

## INTEGRATING CSF, AHP AND GENETIC ALGORITHMS FOR INFORMATION SYSTEMS PLANNING

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**Abstract** - A new integrated model is developed for information systems planning. In this model, entitled HISSPM, a combination of the strengths of Critical Success Factors (CSF) method, Analytic Hierarchy Process (AHP) technique and Genetic Algorithms (GA) is used to identify and prioritize the required information systems. This model considers both qualitative and quantitative factors, as well as the importance of the factors to decision-makers, and can solve problems with relatively wide search space. Comparing the results of the proposed model with those of the famous available models reveals that the proposed model is valid and efficient. The model tested on a real world problem, resulting in a portfolio of prioritized information systems, under certain conditions and constraints, which have alignment with organizational goals, strategies and plans. This model can help encourage managers in optimal or near-optimal decision-making boost investments on required information systems.

**Keywords** - Integrating CSF, AHP, Genetic Algorithms, Information Systems Planning

### INTRODUCTION

In the information age, evaluation, prioritization and selection of information system projects are the major concerns of IS managers. As a matter of fact, no company has enough resources to meet all system projects' needs, nor are all the requests necessarily good ones [1]. Therefore, a method must be applied to prioritize system projects' requests based on the right criteria. This is done in Information Systems Strategic Planning (ISSP) process.

ISSP is the first stage in the system development life cycle. The main purpose of ISSP is to identify which information systems are needed rather than planning the details for any specific system. An IS plan should show which new systems are required. It should also show the sequence in which they should be implemented [2].

Some of the best known IS planning methods include IBM's Business Systems Planning (BSP), Strategic Systems Planning (SSP), Critical Success Factors (CSF) and Method/1 and End/Mean Analysis. Some of these methods deal with the challenging problem of determining the set of IS projects that require implementation within the planning horizon, but they do not provide structured, optimal solutions to the problem of setting up priorities. In other words, they fail to determine the order of project implementation. For example, the CSF method is based on factors which determine the success or failure of the organization. The method involves: definition of organizational objectives, definition of success factors and measures for each, and analysis of the existing information systems. These components define the crucial subsystems, their interrelationships and the information types for each subsystem, but do not determine the order of subsystem implementation [3].

Research has shown that despite the growing number of theoretical frameworks for ISSP, practice still faces four major problems:

1. Need for integration of ISSP and overall corporate strategy [2]; in other words, difficulty assuring consistency with organizational plans and objectives [4].
2. Moderate practical utility of existing ISSP methodologies [2].
3. Limited management involvement and commitment to the ISSP activity [2].
4. IS planning methods do not provide structured, optimal solutions to the problem of setting up priorities [3].

This article attempts to introduce an ISSP model, entitled HISSPM, which aims at solving the major problems mentioned above and to increase the effectiveness of IS planning within organizations. These aims are achieved by combining the strengths of CSF method, AHP technique and genetic algorithms. This model guarantees the alignment of information systems with organizational objectives, strategies and plans. Furthermore, because of the mechanisms considered, the model facilitates active participation of managers and users in information systems planning process.

## LITERATURE REVIEW

The literature review of this study is organized according to the three basic parts of the proposed model: CSF method and information systems prioritization, AHP technique, and genetic algorithms.

## CSF METHOD AND INFORMATION SYSTEMS PRIORITIZATION

Due to the importance and the difficulty of systems planning, it is valuable to have a framework or methodology to guide the process. Over the years, a number of approaches have done a better job of planning [5]. A technique used with great success in a growing number of corporations, analyzes the critical success factors (CSFs) of the enterprise and the executives that manage it [6]. The use of a CSF approach for information systems planning was developed at MIT's Sloan School of Management.

Subsequently, Rockart [7] employed the method to determine the key information needs of top executives [8].

The CSF approach, as conceived by Rockart [7], is essentially an IS planning methodology for top-level management. Bullen and Rockart [9] later extended the application of the CSF concept to other managerial levels within an organization [8].

The CSFs for any business or business function are the limited number of areas (usually four to six) in which satisfactory results will ensure the firm's successful overall performance. These are the activities that have a major impact on short-term effectiveness as well as long-term growth. Although CSFs vary widely with industry and across firms, they are generally derived from the same sources. In order to set information system priorities, the CSFs are analyzed to determine the relative priorities among the systems to be developed. Since CSFs provide strong evidence of areas that management considers important for the success of the organization, it follows that systems supporting these areas should receive priority [10].

