Development of software selection criteria for supply chain solutions

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Abstract
The thrust of this paper is to develop a comprehensive software selection criterion and view information technology related issues in supply chain management. This paper furnishes implicit details of decision support systems, software solutions and factors associated with selection of IT applications for supply chain management. It entails the components of decision support systems and evolution of supply chain management softwares. A brief discussion of the functioning of various modules of the supply chain package is presented. This paper also proposes the use of percentage based weighted Tree in order to choose appropriate supply chain solution(s).

1.0 Evolution of supply chain software

The history of supply chain software evolution started with traditional applications, i.e. payroll and accounting solutions in the 1960s. In this phase software and operating systems were designed to help accounting and file management processes. In parallel, softwares were developed for higher mathematical, scientific and analytical work for the midrange and mainframe computer environment. The 1970s was the period of development of standalone core operational application software such as demand forecasting, planning and scheduling, inventory management, capacity requirement planning, plant location and layout, etc. US firms started using manufacturing requirement planning (MRP-I) practices to plan and manage material acquisition. The calculation took several manual hours to produce a material plan. But in the 1980s computer technology gave a new direction to MRP software development. Electronic data interchange (EDI), simulation and graphical user interface (GUI) technology emerged in the foray. From the MRP-I, first manufacturing resource planning (MRP-II) and then enterprise resource planning (ERP in the early 1990s) concepts were evolved. Forger (1999) noted that ERP, the high level backbone of planning, has traditionally focused on enterprise-wide integration of a company's financials, human resources, purchasing, payroll, order placement and related administrative functions. These applications also include planning and scheduling, material management, inventory control, etc. manufacturing related modules. An ERP approach aims at the overall enterprise's functionality, primarily by developing an integrated database, through which the core information in the enterprise can be optimally integrated (Huang *et al.*, 2001). Pre-1998 there were six standalone planning and execution software. The six are ERP, supply chain planning (SCP), order management system (OMS), warehouse management system (WMS), manufacturing execution system (MES) and transportation management system (TMS). Each deals with the supply chain from its own silo with few if any links to other types (Forger, 1999). The manufacturing software providers understood the complexities involved and developed software solutions from the enterprise as a whole to the supply chain as a whole. After 1998, development effort has been concentrated on the integration of supply chain functionality and use of simulation, GUI and geographic information system (GIS) internationally networked applications. The business to business and business to commerce Web-enabled technology are also being utilised to develop the e-supply chain to give agility to the supply chain (Murillo, 2001). Though standalone applications are still being developed, the overall focus of current development efforts is to create packages that deal with the supply chain as continuum rather than in individual operations.

2.0 Supply chain decision support system

Supply chain decision making involves several problems such as inbound material management, inventory management, logistic-network planning, customer satisfaction, supply chain strategy issues, distribution system management and transportation issues, etc. The question arises how these problems can be tackled. To select and use decision-support systems

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(DSS) effectively, it helps to understand the essential pieces of a properly configured system. The three major components of a DSS are input database and parameters, the analytical tools and the presentation mechanism (Levi *et al.*, 2000).

An input database is a collection of information, that is needed in order to make business decisions. It includes raw material data, supplier base, plant location, layouts, facility, capacity, administrative and other information. The database can be stored as a single entity, distributed database or data warehouse. The databases are managed by database management systems or relational database management system tools (such as Oracle and MS SQL) and can be integrated with supply chain software applications.

Analytical tools represent the models and methods used to analyse the decision problem. These methods are the backbone or logic of analysis in the supply chain management softwares. The tools that are available for performing that evaluation use various methods of problem solving such as linear or integer programming and spreadsheet analysis tools. These tools lack the fundamental capability of evaluating variability in demand, supply time or transit time-key differentiators in competitive performance comparison and analysis. Simulation technology is emerging as a new tool in supply chain management and its basic strength is in evaluating system variation and interdependencies (*Buyer's Guide*, 2000). Hicks (1997) described operation management techniques, network modelling and simulation analysis as solver techniques. Fox *et al.* (1993) suggested use of artificial intelligence (AI) and developed "intelligent agent" as a decision support system. Artificial intelligence is employed by many researchers, Walsh *et al.* (2000) adopted a decomposable, "autonomous agents" approach to specify information supply chain models. Models were defined in terms of their constituent information supply chain "agents" (e.g. suppliers, buyers, distributors, etc.), including also their structural relationships, interaction "protocols" and co-ordination policies. Levi *et al.* (2000) distinguishes analytical tools and as queries, statistical analysis, data mining, online analytical processing (OLAP), calculators, simulation and artificial intelligence. JD Edwards advanced planning solver architecture, summarised solver technology in MRP/DRP logic, OR tools (network, mixed integer, linear, heuristic, constraints based, texture based and simulation with heuristics analytical approaches. Lennox (1997) stresses that supply chain planning system, must consider capacity constraints at all stages and employ a dynamic messaging model view controller architecture or multi-user distributed system. Hence, many techniques can solve models; of course, these techniques depend on the actual form of model. The following are the techniques generally applied to solve SCM business problems.

Presentation mechanisms or visualisation techniques are aids to represent the cumbersome output listings, tables, information and plan in easily conceivable graphical (e.g. charts, graphs, model, etc.) information. Various graphics tools can be employed. "Customised graphical user interfaces (GUIs) allow users to look inside production runs ... through drill down capabilities" (Lennox, 1997). A GIS consists of computer hardware, software and geo-referenced data. Geo-referenced data correspond to a place on the surface of the earth. A GIS is capable of inputting, storing, manipulating, analyzing and outputting geo-referenced data. Similarly, scheduling systems use grant charts to display factory schedules and simulation use animation to illustrate the relationship in a model.

