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SAM/ANP Based Approach for Strategic Information System Project Selection

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Abstract

According to Strategic Alignment Model (SAM), Information system (IS) project selection problems are not only multi-criteria decision-making problems, but also have different relationships among factors that have influences on the selection of IS projects under different IS application goals, and are characterized with the complexity of interdependent relationships among objectives, criteria and candidate projects. Existing methods for the problems did not fully consider the above characteristics of the problems due to the limitations of the tools (e.g. Analytic Hierarchy Process, AHP) they used. Developed by Saaty, Analytical Network Process (ANP) provides a powerful way to resolve the interdependence of elements in decision-making problems. With the attempt of combining ANP methodology with SAM, this paper proposes an integrated approach for strategic decision on IS project selection. SAM is used as the theoretical foundation for problem solving, from which some fundamental relationships for IS project selection are formulated. ANP is used as the framework for modeling the problems. Application steps of the proposed methodology are also outlined.

Key words: Information systems planning, Strategic decision, Strategic alignment, ANP, AHP

1. Introduction and literature review

Information system project selection is one of the most important tasks for information systems planning. Information systems planning has been defined as 'the process of identifying a portfolio of computer-based applications that will assist an organization in executing its business plans and realizing its business goals' (Lederer and Sethi, 1988). In the same way, information system (IS) Project selection (hereafter IS selection) can be viewed as a process of identifying the most desirable information systems applications in which to invest.

Traditionally, Information systems have been used only as a support tool in the day-to-day work within a department of enterprises. Budgetary control, expense reporting, cost accounting, computer aided design (CAD), and etc are the typical applications in the data processing era (Ward and Griffiths, 1996). In these IS applications, the selection of IS projects are judged by their functional fit with the operational requirements of a department, always restricted by business strategy. This simple logic about the linear relationship among business strategy, operational requirements and IS functions provides the foundation for IS selection decisions in that era.

In the strategic information systems era (Ward and Griffiths, 1996), The scope for IS applications is extended to a whole organization, or even to industries. The objectives of IS applications are not merely to solve the operating problems of a particular department. However, the new focus for IS applications is on strategy. It is general believed that strategic information systems (SIS) are essential for a corporation to gain a competitive advantage to attain its business goals. A strategic information system is a system that significantly change business performance, the means the business employs to attain a strategic goal, the way a corporation does business, the way it competes, or the way it deals with customers or suppliers (Ernst and Chen, 1994). Therefore, it is vital to consider all factors surrounding the IS applications in IS selection decisions in order to use IS strategically. The ideas in strategic alignment research reflect the fundamental requirements for current IS applications.

Firstly, strategic alignment is the fit between the implemented IS projects and the organization's objectives (Lederer and Salmelab, 1996). According to the achievements in strategic alignment research, the success of IS applications is dependent upon the alignment of business strategy, information technology strategy (IT strategy), administrative structure, business processes, and adopted information technology and systems (Henderson and Venkatraman, 1993; Luftman, Lewis and Oldach, 1993). This means that many factors other than the operational requirements of departments and IS functions to be considered in the process of IS selection decisions. Business scope, distinctive competences, administrative structure, business processes, role of IS function, triggers for developing IS applications, skills of the people, and so on are the most common factors addressed in the literature of strategic alignment research (e.g. King and Teo, 1997; Das, Zahra, and Warkentin, 1991; Henderson and Venkatraman, 1993). They all have their influences on IS selection and make IS selection a multi-criteria decision making problem.

Secondly, with the foregoing application background for SIS, reciprocal influences of the related factors in IS applications have gained focus among researchers. King and Teo (1997) have identified 4 types of integrations between business planning and information systems planning, which show the reciprocal influences between business strategy and IT strategy. Therefore, it is essential to take the interdependence among business strategy, IT strategy and other factors into account in IS selections.

Thirdly, the diversity and dynamic nature of current external business environment have also a say in IS selections. In today's world, stability is rare and the one thing that will not change is change itself (Luftman, Lewis and Oldach, 1993). To cope with the diversity and dynamics of the external environment, enterprises distinguish themselves from their competitors by using information technology (IT) and information systems to develop their core competences, or reengineering their business processes by setting their administrative structures, business processes and value systems on the foundation of IT/IS applications. In this environment, transforming the enterprises in a way to enable the achievement of competitive and strategic advantage is the essential and topmost objective for IT/IS applications. This calls for characteristics of IS selection problems with multi-objective and uncertainty, and fosters the reshaping of new assumptions about IS selection, and sheds light on solving the problems.

