A Hybrid Strategic Development and Prioritization Model for Information and Communication Technology Enhancement

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ABSTRACT

The information and communication technology (ICT) sector has fostered the growth of several developed and developing countries. Recent studies on ICT-related businesses indicate that focusing on national policies is insufficient and underlines the importance of local and/or regional policies in promoting ICT. The authors propose a hybrid strategic development and prioritization framework for ICT enhancement and use the Delphi method and strengths, weaknesses, opportunities and threats (SWOT) analysis to assist the formulation of the ICT strategies. The analytic hierarchy process (AHP) is applied to weigh the SWOT factors and the technique for order preference by similarity to an ideal solution (TOPSIS) method is used to prioritize the ICT strategies. A comprehensive action plan with internal and external indices is derived from the strategic evaluation and assessment process to monitor the ICT enhancement progress. An application of the proposed framework is presented to demonstrate the simplicity and efficacy of the procedures and algorithms in a three-year study conducted for the State Office of Higher Education in a developing country.

Keywords: *Analytic Hierarchy Process (AHP), Delphi, Information Communication and Technology (ICT), Multi-Criteria Decision Making, Strategic Development, Strengths - Weaknesses - Opportunities - and Threats (SWOT), Technique for Order Preference by Similarity to Ideal Situation (TOPSIS)*

INTRODUCTION

Information and communication technology (ICT) is the combination of informatics technology with other related technologies specifically communication technology. Some researchers have referred to ICT as a term that contains software, hardware, networks and people while others have identified ICT as a process which includes sequences of phases for transforming data into information for decision making (Aldhmour & Shannak, 2009; Hwang, 2003). Nevertheless, most researchers agree that ICT overcomes the limitations of time and space and

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empowers people to communicate effectively. It transforms people into knowledge workers by enabling them to learn and acquire new skills and exploit new opportunities for self-improvement (Mhlanga, 2006). ICT enables the small, medium and micro enterprises networks to become more integrated and more effective across longer distances, operating with more efficiency and conducting more transactions (Chacko & Harris, 2006). There is substantial literature on the potential positive impacts of ICT on the economic growth of developing countries and most developing countries have set road maps for the integration of ICT in business and education (Seo & Lee, 2006). Several recent studies, including Arora and Athreye (2002) and Baliamoune-Lutz (2003), find that ICT has made a significant impact on the economic growth of developing countries. Addison and Rahman (2005) suggest that economies that successfully implement new ICT are able to overcome barriers that have long held them back in their contribution in global trade.

In response, governmental organizations have pushed ICT as a means to provide broad-scale training and to meet the demand for a skilled workforce. As a result, ICT has arguably become one of the most powerful agents for change in most developed and developing countries. It is evident that being a large producer of ICT is not a necessary condition for being an advanced user of ICT and the mere introduction of ICT in education does not in itself change anything (Sutherland et al., 2008). Koski et al. (2002) argue that the development and prioritization of the ICT enhancement strategies is a complex task for most developing countries and focusing on national policies is insufficient and rather underlines the importance of local and/or regional policies in promoting ICT. In this study, we propose a hybrid strategic development and prioritization framework for ICT enhancement. Delphi method and strengths, weaknesses, opportunities and threats (SWOT) analysis are used to formulate the ICT strategies and the analytic hierarchy process (AHP) is applied to weigh the SWOT factors. The technique for order preference by similarity to an ideal solution (TOPSIS) method is used to prioritize the ICT strategies and a comprehensive action plan with internal and external indices is derived to monitor the ICT enhancement progress.

The remainder of this paper is organized as follows. The next section presents a review of the relevant literature. We follow our literature review with a detailed description of the proposed framework. We then present an application of the proposed framework to demonstrate the simplicity and efficacy of the procedures and algorithms in a three-year study conducted for the State Office of Higher Education in a developing country. The last section presents our conclusions and future research directions.

LITERATURE REVIEW

Multi-criteria decision making (MCDM) methods are frequently used to solve real world problems with multiple, conflicting and incommensurate criteria. MCDM problems are generally categorized as continuous or discrete, depending on the domain of alternatives. Hwang and Yoon (1981) have classified the MCDM methods into two categories: multi-objective decision making (MODM) and multi-attribute decision making (MADM). MODM has been widely studied by means of mathematical programming methods with well-formulated theoretical frameworks. MODM methods have decision variable values that are determined in a continuous or integer domain with an infinitive or a large number of alternative choices, the best of which should satisfy the decision maker's (DM's) constraints and preference priorities (Hwang & Masud, 1979; Ehrgott & Wiecek, 2005). MADM methods, on the other hand, have been used to solve problems with discrete decision spaces and a predetermined or a limited number of alternative choices. The MADM solution process requires inter and intra-attribute comparisons and involves implicit or explicit tradeoffs (Hwang & Yoon, 1981).

MADM methods are used for circumstances that necessitate the consideration of different options that cannot be measured in a single dimension. Each method provides a different approach for selecting the best among several preselected alternatives (Janic & Reggiani, 2002). The MADM methods help DMs learn about the issues they face, the value systems of their own and other parties, and the organizational values and objectives that will consequently guide them in identifying a preferred course of action. The primary goal in MADM is to provide a set of attribute-aggregation methodologies for considering the preferences and judgments of the DMs (Doumpos & Zopounidis, 2002). Roy (1990) argues that solving MADM problems is not searching for an optimal solution, but rather helping DMs master the complex judgments and data involved in their problems and advance towards an acceptable solution. Multi-attribute analysis is not an off-the-shelf recipe that can be applied to every problem and situation. The development of MADM models has often been dictated by real-life problems. Therefore, it is not surprising that methods have appeared in a rather diffuse way, without any clear general methodology or basic theory (Vincke, 1992). The selection of a MADM framework or method should be done carefully according to the nature of the problem, types of choices, measurement scales, dependency among the attributes, type of uncertainty, expectations of the DMs, and quantity and quality of the available data and judgments (Vincke, 1992). Finding the "best" MADM framework is an elusive goal that may never be reached (Triantaphyllou, 2000).