As described above, supply chain decision support systems are not simple softwares but are a conglomeration of various emerging software and hardware technologies. EDI, Internet as information wholesaling function (Schmidth, 1999), Web-based technologies, bar-coding with radio frequency data communication technologies to communicate bar coded data efficiently and accurately (Fodor, 1999), business to business and business to commerce technologies are incorporated in the supply chain software solutions. Even software development technology (languages) experienced a massive transformation from SIMULA67 to JAVA, CORBA and Extensible Mark-up Language (XML).

3.0 Supply chain solutions/ package

Supply chain management software applications provide real time analytical systems that manage the flow of information throughout the supply chain network of trading partners and customers in both direction. These solutions incorporate one or more functionality of network strategy/ supply chain configuration, demand planning, manufacturing and distribution planning (supply planning), distribution network management, transportation management and warehouse management. The range of software solutions is not limited to logistics functionality. Hicks (1997) described, "there are essentially four 'tribes' that until fairly recently, have coexisted more or less peacefully in the supply chain

software village. They are the Enterprise Resource Planning (ERP), the Supply Chain Management (SCM), the constrained based Optimisation Tools (OPT) and the Analysis Tools (ANAL)". Fodor (1999), listed 23 softwares as supply chain management tools, including bar coding, CAD/CAM, ERP, purchasing software, electronic data interchange, advanced planning software, MRP systems, etc. Forger (1999) sees six major classes of softwares such as, ERP, SCP, OMS, MES, WMS and TMS that helped to manage supply chains from their individual silos. As the interaction of upstream and downstream companies is increasing, current market trend is consolidating these disparate modules into a single comprehensive supply chain package or suite. A supply chain package generally includes the following components:

- supply chain design/configuration;
- supply chain planning;
- advanced planning and scheduling;
- demand management;
- inventory management;
- work centre execution system;
- warehouse management system;
- transportation management;
- distribution network management;
- customer order management;
- component and supplier management;
- supply chain collaboration.

4.0 Basic requirements of software selection models

The first and foremost requirement of any software selection criterion is to serve the purpose of its purchase by the interested organisation (Lucas, 1986; Robert and William, 1999). In a wider perspective it must be able to accommodate all the factors that directly or indirectly influence the software selection process. The basic requirements of an appropriate decision model are as follows:

- The model should confer the basic requirement of the user and must be able to tap strong functionality of the software solution.
- The model should support factorisation and branching of important attributes to any degree. It must be able to address the unbalanced tree structure of decision attributes.
- It should be able to utilise almost all tangible and intangible information about software. The model must provide an appropriate methodology, which can incorporate all qualitative and quantitative factors and at the same time give parity of scale to incorporate them into a single model.
- The model should be flexible enough to provide a better trade-off across attribute set and measure software rating through aggregation of factors of high importance to lower significance.
- The model should be generic and applicable to almost all types of software application/system selection and must assure a fair comparison to all candidate software systems.
- The model should be easy to understand, employ and less time consuming.

5.0 Software selection models: a brief review

Different software/hardware selection models are discussed in this section, namely linear weighted attribute model, linear assignment model, MAXIMAX, elimination by aspects and analytic heuristic process. All these models involve the comparison of performance rating but they differ in the proportion of performance information utilisation, the extent to which they assures functionality, time and complexities in analysis, etc. Moreover, each model does not yield to the same ranking.

In the linear weighted attribute model various functional relationships had been proposed (Kliejnen, 1980; Pearson and Bailey, 1980). This model allows a better trade-off between good and poor attributes through choice of weightage w_i.

$$Q_i = \sum_{j=1} w_i A_{ij}$$

$j \in J$ (total no. of attributes);
$i \in I$ (total no. of packages).

Where w_i is the weight of significance assigned to jth attribute of ith package. A_{ij} is the performance rating of the jth attribute of ith package and Q_i is the package rating that decides the rank of package.

The linear assignment model is basically an optimization model, which requires the considered package to be ranked for each attribute (Bernardo and Biln, 1977; Billing and Scherer, 1988). A matrix of ranks for the jth attribute of ith package is prepared. A permutation matrix multiplies this matrix. Then the linear programming problem is formulated and solved for maximisation.

MAXIMAX model is easy to apply. This method has a drawback in that it gives similar treatment to all the factors so imparity between least significant and most significant factor cannot be assessed. This method proves sound where all the factors for final comparison are equally important.

Elimination By Aspect is a methodology rather than a model. It has no mathematical

calculation. We have to chose the software solution, which guarantees all the set requirements and standards by the customer.

Davis and Williams (1994) applied analytical heuristic process (AHP) to select and evaluate simulation software. They stressed structuring the decision process to reduce inconsistencies in human judgement. By using "Saaty's scale (ten points based) of intensity for importance" of factors and matrix multiplication they suggested calculation of overall ranking of package.

6.0 The fallacies and inadequacies of earlier models

There are many payoff criteria, performance and selection factors. These factors involve qualitative as well as quantitative characteristics of responses. All models discussed above evaluate package ranking on a common rating or ranking scale. Even AHP and the linear weightage attribute model cannot attribute response in conjunction with qualitative and quantitative responses. In real life decision problems it is not necessary that every thing be evaluated on the same scale. Suppose one person is given task to evaluate a software package. The 13 functionalities are required by company and he has to make a comparison between security, speed, ease of use, training and documentation, runtime error handling, etc. (qualitative data). It is difficult for him to make parity of scale. Consider the second problem associated with that hierarchical structure in which further classification for a particular driver is not possible and the decision-maker is faced with an unbalanced hierarchical structure (or tree). Therefore, it is necessary to evolve a mechanism in the decision model that takes care of disparity of scale for various factors and these two issues must be addressed in order to make the decision model more versatile and adaptive to the unbalanced hierarchical nature of decision problems. Hence, the percentage based weighted tree model is proposed.

