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A Causal Relationship Analysis of Critical Factors to Successful Technology Transfer, based on Grey DEMATEL Method

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Abstract

The purpose of this paper is to propose a framework of critical factors for effective and efficient technology transfer which prioritized by considering their interactional relationships using a Grey-based DEMATEL approach. For this purpose, according to the literature, five main dimensions were identified which totally include 24 factors. Then, to analyze and prioritize the interactional relationships of these factors an online questionnaire shared among professors and experts in this field and finally 20 completed questionnaires collected. To analyze interactions of factors in each dimensions, first, experts' opinion (under uncertainty) stated in form of grey numbers and then unified into a single opinion. Subsequently, to normalize the opinions, the total matrix of all factors are calculated. At the end, interactional relationships of factors analyzed with regards to the values of R, D, R+D and R-D which calculated in DEMATEL approach. The results show effectiveness, influence, and interactional relationships of the critical factors to successful technology transfer.

Keywords: Technology Transfer, DEMATEL, Grey DEMATEL, Critical Factors, Causal Relationships.

Introduction:

Technology transfer (TT) has increasingly been appearing as a relevant and recent subject of research among industries, businesses, governments, nongovernmental firms, and academicians in last decade around the world as well as in Iran. Technology transfer is acquiring enriching recognition in the developing economies, where companies track technologies from outer sources to increase their own core competencies (Theodorakopoulos et al., 2012; Deng and Chen, 2014). Technology transfer process became one of crucial activities in innovation management of products, services and processes; it has also been recognized as a very useful way to be competitiveness among other firms (Kaushik et al., 2014). Organizations may have varied approaches to find their technological assets to gain increased profitability and multi-dimensional total growth; although internal utilization of technological assets (perceive, plan, design, develop, fabricate/manufacture, and sell products, services and processes) has been momentous, interests in external utilization of TT have accelerated in last years. Also, the product life cycle is being shorter constantly because of the rapid growth of technology. To compete in intensely competitive global markets, a business organization should keep developing new technologies to distinguish it from other competitors (Lee et al., 2010). Technology may be pointed to an intricate phenomenon consist of know-how and techniques and may be identified as a system of utilized useful knowledge embodied or manifested in human beings and physical things; and this process of transferring from developed or industrialized countries to yet developing ones may not be feasible without moving into official agreements and following official procedures (Karani, 2001). Organizations have been utilizing advanced technologies to meet current challenges towards new and better products/services, activities /processes, and practices to deliver more efficiency and effectiveness (Kumar et al., 2015a). Transferring of technology yet not received due consideration in development of policy in most of developing countries (Zhao et al., 2015). Technology transfer may be useful for developing countries or less developed ones, to solve technological, environmental, economic and social problems (Gibson, 2011). Without innovative ideas in manufacturing, marketing, and sales to the customer in a lucrative method has proven to be a hard challenge even for the organizations with a best management. Therefore, it is too important to identify critical factors and develop theories for efficient and effective technology transfer (Sung, 2009). Surprisingly, a few studies have been identified the critical factors towards the successful technology transfer considering transactional relationships. Therefore, to meet this research gap, this research identifies and evaluates the critical factors related to successful technology transfer. For this purpose, we suggest to use the Grey-based DEMATEL technique that not only helps to define the interactional relationship between each factor, but also assists to define the importance of each factor with respect to one another.

Theoretical Basis of Research:

Technology Transfer

Technology called to the integration of any tool/technique, any product/process, any physical facilities or the way of doing or making, by which the potential of human being is expanded. In this definition, technology considered as a hardware or physical product (Buratti and Penco, 2001). On the other hand, technology can be defined as “know-how” or technical knowledge that is applying for improving the ability of organization to provide products/services or to achieve a specific objective (Rogers et al., 2001). Since technical knowledge varies widely in the extent of physical visualization, a specific technology can

be a machine, a software code, a process, a handbook, documents, blueprints, operating procedures, a mechanical or electrical constituent, a technique, a patent, or even a person (Palvia et al., 2012). Technology is a crucial factor in the process of industrialization, especially for developing countries (Salahaldeen, 1995).

