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Decision Support Model in Technology Transfer for Technology Receiver

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Abstract

The Technology Transfer process at any stage of its progression, including choosing the Technology Transfer project, choosing the providers and/or receivers and choosing the Technology Transfer method, requires decision-making. In any Technology Transfer, after knowing the technology, it is very important for the receiver of the technology to decide for policies and the appropriate provider of the technology. Using statistical methods and multi-Criteria decision making models, this paper presents a "decision support system" for determining the policies and the appropriate provider of the technology. With respect to the Technology Transfer component, a questionnaire was developed and using the expertise of the field, the main criteria for each component of the T-T were identified and ranked. Then the importance and relationship of the criteria were studied through statistical methods. Finally, having the importance and relationship of the criteria identified, the appropriate polices were determined. Furthermore, using the multi-criteria decision-making models, the appropriate provider of the technology was identified. The case study is jet UAV (Unmanned Air Vehicle).

Keywords: Multi-criteria decision models, Technology Transfer, Statistical methods, UAV (Unmanned Air Vehicle).

INTRODUCTION

Today technology is considered as a strategic factor for any country's economical development and an important means of success for the organizations, which are willing to be active in the scene of global competitions. Technology development can be regarded as the most important step in the industrial and economical development of the developing countries. Since developing countries still lay for behind the mainstream of creating modern technologies, transfer of these technologies from developed countries to these countries seems necessary.

Technology transfer is a linked chain of directed actions through which a series of technology components are utilized in training, absorption, development and economical uses in a place other than the original place of creating the technology, technology transfer is a very complex and difficult process. Technology transfer should be done with taking all of its components, such as equipment, employee, science & organization. So we can expect an economical and social development from the field of technology transfer only if the transferred technology is in consistent with the different social structures, and when all structures contribute to the Technology transfer in a concordant way.

There is a great deal of the literature dealing with the Technology transfer conceptually [1,2]. But, the proposed models in this regard are limited in number. Most of models deal with the economical aspects, and the process planning is usually ignored. [3,4] . The studies on the models often touch the cultural, moral, and psychological consequences of technology transfer [5,6] and also the outcomes of inappropriate technology [7,8] and the economical reasons for it.

Among the conceptual models are Rous & Low which deal with determining the needs of the applicant of technology and the technological contribution respectively. There are also some models, e.g. Ford, which seek to determine the general ways of getting access to technology whether through technology transfer or through research and development. Recently the consequence of technology transfer planning has also been discussed. But there is still a need for models which could guide the determination of technology transfer policies. This lack is due to the fact that most of the decisions for technology transfer are not objective and therefore can not be quantified easily. For determining the policies, the T-T stages should be taken into account. The T-T process is of different and continuous stages which can be divided into three main parts:

a) Choosing and acquiring the technology;

b) Concordance, utilization and absorption of the technology;

c) Developing and spreading the technology.

Each one of these stages such as choosing the T-T project, choosing the provider(s) and receiver(s) of technology and choosing the T-T method requires decision-making at times. There are some articles published on this decision-making. Analytical Hierarchy Process has been used for analyzing the choice of technology for developing countries [9]. Also tabatabaiyan, using a 3-stage model and through some multi-purpose and multi-criteria methods, a model has been proposed for choosing the appropriate project for T-T.

Using the expertise of the field and statistical methods and multi-criteria decision making models, this paper proposes a decision support system for determining the policies and the appropriate provider of T-T. In other words, in this article we

have used statically method with respect to the T-T components for determining the general policies of T-T in different stages of this process such as choosing the provider of the technology, etc. on the other hand we have used multi-criteria decision making to determine a appropriate provider of technology.

The case study of this research is UAV jet technology. This technology was chosen due to its high level of technology and its strategic status. Moreover UAV are multipurpose which are of low-cost production.

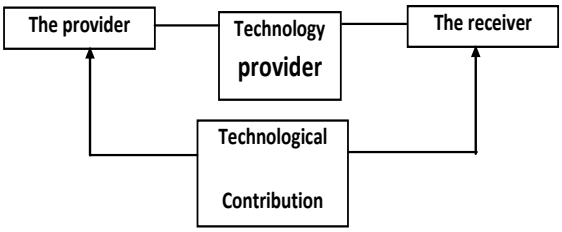

Fig 1. The main components of T-T

METHODOLOGY

In any T-T project after knowing the technology, determining the policies and the appropriate provider of T-T is of great importance for the receiver of the technology. When the receiver of the technology decided to transfer a specific technology, he can then discuss the determination of policies and appropriate provider of T-T.