7.0 Percentage based weighted tree model

As stated earlier, the basic strength of any model lies in its applicability and adaptability to various environments. The proposed model defines software solution merit index (SMI) as the sum of percentage score in aggregation, from different attributes through hierarchical classification. It is indicative of software utility or merit to the organisation. It is meant to assure the selection of software in totality. It facilitates hierarchical classification of different attributes to any level to utilise intricate information regarding any attribute. Its uniqueness in converting all qualitative (like Likert's and Saaty's Scale) and quantitative measures into percentage score promotes unbalanced hierarchical classification and judging attributes at the final level on any scale. This feature brings about the parity of scale between qualitative and quantitative attributes and accommodates both simultaneously. Henceforth SMI put a fair comparison criteria for software selection.

7.1 Nomenclature

SMI = Software solution merit index;
f_p = percentage based score due to primary drivers;
f_s = percentage based score due to secondary drivers;
w_p = weight assigned to primary driver;
w_s = weight assigned to secondary driver;
w_i = weight assigned to ith primary driver;
w_{ij} = weight assigned to jth sub driver of ith primary driver;
w_{ijk} = weight assigned to kth factor, of ith primary drivers' jth sub driver;
S_{ijk} = total score on performance rating earned by kth final level factor for ith primary drivers' jth sub driver;
SS_{ijk} = maximum performance rating that can be earned by kth factor for ith primary drivers' jth sub driver.

7.2 The model

The proposed decision model computes the SMI for a given solution or package. The value of SMI decides the ranking of the solution. This model is built up in stages. The SMI is the summation of percentage based score of primary driver and secondary driver score multiplied by their due weightage.

$$\text{SMI} = w_p f_p + w_s f_s \ldots \quad (1)$$

where $w_p \leq 1, w_s \leq 1$ provided $w_p + w_s = 1$.

In the proposed model "f_p" is built up by say "x" number of primary drivers, and any individual primary driver is further divided into say "y" sub drivers and these sub drivers have further division, then the percentage based score for primary drivers f_p, is determined as:

$$f_p = \sum_i w_{i.} (f_p)_i$$
$$i = 1, 2, 3, \ldots\ldots, x. x \in I \text{ (integer number)} \quad (2)$$

where $w_i \leq 1$ provided $\sum w_i = 1$.

$(f_p)_i$ the percentage based score for ith primary driver is determined as:

$$(f_p)_i = \sum_j w_{ij}(f_p)_{ij}$$

$$j = 1, 2, 3 \ldots\ldots, y.\ y \text{ can vary for values of } i \tag{3}$$

where $w_{ij} \leq 1$ provided $\sum\ w_{ij} = 1$.

Suppose jth sub driver has z factors and it is the final stage of classification then $(f_p)_{ij}$ the sub driver percentage based score for ith primary drivers' jth sub driver is determined as:

$$(f_p)_{ij} = \sum_k w_{ijk}(S_{ijk} * 100/SS_{ijk})_{ijk}$$

$$k = 1, 2 \ldots, z. \text{and } z \text{ can vary for values of } j. \tag{4}$$

Where $w_{ijk} \leq 1$ provided $\sum w_{ijk} = 1$.

From equations (1-4) the value of f_p can be written as:

$$f_p = \sum_i \sum_j \sum_k w_{ijk} w_{ij} w_i ((S_{ijk} * 100)/SS_{ijk}). \tag{5}$$

Similarly for the nth factor of lth secondary drivers' mth sub driver:

$$(f_s) = \sum_l \sum_m \sum_n w_{lmn} w_{lm} w_l ((S_{lmn} * 100)/SS_{lmn}). \tag{6}$$

Hence, SMI for qth Software Solution can be arrived by:

$$\text{SMI}_q = \sum_i \sum_j \sum_k w_{qijk} w_{qij} w_{qi} ((S_{qijk} * 100)/SS_{qijk}) + \sum_l \sum_m \sum_n w_{qlmn} w_{qlm} w_{ql} (S_{qlmn} * 100)/SS_{qlmn}). \tag{7}$$

Equation (7) computes the software solution merit index (SMI) for the considered package.

7.3 Applying percentage based weightage tree model

In this section software requirement attributes will be elaborated. As already stated, requirement factors illustrated in this section are very comprehensive and can directly be applied for the selection of any kind of software package. Identification of all the drivers or the attributes is the first and most important activity in the whole process. Any attribute that is tangible or intangible affects the objectives of software purchase and must be accounted and meticulously chosen. Many researchers and practitioners made attempts to impart software selection factors for selected applications. Sadowski (1998) explained scheduling software selection based on features, integration, platform, price and technology. Banks and Gibson (1997) classify simulation software selection parameters as process input considerations, processing considerations, output considerations, environment consideration, vendor consideration and cost consideration in totality. Their emphasis upon intricate details of each consideration is marvellous in case of simulation software selection. Burmark and Thornberg (2000) and Carole (2000) stressed many user based selection factors. This exercise involved many considerations from various functionalities in the organisation. Hence, brainstorming sessions between the departmental representatives, which are directly and indirectly associated or affected by software purchase further substantiate the identification of selection attributes.

In a broad perspective these factors can be classified into two major groups: primary (or essential) requirements and secondary requirements (or less significant). The primary and secondary requirements are explained by Figures 1 and 2. The primary factors or requirements (e.g. technology, cost, functionality and support/services) are typically easier to measure and can eliminate and/or promote packages early in the evaluation process. Before these higher level requirements are determined, it is wise to establish the organisation's objectives relative to the new information system and to identify constraints realistically. These constraints may be geographical, cross-cultural, governmental regulations, business philosophies and market, etc. The less specific secondary factors include industries covered, vendor strength, vendor vision and other qualitative factors like versatility, ease of use, error in handling, etc.

7.3.1 Primary drivers

Primary drivers form a set of essential requirements and facilities with the software packages. These primary drivers include software functionality, technology, cost, and support and services. These drivers also include specific corporate requirements e.g. customisation, critical modules, etc. Figure 1 represents a pictorial view of primary drivers.

