# Information system selection for a supply chain based on current trends: The BRIGS approach

**Abstract:** Information systems are very crucial in today's organizations and hence the selection of the right system has become a very critical decision. As time has progressed, with new issues affecting the supply chain and the performance metrics being continually rewritten, the responsibility of the information systems have increased manifold. Nowadays information systems are expected to perform a number of functions such as information security, big data handling, green supply chain, risk management etc. and thus the basic problem of system selection is now more complex. Also adding to the complexity is the fact that these new issues are interdependent and most of the times influence other issues in a variety of direct or indirect ways. This study addresses this problem by proposing a new model for information system selection by incorporating the latest trends in the supply chain. It also proposes an integrated methodology, to solve such a problem where interdependence between criteria exists. The advantages of this methodology over other existing techniques are delinking the evaluation of interdependent criteria weights from performance evaluation, flexibility of inputs, ability to handle vagueness and uncertainty in judgements. The methodology is illustrated using a numerical example.

**Keywords**: Supply chain management, information systems, green supply chain, information security, Big Data, fuzzy DEMATEL, fuzzy TOPSIS.

## 1. Introduction

Information sharing has quickly become the core activity for collaboration along the supply chain. This has been made possible by the wide acceptance and implantation of state of the art software systems, duly supported by communication devices [20]. A number of information flows are required in a supply chain, which create a lot of value in the chain and can be viewed as the bonding agent between financial and material flows [50]. Such is the importance of information flows through the chain, that a huge prohibitive cost is believed to be associated with the failure in achieving effective and efficient information flow [8]. An increasing emphasis has thus been placed on choosing the right information system (IS). It is widely accepted that it is impossible to meet all functionalities and requirements with a single system [22]. Also the system having the best technology is not necessarily the best for every firm. The more important aspect is that the system should have the capability to be customized and aligned to the requirements of the firm.

A better IS package is an asset for the firm and in general helps in improving the performance. The major function of these information systems is to integrate the information available from different access points and then disburse it selectively to whomever needs it. There are many benefits that one can gain from a successful information system such as automated processes, accurate and timely information and better e-commerce [31]. Also due to the resultant simplification, standardization and integration of processes, one can achieve higher quality and productivity [32]. But it is not easy to switch over to such systems. The companies need to undergo a lot of structural changes and needs to train the concerned staff and above all should have money to make all these investments [6]. Thus, because of the heavy financial investments and associated risks and benefits to the organization, the ERP system selection is undoubtedly an important decision.

### 1.1 Motivation for this study

There have been several significant developments in the information systems technologies and many recent trends in supply chain management itself, which questions the old methods of rating the performance of information systems. There are also a number of information systems available in the market today, which are capable of fulfilling the basic needs of organizations. That is to say that the technology has become more or less standardized and thus is available to all firms. This was not the case always, because earlier the proprietary information systems prevailed. Only when the rapid acceptance of web technologies and ERP started, the systems moved towards being more standardized and homogeneous [55]. Thus in order to get competitive edge out of the information systems, they are required to do something extra, which the other systems are not capable of and also to be abreast of the new technologies so as to make sure to take care of the recent trends. The best way to ensure that will be to better scrutinize the information systems during their selection. This is possible by adopting a more up to date model for selection. A model, which gives due credit and even extra weight to criterion which bring in the competitive edge. Some of such recent trends in the supply chain are green supply chain, big data analytics, integrated supply chain, risk assessment and information security.

Integration of information systems through the supply chain should improve performances [4]. The need of this integration arises because of inefficiencies and inaccuracies in information flows between firms in the chain. Chain wide adaption of IS will help countering it and also improve inter-enterprise cooperation [9]. One area where an integrated supply chain has immediate effect is the risk management. The first requisite in risk management is the timely access to the true information about disruptions. This helps in preparing rapidly for the response and thus be able to control the situation quickly. Many smaller organizations have the tendency to hide the information and thus it becomes very difficult to know about any problems which are building up in the chain. An integrated information system helps in making the chain more transparent and thus more manageable.

To achieve this though we need the systems to be able to handle the large amounts of data which such an integrated supply chain will produce. Also the systems should be able to make sense of the data by recognizing the patterns for any signs of problems. This is to say that the system should have big data capabilities. Current big data solutions can target tasks such as faster tracking and classification of goods [48], collecting data for transportation logistics planning and scheduling [19], and data analytics for health checking of suppliers and creditors or keeping track of partners' compliance conditions using web mining [64]. It is believed that supply chain collaboration and its processes will improve significantly by big data initiatives [53].

But big data brings big responsibilities to secure that data. Most of the organizations are skeptical of information about their operations being moving out of their control. They fear that these can land in hands of their competitors and thus can cause harm to them. With the supply chains growing to the every nook and corner of the world and the increasing complexity associated with it, the security of the data becomes even important. Information systems in this regard are responsible to protect the sensitive information and should allow the concerned party to have some control and also should ensure that only the needed information is shared and the requisite permissions are taken before sharing it. Encryption technologies should be used to protect the data from hackers. An information system is expected to perform all these duties and in an environment friendly way. Being environment friendly means the IT infrastructure associated with the system should be energy efficient. With increasing scrutiny being done these days for environment friendliness of the practices adopted in firms, they are responding by adopting green practices. These firms have become more cautious about environmental damage caused due to product recycling and also about the global warming issues.

### 1.2 Methodology review

A number of methods have been employed for selecting information systems including Analytical Hierarchy Process (AHP), Data Envelopment Analysis (DEA) and mathematical programming. Because of its simplicity, scoring method is a very popular method [36]. Teltumbde [51] proposed an integrated framework consisting of Nominal Group Technique and AHP. Similarly, Wei *et al.* [60] presented a framework which used AHP as a base for an integrated decision analysis process. They constructed a group evaluation method which systematically identified the objectives and the appropriate attributes. Wei and Wang [59] integrated the two different sets of data, objective and subjective which are received through reports and interviews, using used fuzzy set theory. Santhanam and Kyparisis [44] considered the various interdependencies between different IS platforms and proposed resource optimization through a nonlinear programming model. Lee and Kim [30] proposed selecting the best IS through a combined approach of ANP and goal programming. Bernroider and stix [3] combines the best concepts of two prominent methods i.e. DEA and utility ranking method for the IS selection and then applies on a real life case for numerical illustration. In a recent study, Karsak and Ozogul [26] proposed a novel decision framework for ERP software selection integrating goal programming, fuzzy linear regression and quality function deployment.

The business environment is getting increasingly complex each day. Also the resources at firms are limited and there are a number of issues demanding a share. In such a scenario, selection of the suitable ERP system is complicated by the number of diverse choices available [60]. Adding to the problem is the fact that there are a lot of criteria, both qualitative and quantitative, to be considered. Some of these criteria are easily quantifiable while the others are not. This requires the systems to be able to handle different kinds of inputs i.e. both objective and subjective assessments [56]. The fuzzy theory and grey theory come in handy to tackle this issue of subjective assessments and both of them are capable of dealing with it in an efficient manner. This study proposes a comprehensive methodology for IS selection, which takes into account the information flow risks. This is done using a novel integrated methodology proposed in this study which is based on fuzzy DEMATEL and TOPSIS approaches and is termed fuzzy DEMOPSIS. The methodology gives the flexibility to the experts to enter the inputs in any form they are comfortable in. A numerical illustration is given to explain the workings and also establish the usefulness of the proposed methodology.

The rest of the paper is organized as follows. Section 2 talks in detail about the proposed model and makes the case for five new criteria to be added in information system selection. It also focuses on the interactions between criteria and gives details about how these five new criteria influence each other. Section 3 discusses the techniques which go into the integration and thus the formulation of an integrated methodology. Section 4 explains the methodology being used. Section 5 gives a detailed numerical illustration of the problem solved. Finally, section 6 concludes the paper.