In any T-T process there are certain components. These certain components are shown in Fig 1. According to the receiver's need, the appropriate technology is chosen and then it's transferred from the provider to the receiver following the "policy of mutual technological".

In determining the appropriate policies of T-T for the receiver of the technology, the main components of T-T should be taken into account, and the appropriate policies should be determined according to these components.

In addition, since the T-T process is very broad and complex, the expertise of the field can be used according to the T-T component for determining the appropriate policies. Therefore, based on these components a questionnaire was developed in which the important criteria for each component were specified so that the transfer policies could be determined on the basis of these criteria for each component.

The items in the questionnaire have been set in a way that all four components of the T-T process would be covered. In order to determine the appropriate policy, the criteria which optimize the T-T should be known. In order words it should be specified that which features or criteria in the technology, the provider or the receiver of the technology and technologic contribution lead to a more successful T-T. In so doing, the items of the questionnaire have been designed in a sense that the criteria of success for each component (technology, provider of technology, receiver of technology, technologic contribution) be determined and given a source from 1 to 10 by the respondents.

Since this approach was used after choosing the technology, which is a component of T-T, the item on this component was proposed as "the reasons for choosing that specific technology as the appropriate technology". From this we can say that the first question is about investigating the reasons for selecting this technology. The second component of T-T process is the provider of the technology. the second question is about the criteria of choosing the appropriate provider so that by taking it into account we can determine the important criteria and propose a framework upon which the third question, the expert is asked to specify the main provider of the technology (in this case jet UAV). In other words the second question seeks to determine the criteria of the provider of technology and the

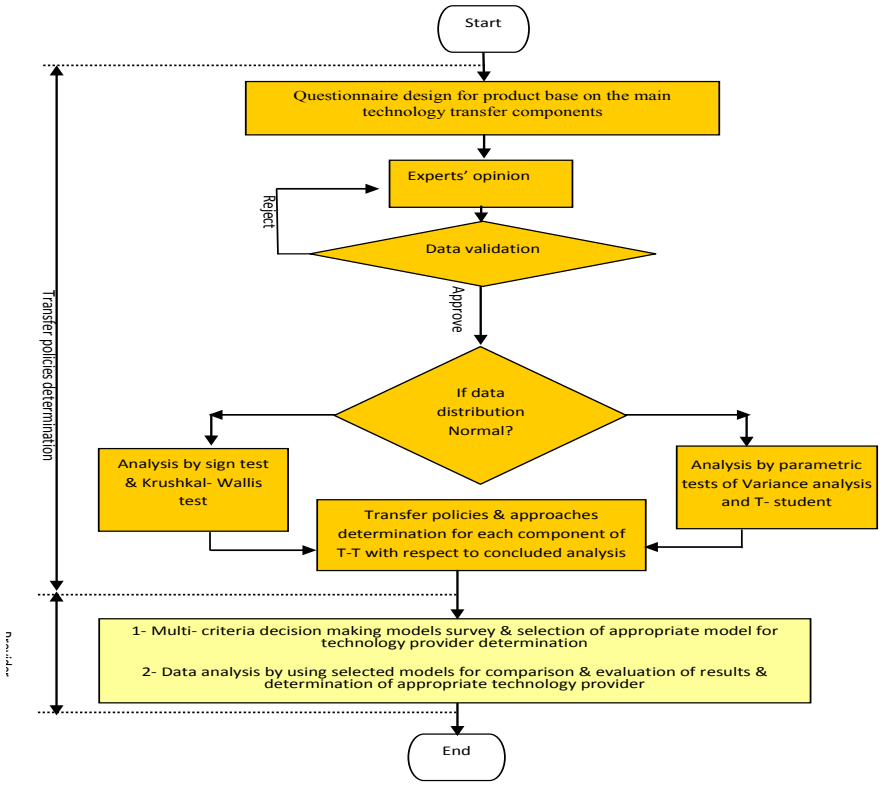

Fig 2. the model for determination of policies & appropriate provider for T-T

third one is asked for the option of choosing the provider. The third component of the T-T process is the receiver. So the fourth question deals with determining the criteria which are necessary for the receiver. The fourth component is the technological contribution for determining whose appropriate conditions, attention has paid to the contract text of T-T. A T-T contract test plays an important role in the appropriate transfer of a technology. Therefore those involved in the business should pay special attention to certain aspects in the T-T contract. The fifth question deals with determining these important aspects (criteria). After specifying the appropriate criteria for each T-T component, statistical methods were employed to determine their respective importance.