Technology transfer is the technology flow from one place to another, (for instance, from one organization to another, from a university to an organization, or from a country to another), which is described as being product embodied, process-embodied or personnel-embodied (Guan et al., 2006). While the hardware aspect of the technology is stressed on the main stream outlook in which technology transfer is considered as one approach process from the transferor to the recipient; the software aspect is emphasized on modern perspective, and according knowledge sharing on a mutual exchange (Dahl and Pedersen, 2004), the technology transfer turns out as a two-way communication process (Buratti and Penco, 2001). Technology transfer also defined as "a broad set of processes coverings the flows of know-how, experience and equipment for mitigating and adapting to climate change amongst different stakeholders" (IPCC, 2000). Generally, the technology is transferred via voluntary economic behaviors of foreign direct investment, trade-in-goods, licensing, workflow, and people movement under the legal protection of intellectual property rights (Hoekman et al., 2005). Technology transfer indicated to a process through which technology moves from one business organization to another (Deng and Chen, 2014). The transferred technology called as a multidimensional commodity which could take many shapes (i.e., tangible/intangible, patented/non-patented) (Bessant and Rush, 1995). A technology successfully transferred when transfers to the recipient not only of the technical knowledge needed for producing the product, but also of the ability to master, develop and produce autonomously the technology underlying such products (Zhao and Reisman, 1992). Therefore, as a strategy to increase competitiveness at the firm and industry levels, technology transfer has been gaining growing recognition not only in the developed world, but also in many developing economies (Lichtenthaler, 2013). Technology transfer generally is any process towards transferring technological know-how from a transferor to a recipient (Buratti and Penco, 2001). Technology transfer is a complex process which requires clear definitions from the outset, to ensure that both the seller and purchaser of technology clearly understand its implications, and try to maximize the benefits for both parties (Salahaldeen, 1995). Technology transfer is a trade off process that enables a recipient firm to access or imitate complete technological capabilities of the donor one (Kotabe et al., 2002). In other words, technology transfer is the movement of technology via some communication channels from one individual or organization or a country to another (Rogers et al., 2001). Technology transfer and therefore information takes on even higher importance for productivity progress in developing countries, which as a group cope with little domestic R&D and subsequently have few new technology domestic sources (Henry et al., 2009).

The technology transfers are usually categorized into three types:

- Type 1: the host institution develops or innovates a technology with foreign institutions collaboration (Das, 2011). This type is advanced level, and known as know-why.
- Type 2: host parties ''import a technology and/or equipment with some in-house technological efforts by the importer'' (Das, 2011). This type is intermediate level, and known as know-what.
- Type 3: constitutes ''import a technology and/or equipment, and also training on operation from other country, as the basic level of operational knowledge'' (Das, 2011). This is basic level, and known as know-how.

Critical Factors of Successful Technology Transfer

Researchers need to critical factors identification; conceptualize theories which may continue to influence technology transfer implementation to relate and explain empirical aspects of technology transfer concept (Wahab et al., 2012). 'Critical factors' are key factors, enablers, or activities crucial towards success of a business or phenomenon, which required to be identified, evaluated and focused (Sukri et al., 2010). Critical factors are the factors that are necessary for success (Luthra et al., 2015). According to Kumar et al. (2015b) five critical factors dimensions to successful technology transfer including 24 constructs from literature review and expert's viewpoints are listed below:

- *Technical features (TF):* The ability of organizations to adopt advanced technology to figure expected benefits out of the technology adoption process may depend on current technical and organizational capabilities (Bell, 1987; Cusumano and Elenkov, 1994).
- *Marketing related benefits and forces (MB):* Effective marketing efforts which required to be focused on increasing innovative willingness organizations to provide information with respect to benefits and knowledge of their products and processes of production to organizations in developing countries (Wang and Carayannis, 2012).
- *Managerial and strategic issues (MS):* The management attitude and approach towards changes may significantly influence technology transfer performance (Holsapple and Joshi, 2000).
- *Regulatory concerns (RC):* Regulatory concerns containing legislative framework may be one of most important factors to successful technology transfer and is often motivated and supported by friendly technology policies; subsidies to increase its usage; and adequate training support (Qiu, 2013; Wang and Brown, 2013).
- *Relative advantage in economic terms (RA)*: The degree which new technology is perceived and evaluated improved in social, functional, economic, satisfaction and convenience parameters when compared with current technology (Cusumano et al., 2015). In this work, we have considered only economic advantages.