Recently, several research attempts have been made to address the reciprocal influences of the related factors in IS selection problems. Meade and Sarkis (1998) proposed a model for logistics and supply chain management systems selections. Raisinghani (2001) also proposed a similar model for electronic commerce decisions. In their models, they considered the reciprocal influences between business strategy and IT strategy. But they did not considered the multi-objective in IS selection decisions while it is worth to do so because it should have different relationships among factors under different IS application goals (e.g. use IS for competitive advantage, organizational transformation, and so on). Furthermore, these models are originated from specific IS applications (e.g. logistics and supply chain applications, electronic commerce applications), they are doubted to be used in other applications, or at least they need to be improved before they can be used in other cases.

In this paper, with the attempt of addressing IS selection problems in general application background and taking the multi-objective in IS selection into consideration, we propose an integrated approach for solving IS selection problems based on Strategic Alignment Model (SAM) and on Analytic Network Process (ANP). In next section, we give a brief discussion of SAM. SAM is used as the theoretical foundation for problem solving, from which some fundamental assumptions about the relationships among factors involved in IS applications are outlined and formulated as the equations for modeling and solving problems. Next, based on the ANP framework, some fundamental constructors for modeling are identified by means of basic concepts of set theory. Finally, an integrated model for IS selection problems is outlined and the process of deriving the weights of the factors of the model is discussed following the ANP methods. Application steps of the proposed methodology are also outlined.

2. SAM and Model Formulation

Developed by Henderson and Venkatraman (1993), SAM is one of the most important models in strategic alignment research. Figure 1 illustrates the relationships among the components of the model.

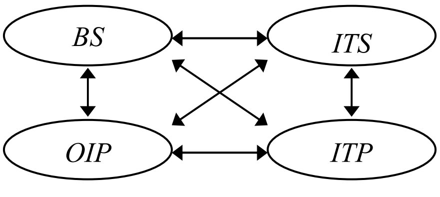

Figure 1. Relationships of elements in SAM

The model identifies four domains in the external and internal operating environment of enterprises. Business strategy (BS) and information technology strategy (ITS) belong to the high level strategic decisions to cope with the diversity and dynamics of the external environment in product market and IT market. Organizational infrastructure and processes (OIP), and IT infrastructure and processes (ITP) belong to the operational decisions that represent the internal arrangement of an enterprise responding to the changes of the external environment. The model reflects the view that business success depends on the harmony of the components among the four domains. Four alignment perspectives are suggested to achieve the harmony: strategy execution, technology transformation, competitive potential, and service level.

SAM provides a framework for reference in IT management. In this paper, three assumptions about the relationships among the components are drawn for IS selection decisions.

(1) In the stable external environment, articulating business strategy drives both the

organizational design and the choice of IS infrastructure as it has been described by the strategy execution perspective. The choice of IS is constrained by the organizational structure. The objectives of IS applications are to make IS functions fit with the requirements in business operation. The traditional requirements analysis process is undertook for such a purpose, which provides a base for IS selection. This assumption about the underlying logic in IS selection can be formalized as:

$$R(OIP) \Rightarrow S(IS) \qquad \cdots\cdots\cdots\cdots \quad (1)$$

It says that analysis of the operating requirements *R(OIP)* determinates the choice of information systems *S(IS)*.

(2) According to the technology transformation perspective. In the changing external environment, taking advantage of IT is a way to cope with the dynamics of the environment. In this case, IS choice should not be constrained by current organizational structures and processes, but instead it should seeks to identify opportunities for organizational transformation that is driven by business strategy. Hence, analysis of IT strategic requirements *R(ITS)* would naturally set up a foundation for IS selection decisions. However, the interdependence among components of business strategy and IT strategy brings about uncertainty and dynamics to the requirements of the two strategies. Therefore, alignment of the two strategies prescribes the choice of information systems. This assumption can be formalized as:

$$\begin{cases} R(ITS) \Rightarrow S(IS) \\ R(ITS) \Leftrightarrow R(BS) \end{cases} \qquad \cdots\cdots\cdots\cdots \quad (2)$$

where relationship $R(ITS) \Leftrightarrow R(BS)$ indicates the need to align the requirements of business strategy and IT strategy.