The procedure of data analysis of criteria through statistical methods is shown in fig. 2 in the section of determining the transfer polices of the proposed model.

In addition to determining the appropriate policy, specifying the appropriate provider of the technology is of the great importance to the receiver of that technology, since the provider of the technology is a component of the T-T. In the second and third questions, the experts were asked to comments on the criteria and the options of the providers of the technology. Having the providers and the criteria for choosing them specified, one can utilize the multi-criteria decision making models for choosing the provider of the technology. How it can be done is illustrated in fig.2 in the criteria of determining the provider.

After developing the questionnaire, it was sent to the experts of the field. After receiving the filled questionnaires, statistical methods and multi-criteria decision-making models were used to analyze them. The data analysis procedures using these methods are discussed in the next section.

Statistical Methods

Statistical analyses are among most common methods of analyzing the questionnaires administered to the experts. After collecting the questionnaire Cronbach alpha coefficient is used to ensure the authenticity of the gathered data. The rationale behind this test is to ensure the degree of the data consistency, when the same method and instrument are employed. To put it another way to see whether the questionnaire are completed accurately and carefully. This test is called reliability test. For applying this test the following statistic is used:

$$Alpha = \left(N \Big/ (N-1)\right) * \left(Sum\left(s_i^2 - s_t^2\right) \Big/ Sum\left(s_i^2\right)\right) \quad (1)$$

Where:

s_t : is standard deviation of the test for all of the scores.

s_i : is the standard deviation of for the scores of the question.

N: is the number of the completed questionnaires.

In this paper the value of this statistic can be obtained through using the SPSS software. After verifying the reliability values, inferential statistics, parametric or non-parametric tests can be used to analyze these values. Of course it depends on the existence of the population distribution function. If the population distribution function is specified, the parametric tests can be used; otherwise it would be better to use non-parametric tests. In this paper first the hypothesis of the normality of the scores is tested to decide whether parametric or non-parametric tests be used in data analysis. If this hypothesis is accepted, the parametric test can be used; otherwise the non-parametric test would be preferred.

The employed parametric test was Variance analysis for finding any difference in the mean of criteria of T-T components and student's T-test for determining the degree of importance of each criteria of T-T components. In the case of using the non-parametric tests, their correspondent to non-parametric test can be used (sign test is the correspondence of student's T-Test and H-Test or Krushkal-Wallis Test is the correspondence of Variance analysis).

Multi-Criteria Decision Making Models

Using the specified criteria, these models are used to choose the best option from among m available options.[10]

We should choose the most appropriate model if we are to use these models in our analysis. Since there is a possibility for interaction between the criteria of choosing the provider of the technology (e.g. when there is an increase in the quality of the technology, an increase in the cost seems acceptable) the model should be selected from compensatory models. Through studying all models one-by-one, it was found out that either AHP or ELECTRE are appropriate, regarding the characteristics of the providers.

Readers who are interested about how these two methods work are referred to the related references. Due to the possibility of sensitivity analysis with AHP, in this model it is employed and for comparing and verifying the result of choosing the provider, we compare its results with those of ELECTRE.

Determining the appropriate policies for transferring the jet UAV technology

Of the questionnaire whose items were described, 15 were sent to the experts, out of which 13 were received back. As discussed before, the reliability of the data was determined using cronbach a, the value of this coefficient, 0.654, was obtained by SPSS software. Since this value is close to 0.7, the reliability of the data is of a relatively acceptable level. Also as each question dealt with only one component of the T-T, in the following section we analyze the experts' responses on each component. (We have employed statistical methods using SPSS, and Minitab Soft wares).

Criteria of Technology

The identified criteria for technology based on the expertise were:

Using technical knowledge for producing other products.

Creation strategic industry in the country.

Appropriate schedule for getting access to technology.

Acquiring high quality technology.

Training skilled human force.