Khandelwal and Ferguson [11] have developed a modified method for prioritization of CSF. In their method, after identifying a number of CSF constructs and designing a survey instrument, for each CSF construct on the survey instrument, the respondents are asked to rate the criticality of the CSF on a four-point Likert scale of 1 (critical) to 4 (not required), or alternatively indicate if they have already achieved that CSF. After rating each of the CSFs, the respondents are asked to review the list, select their top five CSFs and write them in order of importance in the space provided on the survey instrument.

The main strengths of CSF analysis are two-fold: it provides effective support for planning, since the consideration of critical activities develops management insights and it also serves as the effective top level for a subsequent structured analysis [12]. Nevertheless, the major weakness of the approach is that it does not provide structured, optimal solutions to the problem of setting up priorities. In other words, the method defines the crucial subsystems, their interrelationships, and the information types for each subsystem, but does not determine the order of subsystem implementation [3].

To solve the problem of information systems prioritization and selection, some researchers and practitioners have provided structured solutions. For example, Buss [13] suggests an approach to rank computer projects. In his approach, the IS manager as coordinator, users and top executives can contribute to an eight-step process that will reconcile differing perspectives and will permit an orderly ranking of projects. Burch and Grudnitski [1] propose a different approach for information systems project prioritization. Their proposed method entails filling out a systems project request form; preparing a systems project request priority worksheet and finally plotting a system project request priority grid. The points on the grid indicate each project request's level of priority. Shoval and Giladi [3] introduce a method that utilizes the cost-benefit graph, which considers the expected cost and benefit of each of the projects comprising the set, as well as the weight (importance) of the cost and benefit factors to decision-makers. Chen and Gorla [14] propose a model by incorporating fuzzy logic as a decision tool for information system project selection. They model MIS project

selection using fuzzy logic by including both quantitative and qualitative factors. The procedure includes defining quantitative and qualitative factors, defining membership functions, performing fuzzification on the input values, constructing fuzzy inference, and performing defuzzification in order to produce an output value. The project that has the highest output values is selected.

One weakness of the mentioned methods is that as the number of required information systems alternatives increases, the performance of the methods decreases. The major weakness of these methods is that they do not provide optimal solutions, based on comprehensive ranking criteria, to the problem of setting up priorities. Furthermore, they do not provide mechanisms for increasing the involvement and commitment of management and users in the process. To achieve the measure of success, it is essential that there be coordinated participation in the planning and prioritizing process by managers and users throughout the organization. Analytic Hierarchy Process (AHP) is a technique that facilitates active participation of managers and users.

#### **AHP AND ITS RELEVANT APPLICATIONS**

The Analytic Hierarchy Process (AHP) was developed by Thomas L. Saaty [15] and published in his 1980 book, *the Analytic Hierarchy Process*.

This process involves pairwise comparisons. The decision maker starts by laying out the overall hierarchy of the decision. This hierarchy reveals the factors to be considered as well as the various alternatives in the decision. Then, a number of pairwise comparisons are done the result of which will be the determination of factors to be considered as well as the various alternatives in the decision. Then, a number of pairwise comparisons are made, which result in the determination of factor weights and factor evaluations. The alternative with the highest total weighted score is selected as the best alternative [16].

Roper-lowie and Sharp [17] describe the way the Analytic Hierarchy Process (AHP) was applied to a decision concerning the selection of a computer operating system. The method was found to be a useful aid for identifying the criteria upon which a decision depends. It also revealed useful data about the concerns and preferences of decision-makers. Huizingh and Vrolijk [18] explore the appropriateness of Analytic Hierarchy Process (AHP) to support IS decision making. By using methods such as Information Engineering [6], Business System planning [19] or Critical Success Factors [7,20] management identifies a number of information systems that have to be developed. Then, it has to make the decision in which order these systems will be implemented. Determining the priority of each system is not easy because a large number of factors play a role. These factors involve both financial aspects and qualitative factors. Due to the characteristics of the project selection decision, AHP might be applicable. An AHP analysis is described by using the project selection decision as an example.

In a recent research, Lai, Wong and Cheung [21] have reported the results of a case study where the analytic hierarchy process (AHP) technique was employed to support the

selection of a multimedia authorizing system (MAS) in a groups decision environment. Three MAS products were identified and ultimately ranked using AHP. Six software engineers, who were technically competent and experienced, participated in their study. These engineers were trained to use AHP and were asked to apply this technique to select the most appropriate MAS product for adoption. A post-study survey and interview were conducted with all the engineers to collect further feedback on the use of AHP, as compared to their frequently used Delphi technique, in supporting group decisions. The experiment results and survey findings indicated that AHP was preferable to Delphi as AHP helped group members center a discussion around objectives, rather than alternatives. They also found the AHP to be more conducive to consensus building in group decision settings.