Features. Software features and their functionality are the most significant issue of all. These features are not restricted with modular requirements but cover various factors like integration with existing software applications (ERP, MRP, APS, etc.), speed of run and time in implementation, portability of same modules or package with other hardware and software environments etc.

Technology. Technology reigns as the next most important primary driver because before going to buy any package it is essential to check its compatibility with existing hardware, operating systems and

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Figure 1
Primary drivers in software selection

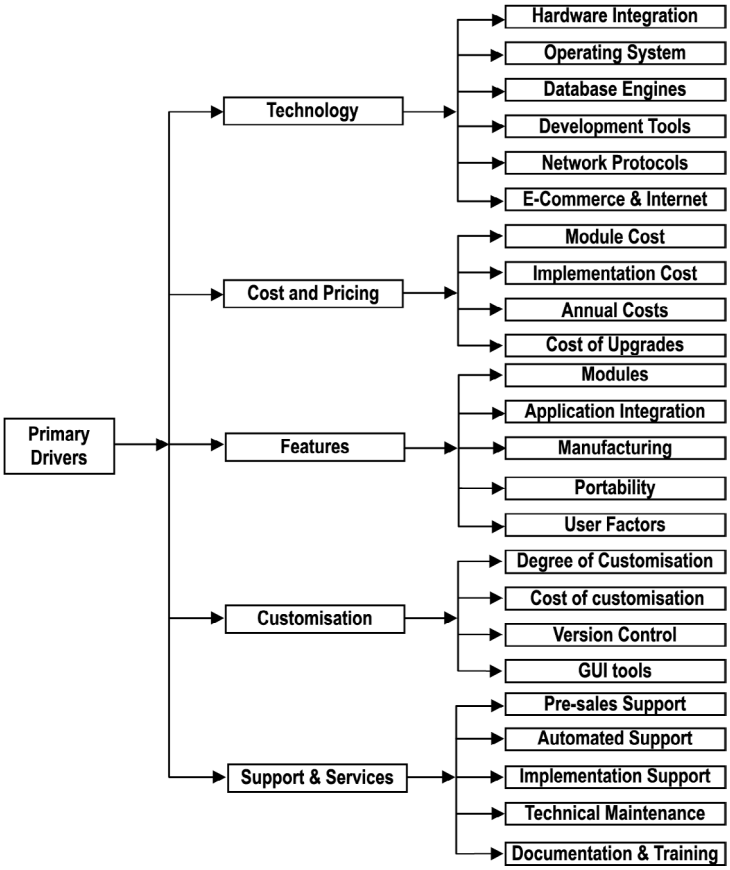
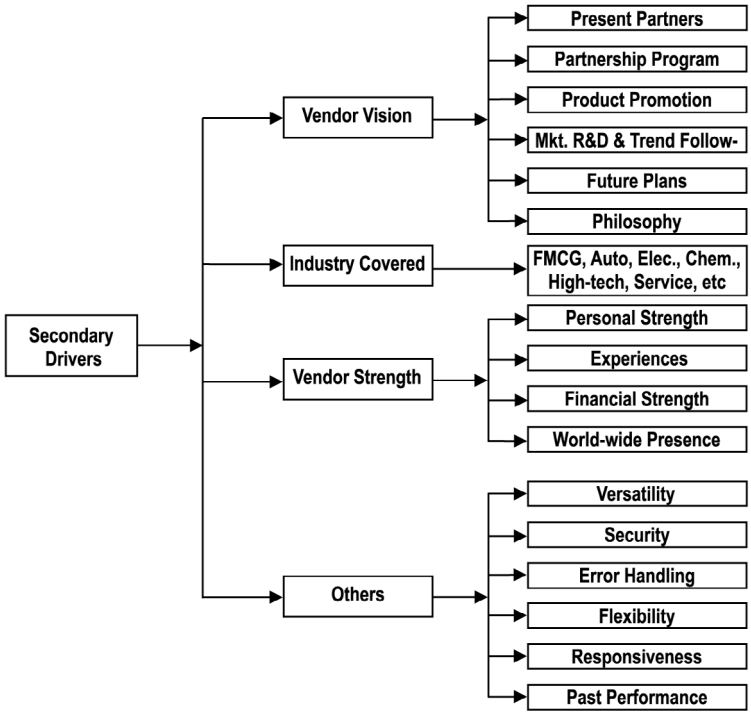


Figure 2
Secondary drivers for software selection



database engines. In the Web-era these softwares must support Internet, network and e-commerce setups. High technology support for business integration is essential in broadening the marketing network.

Support and services. This factor is vital after implementation to ensure continuous uninterrupted functioning of software systems. A software package includes many modules, which are essential for day to day operational requirements. A problem with any module may interrupt part or the whole functioning of the software system. Hence, softwares require technical maintenance support from the vendor. The pre-sales support, automated support (e.g. Web based support) and documentation and training support are accounted under this heading.

Cost. Every firm wants to meet its qualitative and quantitative requirements with minimum cost and minimum time. Software purchase is not an exception. As a rule companies offer very competitive and low basic software cost but charge high rates for additional hardware or special equipment and annual cost. So, in comparison all the static and run time costs should be considered. These costs includes costs per module, total package cost, annual maintenance cost, planning and implementation cost, installation and training cost, cost of upgrades and special hardware cost.

Customisation. This refers to the special requirements of organizations and differs for each organisation and even for departments of the organisation. It is the degree of customisation, which software vendor's offer should be considered. Some vendors do not provide customisation as that can diminish the optimum benefits. Hence, it becomes essential to see that customisation in no way decreases the optimality of the desired results, besides this, one should also keep in mind that the case of no customisation operational changes does not force huge expenses on the organisation.

