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Using Fuzzy DEMATEL method for analyzing the Technology Acceptance Model 2: A case study

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Abstract. Nowadays, the acceptance of new technologies is considered as one of the most important engagements of organizational managers, because by the ever increasing competition among organizations. This issue plays very important role in achievement of permanent competitive advantage. This paper investigates the effective factors in acceptance of new technologies and also implies the relation among these factors. Therefore, for investigation of effective factors in acceptance of new technologies, the Technology Acceptance Model2 (TAM2) is applied, and the relation among comprising components of this model about the acceptance of new technology of Electro-Slag Remelting (ESR) in Isfaryen Steel Company is investigated by the use of Fuzzy DEMATEL method. The results illustrate that Perceived ease of use is strongest determinant in Technology Acceptance Model 2.

Keywords: Technology acceptance, Theoretical extension of technology acceptance model2 (TAM2), DEMATEL method, Fuzzy logic, Electro-Slag Remelting (ESR).

1. Introduction

Technology acceptance was emphasized as one of the most important issues discussed in organizations during the last 20 years [1]. Many models are created and developed for analyzing and describing effective factors in applying and accepting new technologies [2]. Davis in 1989 represented the Technology Acceptance Model [TAM] for describing the relations between conceived incentive motives and application of technology and science. This model shows how users behave against acceptance and use of a new technology [4]. This model is considerably supported by trainee technology management district as a reliable tool for prospecting new technologies. The body of this model is based on two perceived usefulness factor and the perceived ease of use which determine the behavioral intention to use a new technology [5]. After a short time, this model was used as the most common and important conceptual model relate to the technology acceptance in different systems and environments in all over the world [6]. TAM shows that perceived usefulness and the perceived ease of use are two key factors in determination of how technology is accepted by the users [7]. perceived usefulness means the extent in which an individual feels that technology application promotes his job performance [8]. The perceived ease of use also, points to user's vision about the ease of using new technology. Easier learning of the system includes their more positive attitude toward its use. Both perceived usefulness and the perceived ease of use are influenced by external variables. External variables include technology characteristics, instruction, user application in designing system and

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nature of system processes. All external variables indirectly influence on user's behavioral intentions and consequently the use of system. Furthermore, perceived usefulness directly relates with the perceived ease of use [9]. If users feel that new technology is appropriate for their job performance, they will show a positive sense in their use and will have a better attitude in use of new technology. Attitudes also, influence on user's behavioral intentions and real use of system [3]. The aim of TAM model created by Davis was satisfying this prospect that TAM model can be used as a standard model for distribution or prospecting the technology application [9]. Some researchers intended to improve and adjust TAM for increasing the capacity of describing TAM model since its creation[10]. One of the models suggested for adjustment of original model and response to this criticism that why social influences on users are not considered in proportion to technology acceptance in this model, was the TAM2 [11].

2. TAM2 Model

One of the theory frameworks which enhance the manager's perception about user's reaction against technology acceptance is developed model of technology acceptance or TAM2. This model which is shown in figure (1) is created for description of perceived usefulness and functional goals with respect to social affects and subjective structural processes. TAM2 is distinct from TAM model by adding three variables which are subjective norm, voluntariness, and subjective image [12]. According to Davis and Vankatesh, subjective norm is known as an individual perception which most people regard and have a special behavior based on it. Venkatesh and Davis emphasized on this point that subjective norm is a direct determinant factor in the intention to use. Voluntariness variable also points to the extent in which user conceive that the technology acceptance is not compulsive and ultimately subjective image points to an individual intellect about this issue that application of a new technology or innovation will promote his position in his social system. It can totally be said that, the model includes subjective norms , image and voluntariness and experience as well as a perceptual structural process comprised of job relevance, output quality and result demonstrability. Subjective norm directly influences on perceived usefulness and indirectly on intention to use in TAM2 model. Subjective norm also influences on perceived usefulness indirectly and by image. Subjective norm can also directly influence on intention to use [10]. According to Hartwick's research in 1994, the subjective norm influences clearly on user's application of a system when they are relatively unfamiliar to that system [9]. TAM2 model developed the social influence factor and analyzed perfectly two main affecting processes in formation of technology perceived usefulness. So TAM2 has higher capacity for interpretation and description in comparison to TAM [11].