## 2. The proposed model

Regardless of the method, many criteria are often used for the selection process of information systems. Some of them are cost of purchasing, implementation and maintenance, interface with other systems, standardization, learning time for workers, flexibility, etc. The importance assigned to each selection criterion and their nature, keeps changing from one study to another. There are even few attempts to incorporate some criterion from the situation specific and sometimes from the recent trends. But there is no such study which takes care of the recent trends in such a comprehensive way. This is important because of the fact that only if these inclusions are done, can a firm hope of getting the competitive edge over other firms. Some may even argue that the below listed criterion are slowly becoming the main stream and thus carry more weight today than the conventional criteria. While the others will just include them without overstressing their importance. But in either case their inclusion in the criterion list is warranted by just the importance they are gaining in today’s scenario.

### 2.1 BRIGS approach

BRIGS stand for Big data handling (B), Risk management (R), Integrated supply chain (I), Green supply chain (G) and information Security (S). These are the five major issues trending in the supply chain literature today and so it is expected from the information systems today to be ready to address them. Some of the latest studies in these areas, in supply chain context, are given in Table 1 below.

Table 1: Latest studies in supply chain related to these areas

| Area | Studies |
|---|---|
| Big Data | Tan et al., 2015 [49]; Giannakis and Louis, 2016 [18]; Richey et al., 2016 [38]; Wang et al., 2016 [56] |
| Risk | Heckmann et al., 2015 [21]; Schmitt et al., 2015 [45]; Qazi et al., 2016 [37]; Wiengarten et al., 2016 [61]; Wu et al., 2015 [62]; Huong et al., 2016 [25] |
| Integrated | Huong et al., 2016 [25]; Park et al., 2016 [34]; Wiengarten et al., 2016 [61]; Van Donk and Van Doome, 2016 [52] |
| Green | Dubey et al., 2015 [12]; Fahiminia et al., 2015 [14]; Kusi-Sarpong et al., 2015 [28]; Wu et al., 2015 [62] |
| Information Security | Park et al., 2016 [34]; Shafiu et al., 2016 [46]; Xu and Nassar, 2016 [65]; Huong et al., 2016 [25] |

### 2.1.1 Big Data handling

Almost all organizations collect data in order to better understand the operations, make predictions, take better decisions or for simply records purposes. This has been happening from ever since people started businesses. Thus this is not an entirely new phenomenon. What is new though is the fact that with the advancement of digital age and with it the sophisticated systems, both hardware and software, it has become very easy to collect more and more data. Also number of such collection points has increased manifolds and now include, besides sensors, cell phones and laptops. This development brings with it both challenges and opportunities. There is a wealth of information hidden in this data and we need proper systems which can use it to make sense of it and come up with some useful readings from it.

Big analytical power comes in handy in such situation. For example, information about the past medical cases from digital records can help doctors in accurately diagnosing and treating illnesses, and bring down healthcare costs for providers and patients, and hence improve the overall quality and efficiency of healthcare [10]. But before we can do that we need proper storage devices which can store tons of these data. Here we need sophisticated data warehousing packages. Such packages help in easy and efficient storage and retrieval of data. Many of the times this storage and retrieval can be bottleneck process in the overall system. That's why the importance of big data handling in today’s information systems

Advances in data mining software’s have made things possible to go through the enormous amount of data and get useful information out of it. Companies have started to use this new force for their benefits and also are taking increasing interest in tracking customer behavior. They then use this information to customize their products or services or even after sales service to customers. Tesco for example analyzed that the fathers who are responsible for tending the babies at home and hence stuck being alone usually drank more beer. This led them to start sending beer coupons to men who bought diapers [47]. Another big application of big data is inventory management through better analysis of sensor information [53]. As more and more daily gadgets are being used as sensors and they are increasingly being put into a cohesive network, the necessity to have this big data capability and the power which it provides to the firms will only increase. Supply chain management is seeing increasing possibilities to automate some parts of its distribution network, through increasing availability of big data, by increasing use of GPS capable equipment, sensor networks and the concept of "Internet of Things" [1]. Latest trends point towards using machine learning techniques on this data to continually make the systems faster, efficient and more effective.

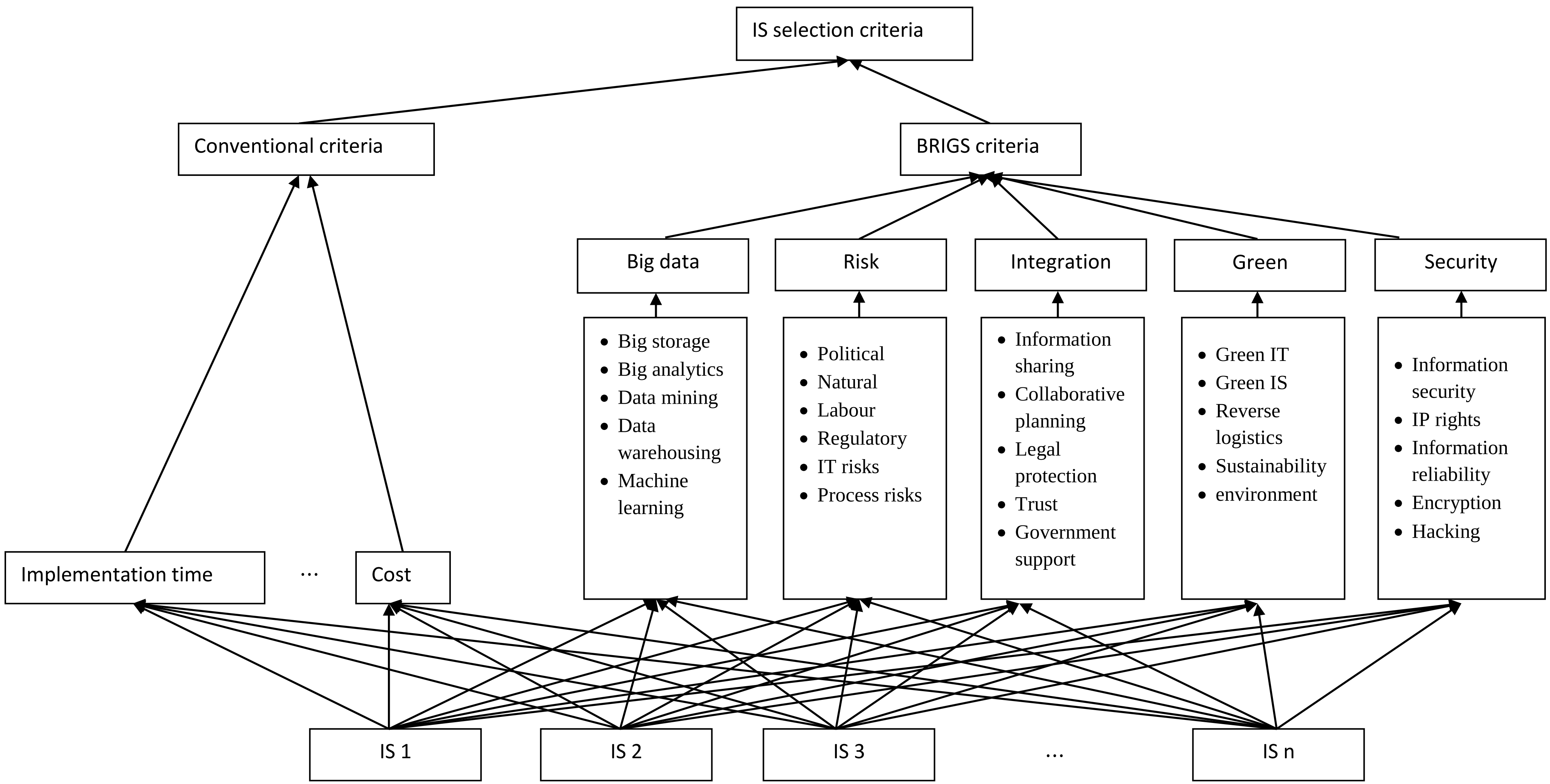


Figure 1: Combined IS selection hierarchy with conventional and BRIGS criteria

### 2.1.2 Risk management

The business environment has been becoming more and more complex. To survive and thrive in such an environment firm's are going global, outsourcing the non core activities to other vendors, opening manufacturing units in low cost countries etc [39]. This has resulted in longer, riskier and more complex supply chains. Consequently a plethora of risks, emanating from different points, are affecting supply chains today. Some of them are political, operational, legal, labor, natural, information technology (IT), regulatory risks etc. Managing such risky supply chains require timely and efficient procurement, management of inventory of raw materials as well as finished goods, accounting of resources etc. The growth in information and communication technologies provides a solution to deal with such situations effectively and efficiently. The most important function of risk management is the quick and effective dissemination of information to all the partners in the chain. Information systems play an important role in achieving this. The extent to which information is shared during such disruption situations develops trust between partners and consequently inculcates a positive relationship between them. This then also opens up the prospect of reducing supply chain efficiencies through collaboration [23].

