan, and N.Y. Ates, A two phase multi-attribute decision-making for new product introduction, *Information Sciences*, **177** (2007).
55. H. Deng, C.H. Yeah, and R.J. Willis, Inter-company comparison using modified TOPSIS with objective weights, *Computers & Operations Research*, **27**(10) (2000).
56. C.H. Yeh, H. Deng, and Y.H. Chang, Fuzzy multi-criteria analysis for performance evaluation of bus companies, *European Journal of Operational Research*, **126**(3) (2000).

Appendix A. Modules and Sub-modules Definition

Code	Criteria and secondary criteria	Definition
DM	**Demand Management**	Identifying and creating demand, modelling, and collaborating, with the network of trading partners.
DM1	Promotion Planning	Allow organisations to plan promotions with their trade collaborators, including simulating, executing, promotion performance.
DM2	Forecasting	Gathers all data that can impact the ultimate demand placed upon the supply chain.
DM3	Life Cycle Planning	Provides the ability to view sell-in and sell-through point of sale data.
DM4	Consensus and Collaborative Planning	Allow the ability for joint sharing and modelling of demand supply gaps between trading partners.
DM5	Event Planning	Product launches, special media and advertising, promotional events, or new store openings need fine planning to be successful.
SCO	**Supply Chain Optimisation**	To design an optimal physical supply chain network and solve long-term strategic problems.
SCO1	Network Optimisation	Performed yearly or whenever major shifts in the supply chain occur.
SCO2	Route and Territory Design	Optimal of regional and geographic logistics strategies to support local markets.

SCO3	Fleet Planning, Routing and Scheduling	Tactically to determine fleet requirements for a specific timeframe. Allow user to determine if they are getting the most expeditious service.
SCO4	Inventory Optimisation for Supply Network	Allow the organisation to create an inventory supply network from multi-tier or n-tier suppliers through to multi-channel to customers.
WMS	**Warehouse Management System (WMS)**	Provide database and user-level tools in order for a company to optimise its storage facilities.
WMS1	Warehouse and Bin Configuration	Communication between the warehouse and the office slows down the multi-bin process.
WMS2	Inventory Control for Warehouses	Tracks product usage and costs, and maintains inventory at optimum levels.
WMS3	Receiving and Quality Control	Enforce the quality control process through a series of system-directed prompts to ensure that product is handled correctly.
WMS4	Put-away, Picking	Making the association between product receipts and storage locations.
WMS5	Cycle Count	Procedure that a small subset of inventory is counted on any given day.
WMS6	Packing and Shipping	Association between an order and series of orders and required packing materials and documentation.
PSP	**Production and Supply Planning**	Allows the solutions to solve for simulation issues extremely quickly, with very large arrays.
PSP1	Long-term Sales, Operations and Capacity Planning	Allow simulation and scenario building, which can be created even in joint meeting sessions.
PSP2	Operational Planning	Aggregate or disaggregate multilevel plans, so the concept of a master production system.
PSP3	Procurement Collaboration	Dynamical collaborates with the supplier to create demand, place orders, and get a systemic response.
PSP4	BOM, Design and Building	Define products as they are designed, as they are ordered, as they are built, or as they are maintained.
PSP5	Routing Design and Optimization	Provide the intelligence that takes a collection of physical links and transforms them into a network that enables packets to travel.
PSP6	Cycle Time Analysis and Optimization	Includes process time, during which a unit is acted upon to bring it closer to an output, and delay time
SPP	**Service Parts Planning**	Enable the creation of service centres, depots, and the positioning of the appropriate inventory and workforce capacity.
SPP1	Parts and Service Planning	Deals with the creation and replenishment of a supply network for service operations.
SPP2	Service Delivery and Execution	Integrate in order to handle the management of depot responsiveness
SPP3	Workforce Optimisation	Used for determining the right skill mix and location of personnel to support service demands.
SPP4	Transportation Planning	Has a significant role to play in the service supply chain.
SPP5	Reverse Logistics	Pickup of parts for delivery to third-party locations for repair.
TMS	**Transportation Management System (TMS)**	Provide the basic components of a shared information system to support.
TMS1	System Definition and Implementation	Include tools and applications to enable the user to create profiles for all contracts, and trade lanes for inter-modal and multi-leg moves.
TMS2	Required Features and Functions	Enable users to perform all key functions when planning, executing and analysing transportation movements.
TMS3	System Analysis and Reporting for Transportation	Enable the user to track carrier performance ad-hoc as well as through structured queries and reports.
ITL	**International Trade Logistics (ITL)**	Enables organisations to make trade decisions by streamlining, accelerating, and integrating complex import and export processes.
ITL1	Advanced Collaboration	The data model should take into account the different roles of all participants and manage these through a set of rule-based processes.
ITL2	Product Description	Includes a description of the product and defines all key characteristics of the any given product.
ITL3	Compliance Model	A data model that considers all these factors, maintaining the inter-relationship at the product, trading partner, and logistics level.
ITL4	Logistics	Provide the user with a set of tools to establish rates, routes, and contracts for preferred transportation modes and providers.
ITL5	Commerce	Enable to obtain an estimated total cost of goods sold as well as a final cost of goods sold, to highlight any variances or discrepancies.
OM	**Order Management**	To implement software that enables business processes and data integration in heterogeneous business and systems environments.
OM1	Order Promising	Responsible for order administrative functions such as CRM, quoting, and other administrative functions.
OM2	Inventory Analysis for Order	Determine how much inventory you should hold, and when you should place inventory orders.