7.3.2 Secondary drivers

These requirements are less important and non-essential in nature. But if added to the package or vendor firm increases the value of the purchase. For many buyers these drivers may be equally considerable issues. These requirements are given in Figure 2. In the following sections these secondary drivers are further elaborated.

- *Vendor strength*. This driver assesses the financial, personnel, industrial knowledge and experience based strength of software vendors. This is especially true with big buyers, as financial weakness of the provider leads to fear of a shut down and uncertainty of uninterrupted maintenance support, service and updates. Market experience especially of the same industry is a plus point to the vendor, as are the previous installations and their performance.
- *Vendor vision*. This is another secondary software selection factor. It includes the vendor's policy, philosophy and network to guide and expand the software market. It also includes R&D efforts towards innovative concepts, product improvement, product promotion, marketing and vision. This is a qualitative factor and its consideration and weight may vary from customer to customer.
- *Industries covered*. This is an important factor while comparing different software packages and vendors. While selecting software for a particular industry, it is not even considered. It signifies the spread of the applicability, which adds value and market to the software package.
- *Other drivers*. These requirements address common software requirements and are subjective in nature, e.g. ease of use. This factor also includes several important factors like versatility, flexibility and responsiveness, error handling and security issues. Security of the software solutions in terms of data smashing and data piracy and fraud is crucial issue and should be given priority. Another problem that arises is that the product performance level is not found to be up to the level desired by the customer. So past performance of the vendor as well as product is also a considerable issue.

7.4 Setting the performance rating system

The next step in the evaluation of supply chain software is to set a performance rating system to measure the attributes. Both qualitative and quantitative measures are adopted to rank packages on different attributes. An attempt is made to exhibit flexibility of model as well as quantify intangible variables. This system is evolved in such a manner that the sanctity of true indicatives of performance of attributes will be maintained.

These attributes can be further branched or classified. For intricate details each of 20 modules can be further assessed in terms of analytical, graphical, logical compatibility with organisational requirements. Tables I and II represent the scheme of the performance rating system with weightage assigned to individual attributes down the hierarchy of classification. The final level score, for all the attributes converted into percentage scores for computation of SMI.

Table I
Performance rating system for secondary attributes

Attributes of level-2	Attributes' weightage for level-2 (%)	Attributes of level-3	Attributes' weightage for level-3 (%)	Data type and rating system
Vendor strength	50	Personnel strength	20	Comparative (1-5 scale)
		SCM experience	30	Comparative (1-5 scale)
		Financial strength	25	Comparative (1-5 scale)
		World wide presence	25	Comparative (1-5 scale)
Industries covered	25			Quantitative (no. of industries supported)
Vendor vision	25	Philosophy	25	Comparative (1-5 scale)
		Partnership/alliances	10	Quantitative (no. of diff. partnerships)
		Product promotion	20	Comparative (1-5 scale)
		Marketing strategy	20	Comparative (1-5 scale)
		Marketing R&D and trends follow-up	15	Comparative (1-5 scale)
		Future plans	10	Comparative (1-5 scale)

7.5 Assignment of weightage to attributes

Here an attempt is made to weight all these factors and established a calculation procedure for the model. A broad perspective of comprehensive requirement in assigning weight to various selection attributes follows. The purpose is to compare different SCM software packages on a general requirement basis and to select a versatile supply chain solution package. To select software according to customer specific requirements one must not rule out other players or software providers in the market. The basis of weightage assignment may vary from firm to firm according to their requirements and objectives.

7.5.1 Weightage to primary drivers

The total weight assigned to primary drivers is 75 percent, which justifies the importance of primary drivers. The total primary weight is further divided among factors according to their importance. The features of the package should be assigned maximum weight. Then importance should be given to technological factors, which are necessary for package suitability to different work environments. Customisation is also an important issue. But working environment and features are always given priority over cost. The weight assigned to functionality is 40 percent, technology 30 percent, to support and services 20 percent and the remaining 10 percent to customisation. Table I represents the weightage assigned to all attributes in the primary driver hierarchy.

7.5.2 Weightage to secondary drivers

The total weight assigned to secondary drivers is 25 percent, which is a justifiable figure because while selecting any software package vendor related issues and other issues are given less priority but considered to an extent and this extent also varies from firm to firm. The total secondary weight is further branched among factors according to their importance. The vendor strength and product's industrial versatility are very important among secondary drivers. Vendor's strength includes financial, knowledge base, personnel strength and experience matters a lot. Vision is the expression of vendor's future course of action regarding the SCM package. Software package purchase is no more a buy and forget deal than technology, and concepts are emerging very fast. The weight assigned to vendor strength is 50 percent, to industrial versatility is 25 percent, vendor vision 25 percent and other factors are excluded from SMI calculations as software selection is discussed on general requirements. Table II represents the weightage assigned to all attributes in the secondary driver hierarchy.

7.6 Computation of SMI

To demonstrate the applicability of the percentage based weighted tree model some supply chain software solution providers are selected. These companies are chosen on the basis of their annual revenue, vision, product versatility, growth rate and their world-wide presence. On these criteria some of the leading companies, including Baan, i2 technologies, InterBiz Supply Chain Group, J.D. Edwards, Logility Inc., Manugistics Inc., Oracle Corporation, PeopleSoft, QAD Inc., SAP Inc, Syncra Software and WebPlan Inc., are considered for the comparison of their products.