Information is even more important in a dynamic environment that produces irregularities and disruptions [35]. To handle risks better, there should be free flow of information between different members in a chain. The firms in the chain will try to restrict this flow by not providing others in the chain with the complete information or may even provide wrong information. The information system should have the capability to weed out such forged information. The usefulness of a risk management tool depends heavily upon the information a firm has about the other partners in the chain. A member in the chain best knows about its own operations and the amount of risks it faces. It has better information about the likelihood and consequences of the risks it might face. Other thing is the flow of information during a disruption. This is the time when there is a huge demand for quality information throughout the chain about what has happened, when it happened, what will be the consequences, how much time will it take to recover etc. Now there can be 2 scenarios, one where the disruption is due to failure of information system itself and the second, when some other type of failure occurs. During the times when information system itself fails, there should be an alternative channel of information flow wherein at least basic information can keep flowing through the chain so that the supply chain keeps functioning at a minimum acceptable level of performance. When the other scenario occurs the information system should immediately document the important information about this event and disperse it to other members as soon as possible.

### 2.1.3 Integrated supply chain

It is a long held belief by the researchers and practitioners alike, that information integration plays an important role in success of supply chain management [11]. It is not possible to have complete IS integration between different firms as there are some information that firms do not like to share. Thus this happens only to a certain extent which can be defined as the degree to which a firm shares its information with suppliers and customers [2]. There are many types of information, many different ways and for different purposes for which information is shared. The role of information systems is to facilitate smooth and timely information sharing between different partners. It should also ensure that the information is shared only to the designated point and is not available anywhere else [17]. This brings in the issue of information security in an integrated supply chain information system. Thus we need proper government institutions which provide the needed legal protection in case of the misuse of the information by another partner in the chain. Such institutions are necessary to instill trust in members of a supply chain, which otherwise are reluctant to share the information about their business process.

The various ways of information integration along the supply chain can be classified under two categories: information sharing and collaborative planning [27]. Both of these elements are vital in supply chain management today and again the responsibility of executing these elements falls on the information system. If the errors creep in the information flow through the supply chain it can drastically hit the efficiency of the chain. Better information systems which can handle integration throughout the chain seamlessly, ensure smooth flow of information and thus help in proper functioning and improve effectiveness and efficiency. This also helps in implementing the above mentioned criterion namely risk management and big data handling. This is because only when the up to date information of the entire chain is available in real time, risk management is possible in true sense. Any distortion or delay in information transfer has the potential in rendering the risk management strategies ineffective because of the delay in implementing right measures. The suppliers also benefit hugely with the availability of timely information in an integrated environment. They are well informed of the activities at the demand end of the chain and can use this information to adapt their systems and thus resulting in the overall increase of efficiency in the system. For example: using information integration to control bullwhip effect in a supply chain.

### 2.1.4 Green supply chain

With rising interest in the overall greening of supply chains, the focus on the role of information systems have also grown. This focus has come up with two ways in which an information system can help in greening the supply chain. This is done by looking at the problem as a sum of two sub issues i.e. green IT and green IS. Whereas green IT is the greening of IT infrastructure and includes the power ratings, the efficiency, disposal etc. of the IT equipment, the idea behind green IS has been that implementation of IS should bring a wide effect in contributing to sustainable business [5]. The green IT view tries to reduce the pollution by incorporating better hardware and software, which is energy efficient, reduces electronic waste and is recyclable. Electricity generation for example can be considered as a major emitter of greenhouse gases and smart IS solutions in the grid can deliver increased efficiency [16]. In a much broader view it is believed that the sustainability across the supply chain is enhanced by the use of green IS. This requires the IS to help in improving the efficiency of major polluters along the chain, such as the transportation and manufacturing sectors [58].

Other than trying to help to reduce the overall emissions through the chain, information systems also help in keeping up to date data about emissions from different points in the chain. This is all the more necessary because as part of social responsibility companies are expected to contribute towards better environment by keeping an eye on the emissions along the chain and doing everything possible to keep improving on this measure. The threat of global warming and ever increasing frequency of the natural disasters are frequently linked with the emissions and the firms are expected to keep their best foot forward in tackling it. It is even argued that it is in the best interests of the firm itself because greening the chain brings in long term benefits through energy efficiency and enhancement in social image. Also driving is the issue of carbon credits, the system devised to push the firms towards adopting such initiatives.

### 2.1.5 Security

Organizations today increasingly share their data through the information systems and it is the duty of the IS to ensure the safety and security of the data [24]. This means that the data should be delivered to the right points only, where it is expected to be delivered. The data should also be suitably encrypted so as to save it from the hackers, who are frequently hired by the rival firms to get their hands on such sensitive data, so as to help them gain an insight into the competitors operations and thus gain an upper hand. A major issue related to such information thefts is the issue of intellectual property (IP). Although there ought to be strict legal processes to make such IP thefts prohibitive, the information system also plays its part in securing these rights. This is made possible by choosing the information system which offers best security features for the information shared through it. This is done by adopting a standard IS and also ensuring that the partners do follow the same standard. Another way is to take over the partner’s information security and upgrade the system throughout the chain [13]. Information security has been gaining increasing importance for securing data all along the chain. This is supported by the recent breach of credit and debit card data at Target, where according to the reports breach was tracked to a third party vendor [33].

## 2.2. The interactions

Today’s world is a complex business world where supply chains run long to almost every corner. One disturbance at one end of the supply chain can quickly reach to the other members in the chain. In this seriously interconnected world it will be foolish to think that it will be such a clean hierarchy of criteria in IS selection. Actually the case is that all these criteria influence each other, some directly and some indirectly, some influences are strong and some are weak, some are positive and some are negative. These influences are sometimes clearly visible and in other cases act silently from the background. The direct influences are normally the strongest ones and indirect influences keep losing their strengths as they are passed on from one layer to another. Thus it is advisable to at least consider the direct influences which make up for the major portion of overall influences. In this section we discuss the influences of criteria on one another. Figure 2 gives an expert views on how the five BRIGS criteria influence each other. Such views are not constant and depend on a variety of factors. They will change with experts, industry in focus, macro and micro environment at that time etc. Two signs are placed on the link connecting two criteria. The one closer to one criterion indicates the strength of that criterion influence on the other. A positive sign is used for strong influence, negative sign for weak influence and no sign is placed if there is no influence. A concise insight has been provided below on these interactions among BRIGS criteria.

Big data handling is surely the biggest of the BRIGS group. This is because of its ability to influence every other criterion directly and in a big way. As the capability of the information system to handle big volumes of data increases and the ability to deduce the information hidden within it, the usefulness of IS grows manifold. It become better prepared to handle risks as it is now able to predict some of them and for others it has timely information available. It also has the positive influence in enhancing the information integration along the chain. The IS can now use its data handling capacity to use all the data available, throughout the chain.