Delphi Method

Delphi method, developed at the RAND Corporation, is a structured group interaction that proceeds through multiple rounds of opinion collection and feedback. Although Delphi dates back to the early 1950s, the most recognized book on the subject is written by Linstone and Turoff (1975). Fischer (1978), Schmidt (1997), Okoli and Pawloski (2004) and Keeney et al. (2006) provide excellent reviews of the method. Each round in Delphi is composed of a written survey followed by feedback to the participants of the statistical scores for each survey question. After each round the participants are pooled again to determine whether their opinions have changed after seeing the results from the previous round(s). Generally, after three or four rounds there is a convergence of opinions and a stabilized group opinion emerges. This group opinion may reflect agreement, disagreement or some of each. The optimum number of participants depends on the number needed to have a representative pooling of views but is typically between 10 to 50 members (Ndour et al., 1992). According to Keeney et al. (2006), "there is no universally agreed criteria for the selection of experts" (p. 208), "there is no magic formula to help researchers decide on who are the experts and how many there should be" (p. 209), and "working on the principle that experts must have knowledge of the subject area, participants cannot be selected randomly" (p. 208).

Analytic Hierarchy Process (AHP)

AHP is a MADM approach that simplifies complex and ill-structured problems by arranging the decision attributes and alternatives in a hierarchical structure with the help of a series of pairwise comparisons. Dyer and Forman (1992) describe the advantages of AHP in a group setting as follows: (1) the discussion focuses on both tangibles and intangibles, individual and shared values; (2) the discussion can be focused on objectives rather than alternatives; (3) the discussion can be structured so that every attribute can be considered in turn; and (4) the discussion continues until all relevant information has been considered and a consensus choice of the decision alternative is achieved.

Saaty (2000) argues that a DM naturally finds it easier to compare two things than to compare all things together in a list. AHP also examines the consistency of the DMs and allows for the revision of their responses. AHP has been applied to many diverse decisions because of the intuitive nature of the process and its power in resolving the complexity in a judgmental problem. A comprehensive list of the major applications of AHP, along with a description of the method and its axioms, can be found in Saaty (1994, 2000), Weiss and Rao (1987), and Zahedi (1986). AHP has proven to be a popular technique for determining weights in multi-attribute problems (Shim, 1989; Zahedi, 1986). The importance of AHP and the use of pairwise comparisons in decision making are best illustrated in the more than 1,000 references cited in Saaty (2000).

The main advantage of AHP is its ability to rank alternatives in the order of their effectiveness in meeting conflicting objectives. AHP calculations are not complex, and if the judgments made about the relative importance of the attributes have been made in good faith, then AHP calculations lead inexorably to the logical consequence of those judgments. AHP has been a controversial technique in the operations research community. Harker and Vargas (1990) show that AHP does have an axiomatic foundation, the cardinal measurement of preferences is fully represented by the eigenvector method, and the principles of hierarchical composition and rank reversal are valid. On the other hand, Dyer (1990a, 1990b) has questioned the theoretical basis underlying AHP and argues that it can lead to preference reversals based on the alternative set being analyzed. To better understand the rank reversal phenomenon, let us assume that three ICT projects $P1$, $P2$, and $P3$ are under consideration. Suppose that AHP has determined that the best ICT project is $P1$, followed by $P2$ and $P3$. This is the first ranking and it is indicated as follows: $P1 > P2 > P3$. Now suppose that project $P2$ is replaced by a worse project $P4$. That is, now we have $P2 > P4$, and project $P2$ is replaced by $P4$ while ICT project $P1$ and $P3$ remain in the pool of projects. When the new set of ICT projects (i.e., ICT projects $P1$, $P4$ and $P3$) are ranked together, $P1$ should still be the best project. Dyer (1990a, 1990b) argues that rank reversal has occurred if $P1$ is no longer the best ICT project. In response, Saaty (1990) contends that rank reversal is a positive feature when new reference points are introduced.

SWOT Analysis

MCDM problems involve the ranking of a finite set of alternatives in terms of a finite number of conflicting decision criteria. More often, decision criteria can be grouped into two contradictory categories, called the "opportunities" and the "threats." Alternatively, opportunities may be called "benefits" or "returns" and threats may be called "costs" or "risks." Higher alternative scores are preferred for opportunities and lower alternative scores are preferred for threats. In practice, two aggregation techniques are used to compute two aggregated indexes and evaluate the alternatives when criteria are divided into the opportunities and threats. The first approach is the opportunities to threat ratio approach (Tavana & Banerjee, 1995) and the second is the opportunities minus threat approach (Tavana, 2004). The former approach is a ratio scale and the latter approach is an interval scale.

Among the many tools and techniques in the strategic management literature, the strengths, weaknesses, opportunities, and threats or SWOT analysis has been widely used by both researchers and practitioners during the last several decades. SWOT is used to segregate the environmental factors and forces into internal strengths and weaknesses and external opportunities and threats (Valentin, 2001; Duarte et al., 2006). Since its inception in the 1950s, SWOT has gained increasing success as a strategic management tool (Panagiotou, 2003). SWOT is still alive and well as the popular framework for classifying environmental factors (Hitt et al., 2000; Anderson & Vince, 2002). Despite its popularity, SWOT has remained a conceptual framework with limited prescriptive power for practice and minor significance for research (Novicevic et al., 2004). In order to eliminate this drawback, SWOT is combined with AHP to prioritize the factors with pairwise comparisons.

SWOT-AHP Analysis

Over the past few years, there has been an increasing application of the integrated SWOT with AHP (Ho, 2008). Kurttila et al. (2000)

proposed the combined SWOT-AHP approach to aid the decision-making in a Finnish forestry. Kajanus et al. (2004) proposed the combined approach to investigate the role of culture in rural tourism. Their approach was similar to the framework presented previously in Kurttila et al. (2000) where the AHP was used to measure the relative importance weightings of the individual SWOT factors. Shrestha et al. (2004) used the integrated framework to analyze the possibilities for silvopasture adoption in south-central Florida. Their approach was similar to those adopted by Kurttila et al. (2000) and Kajanus et al. (2004). Shrestha et al. (2004) applied the integrated framework to agricultural planning and Masozera et al. (2006) adopted the same approach to assess the suitability of the community-based management method to the Nyungwe Forest Reserve in Rwanda. Shinno et al. (2006) presented the combined AHP–SWOT approach to analyze the global competitiveness of Japanese manufacturers of machine tools.