(3) To take full advantages of emerging IT capabilities to sustain long-term competitive advantage, it is reasonable to begin with IT strategy, and then to seek to identify the best set of strategic options for business strategy and the corresponding set of decisions pertaining to organizational infrastructures and processes. This notion is reflected in the competitive potential perspective. By the underlying logic of the notion, it is nature that decision on the choice of IS be centered on business strategy. Instead of analyzing operational requirements, analyzing business strategic requirements *R(BS)* would set up principles for decisions on IS selection. Again the interdependence among the components of the two strategies requires the alignment of the two strategies be achieved, that also prescribes the decisions for IS choice. This assumption is summed up as:

$$\begin{cases} R(BS) \Rightarrow S(IS) \\ R(ITS) \Leftrightarrow R(BS) \end{cases} \qquad \cdots\cdots\cdots\cdots \quad (3)$$

In this paper, we call the above relationships (1), (2), and (3) as IS selection equations, and the domain that dominates the choice of information systems as dominating domain. The domain *OIP* in equation (1), *ITS* in equation (2), and *BS* in equation (3) are such domains. Hence, information systems selection could be viewed as a process of solving the equations.

3. Constructor of the Model

Proposed by Saaty, Analytic Network Process (ANP) (1986, 1996) is a novel method after Analytic Hierarchy Process (AHP) (1980). ANP can be also applied to multi-objective and multi-criteria decisions, but is much powerful than AHP. However, except for a few cases reported from research literature (e.g. Raisinghani, 2001; Meade and Sarkis, 1998; Lee and Kim, 2000, 2001), applications of ANP in the area of IT management are quite rare. Considering the inherent nature of ANP and the characteristics of IS selection decisions as have been indicated above, the authors of this paper argue that it is worth to research on the application of ANP in IS selection problems.

3.1 The Nature of AHP/ANP in Decision Making

AHP is applied to the decision problems with linear relationships among elements. It assumes that the elements of the problem can be organized into a hierarchy. A hierarchy is comprised of a goal, levels of elements and connections (the relationships among elements). These connections are always single direction: from elements in upper levels to elements in lower levels.

ANP is a generalization of AHP. It goes beyond linear relationships among elements and allows inter-relationships among elements. Instead of a hierarchy, ANP based system is a network that replace single direction relationship with dependence and feedback. Therefore, ANP is more powerful than AHP in the decision environment with uncertainty and dynamics. For example, in IS selection problems, if the objectives of IS applications have been identified, say, to fit a particular business strategy, or IT strategy, or operational requirements, the decision on the optimal candidate projects can be made by simply applying AHP to the problem. However, in the changing environment with uncertainty and dynamics, the decision objectives cannot be easily identified because they correlate with other elements that also cannot be identified clearly. In this case, ANP comes to rescue.

From the above discussions, it can be concluded that equation (1) can be solved by applying AHP. Equation (2) and (3) are both composed of two relationships. The first relationship is used to measure the fitness of candidate projects to each strategic objective. This can be accomplished by applying AHP. The second one is used to set priority/preference for each objective under the correlated influences among the elements of the related domains. That is what ANP for.

3.2 Formalization of the SAM/ANP Based Model

The IS equations indicate that decision outcomes are obtained through resolving the correlated influences among the components in the domains of business strategy, IT strategy, and information systems applications. The attributes of the elements and their correlated-influence relationships are essential for building ANP/AHP based model to solve the equations.

In this section, we will use some basic concepts from set theory as constructors for modeling the problems.

3.2.1 Entity Sets

There are three types of sets involved in the IS equations.

(1) **Strategic entity set**. In strategy management, it is a general practice to distinguish strategies into several categories against a particular framework so as to establish a platform for communication among managers of an organization. Miles-Snow model (Miles and Snow, 1978) is such a well-known framework for classification of competitive strategies. It classified competitive strategies into three types: *defender*, *analyzer* and *prospector*. In IT

strategy management world, McFarlan (1984) outlined a well-known framework for classification of IS applications. The framework categorized IS applications into four types: *support*, *key operational*, *high potential*, and *strategic*, depending on their current and expected contribution to business success.

Details about Miles-Snow model and McFarlan model can be found in related literatures (Miles and Snow 1978, McFarlan 1984, Ward and Griffiths 1996).

In this paper, we call above classification frameworks of strategies as strategic entity sets, and the elements in a set as strategic variables. Generally, we also call the set that consists of all possible strategic entity sets as strategic entity space. Correspondingly, we have business strategic entity space and IT strategic entity space that consists of all possible business strategic entity sets and IT strategic entity sets separately.

To model the problem more specifically, let s denote a strategic variable, Es denote a strategic entity set that is a set consisting of strategic variables depending on a particular classification framework, $Es=\{s_1, s_2, ...\}$, and correspondingly, E_{BS} denote a business strategic entity set, E_{ITS} a IT strategic entity set. We also use Σ_{BS} to denote business strategic entity space, $\Sigma_{BS}=\{E_{BS1}, E_{BS2}, ...\}$, Σ_{ITS} to denote IT strategic entity space, $\Sigma_{ITS}=\{E_{ITS1}, E_{ITS2}, ...\}$, and Σ_S to denote strategic entity space, $\Sigma_S=\Sigma_{BS}\cup\Sigma_{ITS}$.