Risk management requires the information system to have information access points at every point in the supply chain where risks can emanate. Also required is the information about elements in external environment which can have effect on the supply chain vulnerability. All this needs capturing data and maintaining it for proper analysis. As the risk management capabilities are increased it directly has effects on data handling capabilities of the system and thus big data is influenced. The green attributes are adversely impacted because of this increase in IS infrastructure. Also risk management requires more and more information to be shared along the chain which influences the information security. This is because as more and more data is shared, the chances of it getting leaked out and falling in wrong hands are substantially increased. Also it can be clearly seen from the above discussion that risk management requires the information system to be integrated along the chain.

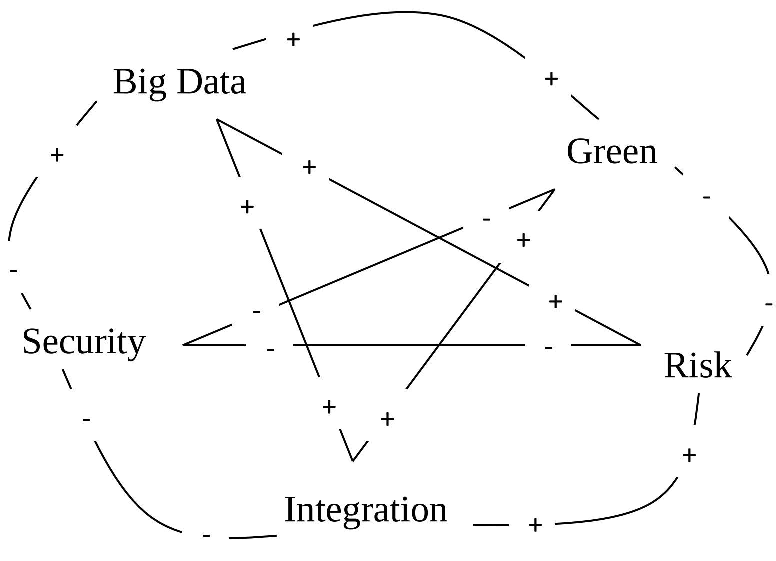


Figure 2: Interdependency network among the BRIGS

IS integration along the supply chain has positive influences to all but one criteria. It increases the importance of big data handling because of the presence of huge data and the requirement of systems which can make better sense of all this data. It influences the risk management in positive way as discussed before. Also it positively influences the green attributes of IS. This is because as the IS is integrated the efficiency of the system increases and thus the same IS performance is achieved with lesser IS infrastructure. But it affects the information security in the negative way as the integrated system provides for more leakage points. Pushing the IS systems to be more green require lesser infrastructure and hence negative influence on big data and risk management, but positive influence on integration and so negative again for information security. Similar influences exist for information security.

## 3. Preliminaries on technique

In real life conditions it is common to have subjective human judgements. This is because it is always not easy to give crisp assessments of the situations. The judgements thus come in the form of linguistic expressions such as good, bad, easy, difficult, long etc. These judgements should be converted to crisp numbers so as to make them suitable to be used in mathematical calculations. This conversion is facilitated by fuzzy logic theory. The required definitions of fuzzy logic are given in Wu and Lee [63]. The integrated methodology uses fuzzy logic and is discussed in the next section and the basics of the methods used in the technique are discussed here.

### 3.1 Fuzzy DEMATEL

Rarely do we get any system in which there are no internal interactions between its factors and also sub factors. The main purpose of DEMATEL method is to study both types of interactions i.e. direct and indirect, and also extent of influence between different sub-systems. The analytical procedure of the proposed method is explained as follows [15, 41, 43]:

Step 1: Assemble a group of experts having experience in the problem area.

Step 2: The expert group finalises criteria and designs the input scale of corresponding fuzzy linguistic numbers.

Step 3: Expert group then assesses the alternatives for each decided criteria. For finding the relationships between criteria $C = \{C_i | i = 1,2 \dots n\}$, experts are asked for pairwise comparisons in linguistic terms. Thus we obtain fuzzy matrices $\tilde{Z}^{(1)}, \tilde{Z}^{(2)}, \dots, \tilde{Z}^{(p)}$ one each for every expert with triangular fuzzy number values. Fuzzy matrix $\tilde{Z}^k$ is called the initial direct relation fuzzy matrix of expert k. denote $\tilde{Z}^k$ as:

$$\tilde{Z}^k = \begin{bmatrix} 0 & \tilde{Z}_{12}^{(k)} & \dots & \tilde{Z}_{1n}^{(k)} \\ \tilde{Z}_{21}^{(k)} & 0 & \dots & \tilde{Z}_{2n}^{(k)} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{Z}_{n1}^{(k)} & \tilde{Z}_{n2}^{(k)} & \cdots & 0 \end{bmatrix}; \; k = 1,2, \dots, P$$

$\tilde{Z}_{ij}^{(k)} = \left(l_{ij}^{(k)}, m_{ij}^{(k)}, u_{ij}^{(k)}\right)$

Without losing generality the $\tilde{Z}_{ij}^{(k)} = (i = 1,2,\dots,n)$ will be set to $z = (0,0,0)$, when it is necessary.

Step 4: Normalizing the above matrices. First consider $\tilde{\alpha}_i^{(k)}$ and $r^{(k)}$ as triangular fuzzy numbers as follows:

$$\tilde{\alpha}_i^{(k)} = \sum \tilde{Z}_{ij}^{(k)} = \left(\sum_{j=1}^{n} l_{ij}^{(k)}, \sum_{j=1}^{n} m_{ij}^{(k)}, \sum_{j=1}^{n} u_{ij}^{(k)}\right)$$

$$r^{(k)} = max\left(\sum_{j=1}^{n} u_{ij}^{(k)}\right) \quad 1 \le i \le n$$

Criteria scales are then transformed, using linear scale transformation, to comparable scales. The resultant normalized matrix of experts denotes as $\tilde{X}^{(k)}$ is given by:

$$\tilde{X}^{(k)} = \begin{bmatrix} \tilde{X}_{11}^{(k)} & \tilde{X}_{12}^{(k)} & \dots & \tilde{X}_{1n}^{(k)} \\ \tilde{X}_{21}^{(k)} & \tilde{X}_{22}^{(k)} & \dots & \tilde{X}_{2n}^{(k)} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{X}_{na}^{(k)} & \tilde{X}_{n2}^{(k)} & \cdots & \tilde{X}_{nn}^{(k)} \end{bmatrix}; \; k = 1,2,\dots,P$$

where, $\tilde{X}_{ij}^{(k)} = \frac{\tilde{Z}_{ij}^{(j)}}{r^{(k)}} = \left(\frac{l_{ij}^{(k)}}{r^{(k)}}, \frac{m_{ij}^{(k)}}{r^{(k)}}, \frac{u_{ij}^{(k)}}{r^{(k)}}\right)$

Similar to the original DEMATEL method, we assume at least one i such that $\sum_{j=1}^{n} u_{ij}^{(k)} < r^{(k)}$. Following equations are used, to calculate$\tilde{X}$, which averages point of view of all the experts:

$$\tilde{X} = \frac{\left(\tilde{x}^{(1)} \oplus \tilde{x}^{(2)} \oplus \dots \oplus \tilde{x}^{(p)}\right)}{p}$$

$$\tilde{X} = \begin{bmatrix} \tilde{X}_{11} & \tilde{X}_{12} & \dots & \tilde{X}_{1n} \\ \tilde{X}_{21}^{(k)} & \tilde{X}_{22}^{(k)} & \dots & \tilde{X}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{X}_{n1} & \tilde{X}_{n2} & \cdots & \tilde{X}_{nn} \end{bmatrix}; \; where \; \tilde{x}_{ij} = \frac{\sum_{k=1}^{p} \tilde{x}_{ij}^{(k)}}{P}$$