Despite the mentioned application of AHP, the main problem with it is the need for very tedious calculations, which can be made easier using personal computer software [22]. Where a large number of alternatives or required information systems exist, say 50 or more, the problem of finding the optimum portfolio is usually very difficult; this is a complex combinatorial problem, with the difficulty lying in the relatively large search space where complete enumeration may be intractable. However, genetic algorithms have already proved useful in solving many combinatorial problems with robust solutions [23].

## **GENETIC ALGORITHM AND ITS RELEVANT APPLICATIONS**

The genetic algorithm was developed by John Holland [24] over the course of the 1960s and 1970s and finally popularized by one of his students, David Goldberg, who was able to solve a difficult problem involving the control of pipeline transmission for his dissertation [25].

Genetic algorithms are stochastic search techniques based on the mechanism of natural selection and natural genetics. Genetic algorithms, differing from conventional search techniques, start with an initial set of random solutions called population. Each individual in the population is called a chromosome, representing a solution to the problem at hand. A chromosome is a string of symbols; it is usually, but not necessarily, a binary bit string. The chromosome evolves through successive iterations, called generations. During each generation, the chromosomes are evaluated using some measures of fitness. To create the next generation, new chromosomes, called offspring, are formed by either (a) merging two chromosomes from current generation using a crossover operator or (b) modifying a chromosome using a mutation operator. A new generation is formed by (a) selecting, according to the fitness values, some of the parents and offspring and by (b) rejecting others so as to keep the population size constant. Fitter chromosomes have higher probabilities of being selected. After several generations, the algorithms converge to the best chromosome, which hopefully represents the optimal or suboptimal solution to the problem [26].

Literature review reveals that genetic algorithms are widely used in operation research and industrial engineering, but have been ignored in the information systems

planning. Genetic algorithms are applied in other areas of information systems, such as integrating genetic algorithms into intelligent systems [27], extending the effectiveness of simulation-based DSS through genetic algorithms [28], and using a genetic algorithm to identify predictors of information systems students success [29]. The proposed model is the first application of genetic algorithms in information systems planning process. In other words, in the proposed model, a combination of the strengths of CSF method, AHP technique and genetic algorithm are used to identify the prioritization of required information systems.

## **A MODEL FOR INFORMATION SYSTEMS PLANNING**

Proposed model for information system planning is presented in Figure 1. In this model, the assumption is that identifying information requirements is done using critical success factor method, as CSF method is a powerful and deservedly popular technique in IS planning [30].

One of the difficulties associated with CSF analysis is that it does not determine information systems priorities. Another weakness is that it does not offer a structured method for prioritization of the CSFs. In the first component of the proposed model, in order to resolve the mentioned weaknesses, prioritization of CSFs are determined using AHP technique, based on the criteria of alignment with organizational objectives, strategies and plans. This prioritization is done by active participation of managers and results in recognition of the most important CSFs in order to allocate the resources needed for development of counterpart information systems.

No company has enough resources to meet all systems project requirements; therefore, it is necessary to determine the priority of organizational units for information systems development. In the second component of the proposed model, priority of organizational units for information systems development is determined using AHP technique, based on their contribution to realize organizational objectives, strategies and plans. Priorities of organizational units affect the allocation of resources to information systems development.

Ranking and assigning priorities to information system projects must be based on right criteria. Researchers and practitioners suggest various criteria for information systems evaluation and prioritization. These criteria can be classified in five categories as follows:

- 1- Strategic factors
- 2- Feasibility factors
- 3- Risk factors
- 4- Organizational benefits
- 5- Quantitative factors