Table 1. Critical factors to successful technology transfer

Dimension	Factors	References
Technical features (TF)	Scientific changes (SC)	Erickson et al. (2012), Siegel et al. (2004), Grange and Buys (2002a, 2002b)
	Technological abilities of suppliers (TS)	Kumar et al. (2014), Rasmy et al. (2005)
	Local suitability of technology (LS)	Klein (2011)
	Compatibility (CP)	Scheraga et al. (2000)
	Functionality (FS)	Dell'Era and Verganti (2010), Abe et al. (2012)
	Reliability (RL)	Lee et al. (2010)

	Trial-ability (TA)	Cook et al. (2012), Saikia (2010)
	Observe-ability (OB)	Cook et al. (2012), Saikia (2010)
Marketing related benefits and forces (MB)	Penetration in new areas (PA)	Kotabe et al. (2002), Simona and Axèle (2012)
	More usage by existing customers (MU)	Cusumano et al. (2015)
	End users support (EU)	Dijk and Yarime (2010), Johnson et al. (1997)
	Market requirements (MR)	Gorschek et al. (2012)
	Competition (CT)	Mohr et al. (2010), Tushman and O'Reilly (2010)
	Judgment about timing (JT)	Bergek et al. (2013)
Managerial and strategic issues (MS)	Strategic implications (SI)	Quinn and Strategy (2013)
	Personnel resources (PR)	Grant (1996)
	Training and development support (TD)	Choi (2009), Bansal (2013)
	Commitment (CM)	Wang and Brown (2013)
Regulatory concerns (RC)	Government authorities (GA)	Pueyo et al. (2011)
	Environmental concerns (EC)	Zhang et al. (2013)
	International bodies (IB)	Zhao et al. (2011), Zhang et al. (2013)
Relative advantage in economic terms (RA)	Cost effectiveness (CE)	Goulder et al. (1999), Johnston et al. (2004)
	Higher margins of profit (HM)	Lee et al. (2012)
	Expected increase in sales (ES)	Autio et al. (2000), Yu et al. (2011)

Research Background:

Recently, many research paper have been published in related to technology transfer. Malik and Hattasinghe (2013) recognized and analysed the main barriers of human resource to technology transfer by taking case studies of 16 multinational enterprises' subsidiaries in Thailand and their findings indicated that the lack of basic skill set and techniques is a critical barrier of technology transfer. Jung et al. (2014) recognized the success and failure factors of technology commercialization in Korea public R&D and indicated that 'Marketing capability' and 'Cooperation with developer' were the most crucial factors for the success and failure of technology commercialization. Kaushik et al. (2014) made a literature review to know background of technology transfer and main contributions given by various researchers in this field and based on findings, proposed a conceptual model for technology transfer. Leischnig et al. (2014) due to an empirical research investigated the impact of alliance management capability, organizational compatibility and interaction quality in inter-organizational technology transfer and results explained linkages between important factors and consequences of interaction quality to figure out the success of inter-organizational technology transfer process. Battistella et al. (2015) recognized the

critical factors through a literature review for technology/knowledge transfer and suggested structure consisting of 6 categories in relevant to the actors involved (sources, recipients and intermediaries). Kumar et al. (2015a) analysed critical barriers of technology transfer to successful technology transfer in which used a AHP method to analyse the critical barriers and presented a benchmarking framework. Newman et al. (2015) explored the relationship between foreign direct investment (FDI) and the productivity of host country domestic firms which their results showed that there were productivity gains related to direct linkages between foreign-owned and domestic firms along the supply chain not captured by regularly used measures of spill overs.

With respect to the research background in this area, a few studies have been identified the critical factors towards the successful technology transfer considering transactional relationships. Therefore, to deal with this research gap, this paper identifies and evaluates the critical factors related to successful technology transfer. For this purpose, we suggest to apply the Grey-based DEMATEL technique that not only assists to define the interactional relationship between each factor, but also helps to define the importance of each factor due to one another.

Research methodology:

Grey System Theory

The grey system theory introduced by Deng (1982) from a grey set. Grey systems theory aim at covering the data and series production for the real patterns modeling that are based on poor (negligible) information (Liu and Lin, 2006). Grey systems theory can handle many of the ambiguities generated from imprecise human decisions (Fu et al., 2001; Li et al., 2007). The grey value is the number of uncertain data (Dong et al., 2006).