Step 5: Compute total-relation matrix$\tilde{T}$. Ensure convergence of $lim_{w \to \infty} \tilde{X}^{w} = 0$. According to the crisp case we define the total-relation fuzzy matrix as:

$$\tilde{T} = \lim_{w \to \infty} (\tilde{X} + \tilde{X}^2 + \cdots + \tilde{X}^w)$$

$$\tilde{T} = \begin{bmatrix} \tilde{t}_{11} & \tilde{t}_{12} & \dots & \tilde{t}_{1n} \\ \tilde{t}_{21} & \tilde{t}_{22} & \dots & \tilde{t}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{t}_{n1} & \tilde{t}_{n2} & \cdots & \tilde{t}_{nn} \end{bmatrix}$$

Where $\tilde{t}_{ij} = \left(l_{ij}^{"}, m_{ij}^{"}, u_{ij}^{"}\right)$

$\left[l_{ij}^{"}\right] = X_l \times (I - X_l)^{-1}$, $\left[m_{ij}^{"}\right] = X_m \times (I - X_m)^{-1}$ and $\left[u_{ij}^{"}\right] = X_{ul} \times (I - X_u)^{-1}$

The amount of $Matrix\ \left[l_{ij}^{"}\right]$,$Matrix\ \left[m_{ij}^{"}\right]$, $Matrix\ \left[u_{ij}^{"}\right]$ and finally matrix $\tilde{T}$ are mentioned above.

Step 6: After computing the matrix $\tilde{T}$, now it is easy to calculate the amount of $\widetilde{D}_i + \tilde{R}_i$ and $\widetilde{D}_i - \tilde{R}_i$ , where $\widetilde{D}_i$ and $\tilde{R}_i$ are sum of the rows and the sum of the columns of matrix $\tilde{T}$, respectively.

Step 7: Fuzzy numbers are now converted into crisp values

Step 8: Draw causal diagram.

**3.2 Fuzzy TOPSIS**

TOPSIS stands for Technique for Order of Preference by Similarity to Ideal Solution. As the name itself suggests, the ordering of the alternatives is done based on their similarity to the ideal solution. Thus the ideal solution and the negative ideal solution are defined and the alternatives are assessed based on their distances from these. These distances are then entered in the formula to calculate the overall score of closeness. The alternative which comes out on top, scores high on both closeness to the ideal solution and distance from the negative ideal. Chen [7] further extended the method to decision making situations with subjective assessments. The details of the method, explained in detail by Kutlu and Ekmekçioglu [29], is given below.

Decision makers use linguistic expressions to register their assessments. The average rating of alternative i with respect to each criterion j, with K decision makers, is given as [7, 42]

$$\tilde{X}_{ij} = \frac{1}{K}\left[\tilde{X}_{ij}^1(+)\tilde{X}_{ij}^2(+) \dots (+)\tilde{X}_{ij}^K\right],$$

Thus the problem can be expressed in matrix format as given below

$$D = \begin{bmatrix} \tilde{X}_{ij} & \tilde{X}_{ij} & \cdots & \tilde{X}_{ij} \\ \vdots & \vdots & \cdots & \vdots \\ \tilde{X}_{ij} & \tilde{X}_{ij} & \cdots & \tilde{X}_{ij} \end{bmatrix},$$

$$W = [w_1, w_2, \dots, w_n],\ j = 1,2,\dots,n,$$

where $w_j$ denotes the importance of $C_j$ and $\tilde{X}_{ij} = (a_{ij}, b_{ij}, c_{ij})$. Scales are converted to comparable scale using linear transformation. Therefore, the normalized matrix $\tilde{R}$ is given as

$$\tilde{R} = \left[\tilde{r}_{ij}\right]_{mxn}$$

where $\tilde{r}_{ij}$ for benefit criteria (B) and cost criteria (C) are

$$\tilde{r}_{ij} = \left(\frac{\tilde{a}_{ij}}{c_j^*}, \frac{\tilde{b}_{ij}}{c_j^*}, \frac{\tilde{c}_{ij}}{c_j^*}\right), \qquad j\epsilon B;$$

$$\tilde{r}_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{b_j^-}{b_{ij}}, \frac{c_j^-}{a_{ij}}\right), \qquad j\epsilon C;$$

$$c_j^* = max_i c_{ij} \quad if\ j\epsilon B;$$

$$a_j^- = min_i a_{ij} \quad if\ j\epsilon C.$$

Considering the different weight of each criterion, we construct the weighted matrix as

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

Where

$$\tilde{v}_{ij} = \tilde{r}_{ij}(.)d\left(C_j\right).$$

Then, we define the fuzzy positive-ideal solution (FPIS, $A^*$) and fuzzy negative-ideal solution (FPIS, $A^-$) as

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

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

Where

$$\tilde{v}_j^* = (1,1,1)\ and\ \tilde{v}_j^- = (0,0,0), \qquad j = 1,2, \dots, n.$$

The distance of each alternative from $A^*$ and $A^-$ can be currently calculated as

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

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

where d(., .) is the distance measurement between two fuzzy numbers calculating with the following formula:

$$d(\tilde{\rho}, \tilde{\tau}) = \sqrt{\frac{1}{3}[(\rho_1 - \tau_1)^2 + (\rho_2 - \tau_2)^2 + (\rho_3 - \tau_3)^2]}$$

where $\tilde{\rho} = (\rho_1, \rho_2, \rho_3)$ and $\tilde{\tau} = (\tau_1, \tau_2, \tau_3)$ are two triangular fuzzy numbers. The values of $\tilde{d}_j^*$ and $\tilde{d}_j^-$ are then used to find closeness coefficient which is used to determine the ranking order of all alternatives. This coefficient is calculated as

$$CC_i = \frac{\tilde{d}_j^-}{\tilde{d}_j^* + \tilde{d}_j^-}, \quad i = 1,2, \dots, m$$

An alternative $A_i$ is closer to the (FPIS,$A^*$) and farther from (FPIS,$A^-$) as $CC_i$ approaches to 1.

**4. Proposed Methodology**

This section details out an integrated approach using the above mentioned methodologies,for information system assessment and thus helping in selection of a suitable information system from a number of alternatives. The methodology consists of steps as given in Figure 3. The methodology is based mainly on fuzzy TOPSIS with the novelty of this study coming in form of the way criteria weights are found out. Criteria weights to be used in fuzzy TOPSIS are calculated using fuzzy DAMTEL method.

The first step in the methodology requires the experts to build the criteria hierarchy which is to be used for performance assessment. This step has to be repeated when a structural change is made in the supply chain or when a new information system is being considered. For the numerical illustration in this study the hierarchy shown in Figure 1 has been used. The second step in the process involves formation of decision matrices as well as formation of direct relation matrices. Both these steps require expert inputs and usually more than one expert is involved because of the subjective criteria. Next these expert inputs are aggregated into one and fuzzy DEMATEL is used to categorize the criteria into two sets i.e. one with overall outward influence and other with inward overall influence. These sets and the DEMATEL scores are then used to come up with criteria weights. This is done by adding a constant multiple of average overall effect score to the individual overall effect score. This is done for all the criteria which lie on outward influence set. The resultant scores are then normalized to get criteria weights. These weights are then used in fuzzy TOPSIS approach to get the final scores on which the alternatives are ranked. This helps the managers, to choose best alternative, through better representation of information avaialble. The individual scores for each criteria are also available so as to help when the managers want to pay particular attention to a particular type of criteria.