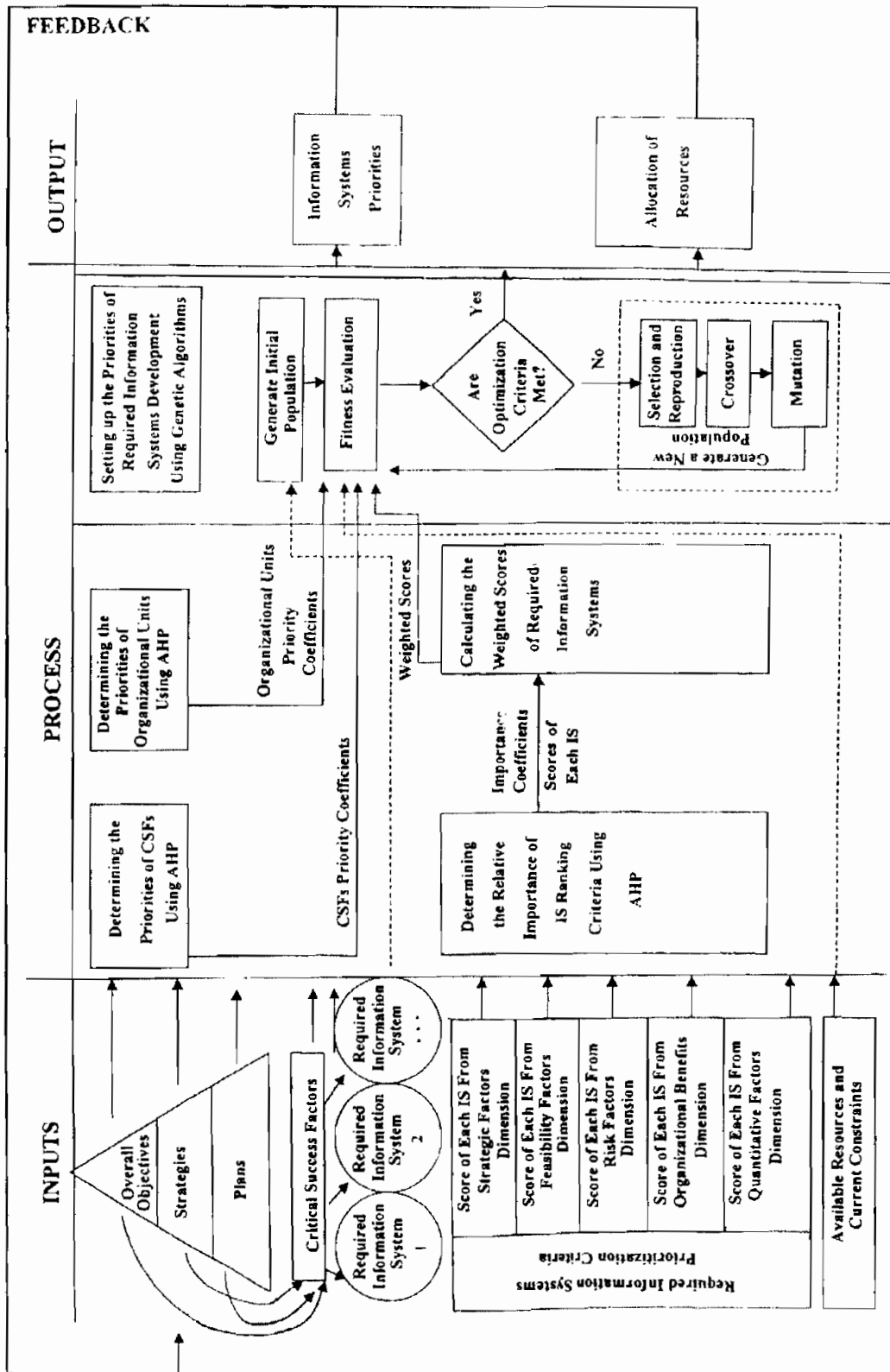


Figure 1. HISSPM: A Model for Information Systems Planning

The mentioned criteria may have different importance comparing each other, based on conditions and contingencies of every organization. Therefore, in the third

component of the proposed model, importance coefficient of information systems ranking criteria is determined using AHP technique. Relative importance of the criteria determines which criterion must be the focus of attention and what the weights of each criterion are in information systems prioritization.

In the fourth component, scores of each required information system are calculated based on the evaluations of managers and users from the five criteria perspectives. The resulting scores and also the resulting coefficients of the first three components are entered into the genetic algorithm component of the model.

Every organization has a large number of potential information system projects. The limited resources of an organization make it impossible to develop and implement all projects simultaneously, and, consequently necessitate making a choice among projects [31]. In the fifth component of the proposed model, genetic algorithms are used in order to find a near-optimal combination of prioritized information systems. The basic idea of genetic algorithms is well-known in the area of operation research and industrial engineering, but not in information systems planning.