The Technique for Order Preference by Similarity to Ideal Solutions (TOPSIS)

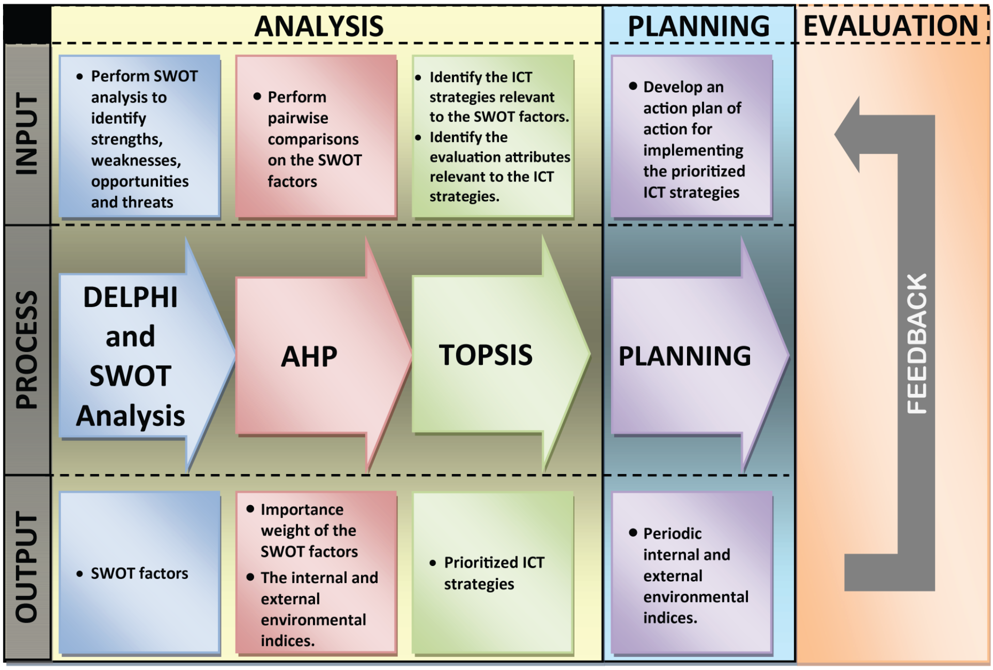
The TOPSIS method was initially presented by Hwang and Yoon (1981). It has been applied to a large number of application cases in advanced manufacturing (Agrawal et al., 1991; Parkan & Wu, 1999), purchasing and outsourcing (Shyura & Shih, 2006; Kahraman et al., 2009) and financial performance measurement (Feng & Wang, 2001). Its basic principle is that the chosen alternatives should have the shortest distance from the ideal solution and the farthest distance from the negative-ideal solution (Lai et al., 1994). The procedure of TOPSIS can be expressed in a series of steps (Hwang & Yoon, 1981).

TOPSIS has been shown to be one of the best MADM methods in addressing the rank reversal issue, which is the change in the ranking of alternatives when a non-optimal alternative is introduced (Zanakis et al., 1998). This consistency feature is largely appreciated in practical applications. Moreover, the rank reversal in TOPSIS is insensitive to the number of alternatives and has its worst performance only in the case of a very limited number of attributes (Zanakis et al., 1998; Triantaphyllou & Lin, 1996). A relative advantage of TOPSIS is its ability to identify the best alternative quickly (Paxkan & Wu, 1997). TOPSIS was found to perform better than AHP in matching a base prediction model. When there were few attributes, TOPSIS had proportionately more rank reversals. When there were many attributes, TOPSIS differed more from simple additive weight results. TOPSIS performed less accurately than AHP on both selecting the top ranked alternative and in matching all ranks of the simulation comparison (Olson, 2004).

PROPOSED FRAMEWORK

The proposed framework depicted in Figure 1 is comprised of the analysis, planning and evaluation phases. The procedure begins with a combined Delphi and SWOT analysis where the DMs perform environmental scanning and internal assessment to identify the strengths, weaknesses, opportunities and threats relevant to the ICT strategy prioritization problem. The output of this process is a set of SWOT factors. The DMs then use the AHP and conduct a series of pairwise comparisons on the SWOT factors. The output of this process is a set of importance weights associated with the SWOT factors. Furthermore, the DMs evaluate the current state by assigning numerical scores to the SWOT factors. The importance weights and the scores associated with the SWOT factors are then integrated to develop the internal and external environmental indices for the current state. Next, the DMs identify the ICT enhancement strategies relevant to the SWOT factors. Furthermore, the DMs identify the attributes relevant to the ICT prioritization process. TOPSIS is used next to prioritize the ICT strategies. The output of the TOPSIS process is a prioritized list of the ICT strategies. In the planning phase, the DMs use the prioritized ICT strategies developed in the analysis phase and develop an action plan. The

Figure 1. The process flow of the proposed framework



internal and external environmental indices are measured periodically and used as a feedback measure to evaluate the action plan.

The details of the proposed framework are described in a six-step process described as follows:

- **Step 1:** In this step, environmental scanning is used to identify the SWOT factors. The purpose of environmental scanning (the analysis of external opportunities and threats) is to evaluate whether the organization can seize opportunities and avoid threats when facing uncontrollable events such as fluctuating prices, political destabilization, social transition, change in the rule of law, etc. The purpose of internal assessment (the analysis of internal strengths and weaknesses) is to evaluate how the organization carries out its internal work such as management, work efficiency, research and development, etc.

- **Step 2:** In this step, the AHP is used to determine the importance weight of the SWOT factors. The process is repeated four times to determine the importance weight of the strengths, weaknesses, opportunities and threats.