However, in SMI calculations the names of companies are disguised and coded in capital letters of Roman script (from A to L) in random fashion. The exhaustive computation

Table II
Performance rating system for primary attributes

Attributes of level-2	Attributes' weightage for level-2 (%)	Attributes of level-3	Attributes' weightage for level-3 (%)	Data type and rating system
Features	40	Modules	45	Quantitative (no. of modules available)
		Application integration	15	Quantitative (integration with other apps.)
		User group factors	10	Qualitative (1-5 scale)
		Manufacturing environment	20	Quantitative (no. of mfg. env. supported)
		Portability	10	Qualitative (1-5 scale)
Technology	30	Hardware platform	20	Quantitative (no. of hardware supported)
		Operating system (OS)	20	Quantitative (no. of OS supported)
		Data base engine (DBEs)	20	Quantitative (no. of DBEs. supported)
		Development tools (DT) support	10	Quantitative (no. of DTs supported)
		Network protocols (NPs) support	15	Quantitative (no. of NPs supported)
		E-commerce and Internet	15	Quantitative (no. of e-com fn. supported)
Support and services	20	Pre-sales support	15	For all attributes the same rating system is applied. Quantitative (0-4)
		Automated support	25	0 for not provided and 4 for free service
		Implementation and consulting	15	1 for hourly rate availability
		Technical maintenance support	25	2 for separate services agreement
		Documentation and trainig	20	3 for covered in annual maintenance
Customisation	10	Analysis of system requirements	15	For all attributes the same rating system is applied
		Programming for system modifications	15	Quantitative (0-4)
		Custom modelling of user's plant environment	15	0 for not provided and 4 for free service
		4GL App. development tools for enhancements	15	1 for hourly rate availability
		GUI development tools	10	2 for separate services agreement
		Object oriented development tools	10	3 for covered in annual maintenance
		Acceptance test planning	10	
		Version control procedures	10	

details for primary and secondary attributes taking the example of solution provider B is explained in the following tables. Table III represents computation of percentage based score and SMI throughout the hierarchical classification of attributes for solution provider B. The details of the percentage based score for all the software solution providers in comparison is given in Table IV.

8.0 Results

Table V shows the software solution merit index (SMI) and its break-up in primary, secondary features, technological and support and service basis. This table testifies that B's SMI is greatest of all followed by the G, J and F. In the following sections the rationale and interpretation of these results is discussed.

8.1 Comparison by SMI

As indicated in Table V, solution provider *B* emerged as a leader. Its position can be sighted in its product's better features backed by the sound technology and adequate support and services provided. Feature wise it comes close second to solution provider *F*, which is its real competitor. The second position of solution provider *G* is sighted in its strong technological backing and support and service set-up worldwide. Although *G*'s main business is providing database solutions, its e-business suit which includes supply chain and other business solutions address the "hours' need" of e-supply chain. Its technological backup to its products is very exhaustive. Next position is acquired by solution provider *J*, originally a leading provider of ERP solutions, which has maintained its pro-active business policy and used its worldwide support and development platform to sell its product. It deserves its place due to a strong financial and visionary approach.

Feature wise *J* has not scored well, because its supply chain package is designed to integrate and complement the ERP package. That is the reason of *J*'s great market showings.

8.2 Comparison by solution features

It will be injustice to the objectives of the criteria adopted if this section is concluded without discussing the peace-meal break-up of the SMI. The first and foremost requirement of the supply chain solutions is they must satisfy the module specific requirements and application integration with the business environment of the customer. They should be designed for the manufacturing/service environment of the customer/company. The leader in this aspect is *F*, which has a sound functionality and integration with current business requirements. The second spot is occupied by the leader *B*. Both of these SCM solution providers are strongly emerging as market leaders. The supply chain solutions of *J* are rated next by features.

8.3 Comparison by technology

Technology is an important aspect of supply chain package selection. This includes the hardware compatibility, requirement of the client-server/host platform, and integration with database and Internet. It must support network protocol and other Internet related technology like e-mail, Internet-telephony; etc. Generally this factor is considered to attenuate the list of candidate packages available. But to compare supply chain packages it is very important that SCM solutions should support most of the hardware and operating system requirements used by the industries. In this context solution provider *G* turned out leader followed by the *B*, *F*, *E* and *J*. The reason is *B*'s main business is providing database and other technologies.

8.4 Comparison by vision

To become the market leader it is necessary for that software solution provider to have proactive vision towards its goal. It must follow the proper strategy to capture and sustain a sizeable market. In this analysis, *B* is found with the strongest vision of all. Due to its unique value propositions and aggressive marketing strategy it is market leader as well. *F*, with its product range and its ability to provide constrained based software solutions, put it behind *B*; *J* and *I* follow them.

The secondary drivers, namely vendor vision, vendor strength and industries for which the product is designed are less considerable issues. But when you buy software solutions, you plan for the future and technology is evolving very fast. Hence, the vendor related issues like the financial strength, experience and knowledge of industry, etc. matters a lot.

9.0 Conclusions

Supply chain solutions are vital in day-to-day business transactions. They are critical to managing two way information flow across the network, regulating material flow (not physical) in the organisation and providing a decision support system. Some of the software modules take care of supply side management processes like supplier management, e-procurement and material management and supply chain network