In other words, the main reasons for selecting jet UAV technology as an appropriate technology are the criteria mentioned above. First we run the normal scores test on the scores given to the criteria by the experts. Kolmogorov - Smirnov test can be used in this regard. The results of the test revealed that all scores of the criteria are of acceptable normal distributions. Therefore parametric tests could be used. one-way Variance analysis can be used for finding significant difference between the mean of technology criteria. First we test the necessary hypotheses for the Variance analysis. Three conditions must be met for this test: normal distribution of each criterion, homogeneity of the variance criteria, independence

of the data for each criterion. These hypotheses were tested using kolmogorov – Smirnov test, Bartlett's test, and Sign test respectively. Running these tests, we found out that data for technology criteria were confirmed at the significance level of 0.05, and Variance analysis can be used to test whether there is a difference in the mean(s) of the criteria. The results of the Variance analysis test are as follow:

Source	*DF*	*SS*	*MS*	*F*	*P*
Attribute	*4*	*14.06*	*3.52*	*0.80*	*0.530*
Error	*58*	*255.02*	*4.40*		
Total	*62*	*269.08*			

Since $0.8 < 3.67 = f_{0.01,4,58}$, Variance analysis test dose not confirm any difference between means of technology criteria. This analysis showed that there was not a significant difference between means of the technology criteria, Student's *T*-test can be used for determining the degree of importance of each criterion. We consider a criteria as important criteria if the hypothesis of $\mu>8$ is not rejected for the hypothesis $\mu\leq 8$. The results for the technology criteria show that three criteria of "**creation a strategic industry in the country", "acquiring high quality technology**", and **"training skilled human force" are the main reasons for choosing the transfer of jet UAV technology.** With these result, attention should be taken in training the human force during the transfer process, and also in choosing a technology with an appropriate level of quality. It should be noted that the value of 8 was set according to the values of the mean of scores given by the experts.

Criteria of Technology Provider

The identified criteria for the provider of the technology based on the expertise are as follow:

The quality of the provider's technology

Training the human force by the provider of the technology

The political relationship between two countries

Guarantees

Providing spare parts by the provider

Services after selling

Providing documentation, software, and technical knowledge of design, production and testing

Providing hardware and special equipment.

We test the normality of the given scores. The results of the normal score test showed that all criteria of the provider of the technology are of an acceptable level of normal distribution. Through running the necessary tests, three hypotheses of normality, data independence, and homogeneity of variances were confirmed. There fore we could run the Variance analysis test:

Source	*DF*	*SS*	*MS*	*F*	*P*
Attribute	*6*	*20.14*	*3.36*	*2.06*	*0.068*
Error	*77*	*125.67*	*1.63*		
Total	*83*	*145.81*			

Since $2.06 < 3.08 = f_{0.01,6,77}$, Variance analysis test doesn't confirm any difference between means of the criteria of the provider. This analysis showed that there was not a significant difference between means of criteria's significance.

Student's *T*-test can be used for determining the degree of importance of each criterion. By running the test we found out that four criteria, "**the quality of provider's technology**", "**providing documentation**", "**software and technical knowledge of design, production, and testing**" and "**Providing hardware and special equipment**", are the main criteria of the provider of the technology.

Criteria of Technology Receiver

The identified criteria for the receiver of the technology based on the expertise are as follow:

Using experienced and expert human force by the receiver of the technology.

Having access to the required hardware.

Having access to the required soft ware.

Required organizations in the receiver country.

Necessary bargain at the time of setting the contract by the receiver of the technology.

Using very high scientific standards by the receiver of the technology.

Having necessary credits for the project.

We test the normality of the scores given to the criteria by the experts. The results of the test show that all the criteria data of the receiver of the technology have an acceptable normal distribution. Therefore parametric tests can be used for the analysis of the criteria data. The hypotheses of normality and independence of the data is confirmed. But when running the test of homogeneity of variances we find out that the homogeneity variances is not confirmed. Therefore we use stabilization transformation of variance. Giving different values to λ and interpolation. 2.5 can be used as an appropriate value for the stabilization of variance. In this case we extend the data to the power of 2.5 to make the variances homogeneous. By running the Variance analysis test we have:

Source	*DF*	*SS*	*MS*	*F*	*P*
Attribute	*6*	*190186*	*31698*	*11.88*	*0.000*
Error	*83*	*221467*	*2668*		
Total	*89*	*411653*			

Since $11.88 > 3.07 = f_{0.01,6,83}$, the Variance analysis test confirms the difference between means of criteria of the receiver of the technology. Paired comparisons of the means, can be used to identify the factor responsible for the difference between the means. In this case, the multivariate test of Duncan is used. Results show two criteria of using experienced and expert human force by the receiver of the technology and having necessary credits for the project are placed into a group and other factors into an other group. In other words these two criteria had a larger mean compared to other criteria.