- **Procedure 2.1:** Construct an $n \times n$ pairwise comparison matrix of the strength factors, $A = \left[a_{im}\right]$, where $a_{im} = w_i / w_m$:

$$A = \left[a_{im}\right] = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ \frac{1}{a_{12}} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ \frac{1}{a_{1n}} & \frac{1}{a_{2n}} & \cdots & 1 \end{bmatrix} \qquad i, m = 1, 2, \ldots, n. \tag{1}$$

The column sums are $\sum_i w_i / w_1$, $\sum_i w_i / w_2$, …, $\sum_i w_i / w_n$. The weights are just the reciprocals: $w_1 / \sum_i w_i$, $w_2 / \sum_i w_i$, …, $w_n / \sum_i w_i$. Since A is rank-1 matrix with diagonal entries all 1, it has unique nonzero eigenvalue n and all other eigenvalues are zeros. Next, the pairwise comparison matrix is normalized and the $w_1, w_2, ..., w_i$ weights are obtained.

In practice, the pairwise comparison matrix is not perfectly consistent. Saaty (2000) suggests a measure of consistency for the pairwise comparisons. When a DM's judgments are perfectly consistent, the maximum eigenvalue of the strengths $(\lambda_{\max})$ equals the number of strengths that are compared (n). Typically, the responses are not perfectly consistent, and $\lambda_{\max}$ is greater than n . The larger the $\lambda_{\max}$, the greater is the degree of inconsistency. Saaty (2000) defines a consistency index $CI = \left(\lambda_{\max} - n\right)/\left(n-1\right)$ and provides a random index (*RI*) table for the matrices of order *3* to *10*. This *RI* is based on the simulation of a large number of randomly generated weights. Saaty (2000) recommends a consistency ratio $CR = CI / RI$ for the same order matrix. A *CR* of *0.10* or less is considered acceptable. When the *CR* is unacceptable, DMs are alerted to that fact and requested to revise their weights to make them more consistent.

- **Procedure 2.2:** Repeat procedures 2.1 three additional times to obtain the importance weights of the remaining weaknesses, opportunities and threats.

- **Step 3:** In this step, we use a 1-5 Likert scale to assign a performance score to each SWOT factor $\left(p_i\right)$ and evaluate the current state of the internal and external environments. The Likert scale used for the strengths and opportunities includes: 1=non-effective, 2=less effective, 3=fair, 4=more effective and 5=very effective. The Likert scale used for the weaknesses and threats includes: 1=very low, 2=low, 3=fair, 4= high and 5=very high.

- **Step 4:** In this step we develop two indices for benchmarking purposes: the internal environmental index and the external environmental index. First, we find a total score $\left(S\right)$ for the strengths $\left(S_s\right)$, weaknesses $\left(S_w\right)$, opportunities $\left(S_o\right)$ and threats $\left(S_t\right)$ using the following equation:

$$S = \sum_{i=1}^{n} p_i . w_i \quad , 0 \le S \le 5. \tag{2}$$

Next, we use the following equation to find the internal environmental index $\left(\bar{D}_I\right)$ which is the Euclidean distance of the current internal index $\left(S_s, S_w\right)$ from the ideal point $\left(5.0, 1.0\right)$:

$$\bar{D}_I = \sqrt{\left(S_s - 5\right) + \left(S_w - 1\right)}, \quad 0 \le \bar{D}_I \le 5.657. \tag{3}$$

We then use the following equation to find the external environmental index $\left(\bar{D}_E\right)$ which is the Euclidean distance of the current external index $\left(S_o, S_t\right)$ from the ideal point $\left(5.0, 1.0\right)$:

$$\bar{D}_I = \sqrt{\left(S_s - 5\right) + \left(S_w - 1\right)}, \quad 0 \le \bar{D}_I \le 5.657. \tag{4}$$

The smaller Euclidean distance, the closer we are to the ideal point.

- **Step 5:** In this step, we develop an AHP hierarchy which consists of J ICT strategies for reaching the goal, and K attributes that relate to the strategies to the goal. We use AHP and determine a set of importance weights for the K attributes denoted as $w_1, w_2, ..., w_k$.
- **Step 6:** In this step, TOPSIS is used to prioritize the ICT strategies. The basic idea in TOPSIS is that the chosen strategy should have the shortest distance from the positive-ideal strategy and the farthest

distance from the negative-ideal strategy (Hwang & Yoon, 1981).

Consider J strategies denoted as $A_1, A_2, \ldots, A_j$. The rating of the *k*th attribute for ICT strategy A_j is denoted as f_{kj}.

- **Procedure 6.1:** Calculate the normalized decision matrix. The normalized value r_{kj} is calculated as:

$$r_{kj} = f_{kj} \Big/ \sum_{j=1}^{J} f_{kj}^2, \quad j = 1,2,\ldots,J;\ k = 1,2,\ldots,K. \tag{5}$$

- **Procedure 6.2:** Calculate the weighted normalized decision matrix. The weighted normalized value v_{kj} is calculated as;

$$v_{kj} = w_k . r_{kj} \qquad j = 1,2,\ldots,J, k = 1,2,\ldots,K, \tag{6}$$

where w_k is the weight of the *k*th attribute and $\sum_{k=1}^{K} w_k = 1$.

- **Procedure 6.3:** Determine the positive ideal strategy and the negative ideal strategy:

$$A_j^+ = \left\{v_1^+, v_2^+, \ldots, v_k^+\right\} = \left\{\left(\max_j v_{kj} \mid k \in I'\right), \left(\min_j v_{kj} \mid k \in I''\right)\right\}, \tag{7}$$

$$A_j^- = \left\{v_1^-, v_2^-, \ldots, v_k^-\right\} = \left\{\left(\min_j v_{kj} \mid k \in I'\right), \left(\max_j v_{kj} \mid k \in I''\right)\right\}, \tag{8}$$

where I' is associated with the strength and opportunity factors (benefit factors) and I'' is associated with the weakness and threat factors (cost factors).