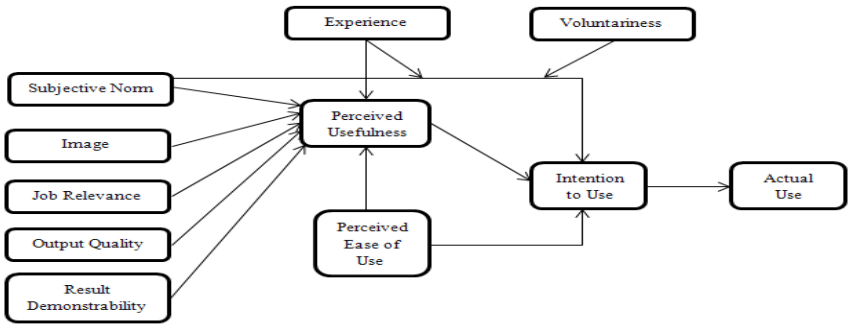

Fig.1: Modified technology acceptance model(TAM2)

The technology acceptance is used in various studies and fields. Some of the studies emphasized on the technology acceptance[11] and some others emphasized on the relations between the technology acceptance and affecting variables[10][9][12] TAM2 model is also dependant on this group[13].

3. Fuzzy DEMATEL

Decision Making Trial and Evaluation Laboratory (DEMATEL) was first introduced at Battelle Memorial Institute of Geneva Research Center . This method was applied in relation to complicated problems of the world such as famine, energy, environmental protection and etc in that time. DEMATEL is one the multi criteria decision making instruments and has the ability to convert the qualitative designs to the

quantitative analysis [9]. The aim of DEMATEL is to convert the relation between criterions, causal dimensions from a complex system to an understandable structural model of that system[14].

The DEMATEL`s steps:

We specify evaluation factors according to expert committee's opinion and research background.

We determine each factor influences on whole system, according to expert's opinion. To do so, we use discussed wordy expressions in table1. After that we used CFC method (Equations 1 to 9) to convert the fuzzy results into crisp value.

Table1: the correspondence of linguistic terms and values

Linguistic values	Linguistic terms
[0.75,1,1]	Very high influence(VH)
[0.5,0.75,1]	High influence(H)
[0.25,0.5,0.75]	Low influence (L)
[0,0.25,0.5]	Very low influence (VL)
[0,0,0.25]	No influence (NO)

$$XL_{ij}^{k} = (L_{ij}^{k} - \min_{1\le k\le k} L_{ij}^{k}) / \Delta_{\min}^{\max} \quad (1) \qquad XM_{ij}^{k} = (M_{ij}^{k} - \min_{1\le k\le k} L_{ij}^{k}) / \Delta_{\min}^{\max} \quad (2)$$

$$Xr_{ij}^{k} = (r_{ij}^{k} - \min_{1\le k\le k} L_{ij}^{k}) / \Delta_{\min}^{\max} \quad (3) \qquad \Delta_{\min}^{\max} = \max r_{ij}^{k} - \min L_{ij}^{k} \quad (4)$$

$$Xls_{ij}^{k} = \frac{Xm_{ij}^{k}}{(1 + Xm_{ij}^{k} - Xl_{ij}^{k})} \quad (5) \qquad Xrs_{ij}^{k} = \frac{Xr_{ij}^{k}}{(1 + Xr_{ij}^{k} - Xm_{ij}^{k})} \quad (6)$$

$$X_{ij}^{k} = \left[Xls_{ij}^{k}(1 - Xls_{ij}^{k}) + Xrs_{ij}^{k}.Xrs_{ij}^{k}\right]/(1 + Xrs_{ij}^{k} - Xls_{ij}^{k}) \quad (7)$$

$$BNP_{ij}^{k} = \min L_{ij}^{k} + X_{ij}^{k}\Delta_{\min}^{\max} \quad (8) \qquad a_{ij} = \frac{1}{k}\sum_{k}^{1\le k\le k} BNP_{ij}^{k} \quad (9)$$

A= $[a_{ij}]$ is direct relations matrix of experts opinions.