For example, *defender*, *analyzer*, and *prospector* are all strategic variables of Miles-Snow classification framework, so we have a business strategic entity set E_{MS}.

$E_{MS}=\{s_1, s_2, s_3\}=\{defender, analyzer, prospector\}\in\Sigma_{BS}\subset\Sigma_S$,

Support, *key operational*, *high potential*, and *strategic* are all strategic variables of McFarlan IS classification framework, so we have a IT strategic entity set E_{ISM},

$E_{ISM}=\{s_1', s_2', s_3', s_4'\}=\{support, key\ operational, high\ potential, strategic\}\in\Sigma_{ITS}\subset\Sigma_S$.

(2) **Criteria set**. Criteria set is a set that consists of criteria that indicate the attributes of a strategic variable. Table 2 in section 4 of this paper illustrates a criteria set for the strategic variables in Miles-Snow framework. A criterion can be decomposed into sub-criteria, and the set of all the sub-criteria of a criterion is called as sub-criteria set. As a general case, different strategic variables have different criteria sets, and different criteria have different sub-criteria sets. In this paper, we use criteria variable or simply criteria to denote criteria or sub-criteria, criteria set to denote criteria set or sub-criteria set.

Let $t_1, t_2, ...$ be the criteria of a criterion or strategic variable, the corresponding criteria set can be denoted by $T_i=\{t_1, t_2, ...\}$. The criteria set space that consists of all possible criteria sets can be denoted by $\Sigma_T=\{T_1, T_2, ...\}$.

(3) **Decision objects set**. The choice of information systems is the decision on a limited number of candidate projects in the decision space, denoted by Σ_O, that consists of all possible IS candidate projects. We call the candidate projects in a decision problem as decision object set, denoted by $O=\{o_1, o_2, ...\}\subset\Sigma_O$.

In the following part of the paper, we use entity set to denote any of the above three sets, denoted by E. The strategic entity set (business strategic entity set or IT strategic entity set) that has direct influences on the choice of information systems is called as objective entity set, that is in the dominating domains of IS equations. The elements of an objective entity set are called as objective variables.

3.2.2 Relationships and entity dependency

Let E_A and E_B be two different entity sets with n and m elements separately, $E_A=\{a_1, a_2, \dots, a_n\}$, $E_B=\{b_1, b_2, \dots, b_m\}$.

Definition 1 $R(a_k, E_B)$ is the relationship between element a_k and entity set E_B, $a_k \in E_A$, if a_k can establish a particular connection with every elements of E_B.

Definition 2 Regarding E_A and E_B, for every $a_k \in E_A$, $k=1, 2, \dots, n$, if relationship $R(a_k, E_B)$ can be established, the set of relationships $\{R(a_1, E_B), R(a_2, E_B), \dots, R(a_n, E_B)\}$ is called as the entity dependence of E_B on E_A, denoted by $R(E_A, E_B)$.

Three types of relationships can be identified among above three types of entity sets Σ_S, Σ_T, and Σ_O.

(1) **Hierarchy relations**. The relationships between strategic variables and their corresponding criteria sets, criteria and their corresponding subcriteria are hierarchy relations. A hierarchy structured model in the IS equation can be represented as:

$$MA=(\Omega_A, \Sigma_A),$$

where $\Sigma_A= \{T_1, T_2, \dots\}$, $T_1, T_2, \dots \in \Sigma_S \bigcup \Sigma_T$, $\Omega_A= \{R(a_k, T_i) \mid a_k \in T_j,\ T_j, T_i \in \Sigma_A, \text{ and } T_j \neq T_i\}$, and for $a' \in T' \in \Sigma_A$, $a'' \in T'' \in \Sigma_A$, if $R(a', T'') \in \Omega_A$, then $R(a'', T') \notin \Omega_A$.

(2) **Decision relations**. It is the relations between criteria and decision object set. In IS equations, the evaluations of candidate projects are obtained through these relations. A decision relation model can be represented as:

$$MD=(\Omega_D, \Sigma_D),$$

where $\Sigma_D=\{T_1, T_2, \dots, O\}$, $T_1, T_2, \dots \in \Sigma_T$, $O \in \Sigma_O$, $\Omega_D=\{R(a_k, O) \mid a_k \in T_i,\ T_i \in \Sigma_D, \text{ and } T_i \neq O\}$.