Table III
Computation of percentage based score and SMI for solution provider B

SMI	Weightage Level-1 Level-2 (W_{pi}) Level-3 (W_{pij}) (%)	Score at Level-1 W_{pi}*(D) W_{pij}*(Ci)	Score at Level-2 (D) W_{pij}*(Ci)	Absolute score (A)	Maximum score (B)	Percentage score (C) (A*100/B)
SMI= 0.75* Primary + .25* Secondary		62.26				
Primary[a]	75	62.31				
1. Features[b]	40		67.91			
i) Modules[c]	45		29.25	13	20	65.000
ii) Application integration	15%		7.50	5	10	50.000
iii) User group factors	10		8.00	4	5	80.000
iv) Manufacturing environment	20		16.92	11	13	84.620
v) Portability	10		6.00	3	5	60.000
2. Technology[b]	30		53.71			
i) Hardware platform[c]	20		10.91	4	11	54.550
ii) Operating system	20		8.89	10	27	44.450
iii) Data base engine supported	20		12.50	5	8	62.500
iv) Development tools supported	10		3.85	5	13	38.460
v) Network protocol support	15		8.33	10	18	55.560
vi) E-commerce and Internet	15		9.23	8	13	61.540
3. Support and services[b]	20		67.08			
i) Pre-sales support[c]	15		13.75	33	36	91.670
ii) Automated support	25		18.75	18	24	75.000
iii) Implementation and consulting	15		3.38	9	40	22.500
iv) Technical maintenance support	25		17.71	34	48	70.830
v) Documentation and training	20		13.50	27	40	67.500
4. Customisation[b]	10		56.25			
i) Analysis of system requirements[c]	15		3.75	1	4	25.000
ii) Programming for system modifications	15		8.50	2	4	50.000
iii) Custom modeling of user's plant environment	15		8.50	2	4	50.000
iv) 4GL App. development tools for enhancements	15		3.75	1	4	25.000
v) GUI development tools	10		0.00	0	4	0.000
vi) Object oriented development tools	10		5.00	2	4	50.000
vii) Acceptance test planning	10		10.00	4	4	100.000
viii) Version control procedures	10		7.50	3	4	75.000
Secondary[a]	25	62.11				
1. Vendor strength[b]	50		66.50			
i) Personnel strength[c]	20		12.00	3	5	60.000
ii) SCM experience	30		19.50	7	10	70.000
iii) Financial strength	25		20.00	4	5	80.000
iv) World wide presence	25		15.00	3	5	60.000
2. Industries covered[b]	25		55.56	10	18	55.560
3. Vendor vision[b]	25		70.80			
i) Philosophy[c]	25		20.00	4	5	80.000
ii) Partnership/alliances	10		6.80	17	24	68.000
iii) Product promotion	20		12.00	3	5	60.000
iv) Marketing strategy	20		12.00	3	5	60.000
v) Marketing R&D and trends follow-up	15		12.00	4	5	80.000
vi) Future plans	10		8.00	4	5	80.000

Notes: [a] Level 1 attributes; [b] Level 2 attributes; [c] Level 3 attributes

planning, etc. Advanced planning and scheduling, work-centre execution, demand management, inventory management, etc. support day to day operations in the organisation and distribution network management. Transportation management, warehousing management system customer order management, order fulfilment, etc. modules help in managing downstream management functions with an organisation. With emerging analytical tools and enabling technologies, it is possible to develop

Table IV
Percentage based score for all solution providers

	Solution providers[a]											
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**
1. Features[b]	58.56	67.91	50.23	63.16	52.64	68.73	62.16	56.31	63.23	65.98	36.54	47.46
i) Modules[c]	55.00	65.00	40.00	60.00	55.00	70.00	50.00	50.00	60.00	65.00	30.00	50.00
ii) Application integration	50.00	50.00	40.00	40.00	30.00	40.00	50.00	50.00	40.00	50.00	30.00	30.00
iii) User group factors	60.00	80.00	60.00	60.00	80.00	80.00	60.00	60.00	60.00	80.00	60.00	60.00
iv) Manufacturing environment	69.23	84.62	76.92	84.62	61.54	76.92	84.62	69.23	76.92	76.92	46.16	53.85
v) Portability	60.00	60.00	40.00	60.00	40.00	80.00	80.00	60.00	80.00	60.00	40.00	40.00
2. Technology[b]	39.77	53.71	41.88	37.83	45.63	51.77	53.86	35.94	41.31	43.24	33.92	34.55
i) Hardware platform[c]	36.37	54.55	54.55	27.28	54.55	54.55	54.55	27.28	45.46	36.37	36.37	27.28
ii) Operating system	33.33	44.45	40.74	33.33	37.04	48.54	66.67	37.04	37.04	40.74	44.45	25.93
iii) Data base engine supported	50.00	62.50	37.50	50.00	50.00	50.00	37.50	37.50	37.50	50.00	37.50	37.50
iv) Development tools supported	30.77	38.46	30.77	23.08	23.08	30.77	15.39	23.08	15.39	30.77	23.08	23.08
v) Network protocol support	38.89	55.56	27.78	27.78	61.54	66.67	83.33	50.00	66.67	44.45	22.22	55.56
vi) E-commerce and Internet	46.15	61.54	53.85	61.54	38.46	53.85	53.85	38.46	38.46	53.85	30.77	38.46
3. Support and services[b]	46.06	67.08	71.08	58.23	56.19	60.80	65.84	56.48	60.37	63.35	42.75	51.85
i) Pre-sales support[c]	75.00	91.67	80.56	91.67	83.33	80.33	100.0	86.11	83.33	83.33	55.56	61.11
ii) Automated support	58.33	75.00	87.50	62.50	79.17	79.17	66.67	62.50	79.16	75.00	66.67	70.83
iii) Implementation and consulting	25.00	22.50	25.00	25.00	22.50	50.00	50.00	22.50	27.50	40.00	22.50	67.50
iv) Technical maintenance support	47.91	70.83	87.50	60.42	52.08	45.83	66.67	56.25	45.83	60.42	37.50	35.42
v) Documentation and training	22.50	67.50	57.50	50.00	37.50	50.00	50.00	52.50	62.50	55.00	25.00	30.00
4. Customisation[b]	50.00	56.25	46.88	31.25	25.00	50.00	56.25	34.38	34.38	37.50	25.00	25.00
i) Analysis of system requirements[c]	25.00	25.00	25.00	25.00	25.00	50.00	75.00	25.00	25.00	50.00	25.00	100.0
ii) Programming for system modifications	25.00	100.0	25.00	25.00	25.00	50.00	50.00	25.00	25.00	50.00	50.00	0.00
iii) Custom modeling of user's plant environment	0.00	50.00	25.00	25.00	25.00	25.00	50.00	25.00	25.00	50.00	25.00	50.00
iv) 4GL App. development tools for enhancements	25.00	25.00	25.00	25.00	0.00	0.00	50.00	75.00	50.00	0.00	0.00	0.00
v) GUI development tools	100.0	0.00	25.00	25.00	0.00	75.00	50.00	75.00	50.00	50.00	0.00	0.00
vi) Object oriented development tools	100.0	50.00	100.0	25.00	0.00	75.00	0.00	0.00	50.00	25.00	25.00	0.00
vii) Acceptance test planning	25.00	100.0	50.00	25.00	25.00	50.00	100.0	25.00	25.00	25.00	25.00	50.00
viii) Version control procedures	100.0	75.00	100.0	75.00	100.0	75.00	75.00	25.00	25.00	50.00	50.00	0.00

(continued)

decision support systems with real time analysis and online processing capabilities. Sophistication of software tools and emerging technology prompt business houses to consider several pre-implementation, implementation and post implementation issues in order to select appropriate software systems to manage their supply chain.