The genetic algorithms component itself consists of five main sub-components. The first sub-component is 'chromosomal representation'. Each chromosome represents a candidate solution to the problem and comprises a string of genes. These genes are usually composed of binary, integer, or real values [23]. In this paper, the binary alphabet {0, 1} is selected, so that:

$$X_i = \begin{cases} 1 & \text{if information system } i \text{ is selected} \\ 0 & \text{otherwise} \end{cases}$$

The second is 'initial population'. It is necessary to create an initial population to serve as the starting point for the genetic algorithms. This population can be created randomly or by using specialized, problem specific, information [23].

Those working with genetic algorithms on other problems have used anywhere from 10,000 members to only 30, thus, the correct number is often the result of the specific problem to be solved, the genetic algorithm style (e.g. simple or steady-state) and the chromosome mapping and processing. For binary chromosome, one rule of thumb is to use a population of about five or six times the number of bits in the chromosome [32]. In this paper, the size of the population is determined using the mentioned rule of thumb.

The third sub-component is 'fitness evaluation'. Fitness evaluation involves defining an objective or fitness function against which each chromosome is tested for suitability for the environment under consideration. A high fitness value indicates a better solution than a low fitness value. As the algorithm proceeds, the individual fitness of the 'best' chromosome is expected to increase as is the total fitness of the population as a whole.

The fourth is 'selection'. It is necessary to select chromosomes from the current population for reproduction. The selection procedure picks out two parent chromosomes based on their fitness values, where the higher the fitness value, the higher the



probability that a chromosome is selected. The parent chromosomes are, then, used by the crossover and mutation operators to produce two offspring (which inherit the best characteristics of both parents) for the new population [23]. Reid [33] believes that the simplest, and one of the most widely employed, of the selection methods that currently exists is 'proportional selection', also known as 'roulette wheel selection'. In this paper, we use roulette wheel selection strategy.

The last sub-component is crossover and mutation. Once a pair of chromosomes has been selected, crossover can take place to produce offspring. A crossover probability of 1.0 indicates that all the selected chromosomes are used in reproduction [23]. However, empirical studies [34,35,36,23,37,32,38,39] have shown that better results, depending on the problems, are achieved by assuming a crossover probability of between 0.40 and 1.0. In the proposed model, after experimental analysis of the following values, 0.75, 0.80, 0.90, 0.95 and 1.0, the rate of 0.90 is used as the best solution was obtained from it.

If only the crossover operator is used to produce offspring, one potential problem that may arise is that if all the chromosomes in the initial population have the same value at a particular position, then all future offspring will have this same value at this position. To combat this undesirable situation, a mutation operator is used. This allows for random alteration of the genes (0 becomes 1 or vice versa). Typically, this occurs infrequently and, thus, mutation is of the order of about one bit changed in a thousand tested. Each bit in each chromosome is checked for possible mutation by generating a random number between zero and one, and if this number is less than or equal to the given mutation probability, the bit value is changed [23]. Over a wide range of applications, a mutation rate of between 0.05 and 0.001 has often been used [34,35,40,25,32]. In the proposed, model after the experimental analysis of the following values, 0.05, 0.027, 0.01, 0.005 and 0.001, the rate of 0.01 was selected, since the best solution was obtained from it.

This completes one cycle of the genetic algorithm. The fitness of each chromosome in the new population is then evaluated, and selection, crossover and mutation take place once again until the termination criterion has been satisfied. If the optimization criteria are met, the result will be a near-optimal set of prioritized information systems that can be considered for future developments.

After designing the proposed model, in order to evaluate its validity, the data were used by researchers in the most important models such as Burch and Grudnitski [1], Shoal and Giladi [3], Chen and Gorla [14]. The results show that the proposed model has better performance than the mentioned models.

Then, the proposed model is applied in the real environment. Information systems requirements of a public organization are identified using the CSF method. On the other hand, the proposed model is applied for selection and prioritization of the identified information systems. This provides a basis for comparison of performance of the proposed model against the CSF method.

In the first component of the proposed model, priorities of the CSFs are determined, based on the degree of alignment with organizational objectives, strategies and plans.

Results of the first component are shown in Table 1.

Table 1: Coefficients of the Priorities of the Identified CSFs

<b>Organizational Units CSFs</b>	<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>	<b>E</b>
<b>CSF<sub>1</sub></b>	0.4215	0.2212	0.3340	0.1445	0.2798
<b>CSF<sub>2</sub></b>	0.0737	0.1989	0.2786	0.4940	0.1470
<b>CSF<sub>3</sub></b>	0.0285	0.1469	0.2204	0.0654	0.4217
<b>CSF<sub>4</sub></b>	0.1000	0.1842	0.1148	0.2155	0.0678
<b>CSF<sub>5</sub></b>	0.1436	0.2438	0.0488	0.0773	0.0804

In the second component of the model, priorities of organizational units for information systems development are determined. The results of this component are shown in Table 2.