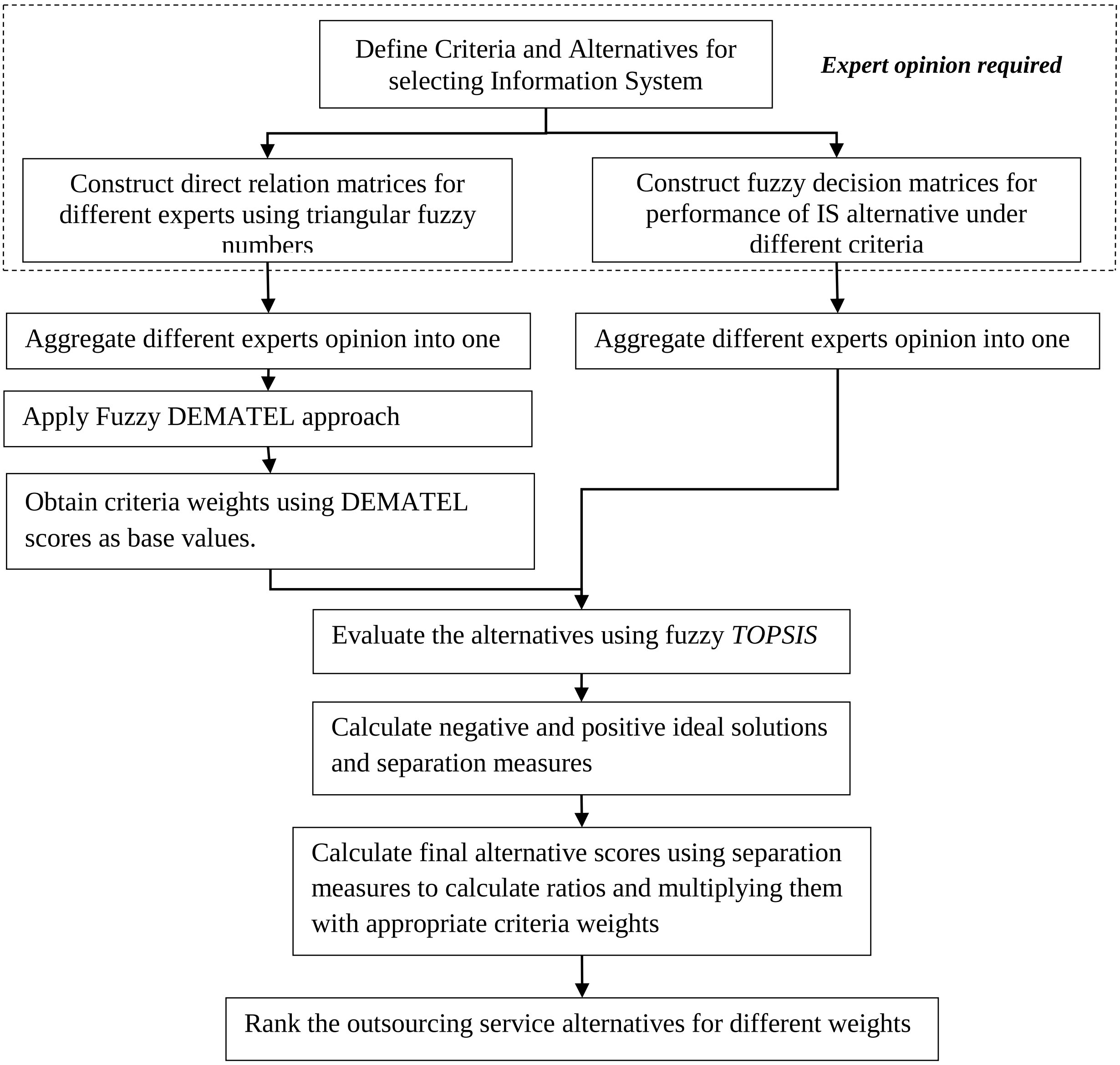


Figure 3: Proposed methodology for information system selection

### 4.1 Advantages

Although it is impossible to compare techniques in this class based on their results, because two ranks cannot be compared to tell which is the better rank, there are several obvious advantages and are discussed here. The advantages of this methodology over the existing ones include the flexibility to choose the weights independently from the performance analysis of the alternatives. This helps in quickly changing only the part which needs to be changed rather than going through the entire process again. For example if the scenario changes and weights should be revised it can be done without going through the pain of recalculating the performance values. Also important is the fact that the method can handle imprecise information and also the information in linguistic form. At every step in the process the methodology is ready to accept linguistuc inputs and thus has the ability to deal with the vagueness and uncertainty in judgements. The numerical illustration given in the next section shows clearly the advantages when inputs are available in different forms i.e. fuzzy intervals, crisp numbers or linguistic assessments.

Also when compared to the popular techniques such as ANP this methodology scores on the fact that it is not hindered by the need of strictly consistent matrices. Preparing consistent pairwise comparison matrices is a tough task because it is hard for a human expert to be consistent in his observations. The inputs in the proposed methodology are processed in one go and doesnt need many iterations for perfecting the input matrices. This way it becomes more easy to handle group decision making. The increase in complexity and processing time for ANP increases with increasing number of decision makers. This methodology doesnt suffer from this handicap and can deal with big numbers of decision makers with ease.

## 5. Numerical illustration

This section illustrates the proposed methodology using a numerical example. The example considered in this study has seven alternatives. Also there are a total of seven criteria on which the alternatives are evaluated. The input matrix is given in Table 2. The criterion values that fill up the decision matrix come from three different experts. It is always advisable to have opinion of more than one expert when such subjective assessments are involved. As can be seen from the decision matrix, this methodology provides the flexibility of giving inputs in form of linguistic expressions as well as crisp numbers. This is useful in the way that it is very hard to evaluate the subjective criteria and linguistic assessments are the best way to capture the opinion of experts in such situations. Table 2 has mixed input styles. Two criteria i.e. cost and implementation time have better information available and hence been given in fuzzy triangular numbers. For other criteria linguistic terms, given in Figure 4, have been used.

Table 2: Data used to evaluate and justify IS investments

| IS | Cost ($ millions) | Implementation time (days) | Big data | Risk | Integration | Green | Security |
|---|---|---|---|---|---|---|---|
| 1 | (5.3,5.8,6.3) | (30,32,35) | VP,VP,G | P,G,P | F,P,VG | VG,VP,P | P,VP,P |
| 2 | (3.9,4.1,4.5) | (39,42,45) | P,G,P | P,P,P | VG,F,VG | G,F,VP | F,VG,VP |
| 3 | (4.5,5.0,5.5) | (25,28,31) | VG,VG,F | P,VP,VG | F,VG,VG | F,VG,VG | VG,G,VP |
| 4 | (3.1,3.4,3.9) | (42,44,46) | G,VP,F | VP,F,F | F,VP,G | VG,F,F | VP,P,VP |
| 5 | (3.9,4.6,4.9) | (49,54,56) | F,F,VG | F,VG,P | VG,VG,G | VG,F,P | VP,VG,F |
| 6 | (6.1,6.7,7.0) | (37,39,44) | G,P,G | P,VG,F | VG,VG,VG | VG,F,P | F,VP,VP |
| 7 | (4.0,4.4,4.8) | (44,47,50) | F,VG,VP | VG,VG,F | F,P,VP | G,VP,F | F,F,F |

As different criteria have different importance under the context of the problem at hand, weights must be assigned. This is done by using a novel method proposed in this study which is based on the popular fuzzy DEMATEL technique. The inputs are given by an expert committee, in the form of linguistic assessment, which are then used to form the weights. These linguistic assessments are then converted to fuzzy numbers using pre set values for them. The values for linguistic assessments, given by experts, is given in Table 3.

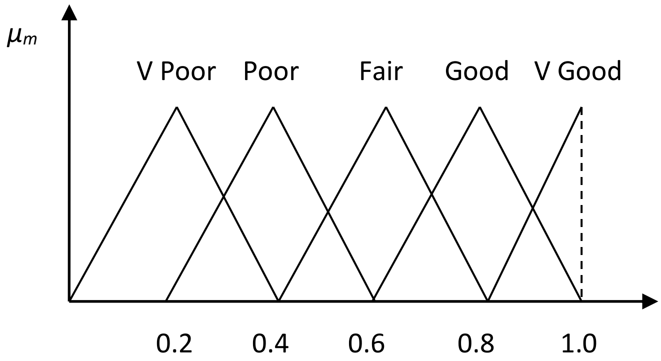


Figure 4: Membership functions for criteria values.