Obtaining total relations matrix T- I is identity matrix $n \times n$ and $T = [t_{ij}]$ elements indicate the direct and indirect influences of factor i on factor j. so matrix T can be indicator of general relations between each pair factor in the system. Matrix D is the normalized matrix. $D = [d_{ij}]$, $0 \le d_{ij} \le 1$.

$$D = \frac{1}{\max_{1\le i\le n}\sum_{j=1}^{n} a_{ij}} A \quad (10) \qquad T = D(I - D)^{-1} \quad (11)$$

Calculation of row summation and column summation of T matrix – i row summation is indicator of all direct and indirect influences of i factor on all other factors and so can call r_i as the influencing degree. C_j is similarly, the column summation and we can call it as influenced degree of j factor.

$$r_i = \sum_{1\le i\le n} t_{ij} \quad (12) \qquad C_j = \sum_{1\le i\le n} t_{ij} \quad (13)$$

Therefore, when $i = j$, $r_i + C_i$shows both the influence which i factor can have on other factors of system and also the influences of other factors of system on i factor. So, $r_i + C_i$show the significant degree of i factor in whole system, and $r_i - C_i$indeed shows the influence of i on system. If $r_i - C_i$ is positive, i factor will be influential on system and if $r_i - C_i$is negative, i factor is an influenced factor of other factors group.

We show the diagram of factors influencing on $r_i - C_i$and $r_i + C_i$bases. This diagram is drawn by $(r_i + C_i, r_i - C_i)$ coordinate [15].

4. Case study

Isfaryen Steel Company is known as the greatest manufacturer of smithy steel slabs in Iran. This complex has the annual manufacturing capacity of 81,000 ton product kinds. This company has recently started to apply new techniques in this field for completion of product line and probability of competing with foreign strong competitors. One of these new technologies is ESR technology which is conducted from Austria to this complex in 1390. Application of this new technology has many advantages as promoting product capacity of melting in melting unit and bullions up to 180,000 ton in a year and qualitative improvement of present production of complex and creating the manufacturing possibility of consumable products by the use

of ESR technology and improving manufactured bullions in melting and bullion unit and producing high quality and very clean steels.

Fuzzy DEMATEL technique is applied in this paper for investigation of causal relations among components of theoretical extension of technology acceptance model2. Key success factors were identified by this method to help organizations to focus on new technology entrance and its harmony with internal processes. It is obvious that organization's more attention to key factors of new technology acceptance by users will simplify the implementation and application possibility of these technologies and makes the successful situations more effective in technology transformation project.We called factors in this order: X_1- experience, X_2- voluntariness, X_3- subjective norm, X_4- image, X_5- job relevance, X_6- output quality, X_7- result provability, X_8- perceived usefulness, X_9- perceived ease of use, X_{10}- the intention to use, X_{11}- user's behavior.6 experts and specialists who had sufficient experience and skill in transformation of some technologies were requested to express their opinions and the direct relations matrix was obtained after defuzzification stage and incorporating the opinions of 6 people. (Equations 1 to 9). It should be mentioned that experts use Linguistic terms (table1) in filling the questionnaire.

Table2: General relations matrix -T Matrix

	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}
x_1	0.279	0.344	0.303	0.274	0.365	0.336	0.277	0.520	0.412	0.467	0.354
x_2	0.296	0.298	0.288	0.262	0.349	0.298	0.279	0.479	0.389	0.444	0.353
x_3	0.376	0.465	0.315	0.360	0.428	0.413	0.340	0.581	0.440	0.504	0.455
x_4	0.293	0.398	0.285	0.213	0.342	0.312	0.276	0.501	0.340	0.404	0.395
x_5	0.341	0.425	0.350	0.302	0.339	0.398	0.325	0.560	0.382	0.473	0.434
x_6	0.402	0.385	0.405	0.302	0.440	0.319	0.326	0.567	0.393	0.485	0.437
x_7	0.408	0.414	0.394	0.288	0.434	0.402	0.272	0.573	0.400	0.458	0.443
x_8	0.465	0.512	0.450	0.393	0.507	0.469	0.413	0.552	0.472	0.591	0.526
x_9	0.435	0.476	0.421	0.310	0.473	0.410	0.358	0.610	0.377	0.537	0.484
x_{10}	0.439	0.487	0.428	0.339	0.476	0.438	0.360	0.609	0.477	0.454	0.519
x_{11}	0.349	0.431	0.322	0.272	0.433	0.364	0.320	0.529	0.417	0.476	0.344

Table3: calculating the influences of each factor

	r_i	C_i	$r_i + C_i$	$r_i - C_i$
X_1	3.932	4.083	8.015	-0.152
X_2	3.734	4.636	8.369	-0.902
X_3	4.677	3.963	8.640	0.714
X_4	3.758	3.315	7.073	0.443
X_5	4.328	4.585	8.913	-0.258
X_6	4.462	4.161	8.623	0.301
X_7	4.485	3.546	8.031	0.939
X_8	5.351	6.080	11.431	-0.729
X_9	4.892	4.497	9.389	0.395
X_{10}	5.027	5.292	10.319	-0.265
X_{11}	4.257	4.744	9.001	-0.487