Table 2: Coefficients of the Priorities of the Organizational Units

<b>Organizational Units</b>	<b>Coefficients</b>
A	0.4293
B	0.2513
C	0.1320
D	0.1290
E	0.0485

The results of the third component, for determining the relative importance of information systems ranking criteria, are shown in Table 3. The results indicate that strategic factors criterion is the most important.

Table 3: Coefficients of the Priorities of the Information Systems Ranking Criteria

<b>IS Ranking and Prioritization Criteria</b>	<b>Importance Coefficients</b>
Strategic Factors	0.4043
Feasibility Factors	0.1899
Risk Factors	0.1061
Organizational Benefits	0.1958
Quantitative Factors	0.1030

In the fourth component of the model, scores of each identified information system are calculated based on the five criteria. The scores resulting from this component and the resulting coefficients of the first three components are entered into the genetic

algorithms component of the model.

In the fifth component, the genetic algorithms are used to find near-optimal combinations of identified information systems. When implementing a genetic algorithm (GA), values need to be set for the various parameters, such as population size, crossover rate and mutation rate. The problem consists of thirty-seven identified information systems; therefore, a population of about 222 was optimal for a chromosome of 37 bits. However, due to resource constraints considered in the fitness function, a population of 1500 chromosomes is used. As previously mentioned, the rates of crossover and mutation are 0.90 and 0.01 respectively.

As perceived in Figure 2 and Table 4, the genetic algorithm converged in the eighth generation. Maximum fitness value in the range of  $0 \leq \text{fitness} \leq 1$  is 0.3203. So, the optimal set of prioritized information systems is determined.

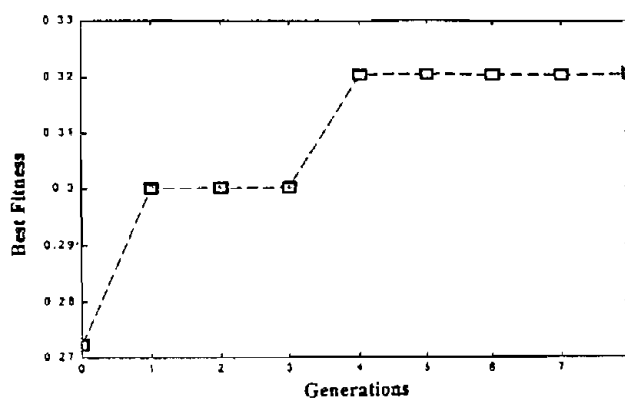


Figure 2: Optimization Procedure for Information Systems Prioritization

Table 4: Fitness Results Using GA (Crossover Rate = 0.90, Mutation Rate = 0.01) for the Problem of IS Prioritization

Generation	Fitness value $0 \leq \text{Fitness} \leq 1$			
	Maximum	Minimum	Mean	Std. Dev.
0	0.2732	0.0000	0.0045	0.0303
1	0.3001	0.2479	0.2706	0.0087
2	0.3001	0.2723	0.2757	0.0081
3	0.3001	0.2728	0.2911	0.0091
4	0.3203	0.3001	0.3004	0.0091
5	0.3203	0.3001	0.3026	0.0055
6	0.3203	0.3029	0.3121	0.0085
7	0.3203	0.30203	0.3203	0.0000
8	0.3203	0.3203	0.3203	0.0000
9	0.3203	0.3203	0.3203	0.0000

In order to test the hypothesis and accordingly the model, the results of the CSF

method are compared with those of the proposed model through considering the degree of alignment of resulting information systems with organizational objectives, strategies and plans. As perceived in Table 5, the 'Mann-Whitney U' test reveals that the set of IS resulting from the proposed model have more alignment with organizational objectives, strategies and plans than those resulting from the CSF method. Therefore, the proposed model can more effectively provide information systems portfolios that support organizational objectives, strategies and plans.