- **Procedure 6.4:** Calculate the separation measures using the *n*-dimensional Euclidean distance. The distance between the ICT strategy and the positive ideal ICT strategy is given as:

$$D_j^+ = \sqrt{\sum_{k=1}^{K} (v_{kj} - v_k^+)^2}, \quad j = 1,2,\cdots,J. \tag{9}$$

Similarly, the distance between the ICT strategy and the negative ideal ICT strategy is given as:

$$D_j^- = \sqrt{\sum_{k=1}^{K} (v_{kj} - v_k^-)^2}, \quad j = 1,2,\cdots,J. \tag{10}$$

- **Procedure 6.5:** Calculate the relative closeness to the ideal ICT strategy. The relative closeness of the ICT strategy A_j is given as:

$$CC_j = \frac{D_j^-}{D_j^+ + D_j^-}, \quad j = 1,2,\cdots,J. \tag{11}$$

- **Procedure 6.6:** Rank the preference order of the ICT strategies.

CASE STUDY

In this section, we present an application of the proposed framework to demonstrate the simplicity and efficacy of the procedures and algorithms in a three-year study conducted for the State Office of Higher Education in the Islamic republic of Iran. This study was intended to promote and enhance ICT training and education in the colleges and universities statewide. The State Commissioner of Higher Education formed a committee of 12 educators (hereafter referred to as DMs) to supervise this project. The commissioner and the DMs agreed to use the framework proposed in this study to analyze, plan and evaluate the ICT enhancement project.

Step 1: In this step, we conducted a series of Delphi rounds to identify the SWOT factors relevant to the ICT enhancement project. Each of the 12 DMs were asked to individually identify the applicable strengths, weaknesses, opportunities and threats. Each DM compiled his/her personal set of SWOT factors anonymously made available to the remaining DMs.

Table 1. A comprehensive listing of the SWOT factors

Strengths	S1	Appropriateness and availability of space for developing ICT
	S2	Grow in admission of ICT related university majors
	S3	Appropriate trend of scientific articles related to ICT in international conferences and journals
	S4	Relatively appropriate quantity of ICT
	S5	Applying internet for educational process
	S6	Existence of ICT macro plans
	S7	Intellectuality of decision makers to develop functionality of ICT
Weaknesses	W1	Slow grow in the students and graduates of ICT related majors
	W2	Lack of ICT instructors at universities
	W3	Low condition of international communications of ICT universities
	W4	Lack of organizing ICT conferences
	W5	Lack of ICT related MSc and PhD thesis
	W6	Low quality of ICT
	W7	No goal in conducting ICT related students
	W8	Lack of required laboratory tools in ICT fields
	W9	Lack of transferring experiences from experts
	W10	Low rate of internet connections
	W11	Low numbers of computers
	W12	Low rate of internet consumption
	W13	Low quality of ICT services
	W14	Low availability of electronic libraries
	W15	Lack of e-library at universities
	W16	Low quality of firms websites
	W17	Limited application of LAN-INTERNET and EXTRANET
	W18	Inappropriate usages of internet for students welfare processes
	W19	Lack of admitting virtual students
	W20	Slow speed in implementing ICT development plans
	W21	Lack of a unique responsible agent to facilitate ICT development plans
	W22	No relationship between ICT graduates and their jobs
	W23	Little function of universities in developing ICT plans
	W24	Existence of barriers for universities to develop ICT
	W25	Lack of budgets for implementing ICT projects

continued on the following page

Table 1. Continued

Opportunities	O1	Appropriate laws related to ICT
	O2	Appropriate position of It in long run plans
	O3	Existence of rule bases to incorporate IT in organizations
	O4	Companies' readiness to employ university graduates
	O5	Increasing trend in fulfillment of research projects in the field of ICT
	O6	Existence of numerous corporations in the field of ICT
	O7	Managers' will in employing experts of ICT
	O8	Allocating desirable funds to organizations to develop ICT
	O9	Desirable expansion of internet network
	O10	Desirable expansion of Internet networks
	O11	Appropriate age pyramid of society to adopt ICT
	O12	Suitable share of ICT in the general budget
	O13	Directed ICT macro development plans
	O14	Appropriate influence rate of phone
	O15	Appropriate influence rate of mobile phone
	O16	Appropriate influence rate of internet
	O17	Desirable development of optical fiber
	O18	Increasing number of internet service provider such as: ISP, ICP, PAP, IDC, VIOP
Threats	T1	Lack of experts in the field of ICT
	T2	Lack of appropriate framework to employ students in doing research projects in the field of ICT
	T3	Lack of comprehensive support for educating human resources in the field of ICT
	T4	Being behind from E-GOVERNMENT program
	T5	Low functionality of active ICT firms
	T6	Low contribution of firms in ICT macro projects
	T7	Low usage rate of IT in families
	T8	Lack cultural activities to support adoption of ICT
	T9	Old-fashioned management style
	T10	Low rate of ICT dependent indices in families
	T11	Lack of research centers in the field of ICT
	T12	Lack of ICT research centers
	T13	Low rate of ADSL diffusion
	T14	Low rate of personal computers among families
	T15	Insufficient expansion of internet bound width

In round 1, a list with 389 SWOT factors was developed. The DMs were then asked to consider the group list with 389 factors as feedback and revise and resubmit their SWOT factors. A new list with 208 SWOT factors was developed in the second round. The new set of 208 SWOT factors was anonymously shared among the DMs who were asked to revise and

Table 2. The weights and the scores associated with the strength factors

Strength	Importance Weight	Performance Score	Overall Weighted Score
S1	0.092	2.25	0.207
S2	0.094	2.75	0.259
S3	0.114	2.75	0.314
S4	0.107	3.00	0.321
S5	0.173	2.25	0.389
S6	0.156	2.00	0.312
S7	0.263	3.25	0.855
Total Strength Score $\left(S_s\right)$			2.657

resubmit their SWOT factors again. In round 3, a list with 97 SWOT factors was developed. Again, this list was shared with all the DMs and they were asked to consider this feedback and revise and resubmit their SWOT factors. This process was repeated one more round. A new list with 58 SWOT factors was developed in the fourth round. The DMs agreed that they could no longer shorten the list and a decision was made to use the 58 SWOT factors with 7 strengths, 25 weaknesses, 18 opportunities and 15 threats which are presented in Table 1.

In Steps 2 and 3, the DMs used AHP individually and determined the importance weight of the 58 SWOT factors divided into strength, weakness, opportunity and threat sets. They also evaluated the current state of the internal and external environments by using a 1-5 Likert scale and assigning their performance scores to the SWOT factors. The individual weights and scores were averaged to produce the overall weighted scores for the strengths, weaknesses, opportunities and threats presented in Tables 2 through 5.