Table 3: Linguistic values for the corresponding linguistic terms [31]

| Linguistic terms | Linguistic values |
|---|---|
| No influence(NI) | (0,0,0.25) |
| Low influence(LI) | (0,0.25,0.5) |
| Medium influence(MI) | (0.25,0.5,0.75) |
| High influence(HI) | (0.5,0.75,1.0) |
| Very high influence(VHI) | (0.75,1.0,1.0) |

The committee consisted of 3 experts. Table 4 details out the evaluations filled by these experts on how one criterion influences the other.

Table 4: Expert opinion entries in form of linguistic assessment

| | C1 | C2 | C3 | C4 | C5 | C6 | C7 |
|---|---|---|---|---|---|---|---|
| C1 | NI,NI,NI | HI,MI,VHI | MI,MI,MI | LI,NI,NI | VHI,LI,VHI | HI,VHI,VHI | NI,LI,VHI |
| C2 | HI,VHI,MI | NI,NI,NI | NI,HI,LI | MI,HI,HI | MI,MI,LI | MI,NI,HI | VHI,NI,NI |
| C3 | VHI,LI,NI | VHI,NI,VHI | NI,NI,NI | NI,LI,MI | MI,HI,HI | MI,NI,HI | LI,HI,VHI |
| C4 | NI,VHI,NI | VHI,VHI,NI | MI,VHI,LI | NI,NI,NI | VHI,HI,HI | HI,NI,LI | HI,MI,VHI |
| C5 | HI,MI,LI | LI,VHI,MI | VHI,NI,VHI | NI,VHI,VHI | NI,NI,NI | MI,NI,NI | HI,VHI,NI |
| C6 | HI,VHI,LI | HI,LI,LI | HI,HI,LI | MI,MI,NI | NI,MI,LI | NI,NI,NI | LI,LI,NI |
| C7 | LI,HI,LI | HI,MI,MI | NI,NI,HI | LI,MI,VHI | HI,HI,VHI | HI,HI,VHI | NI,NI,NI |

After this the remaining steps of the fuzzy DEMATEL methodology are followed as explained in section 3.2. All these calculations end up with the values of D, R, (D+R) and (D-R). The corresponding values are shown in Table 5.

Table 5: Values of D, R, (D+R) and (D-R)

| | D | R | (D+R) | (D-R) |
|---|---|---|---|---|
| C1 | (0.5537, 1.4363, 5.8738) | (0.6091, 1.5019, 5.9259) | (1.1628, 2.9382, 11.7997) | (-5.3722, -0.0655, 5.2647) |
| C2 | (0.6758, 1.6467, 6.2936) | (0.5249, 1.3499, 5.8071) | (1.2007, 2.9967, 12.1007) | (-5.1312, 0.2968, 5.7687) |
| C3 | (0.5205, 1.3384, 5.7056) | (0.5587, 1.4003, 5.7861) | (1.0792, 2.7387, 11.4917) | (-5.2656, -0.0619, 5.1469) |
| C4 | (0.4532, 1.2107, 5.3219) | (0.6931, 1.6005, 6.1355) | (1.1463, 2.8112, 11.4574) | (-5.6823, -0.3898, 4.6288) |
| C5 | (0.6680, 1.6616, 6.5351) | (0.6253, 1.4669, 5.7430) | (1.2933, 3.1285, 12.2782) | (-5.0750, 0.1947, 5.9099) |
| C6 | (0.5814, 1.3889, 5.8489) | (0.3546, 1.1278, 5.3054) | (0.9360, 2.5167, 11.1544) | (-4.7240, 0.2611, 5.4943) |
| C7 | (0.5355, 1.3256, 5.4773) | (0.6225, 1.5611, 6.3533) | (1.1580, 2.8866, 11.8306) | (-5.8179, -0.2355, 4.8548) |

The next step is to defuzzify these values and these are shown in Table 6. The values clearly show that the $(D+R)^{def}$ values are all positive whereas the $(D-R)^{def}$ values are both positive and negative. The positive values indicate the overall outward influence and overall negative influence for the negative values. The values indicate the strengths of these influences and it can be deduced from the values that C6 is the criteria with the highest overall outward influence and C5 with the highest effect. Using these values as criteria weights the problem is now solved using fuzzy TOPSIS method. The expert opinions in Table 1 are now used to solve this problem. The values in the decision matrix are first aggregated using fuzzy arithmetic mean and then these values are used to find the ideal and anti-ideal solution for each criterion. The resulting values are shown in Table 7.

Table 6: Defuzzified values of (D+R) and (D-R)

| **Criteria** | **$(D+R)^{def}$** | **$(D-R)^{def}$** | **Normalized weights** |
|---|---|---|---|
| **C1** | 4.3628 | -0.0455 | 0.1311 |
| **C2** | 4.4502 | 0.2648 | 0.1660 |
| **C3** | 4.1698 | -0.0455 | 0.1253 |
| **C4** | 4.2220 | -0.3682 | 0.1269 |
| **C5** | 4.5752 | 0.2359 | 0.1697 |
| **C6** | 3.9482 | 0.2678 | 0.1509 |
| **C7** | 4.3308 | -0.2655 | 0.1301 |

Table 7: The performance values of the alternatives in form of interval data.

| **Criteria** | **Ideal Solution** | **Anti-Ideal Solution** |
|---|---|---|
| **C1** | (3.1000, 3.4000, 3.9000) | (6.1000, 6.7000, 7.0000) |
| **C2** | (25.0000, 28.0000, 31.0000) | (49.0000, 54.0000, 56.0000) |
| **C3** | (2.0000, 2.6000, 2.8000) | (0.6000, 1.2000, 1.8000) |
| **C4** | (2.0000, 2.6000, 2.8000) | (0.6000, 1.2000, 1.8000) |
| **C5** | (2.4000, 3.0000, 3.0000) | (0.6000, 1.2000, 1.8000) |
| **C6** | (2.0000, 2.6000, 2.8000) | (1.0000, 1.6000, 2.0000) |
| **C7** | (1.4000, 2.0000, 2.4000) | (0.2000, 0.8000, 1.4000) |

These values are then used to find distances of the expert entries of each alternative under each criterion. These distances are given in Table 8.

Table 8: Distances of alternatives from extreme solutions

| **IS** | **Distance from Ideal Solution** | | | | | | | **Distance from Anti Ideal Solution** | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C1 | C2 | C3 | C4 | C5 | C6 | C7 |
| **1** | 2.4 | 4.5 | 1.4 | 1.0 | 1.0 | 1.0 | 1.0 | 0.85 | 21.5 | 0.0 | 0.4 | 0.8 | 0.0 | 0.2 |
| **2** | 0.75 | 14.0 | 1.0 | 1.4 | 0.4 | 1.0 | 0.2 | 2.55 | 11.5 | 0.4 | 0.0 | 1.4 | 0.1 | 1.0 |
| **3** | 1.6 | 0.0 | 0.0 | 1.0 | 0.4 | 0.0 | 0.0 | 1.65 | 25.5 | 1.4 | 0.4 | 1.4 | 1.0 | 1.2 |
| **4** | 0.0 | 16.5 | 1.0 | 1.2 | 1.4 | 0.4 | 1.2 | 3.2 | 10.0 | 0.4 | 0.2 | 0.4 | 0.6 | 0.0 |
| **5** | 1.1 | 25.5 | 0.4 | 0.6 | 0.2 | 0.6 | 0.2 | 2.15 | 0.0 | 1.0 | 0.8 | 1.6 | 0.4 | 1.0 |
| **6** | 3.2 | 12.0 | 0.6 | 0.6 | 0.0 | 0.6 | 1.0 | 0.0 | 13.5 | 0.8 | 0.8 | 1.8 | 0.4 | 0.2 |
| **7** | 0.95 | 19.0 | 0.8 | 0.0 | 1.8 | 1.0 | 0.2 | 2.25 | 6.5 | 0.6 | 1.4 | 0.0 | 0.1 | 1.0 |

These values are then used to find the ratios as discussed in section. These ratios are then multiplied with the corresponding criteria weights as found before. The corresponding values are then aggregated to get the final scores of the alternative and are used to rank the alternatives. The values are tabulated in the Table 9. The rankings based on these values are given as IS5 > IS2 > IS1 > IS7 > IS3 > IS6 > IS4.