(3) **Network relations**. There are four reciprocal influences between two entity sets E_{S_i} and E_{S_j}: $R(E_{S_i}, E_{S_j})$, $R(E_{S_j}, E_{S_i})$, $R(E_{S_i}, E_{S_i})$ and $R(E_{S_j}, E_{S_j})$. Let $E_{S_1}, E_{S_2}, \dots$ be different strategic entity sets, the four reciprocal influences form a network model that can be represented as:

$$MD=(\Omega_N, \Sigma_N),$$

where $\Sigma_N=\{E_{S_1}, E_{S_2}, \dots\}$, $E_{S_1}, E_{S_2}, \dots \in \Sigma_S$, $\Omega_N=\{R(E_{S_i}, E_{S_j}) \mid E_{S_i}, E_{S_j} \in \Sigma_N\}$.

Therefore, IS equations can be solved by a decision system that is built up by the above three models: MN, MA, and MD, denoted by (MN, MA, MD). The subsystem (MN, MA) is called as control system in which the link between the two models of MN and MA is through an objective entity set. Decision model MD also makes up a subsystem (MD) called as decision system. Figure 2 illustrates a typical model with two strategic entity sets.

In control system, hierarchy model MA is used to derive the weights for every criterion in criteria set $T_1, T_2, \dots$. Network model MN is used to measure the preferences for every strategic variable in strategic sets E_{SA} and E_{SB}.

Decision system takes the measurement for every candidate projects in object set $O=\{o_1, o_2, \dots\}$ against the criteria in the lowest level of hierarchy through decision model MD.

4. Supermatrix and Basic Operations for AHP/ANP

4.1 Basic operations

Decision outcome of IS equations depends on the resolving of the influences among the components of different entity sets. In ANP/AHP the influences are measured by weights or preferences of the elements in the models.

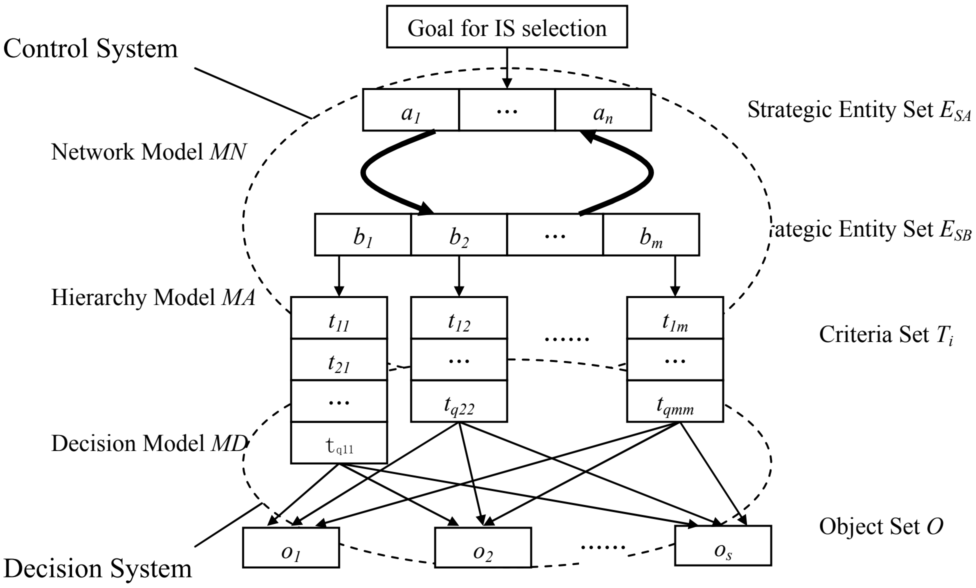

Figure 2. SAM/ANP based framework for IS selection decision

The essence of ANP/AHP decision depends on two basic operations, paired comparisons and deriving weights of homogeneous elements through the principal eigenvector of the matrix obtained from paired comparisons. ANP/AHP provide a ratio scaled comparison framework to measure the influences of elements with respect to a particular criterion by making pairwise comparisons among the homogeneous elements, from which a comparison matrix is formed. The 1-9 reciprocal ratio scale proposed by Saaty is the most commonly used one. Computing the principal right eigenvector of the comparison matrix, the weights of the corresponding elements in AHP model are hence derived. The complicated weights or preferences of elements under the reciprocal influences in ANP model are derived from a so-called supermatrix (Saaty, 1996).

Therefore, the measurement of the influences in IS equations can be described as a comparison operator in a ratio scaled comparison framework, denoted by Θ. For relation $R(a_k, E_B)$, $a_k \in E_A$, and E_A, E_B are any entity sets, let H be the 1-9 based reciprocal ratio scale, $H=\{h_1, h_2, ...\}=\{1, 2, ..., 9, 1/2, 1/3, ... , 1/9\}$.