In Step 4, we determined the internal and external environmental indices for benchmarking purposes. As shown in Figure 2, the ideal internal index (where the strengths/opportunities are maximized) and the ideal external index (where the weaknesses/threats are minimized) were identified with the (5.00, 1.00) coordinates on the graph. The weights and the scores given by the 12 DMs produced an internal environmental index with the coordinate (2.657, 4.113) and a Euclidean distance of 3.896 from the ideal internal environmental index for the current state. Similarly, an external environmental index with the coordinate (3.158, 4.142) and a Euclidean distance of 3.642 from the ideal external environmental index for the current state was produced. In general, the current state was much further away from the ideal (best possible) point than the nadir (worse possible) point for both the internal and external environments. In summary, strategic alternatives with smaller Euclidean distance from the ideal point are preferred to strategic alternatives with larger Euclidean distance from the ideal point. In contrast, strategic alternatives with larger Euclidean distance from the nadir point are preferred to strategic alternatives with smaller Euclidean distance from the nadir point. We should note that changing the composition of the decision making group may result in new judgments and different Euclidean distances. The human judgment is the core input in our model. Our approach helps the DMs to think systematically about complex MCDM problems

Table 3. The weights and the scores associated with the weakness factors

Weakness	Importance Weight	Performance Score	Overall Weighted Score
W1	0.034	3.50	0.119
W2	0.046	5.00	0.230
W3	0.030	5.00	0.150
W4	0.029	4.00	0.116
W5	0.037	4.25	0.157
W6	0.037	3.75	0.139
W7	0.045	4.25	0.191
W8	0.037	4.50	0.167
W9	0.045	4.00	0.180
W10	0.026	3.50	0.091
W11	0.025	2.25	0.056
W12	0.036	4.25	0.153
W13	0.052	4.50	0.234
W14	0.033	3.50	0.116
W15	0.028	5.00	0.140
W16	0.020	3.50	0.070
W17	0.035	4.75	0.166
W18	0.018	3.50	0.063
W19	0.031	4.00	0.124
W20	0.057	4.00	0.228
W21	0.057	4.25	0.242
W22	0.040	3.50	0.140
W23	0.056	3.75	0.210
W24	0.071	4.00	0.284
W25	0.077	4.50	0.347
Total Weakness Score $\left(S_w\right)$			4.113

Table 4. The weights and the scores associated with the opportunity factors

Opportunity	Importance Weights	Performance Score	Overall Weighted Score
O1	0.066	3.75	0.248
O2	0.081	4.00	0.324
O3	0.038	3.00	0.114
O4	0.047	2.25	0.106
O5	0.062	2.50	0.155
O6	0.054	3.25	0.176
O7	0.064	2.50	0.160
O8	0.080	2.75	0.220
O9	0.035	3.50	0.123
O10	0.035	2.00	0.070
O11	0.073	4.50	0.329
O12	0.085	2.75	0.234
O13	0.057	3.00	0.171
O14	0.029	4.75	0.138
O15	0.027	3.50	0.095
O16	0.048	2.25	0.108
O17	0.057	3.25	0.185
O18	0.062	3.25	0.202
Total Opportunity Score $\left(S_o\right)$			3.158

and improves the quality of the decisions. We decompose the problem process into manageable steps. This decomposition encourages DMs to carefully consider the elements of uncertainty. The proposed structured framework does not imply a deterministic approach in MCDM. While our approach enables DMs to assimilate the information and organize their beliefs in a formal systematic approach, it should be used in conjunction with management experience and expertise. Managerial judgment is an integral component of the process; therefore, the effectiveness of the model relies heavily on the DM's cognitive capabilities.

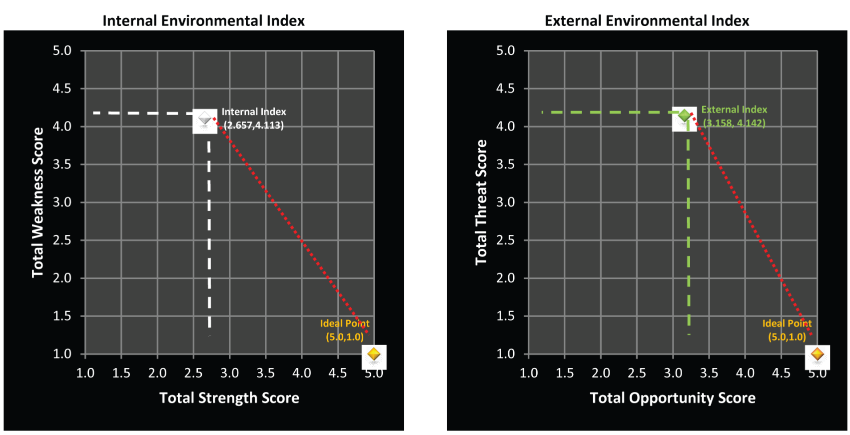
In Step 5, the DMs developed the AHP hierarchy presented in Figure 3 which consisted of four ICT strategies and 10 attributes for promoting and enhancing statewide ICT training and education in the colleges and universities.

The 58 SWOT factors developed earlier were used to derive the four ICT strategies presented in Table 6.