The proposed comprehensive selection criterion and percentage based weighted tree model compute the software solution merit index (SMI) for the given software package according to criteria established and weight assigned to factors at each stage. The proposed model has a unique flexibility that number of stages need not to be same for all the drivers. In other words, any factor or driver can be branched to any extent in the tree model. This branching is independent of the number of stages. This model assures the full utilisation of information available, permits better trade-offs between factor performance ratings, and can be adjusted for unique needs. This model can be applied with

Table IV

	Solution providers[a]											
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**
Primary driver score	49.57	62.32	51.56	51.38	48.48	60.18	59.81	48.04	53.20	55.79	35.84	42.23
1. Vendor strength[b]	68.00	66.50	59.00	77.00	50.00	58.00	79.00	60.00	63.00	75.00	23.00	39.00
i) Personnel strength[c]	60.00	60.00	60.00	80.00	60.00	60.00	80.00	80.00	60.00	80.00	20.00	20.00
ii) SCM experience	70.00	65.00	40.00	70.00	60.00	70.00	60.00	30.00	70.00	80.00	30.00	50.00
iii) Financial strength	80.00	80.00	80.00	80.00	60.00	80.00	80.00	80.00	80.00	80.00	20.00	60.00
iv) World wide presence	60.00	60.00	60.00	80.00	20.00	20.00	100.0	60.00	40.00	60.00	20.00	20.002
Industries covered[b]	44.44	55.56	50.00	38.89	55.56	44.44	66.67	55.56	38.89	66.67	22.22	33.33
3. Vendor vision[b]	60.40	70.80	49.00	60.40	68.20	70.00	54.20	47.80	66.00	66.80	47.20	63.20
i) Philosophy[c]	60.00	80.00	40.00	60.00	60.00	80.00	60.00	60.00	60.00	80.00	40.00	60.00
ii) Partnership/alliances	64.00	68.00	40.00	64.00	32.00	40.00	32.00	28.00	40.00	68.00	32.00	32.00
iii) Product promotion	60.00	60.00	40.00	40.00	100.0	80.00	40.00	40.00	80.00	60.00	60.00	80.00
iv) Marketing strategy	60.00	60.00	60.00	80.00	80.00	60.00	80.00	60.00	80.00	40.00	60.00	80.00
v) Marketing R&D and trends follow-up	60.00	80.00	60.00	60.00	40.00	80.00	40.00	40.00	60.00	80.00	40.00	60.00
vi) Future plans	60.00	80.00	60.00	60.00	80.00	60.00	60.00	40.00	60.00	80.00	40.00	40.00
Secondary driver score	54.32	62.11	52.00	53.80	57.33	54.22	66.64	54.73	51.70	68.79	28.66	42.22
Software solution merit index (SMI) = 0.75* Primary driver score + 0.25* Secondary driver score	50.76	62.26	51.67	51.99	50.69	58.69	61.52	49.71	52.82	59.04	34.05	42.22

Notes: [a] Level 1: secondary drivers; [b] Level 2: attributes; [c] Level 3: attributes

Table V
Software solution merit index (SMI) for solution providers

Solution providers	Features	Technology	Support and service	Customisation	Primary score	Vendor vision	Vendor strength	Industries covered	Secondary score	SMI
Weightage (%)	40	30	20	10	75	50	25	25	25	
A	58.558	39.773	46.06	50.000	49.567	60.400	68.000	44.440	65.570	50.755
B	67.905	53.711	67.083	56.250	61.379	70.800	66.500	55.560	74.590	62.264
C	50.230	41.88	71.084	46.875	51.560	49.000	59.000	50.000	61.480	51.670
D	63.155	37.828	58.231	31.250	51.382	60.400	77.000	38.890	57.380	51.985
E	52.635	45.626	56.187	25.000	48.479	68.200	50.000	55.560	64.750	50.692
F	68.730	51.773	61.09	50.000	60.554	70.000	58.000	44.440	66.390	58.971
G	62.155	53.86	65.835	56.250	59.812	54.200	79.000	66.670	78.690	61.518
H	56.308	35.941	56.479	34.375	48.039	47.800	60.000	55.560	68.030	49.711
I	63.230	41.309	60.372	34.375	53.196	66.000	63.000	38.890	52.460	52.821
J	65.980	43.244	63.355	37.500	55.786	66.800	75.000	66.670	81.150	59.036
K	36.540	33.921	42.752	25.000	35.842	47.200	23.000	22.220	40.980	34.047
L	47.463	34.553	51.854	25.000	42.222	63.200	39.000	33.330	46.720	42.220

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little computational difficulty and complexity. Its strength lies in the fact that it requires moderate time for implementation and comparison.

The software selection criteria are very comprehensive and can be applied to selection of any kind of software solution selection. To make it specifically applicable to supply chain solutions several sub factors are included which may not be useful for other software selection, e.g. database engine used may not be significant in selection of word processing software.

In summary, the proposed criteria and model impart enough space for modification in the factor weightage, utilisation of full information, flexibility in the extent of classification and are widely applicable.

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