Table 9: Alternative performance scores

| **IS Alternatives** | **Ratio** | | | | | | | **Scores** |
|---|---|---|---|---|---|---|---|---|
| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | |
| **1** | 0.2615 | 0.8269 | 0.0 | 0.2857 | 0.4444 | 0.0 | 0.1667 | 0.5121 |
| **2** | 0.7727 | 0.4510 | 0.2857 | 0.0 | 0.7778 | 0.0909 | 0.8333 | 0.5709 |
| **3** | 0.5077 | 1.0 | 1.0 | 0.2857 | 0.7778 | 1.0 | 1.0 | 0.4117 |
| **4** | 1.0 | 0.3774 | 0.2857 | 0.1429 | 0.2222 | 0.6 | 0.0 | 0.3625 |
| **5** | 0.6615 | 0.0 | 0.7143 | 0.5714 | 0.8889 | 0.4 | 0.8333 | 0.6978 |
| **6** | 0.0 | 0.5294 | 0.5714 | 0.5714 | 1.0 | 0.4 | 0.1667 | 0.3896 |
| **7** | 0.7031 | 0.2549 | 0.4286 | 1.0 | 0.0 | 0.0909 | 0.8333 | 0.4988 |

Sensitivity analysis on the values is performed next and the results ascertain the effect of finding criteria weights in this way.

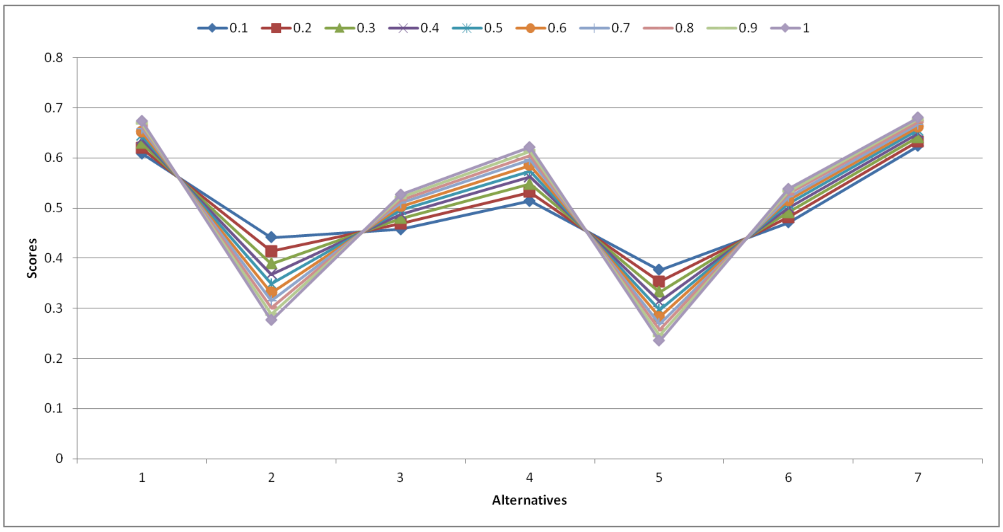


Figure 5: Effect of the changing multiplying factor on the alternative performance scores

This analysis is performed for the multiplying factor which is varied from 0.1 to 1.0 so that the additive part changes and thus as we increase this factor the criteria which have overall outward influence get more weight and thus their importance increases. We can see from Figure 5 that the increase in the value of this factor normally affects the alternative scores in a uniform way albeit the magnitude of the effect is different for different alternatives. For example the magnitude of effect on the scores of alternative 2 and 5 is more than that of the magnitude of effect on alternative 1 and 7. Also the affect is in opposite directions i.e. 2 and 5 see their scores decreased whereas the scores of 1 and 7 are increased. Due to this difference in magnitude of the affect on scores and also the direction of the affect, the rankings of the alternatives usually change as we move around the multiplying factor. This is shown in Figure 6 where it is evident from the crisscross of the lines how the rankings continuously change as we change the factor.

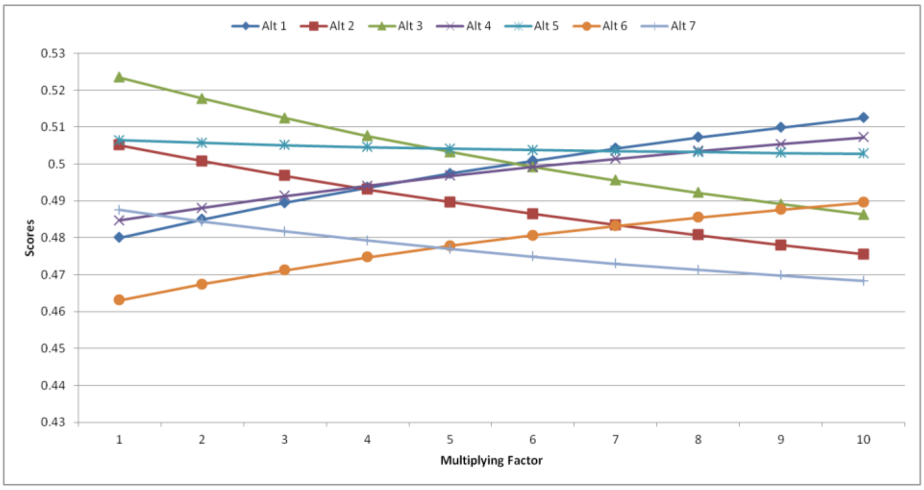


Figure 6: Changing alternative ranks as the multiplying factor is changed

The management thus should choose the factor judiciously taking into account the situation. For example if it is evident from history that one criteria usually has a big influence on the other factors then the criteria with overall outward influence should carry more weight and thus the multiplying factor should be kept large.

## 6. Conclusion and future research

Information systems help the partner firms in a supply chain to make better use of information available by synchronizing and integrating data. They are critical and indispensable tools in today's rapidly changing and highly uncertain world. The selection of IS is a very tough decision because of the number of alternatives available in the market. This study proposes a new model for selection of IS and also proposes a new integrated methodology to solve it. The model emphasizes on adding new criteria to the conventional ones. These new criteria reflect the new trends which are affecting the supply chain today and information systems are expected to be ready to deal with them. This study proposes BRIGS approach wherein the five new criteria i.e. big data, risk assessment, integrated supply chain, green supply chain and information security. The study dealt in detail on why these new criteria are important and also detailed out each one of them. Also the interactions between these criteria were discussed. The proposed model was solved using an integrated methodology. The subsequent selected alternative is robust in handling the factors prevalent currently.

Other than the five new criteria identified, there are other factors also such as internet of things and machine learning. These are fast changing the landscape of data handling and thus information systems. For example these directly affect the manpower required for operating IS, but on the other hand increases energy consumption due to greater computation requirements. Further research studies should include them and also provide for extensions in the current methodology. Also the criteria in BRIGS can have different importance depending on which part of the world the supply chain is situated. Also this importance will keep changing with time. Another extension of this study can be by changing methodology.

Like DEMATEL there are other methods which can handle interactions among criteria. Analytical Network Process is one of the other popular techniques.

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