Let X as a universal set, G as Grey set of universal set X, $\overline{\mu_G}(x)$ and $\underline{\mu_G}(x)$ will be defined as the top and bottom limit of the G membership function as in equation (1):

$$\underline{\mu_G}(x): X \to [0,1] \quad , \quad \overline{\mu_G}(x): X \to [0,1] \qquad (1)$$

Equation $\overline{\mu_G}(x) \geq \underline{\mu_G}(x)$ is obvious, so the equation of the grey set will become to fuzzy set in which indicates the grey theory is conclude fuzzy and flexibility cases in the contact of hard phase (Nezhad et al., 2009). In this paper, the number of grey $\otimes X_{ij}^{p}$ for P decision is considered to evaluate the effect of i criterion on j:

$$\otimes . X_{ij}^{p} = \left[\underline{\otimes} X_{ij}^{p}, \overline{\otimes} X_{ij}^{p}\right] \qquad (2)$$

The grey data converts to crisp number as following three steps:

1. Normalization:

$$\Delta_{Min}^{Max} = Max_j \overline{\otimes} X_{ij}^{p} - Min_j \underline{\otimes} X_{ij}^{p} \qquad (3)$$

$$\underline{\otimes} \tilde{X}_{ij}^{p} = \left(\underline{\otimes} X_{ij}^{p} - Min_j \underline{\otimes} X_{ij}^{p}\right) / \Delta_{Min}^{Max} \qquad (4)$$

$$\overline{\otimes} \tilde{X}_{ij}^{p} = \left(\overline{\otimes} X_{ij}^{p} - Min_j \underline{\otimes} X_{ij}^{p}\right) / \Delta_{Min}^{Max} \qquad (5)$$

2. Calculate total normalized crisp value:

$$Y_{ij}^{p} = \frac{(\underline{\otimes} X_{ij}^{p}(1-\underline{\otimes} X_{ij}^{p}) + (\overline{\otimes} X_{ij}^{p} \times \overline{\otimes} X_{ij}^{p})}{1-\underline{\otimes} X_{ij}^{p} + \overline{\otimes} X_{ij}^{p}} \qquad (6)$$

3. Calculate the crisp value:

$$Z_{ij}^{p} = Min_{j} \underline{\otimes} X_{ij}^{p} + Y_{ij}^{p} \Delta_{Min}^{Max} \qquad (7)$$

From equation (8) is used to turn viewpoints into a unit view

$$Z_{ij}^{p} = \frac{1}{p}(Z_{ij}^{1} + Z_{ij}^{2} + ... + Z_{ij}^{p}) \qquad (8)$$

DEMATEL

Decision-making trial and evaluation laboratory (DEMATEL) approach originally developed by the Battelle Memorial Institute of Geneva. It could structure and manage complex interactional relationship among the criteria using a combination of matrices or graphs, and also intended to resolve the complex problem by understanding the specific problem, the cluster of intertwined problem, and recognition of workable solutions via a hierarchical structure (Wang et al., 2012; Wu, 2012; Jeng and Tzeng, 2012; Hsu et al., 2013). DEMATEL approach based on assumptions of a system that consist of a variable set and paired comparisons and the relationship among these variables is made with mathematical models (Büyüközkan and Çifçi, 2012). In comparison with other multi-attribute decision-making approaches such as Analytical Hierarchical Process (AHP), in which criteria are assumed independent; DEMATEL is a structural modeling approach that aims at figuring out the interdependence amongst the elements of a system by a causal diagram (Tseng, 2009; Wu et al., 2010).

In this method, firstly, a direct relation matrix organized according to experts' viewpoints and the critical factors. The resulting T-matrix is an $n \times n$ matrix which represents interactions criteria, as T_{ij} refers to the degree of effect of *i* criterion on *j* criterion, $T = \lfloor T_{ij} \rfloor_{n \times n}$.