We finally show the obtained influences of DEMATEL method on TAM2 model. (Figure 3)

5. Conclusion

There are always three fundamental problems in experimental studies of technology acceptance model which should be heightened: 1. Do users have sufficient experience and perception in the use of regarding technology? 2. Are the external variables of technology acceptance model independent? 3. Difficult accessibility to appropriate statistical universe for related experimental studies with complicated technologies. We have used Fuzzy DEMATEL method in this paper and for being dominant on discussed problems as well as removing the existing ambiguities in some of the judges. It has the ability to clearly express the causal relations between factors of the theoretical extension of technology acceptance model 2 and the extent of each factor's influence on technology acceptance by users. To do so, we have obtained the diagram of factor's influence after necessary calculations and we have shown the average of horizontal and vertical quantities 0.00, 8.891 for simpler analysis of diagram. The right hand factors of average lone 8.891 enjoy

more significance. The factors located above the line 0.00 have the most influence on relations network and are located in influential or causal group and factors which are under this line are located in dysfunctional or influenced groups. This diagram can be divided to four zones for accurate analysis of factor's influences: zone one, in which factors have the least relations or in other words, factors which are independent and their significance is low. X_1- experience and X_2- voluntariness are in this zone. Zone two is indicator of causal relations but their influence on factor's network is trivial. X_3- subjective norm, X_4- image, X_6- output quality and X_7- result provability are in this zone. Zone three indicates factors with high significance but is located in dysfunctional group. These factors are in fact the main problems in factor network and organization must immediately solve them. X_5- job relevance, X_8- perceived usefulness, X_{10}- intention to use and X_{11}- user's behavior are in this zone. Zone four indicates factors which have high significance and are also located in causal group and are actually the most important factors. These factors are called key success factors and management can solve the existing problems and limitations by concentrating on them. X_9- perceived ease of use is known as an important and key factor.

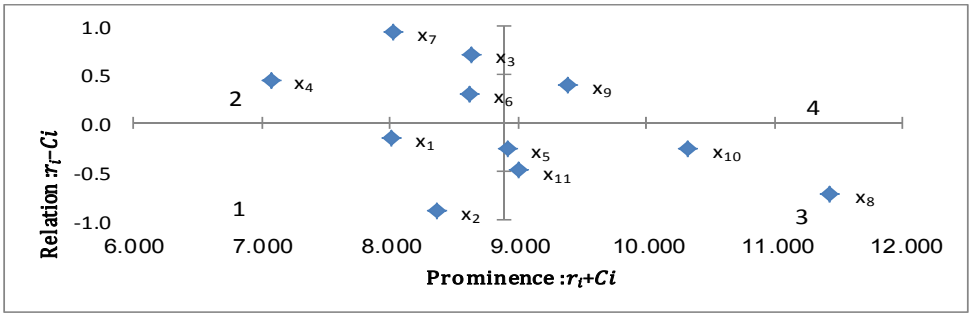

Fig. 2: the casual diagram

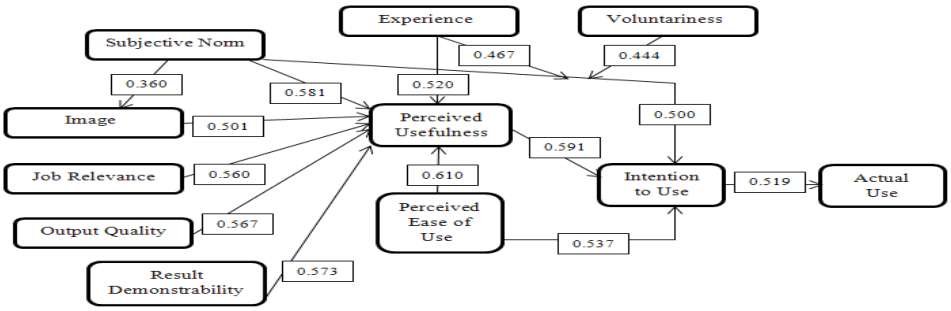

Fig. 3: Fuzzy DEMATEL relations on TAM2 model

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