Student's *T*-test can be used for determining the degree of importance of each criterion. Regarding the results of the test, we can see that two criteria of "**using experienced and expert human force**" and **"having necessary credits for the project**" are the main effective factors for the receiver to get satisfactory result from the transfer project of jet UAV technology. Other three factors, i.e. hardware, software, and organization are the secondary factors for the receiver's success in this project.

Criteria of Technologic Contribution

The identified criteria for the technologic contribution based on the expertise are as follow:

The method of transferring the jet UAV technology.

The percentage of the transferred technology during each year and at the end of the contract.

License for exporting to the receiver of the technology by the provider.

Commitment to contribute during and after the project of T-T.

Training course by the provider of the technology.

Support for providing parts and subsystems by the provider of the technology.

Through running the necessary tests, three hypotheses of normality, data independence, and homogeneity of variances were confirmed. Therefore we can run the Variance analysis test with the following results:

Source	*DF*	*SS*	*MS*	*F*	*P*
Attribute	*5*	*42.55*	*8.51*	*5.01*	*0.001*
Error	*71*	*120.62*	*1.70*		
Total	*76*	*163.17*			

Since $5.01 > 3.26 = f_{0.01,5,71}$, the Variance analysis test shows a difference between the means of criteria therefore again the multivariate test of Duncan is used. The result of this test shows that the significant difference between the means results from the mean of the criteria "license for exporting to the receiver of the technology by the provider" and other criteria, and due to this criterion is unimportant.

Student's *T*-test can be used to determine the degree of the important. The results of the above hypothesis testing reveal that two criteria of "the percentage of transferred technology during each year and at the end of the contract" and "license for exporting to the receiver of the technology by the provider" are considered as unimportant and other criteria as important. Due to criterion of "training course" is a important criterion, when a contract, emphasis should be placed by the provider on enforcing a comprehensive training course during the time of transfer, installation conformation, and absorption of the technology in the different administrative stages, support for providing parts and subsystems by the provider of the technology. The criterion of ", method of T-T" has been identified as a important criterion. The study of the characteristics of the transfer project of jet UAV technology suggests that only there are three methods of "direct external investment", "joint contribution", and "license contracts" for T-T. Due to the strategic nature of jet UAV and it's being not among mass-produced goods, direct investment does not see an appropriate option. Joint contribution is also more appropriate when we are at an acceptable level in a given technology and through joint contribution process we are looking for getting to a higher level of technology. The use of license contracts is in priority. Proceeding through license contract, along with employing scientific and technical staff; importing investment goods and machinery; and contracts of technical and engineering contribution at the first stage, and using inverse engineering at the later stages (if possible) seems the most appropriate method.

Determining Appropriate Provider For The Transfer Project Of Jet Uav Technology

As it was noted already, eight main criteria were identified based on the expertise. Regarding the present criterion and the providers of jet UAV technology, multi-criteria decision-making model can be used to choose the appropriate provider. Through the analyses done curlier, ELECTRE and AHP methods were identified as appropriate method. At this stage the output obtained from the experts (responses the 2nd and 3rd items of the questionnaire) is entered into expert choice (EC) software as the input and is analyzed as an AHP model.

AHP model is of at least 3 stages: the objective line in which the objective of the AHP in making a decision is discussed. In this case, the objective is to choose the most appropriate provider of jet UAV technology. By selecting AHP model not only the appropriate provider, but also the providers at the next ranks are identified. There should normally be some criteria for comparing the providers of the technology, that for this paper were identified based on the opinion of the experts in the field. Using a questionnaire eight criteria were identified, in which these criteria stand second level of the hierarchy. Appropriate options for provider which should be placed in the third level of the hierarchy, were specified by the questionnaire.

With respect to the accurateness and efficiency of the criteria of choosing the provider and also the a fare-mentioned providers, these criteria and providers as a questionnaire and in the form of some tables were given to the experts to compare first the criteria of the provider and second the providers with each other in terms of the different criteria of the provider of the technology.

After entering the objective, criteria and related paired comparisons, providers and related paired comparisons, into EC software, the entire AHP process was run mechanically by the software.

The software's output was the paired comparisons of the criteria and providers, ranking or priority of the criteria and providers. Priorities of the providers in relation to each other, Priorities of the criteria in relation to each other are shown in figure 3 and figure 4 respectively.