Table 5: Results of Comparing the Proposed Model with the CSF Method Using Mann-Whitney Test

Degree of alignment with organizational objectives, strategies and plans	Frequency of Respondents	Mean Ranks	Sum of Ranks
The set of IS resulting from the proposed model	25	36.08	902.00
The set of IS resulting from the CSF method	27	17.63	476.00
Sum of frequency	52		
Mann-Whitney U = 98.000 Wilcoxon W= 476.000 Z = 4. 386 Asymp. Sig. (1-tailed)= 0.000			

## CONCLUSION

The literature review reveals that the proposed model which is a combination of the strengths of CSF method, AHP technique and genetic algorithm, is a new one in the information systems planning literature. The proposed model considers both qualitative and quantitative factors, as well as the weight of the factors to decision – makers, and can solve problems with relatively wide search space. Furthermore, this model guarantees the alignment of information systems with organizational objectives, strategies and plans; facilitates active participation of managers and users in information systems planning process and, therefore, increases the effectiveness of the process.

Comparing the results of the proposed model with those of the famous available models reveals that the proposed model is valid and efficient. The model tested on a real world problem, resulting in a portfolio of prioritized information systems, under certain conditions and constraints, which have alignment with organizational goals, strategies and plans. This model can help managers in optimal or near optimal decision-making invest on required information systems.

## REFERENCES

- [22] Abdul-Hamid, Y. T., A. K. Hochher, and M. K. Khan, *An analytic hierarchy*

- process approach to the choice of manufacturing plant layout*, Proceeding of the Institution of Mechanical Engineers, part B, Journal of Engineering Manufacture, vol. 213, issue 4, 1999, pp. 397-406.
- [31] Ahituv, Niv and Seev Neumann, *Principles of information systems for management*, U.S.A., Dubuque, Wm. C. Publishers, Third Edition, 1990.
- [4] Alter, Steven, *Information systems: a management perspective*, N.Y., Addison Wesley Company, 1999.
- [10] Awad, Elias M., *Management information systems: concepts, structure, and applications*, Menlo Park, Calif., Benjamin / Cummings pub. Co., 1988.
- [37] Borgelt, Ken, *Software test data generation from a genetic algorithm*, In: Industrial Applications of Genetic Algorithms, Edited by Charles L. Michael Freeman, Florida, CRC press, 1999.
- [9] Bullen, C.V. and Rockart, J. R., *A primer on critical success factors*, in Rockart, J. F. and Bullen, C. V. (eds), *The rise of managerial computing: the best of the center for information systems research*, Sloan School of Management, Massachusetts Institute of Technology, 1986, pp. 383-423.
- [8] Bulter, Tom and Brian Fitzgerald, *New light through old windows: the interpretive foundations of the CSF concept and method*, In: Business Information Technology Management: Alternative and Adaptive Futures, Edited by Ray Hackney and Dennis Dunn, New York, St. Martin's Press, LLC., 2000.
- [1] Burch, John and Gary Grudnitski, *Information systems-theory and practice*, Singapore, John Wiley & Sons, Inc., Fifth Edition, 1989.
- [13] Buss, Martin D. J., *How to rank computer projects*, Harvard Business Review, Number 1, January/February 1983, pp.118-125.
- [20] Byers, C. R. and D. Blume, *Tying critical success factors to system development*, Information and Management, vol. 26, No. 1, 1994, pp. 51-61.
- [27] Chaundry, Sohail S., Michael W. Varano, and Lido Xu, *Systems research, genetic algorithms and information systems*, Systems Research and Behavioral Sciences, Sys. Res., vol. 17, 2000, pp. 149- 162.
- [14] Chen, Kuanchin and Narasimhaiah Gorla, *Information systems project selection using fuzzy logic*, IEEE Transactions on Systems, Man, and Cybernetics- PART A: Systems and Humans, vol. 28, No. 6, November 1998, pp. 849-855.
- [28] Fazlollahi, Bijan and Rustam Vahidov, *Extending the effectiveness of simulation-based DSS through genetic algorithms*, Information and Management, vol. 39, No. 1, November 2001, pp. 53-65.
- [26] Gen, Mitsuo and Runwei Cheng, *Genetic algorithms & engineering design*, New York, John Wiley & Sons, Inc, 1997.
- [34] Grefenstete, John J., *Optimization of control parameters for genetic algorithms*, IEEE Transactions on Systems, Man, and Cybernetics, vol. SMC-16, No. 1, January/February 1986.
- [25] Haupt, Randy L. and Sue Ellen Haupt, *Practical genetic algorithms*, New York, John Wiley & Sons, Inc., 1998.
- [24] Holland, J. H., *Adaptation in Natural and artificial systems*, Ann Arbor, The