Table 5. The weights and the scores associated with the threat factors

Threat	Importance Weight	Performance Score	Overall Weighted Score
T1	0.068	3.50	0.239
T2	0.071	4.50	0.319
T3	0.062	4.50	0.277
T4	0.083	3.50	0.289
T5	0.065	4.25	0.277
T6	0.077	3.75	0.290
T7	0.046	4.50	0.209
T8	0.094	5.00	0.469
T9	0.104	4.50	0.469
T10	0.042	3.75	0.157
T11	0.080	4.50	0.358
T12	0.050	4.50	0.224
T13	0.035	3.00	0.104
T14	0.064	3.50	0.225
T15	0.059	4.00	0.236
Total Threat Score $\left(S_t\right)$			4.142

Figure 2. The internal and external environmental indices for the current state (t=0)



$\overline{D}_I = 3.896$ $\overline{D}_E = 3.642$

Figure 3. The TOPSIS attributes

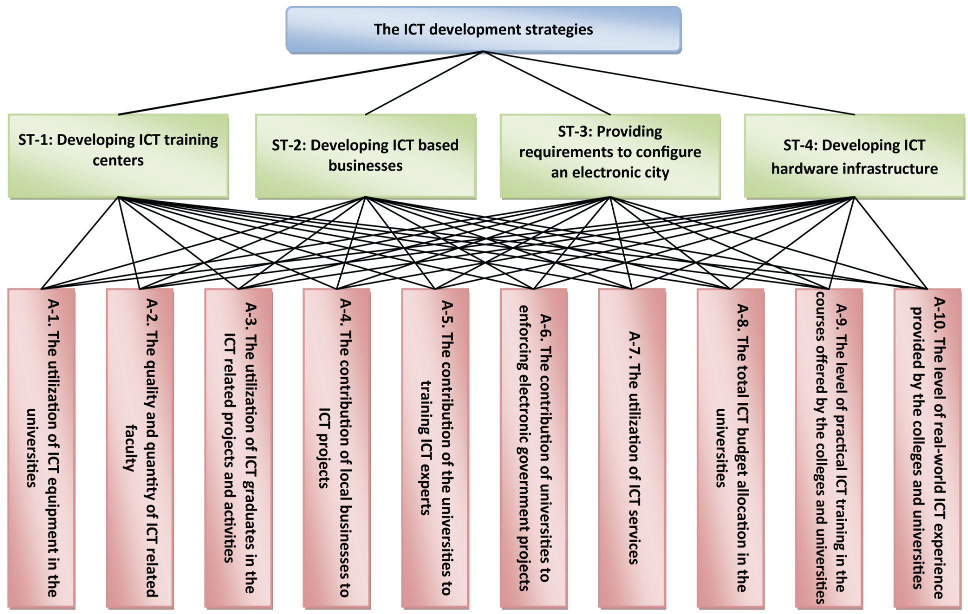


Table 6. The ICT strategies and their relevant SWOT factors

Dependent Factors	Strategy	
S1-S7,	Developing ICT training centers	**ST-1**
W1-W25,		
O2-O5, O9, O11-O13, O17, O18 and		
T1-T4, T6, T11.		
S4, S7,	Developing ICT based businesses	**ST-2**
W4-W7, W9, W22,		
O1-O3, O5- O8, O11, O12 and		
T1, T2, T4-T6, T9, T11.		
S1, S3, S4, S7,	Providing requirements to configure an electronic city	**ST-3**
W2-W9, W12, W14, W15, W17, W20, W22-W24,		
O3, O5, T1, T2, T4 and		
T7-T10, T12-T15.		
W8, W10-W16, W21,	Developing ICT hardware infra-structure	**ST-4**
O9, O16-O18 and		
T1,T4, T11-T13, T15.		

In Step 6, TOPSIS was used to prioritize the four ICT strategies. We calculated the normalized decision matrix and the weighted normalized decision matrix. The individual scale removed strategy-attribute performance scores were averaged for the group. The group performance scores for the four ICT strategies and the 10 attributes are presented in Table 7.

In addition, the DMs used AHP individually and developed their importance weights for the 10 attributes used in TOPSIS. The weights presented in Table 8 shows the group importance weights.

In order to determine the positive ideal strategy and the negative ideal strategy, we constructed the strategy-attribute weighted normalized matrix and the TOPSIS positive and negative ideal solutions as presented in Tables 9 and 10.

The overall TOPSIS results are presented in Table 11. As shown in Table 11, strategy 1 was ranked first, followed by strategies 3, 4, and 2. This ranking was reported to the State Commissioner of Higher Education who in turn agreed to implement the four strategies according to the priorities established by the 12 member committee.

At the end of the first, second and third year; the 12 member committee repeated their evaluation of the action plan developed earlier to implement the four ICT strategies. The data collected during the three years is graphically depicted in Figure 4.

Figure 4 shows a significant statewide progress towards the promotion and

Table 7. The scale removed strategy-attribute performance score matrix

Strategy	Attribute									
	A-1	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
ST-1	0.609	0.674	0.575	0.390	0.629	0.449	0.289	0.609	0.547	0.730
ST-2	0.609	0.481	0.411	0.234	0.449	0.449	0.481	0.435	0.390	0.313
ST-3	0.435	0.481	0.575	0.703	0.090	0.449	0.674	0.609	0.234	0.313
ST-4	0.261	0.289	0.411	0.547	0.629	0.629	0.481	0.261	0.703	0.521

Table 8. The attribute importance weights

Attribute	Importance Weight $\left(w_i\right)$
A-1	0.091
A-2	0.078
A-3	0.132
A-4	0.105
A-5	0.069
A-6	0.136
A-7	0.089
A-8	0.151
A-9	0.071
A-10	0.077

Table 9. The strategy-attribute weighted normalized matrix

Strategy	Attribute									
	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	A-9	A-10
ST-1	0.056	0.053	0.076	0.041	0.044	0.061	0.026	0.092	0.039	0.056
ST-2	0.056	0.038	0.054	0.025	0.031	0.061	0.043	0.066	0.028	0.024
ST-3	0.040	0.038	0.076	0.074	0.006	0.061	0.060	0.092	0.017	0.024
ST-4	0.024	0.023	0.054	0.057	0.044	0.085	0.043	0.040	0.050	0.040

Table 10. The TOPSIS positive and negative ideal solutions

Ideal	Attribute									
	A-1	A-1	A-1	A-1	A-1	A-1	A-1	A-1	A-1	A-1
A_j^+	0.056	0.053	0.076	0.074	0.044	0.085	0.060	0.092	0.050	0.056
A_j^-	0.024	0.023	0.054	0.025	0.006	0.061	0.026	0.040	0.017	0.024

enhancement of the ICT strategies. During the initial state (t=0), the internal environmental index had a distance of 3.896 from the ideal index where as in the second year this distance was reduced to 3.579. The distance was further reduced to 3.220 and 2.267 in years 2 and 3 resulting in a 41.8% overall improvement (reduction in the Euclidean distance). Similarly, during the initial state (t=0), the external environmental index had a distance of 3.642 from the ideal index where as in the second year this distance was reduced to 3.165. The distance was further reduced to 2.816 and 2.016 in years 2 and 3 resulting in a 44.7% overall improvement (reduction in the Euclidean distance).