Fig 3. Priorities of the providers in relation to each other

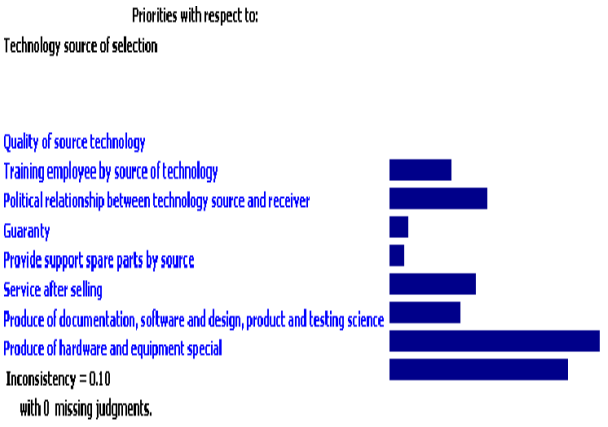

Fig 4. Comparison of relative value criteria with respect to each other in EC software

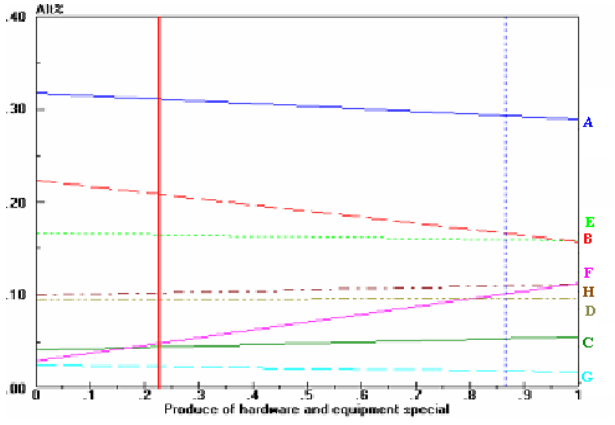

Fig 5. Gradient: shows the priority of provider for different value of "produce of hardware and special equipment"

As it is clear in the figures, in the case study, the technology provider company **A** among the eight providers and the criteria "**produce of documentation, software and design, product and testing science**" among the criteria are the first priorities.

In the case study, jets UAV, all inconsistency ratios obtained by this software were less than 0.1, which shows a relatively high consistency among the experts' judgments and there is no need to review and re-evaluation.

Sensitivity analysis can be easily done in EC software, in this software sensitivity analysis is in the form of some plots that each of them can provide the researcher with some interesting views. Gradient plot shows the sensitivity of change in the priority of the providers with change in priority of the criteria. Gradient plot of Fig. 5 changes the criteria of "produce of hardware and special equipment" from zero to one, the priority of the providers for different values are shown in the figure.

For verifying the results obtained from AHP method, priorities of the providers are made based on ELECTRE. The needed data for this method is the decision-making matrix which was based on the expertise.

By doing the relevant calculations, priorities of the providers of the technology are as follow: A, B, D, E, C, H, F, and G.

Due to the small difference between the results of two methods we can generally conclude that companies **A** and **B** are identified as the most appropriate providers, and other companies are classified in a way that **D** and **E** are placed in the next priority, **C** and **H** in the next and **F** and **G** occupy the last priority. The reason for this small difference in the results of the method may result from the difference in the nature of the methods' assessments. In the AHP if the value of an option (provider) is large in relation to a criterion, this compensates for its low value in relation to other criteria. However this compensation of one for some is not applied in ELECTRE method. AHP is sensitive to the option's low or high values in relation to a criterion, but ELECTRE shows a less degree of sensitivity in this regard.

CONCLUSION

Today T-T is an in evitable path to be followed by many organizations and countries. In any T-T project after coming know the technology. It is very important to the receiver of the technology to determine the appropriate policies and providers of the technology. This paper which has been done in this regard presents a model for determining the appropriate policies and provider of technology, based on the expertise and using statistical methods and multi-criteria decision-making, jet UAV technology was selected as the case study for assessing the proposed model.

As developing of the questionnaire was based on the T-T components, the main criteria were identified for each component. Appropriate policies can be determined based on the specification of these criteria for each T-T component. In general success of the T-T project can be attributed to the following factors: the technology being strategic, getting high quality technology, training employee service after selling by the provider, produce of documentation, software and design, product and testing science, providing hardware and special equipment by the provider, using experienced and expert employee by the receiver, having necessary credits for the project, the method of transferring jet UAV technology, commitment to contribute during & after the T-T course by the provider, and support spare parts and subsystems by the provider of the technology, forever using multi-criteria decision-making models and expert choice software, a model was developed for identifying the criteria and determining the priority of the providers of the technology. This model was assessed in the complex industry of jet UAV production, an industry which is subject to radical changes, and the results were presented in this document.

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