OM3	Sourcing Management	Attribute of a distributed order fulfilment system is the ability to do multi-stage sourcing and assembly.
OM4	(Manufacturing) Order Tracking	Allows online tracking of any product among all manufacturing process.
OM5	Inbound and Assembly Coordination or Multi-site Staging	Many orders are sourced and built by a network of partners. Frequently, notification of cancellations does not occur.
OM6	Shipment Tracking	Through this online tracking facility, you can get real time status information on your shipment.
SCE	**Supply Chain Event Management**	Designed to monitor, notify, analyse, measure, and control business process and execution types of activities.
SCE1	Metrics and Formula Library for Data	Data required for calculating metrics should be continuously collected in parallel with process assessment and improvement.
SCE2	Rules and Alerts Hierarchy Setup for Events	A hierarchy set up lets you group content into a hierarchy that makes content easier to find.
SCE3	Data Drilling, Aggregating, and Exploding for Data mining	Substitute or replace the traditional business intelligence system by providing real-time views of data, working off a dynamic database.
SCE4	Price Deviation Analysis	Costs, price deviations are identified and presented real-time in the deviation monitor, giving the finance depart. a unique tool to act on.
SCE5	Engineering Change Order Tracking	Efficiently manage design review and approval for multiple types of engineering change orders across the extended product team.
SCE6	Inventory Shortage Analysis for Supply	Offers some inventory prediction and/or management capabilities.
SCE7	Quality Data Analysis	Take account every point of data significance in analysis period.
SCE8	Equipment, Breakdown Analysis	The reliability analysis section of module may be used to guide you towards setting the correct tasks.
SCE9	Demand Volatility Analysis	Determining initial demand at the start of a dispatch interval used to launch the demand forecast.
SCE10	Analysis of Logistics inefficiencies	Analysing out inefficiencies from logistics is a specialized endeavour that requires a clear overview of every link in the chain.
SCE11	Risk Management	Attempting to identify and then manage threats that could severely influence or bring down the organisation.
SRM	**Supplier Relationship Management (SRM)**	Includes interactions with the supply base throughout the full lifecycle of processes from design through to fulfilment.
SRM1	Collaboration in Design and Requirements Identification	Provide collaboration tools that allow suppliers to participate as a member of the team that sets requirements and targets.
SRM2	Commodity Management	Tools for analysing global spend across many dimensions are needed to come up with optimum sourcing decisions.
SRM3	Supplier Management	Enables finding and qualifying the best supplier, maintaining the list of approved suppliers, maintaining and accessing a database.
SRM4	RFx (Request For x) and Contract Management	Tools for creating and distributing a request for information, request for proposal, or request for quotation.
SRM5	Catalogue Management for Product	To import data from the supply base, this is generally stored in a vast variety of formats and using a variety of different semantics.
SRM6	MRP or Requisition-Driven Procurement	Allow users to buy from catalogues, automatically route requisitions for approval, provide tracking of approval status, generate and send purchase orders.
SRM7	Price, Discounts, Cost Management	Provides functions to monitor and analyse purchase price variance, which is the key to controlling costs.
SRM8	Return Management	For situations where components are being returned to and repaired or replaced by suppliers.
SRM9	Quality and Engineering Change Order Management	Quality focuses primarily on supporting the certification process for components, as well as managing the corrective action process.