Table 1 Comparison matrix $A(a_k, E_B)=(c_{ij})$ *for* relationship $R(a_k, E_B)$

a_k, Θ	b_1	b_2	···	b_m
b_1	c_{11}	c_{12}	···	c_{1n}
b_2	c_{21}	c_{22}	···	c_{2m}
···	···	···	···	···
b_m	c_{m1}	c_{m2}	···	c_{mm}

Definition 3 For operator Θ in relation $R(a_k, E_B)$, a matrix can be established in the form of table 1, where for any pairs of elements (b_i, b_j), $b_i, b_j \in E_B$, we have $c_{ij}=b_i \Theta b_j \in H$, and $c_{ij} \times c_{ji}=1$, $i, j =1, 2, ..., m$. The matrix is called as comparison matrix of relation $R(a_k, E_B)$ with respect to operator Θ, denoted by $A(a_k, E_B)=(c_{ij})$.

Comparison matrix $A(a_k, E_B)$ is a $m \times m$ matrix. It reflects the relative influences of element a_k in E_A on each one in E_B. And by the principle of AHP/ANP we have:

Weight deriving operation 1 The relative weights of elements in entity set E_B with respect to the relation $R(a_k, E_B)$ and operator Θ are derived through computing the principal right eigenvector of comparison matrix $A(a_k, E_B)$, denoted by $W(a_k, E_B)$.

Let's describe the process of computing the principal right eigenvector of matrix A in the form of a function $EGV(A)$. Hence, above weight deriving operation can be represented as $W(a_k, E_B)= EGV(A(a_k, E_B))$.

Definition 4 All the principal right eigenvectors of comparison matrixes $A(a_1, E_B), A(a_2, E_B), \dots, A(a_n, E_B)$ of dependence $R(E_A, E_B)$ form a $m\times n$ matrix, called as the weight matrix of dependence $R(E_A, E_B)$, and denoted by $W(E_A, E_B)$, that is

$W(E_A, E_B)=(W(a_1, E_B), W(a_2, E_B), \dots, W(a_n, E_B))$,

where $W(a_k, E_B)=EGV(A(a_k, E_B)), k=1, 2, \dots, n$.

4.2 Supermatrix formation

Supermatrix is essential to ANP. It is used to derive the complicated weights or preferences of elements in network models.

Generally, two types of dependence may be encountered in the models (see figure 3) (Meade and Sarkis, 1998): (1) self-dependence in which an entity has dependence on itself, e.g. $R(E_A, E_A)$ and $R(E_B, E_B)$; (2) interdependence in which an entity has dependences on other entities, e.g. $R(E_A, E_B)$ and $R(E_B, E_A)$.

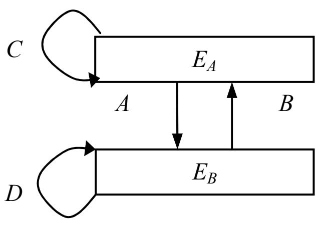

Figure 3. Entity Dependency

Apply the above definitions and operation to figure 3, four weight matrixes $W(E_A, E_B), W(E_B, E_A), W(E_A, E_A)$ and $W(E_B, E_B)$ for the corresponding dependences are obtained. Combining the matrixes in form (a) in figure 4, a supermatrix is formed, denoted by S.

In case of there are no any self-dependence exists in figure 3, or the self-dependences are too weak to be considered, the weight matrixes $W(E_A, E_A)$ and $W(E_B, E_B)$ are both zero matrix, and the supermatrix gives the form (b) in figure 4.

$$S=\begin{array}{cc} & \begin{array}{cc} \overset{E_A}{a_1a_2\cdots a_n} & \overset{E_B}{b_1b_2\cdots b_m}\end{array} \\ \begin{array}{cc} E_A & \begin{array}{c}a_1\\a_2\\\vdots\\a_n\end{array}\\ E_B & \begin{array}{c}b_1\\b_2\\\vdots\\b_m\end{array}\end{array} & \begin{pmatrix} W(E_A, E_A) & W(E_B, E_A)\\ & \\ W(E_A, E_B) & W(E_B, E_B)\end{pmatrix}\end{array}$$

(a)

$$S=\begin{array}{cc} & \begin{array}{cc} \overset{E_A}{a_1a_2\cdots a_n} & \overset{E_B}{b_1b_2\cdots b_m}\end{array} \\ \begin{array}{cc} E_A & \begin{array}{c}a_1\\a_2\\\vdots\\a_n\end{array}\\ E_B & \begin{array}{c}b_1\\b_2\\\vdots\\b_m\end{array}\end{array} & \begin{pmatrix} 0 & W(E_B, E_A)\\ & \\ W(E_A, E_B) & 0\end{pmatrix}\end{array}$$