- University of Michigan Press, 1975.
- [18] Huizingh, Eelko K. R. E. and Han C. J. Vrolijk, *Decision support for information systems management: applying analytic hierarchy process*, <http://docserver.Ub.Rug.Nl/eldoc/som/95B26/application/pdf>, 1995.
- [23] Hurley, Stephen, Luiz Moutinho, and Stephen F. Witt, *Genetic algorithms for tourism marketing*, *Annals of Tourism Research*, vol. 25, No. 2, 1998, pp. 498-514.
- [19] IBM, *Business systems planning: information systems planning guide*, Manual Number, GE20-527-4, 1984.
- [11] Khandelwal, Vijay K. and Jeff R. Ferguson, *Critical success factors (CSFs) and the growth of IT in selected geographic regions*, IEEE, Proceedings of The 32nd Hawaii International Conference on System Science, 1999, pp.1-13.
- [40] Kim, Jung-ug and Yong-dae Kim, *Simulated annealing and genetic algorithms for scheduling products with multi-level product structure*, *International Journal of Computers and Operations Research*, vol. 23, No.9, 1996, pp. 857-868.
- [21] Lai, Vincent S., Bo K. Wong and Waiman Cheung, *Group decision making in a multiple criteria environment: a case using the AHP in software selection*, *European Journal of Operational Research*, 137, 2002, pp. 134-144.
- [38] Marshall, Darrin J., *Data mining using genetic algorithms*, In *Industrial Applications of Genetic Algorithms*, Edited by Charles. L Michael Fecman, Florida, CRC press, 1999.
- [6] Martin, James with Joe Leben, *Strategic information planning methodologies*, Englewood Cliffs, New Jersey, Second Edition, 1989.
- [2] Mentzas, Gregory, *Implementing an IS strategy-a team approach*, *Long Range Planning*, vol. 30, No. 1, 1997, pp. 84-95.
- [32] Rahmat-Samii, Yahya and Eric Michielssen, *Electromagnetic optimization by genetic algorithms*, New York, John Wiley and Sons, Inc., 1999.
- [33] Reid, D. J., *Genetic algorithms in constrained optimization*, *Math. Compute. Modeling*, vol. 23, No. 5, 1996, pp. 87-111.
- [16] Render, Barry and Ralf M. Stair, Jr., *Quantitative analysis for management*, New Jersey, Prentice Hall, Inc., Sixth Edition, 1997.
- [12] Robson, Wendy, *Strategic management and information systems-an integrated approach*, London, Financial Times Management (Pitman Publishing), Second Edition, 1997.
- [7] Rockart, John F., *Chief executives define their own data needs*, *Haward Business Review*, vol. 57, No. 2, March/April 1979, pp. 81-93.
- [17] Roper-Lowe, G. C. and J. A Sharp, *The analytic hierarchy process and its application to an information technology decision*, *Journal of the Operational Research Society*, vol. 41, No. 1, 1990, pp. 49-59.
- [15] Saaty, Thomas, *The analytic hierarchy process*, New York, McGraw-Hill Book Company, 1980.
- [36] Sannomiya, Nobuo and Kyoichi Tatemura, *Application of genetic algorithm to a parallel path selection problem*, *International Journal of Systems Science*,

- vol.27, No. 2, 1996, pp. 269-274.
- [35] Schaffer, J. David, Richard A. Caruana, Larry J. Eshelman and Rajarshi Das: *A study of control parameters affecting online performance of genetic algorithms for function optimization*, ICGA, 1989, pp. 51-60.
- [29] Sexton, Randall S., *Neural networks refined: using a genetic algorithm to identify predictors of IS student success*, The Journal of Computer Information Systems, vol. 41, Issue 3, 2001, pp. 42-47.
- [3] Shoval, Peretz and Ran Giladi, *Determination of an implementation order for IS projects*, Information and Management, vol. 31, 1996, pp. 67-74.
- [5] Sprague, Ralph H., Jr. and Barbara C. McNurlin, *information systems management in practice*, Englewood Cliffs, New Jersey, Prentice-Hall, Inc., 1993.
- [39] Wand, Steve, *Simulation of an artificial eco-system using genetic algorithms*, In: *Industrial Applications of Genetic Algorithms*, Edited by Charles L. Michael Freeman, Florida, CRC press, 1999.
- [30] Ward, John and Pat Griffiths, *Strategic planning for information systems*, England, John Wiley and Sons Ltd., Second Edition, 1996.