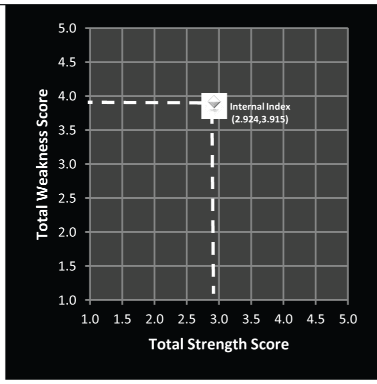
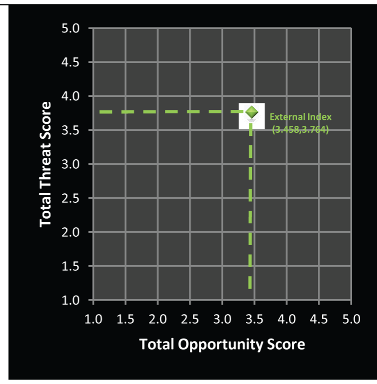
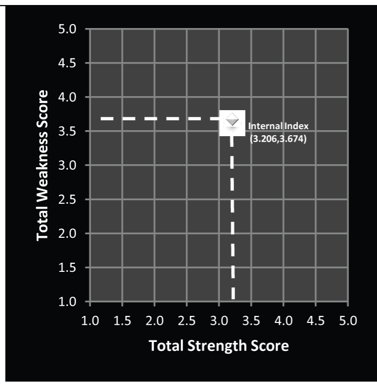
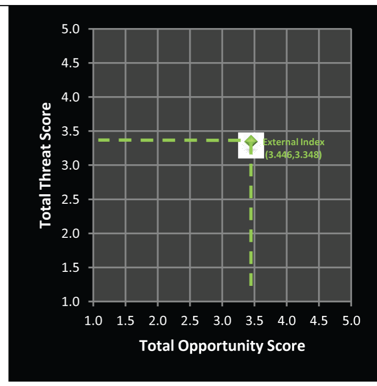
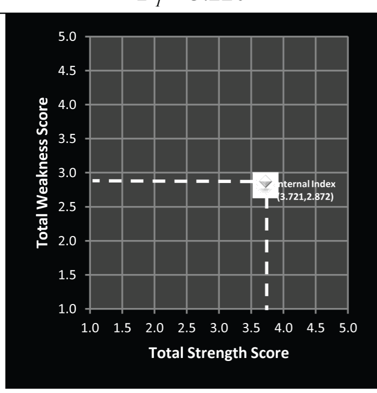
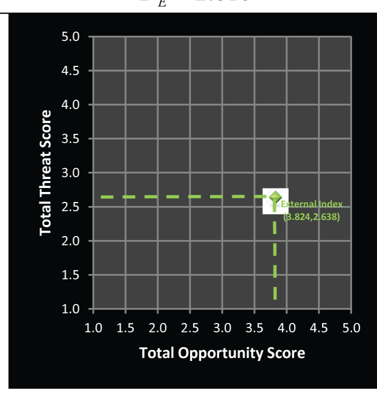
CONCLUSION AND FUTURE RESEARCH DIRECTIONS

The diffusion of ICTs in the public sector can have a major impact on social and economic growth of developing countries. These technologies offer enormous opportunities for developing countries to compete within a global economy and improve the societal well being. Most developing countries have set road maps for the integration of ICT in higher education. However, when confronted by the range of assessment methods, policy makers in government agencies struggle to evaluate ICT enhancement

Table 11. The TOPSIS overall results

Strategy	D_l^+	D_l^-	CC_j	Ranking
ST-1	0.054	0.091	0.628	**1**
ST-2	0.080	0.054	0.403	**4**
ST-3	0.068	0.085	0.556	**2**
ST-4	0.077	0.069	0.473	**3**

Figure 4. The internal and external environmental indices for states t=1, t=2 and t=3

<table>
<tr><th>Time Period</th><th>Internal Environmental Index</th><th>External Environmental Index</th></tr>
<tr><td>t=1</td><td>
$\bar{D}_I = 3.579$</td><td>
$\bar{D}_E = 3.165$</td></tr>
<tr><td>t=2</td><td>
$\bar{D}_I = 3.220$</td><td>
$\bar{D}_E = 2.816$</td></tr>
<tr><td>t=3</td><td>
$\bar{D}_I = 2.267$</td><td>
$\bar{D}_E = 2.016$</td></tr>
</table>

strategies and formulate an action plan most appropriate for their needs.

We propose a hybrid strategic development and prioritization framework for evaluating ICT enhancement strategies and developing an action plan for monitoring the ICT enhancement efforts. The contribution of the proposed approach is fivefold: (1) it addresses the gaps in the ICT literature on the effective and efficient assessment of the ICT enhancement strategies; (2) it uses the Delphi method and SWOT analysis to assist the formulation of the ICT strategies; (3) it uses the AHP to weigh the SWOT factors and the TOPSIS method to prioritize the ICT strategies; (4) it derives an action plan with internal and external indices to monitor the ICT enhancement progress; and (5) we present the results of a real-world case study to demonstrate the applicability of the proposed framework and exhibit the efficacy of the procedures and the algorithms. We show that the proposed approach can help a group of policy makers to think systematically by decomposing the ICT strategy evaluation process into manageable steps and integrating the results to arrive at a solution consistent with managerial goals and objectives.

Although the benefits of ICTs are still in its infancy, tremendous potentials lie ahead. We stress that our contribution addresses yet a small part of the issues that are involved with ICT enhancement and strategy assessment research. We hope that the study presented here can inspire others to pursue further research in this area. Additional future research considering correlation coefficients between the costs and benefits of ICT is challenging but necessary to gain insight into the interaction influence in ICT enhancement initiatives.

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