(b)

Figure 4. Supermatrix formation

4.3 Deriving preferences from supermatrix

ANP derives the preferences of the corresponding elements in supermatrix S through a limit process. For this purpose, column stochastic (all its columns sum to unity) is required for S. Furthermore, if S is irreducible and primitive, then $\lim_{n\to\infty}S^n$ converges to a matrix, in which all its columns are identical and proportional to the principal right eigenvector of S. In the case of supermatrix in form (*b*), we have

$$\lim_{k\to\infty} S^k = (W_1, W_2, \dots, W_n, V_1, V_2, \dots, V_m),$$

where $W_1=W_2=\cdots=W_n=W, V_1=V_2=\cdots=V_m=V$.

Weight deriving operation 2 The complicated weights of elements in entity E_A and E_B

under the influences of their interdependences can be obtained by raising the supermatrix S in form (b) to the limit power S^{2k+1}, where k is an arbitrarily large number that allows S^{2k+1} converges to a relative stable matrix, in which the first n values in vector V are the preferences for the elements in E_A and the last m values in vector W are the preferences for the elements in E_B.

4.4 Desirability index and decision making

Decision of the optimal IS candidate project is obtained through synthesizing of the weights and preferences derived from the decision system *(MN, MA, MD)* into a desirability index for each candidate project. The desirability index of a candidate project can be recursively defined as:

$$I_{o_i}(t)=\sum W_{t_k} \times I_{o_i}(t_k)\ ,$$

where $I_{o_i}(t)$ is the desirability index of decision object o_i with respect to criterion t, $t, t_k \in \Sigma_A \cup \Sigma_D \cup \Sigma_N$, t_k is the subcriterion of t, W_{t_k} is the weight of t_k. It can be computed out in the following way:

(1) If $t \in \Sigma_D$, $I_{o_i}(t)$ is the weight of the decision object o_i, it can be obtained through applying definition 3 and weight deriving operation 1 to the decision model *MD*.

(2) If $t \in \Sigma_A$, W_{t_k} is derived through applying definition 3 and weight deriving operation 1 to the hierarchy model *MA*.

(3) If $t \in \Sigma_N$, $I_{o_i}(t)$ is the final desirability index of decision object o_i, denoted by I_{o_i}. W_{t_k} is the preference of o_i measured by the decision makers with respect to strategic variable t, and it is derived through applying definition 3-4 and weight deriving operation 2 to the network model *MA*.

After all desirability indexes for every decision object o_i are computed out, the optimal choice of the candidate projects is obtained through following expression:

optimal choice of the decision object $= max\{ I_{o_i} \mid o_i \in O\}$

5. Application Steps

The steps for utilizing the proposed model in IS project decisions are described with an illustration example.

Step 1: Identifying the goal for IS selection and the dominating domain.

The proposed model incorporates three IS application goals in the IS equations: executing business strategies, facilitating technology transformation, and sustaining competitive advantage separately. When the goal is identified, the dominating domain is also identified accordingly, it is *OIP*, *ITS*, or *BS* correspondingly.

Step 2: Identifying entity sets and their variables in each domain of the equations.

For example, if the goal for IS applications of an enterprise is to obtain competitive advantage, based on Miles-Snow business strategic classification framework and McFarlan IS classification framework, we have business strategic entity set E_{MS} and IT strategic entity set E_{ISM}, and the dominating domain is *BS* and objective entity is E_{MS}.

Step 3: Identifying criteria for every strategic variable in the objective entity sets and subcriteria for every criterion, and deriving their weights.

Table 2 illustrates a criteria set which is used for the judgment of strategic variables in Miles-Snow business strategic classification framework. After the criteria have been identified, their weights can be derived through AHP, in which definition 1, 3 and weight deriving operation 1 are applied.

Table 2 A criteria set for strategic variables in Miles-Snow framework

Defender	Analyzer	Prospector
Low cost	Low cost	Improvement of organizational innovation and creative ability
Specialization in production and service	Specialization in production and service	Influences on the focus of market
Improvement in effectiveness and efficiency	Improvement in effective and efficiency	Improvement in the distribution channels
Strengthening in process control	Improvement of organizational innovation and creative ability	Personality oriented mgt
Performance mgt	Flexibility and diversification in mgt	Flexibility and diversification in mgt
Vertical integration	Influences on the focus of market	Improvement in effectiveness and efficiency

Step 4: Supermatrix formation through the resolving of entity dependences.

In the illustrated example, Entity dependence $R(E_{ISM}, E_{MS})$ is resolved by pairwise comparisons among the three business strategic variables through answering the question *'Compared with two business strategic variables, which one is more suitable for the implementation of IS application model s'?'* With each $s' \in E_{ISM} = \{s_1', s_2', s_3', s_4'\} = \{support, key\ operational, high\ potential, strategic\}$, a comparison matrix is formed. Table 3 illustrates an example of the matrix for $s' =$ '*support*'.

Table 3 comparison matrix of business strategic variables with respect to 'support' IS model

Support, Θ	*Defender*	*Analyzer*	*Prospector*	*Eigenvectors*	*CI*
Defender	1	2	5	0.5813	*0.0018*
Analyzer	1/2	1	3	0.3092	
Prospector	1/5	1/3	1	0.1096	

In the same way, the comparison matrixes with respect to the IS application models of *'key operational'*, *'high potential'*, and *'strategic'* are also obtained, their principal right eigenvectors are the 1st, 2nd, 3rd, and 4th line of the weight matrix $W(E_{ISM}, E_{MS})$ separately (on the bottom left block of table 4).

Table 4 Supermatrix *S* of the illustration example

	support	*key oper.*	*high pote.*	*strategic*	*Defend.*	*Analyz.*	*Prosp.*
support	0	0	0	0	0.3049	0.0849	0.0631
key oper.	0	0	0	0	0.5030	0.3565	0.1173
high pote.	0	0	0	0	0.1335	0.3773	0.2750
strategic	0	0	0	0	0.0586	0.1813	0.5446
Defender	0.5813	0.1638	0.0982	0.0882	0	0	0
Analyzer	0.3092	0.5390	0.3339	0.2431	0	0	0
Prospec.	0.1096	0.2973	0.5679	0.6687	0	0	0

Applying the same process to entity dependence $R(E_{MS}, E_{ISM})$, weight matrix $W(E_{MS}, E_{ISM})$ (on the top right block of table 4) is also obtained by answering the question *'Compared with two IS application models, which one is more suitable for the implementation of business* *strategy s?'*.

Step 5: Deriving the preferences of strategic variables from the supermatrix with respect to the decision goal.

The supermatrix S is formed from combining weight matrixes $W(E_{ISM}, E_{MS})$ and $W(E_{MS}, E_{ISM})$. Table 4 shows the supermatrix of the example.

Raising the supermatrix S to the limit power S^{31}, the preferences for the IS application model *support, key operational, high potential,* and *strategic* are obtained, they are (0.111, 0.266, 0.288, 0.335), and also the preferences for the business strategies *defender, Analyzer,* and *Prospector* are (0.166, 0.355, 0.479).

Step 6: Applying AHP process to decision model MD to derive the weights of each candidate project with respect to every criterion in the lowest level of the hierarchy.

Criteria obtained through step 3 and the candidate projects $O=\{o_1, o_2, ...\}$ form the decision model MD. In the illustration example, comparison matrixes are obtained from answering the question *'With respect to a criterion t, compared with two candidate projects, which one is fitter to the criterion?'* The number of comparison matrixes is identical to the number of criteria that control the comparisons.

The weights of the candidate projects with respect to a criterion are obtained through computing the eigenvector of the corresponding comparison matrix.

Step 7: Synthesizing weights and preferences into desirability index and making decisions.

According to the processes described in section 4.4, all the weights and preferences obtained through the above steps are synthesized into a desirability index for every candidate projects, and then the decision on the choice of the most desirable information system can be derived.

6. Concluding remarks

Based on the well-known Strategic Alignment Model, we have presented an integrated model for IS project selection in this paper. In our model, we have identified three types of IS project decision approaches under different IS application goals, that is, executing business strategies, facilitating technology transformation, and sustaining competitive advantage. In order to use the model for making decision on IS project selection, we introduce an ANP/AHP based method to derive the weights for every elements involved in the model.

The alignment between business strategy and IT strategy is a key factor for the success of IS applications. For the strategic use of IS, it is very important to consider the interdependent relationship between business strategy and IT strategy because it represents the reciprocal influence between the two strategies, which exits in real IS application world. Although there are several other models to address the interdependent relationship between the two strategies, this paper attempts to address the problem in a general case and provide a generalized modeling technique for managerial decision making in IS selection problems that has not been fully explored by researchers or practitioners in IS management field.

However, in this paper, we did not apply the model to real-world IS selection problems. Then, in further research, it is need to show an application of real-world problems. Furthermore, there are other interdependent relationships among factors surrounding IS applications other than the reciprocal influence between the two strategies. Examples are the interdependent relationships between criteria and strategy, decision object and strategy, and so on. It will be beneficial to consider these interdependent relationships in IS selection decision making. We will address these points in our future research.

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