Then we make the normalized matrix of direct relation (S), $S = \lfloor S_{ij} \rfloor_{n \times n}$, where $0 \le S \le 1$. Instructions of making the matrix S are according to equations (9) and (10) as follows:

$$K = \frac{1}{MAX_{1 \le i \le n} \sum_{j=1}^{n} a_{ij}} \qquad (9)$$

$$S = K \times T \qquad (10)$$

Then, the total relation matrix (T) made by equation (11), where *I* represent an $n \times n$ identity matrix:

$$M = S(I - S)^{-1} \qquad (11)$$

R and D indicate to the sum of rows and columns calculated form the equations (12), (13) and (14) as follows:

$$M = m_{ij} \qquad i, j=1, 2\ldots, n \qquad (12)$$

$$R = \left\lfloor \sum_{j=1}^{n} m_{ij} \right\rfloor_{n \times 1} \qquad (13)$$

$$D = \left[\sum_{j=1}^{n} m_{ij}\right]_{1\times n} \quad (14)$$

Finally, to determine the interactional (cause and effect) relationships, (R) reflects effectiveness of a factor on other factors (effectiveness of variables), (D) for each factor indicates the impact of other factors on it (influence of variables), the "Influence" horizontal axis vector (R+D) shows how much importance the criterion has, and the "Relation" vertical axis (R-D) categorizes criteria into a cause group and an effect group. When (R-D) is positive, the criterion will be assigned to the cause group, and when negative, the effect group (Hung, 2011).

Research Findings:

In this paper, according to the literature and research background the most important factors to successful technology transfer identified in five main dimensions which totally include 24 factors. Next, to evaluate the interactional relationships of factors an online questionnaire was designed with one-by-one questions, in which asked from respondents to how each factor affect to other factors using linguistic variables (no affect, very low affect, low affect, high affect, very high affect). Then, the online questionnaire link distributed to professors and experts in this subject which finally 20 completed questionnaires collected to analyze interactions among the factors using Grey-based DEMATEL method. The demographic statistics of respondents are demonstrated in Table 2.

Table 2. Demographic statistics of respondents

Sex		**Age**				**Education**		
Male	Female	Under 30	30-40	40-50	over 50	BA	MA	PhD
13	7	4	4	7	5	2	8	10

Next, after receiving the questionnaires, according to Fu et al. (2012) the responses from linguistic variable turned into grey value range (Table 3) and then according to equations (3) to (7), experts' opinions of grey numbers are converted to crisp numbers and all opinions are unified into a single view by equation (8).

Table 3. Linguistic scales of importance weight of factors

Linguistic variable	**Grey values**
Very low	[0,0.3]
Low	[0.3,0.5]
Medium	[0.4,0.7]
High	[0.5,0.9]
Very high	[0.7,1.0]

Then, the crisp numbers normalized in DEMATEL using the equations (9) and (10), and total matrix of each of the main dimensions and their sub-factors are calculated using equation (11). Finally, the values of R, D, R+D and R-D are calculated. The results of Grey-based DEMATEL analysis are shown in Table 4.

Table 4. Results of Grey-based DEMATEL analysis for critical factors to successful technology transfer

Factors		R	Rank	D	Rank	R+D	Rank	R-D
Technical features (TF)		3.130918887	4	3.478835072	2	6.609753959	4	-0.347916185
Marketing related benefits and forces (MB)		4.200052603	1	2.756892251	5	6.956944854	2	1.443160353
Managerial and strategic issues (MS)		2.823451585	5	4.447376601	1	7.270828186	1	-1.623925016
Regulatory concerns (RC)		3.312966756	3	3.472586417	3	6.785553173	3	-0.159619661
Relative advantage in economic terms (RA)		3.498306328	2	2.810005818	4	6.308312146	5	0.688300509
Technical features (TF)	SC	5.686013644	1	4.968156684	5	10.65417033	3	0.71785696
	TS	5.302308506	3	3.765893043	7	9.068201549	6	1.536415462
	LS	3.728923467	7	4.371723312	6	8.100646779	7	-0.642799845
	CP	4.920829825	5	5.737280891	1	10.65811072	2	-0.816451066
	FS	4.549536214	6	5.161724715	4	9.711260929	5	-0.612188501
	RL	5.312493568	2	5.362013729	3	10.6745073	1	-0.049520162
	TA	4.958130404	4	5.40305702	2	10.36118742	4	-0.444926616
	OB	3.456797733	8	3.145183966	8	6.601981699	8	0.311613767
Marketing related benefits and forces (MB)	PA	2.321228149	2	1.011720904	5	3.332949052	4	1.309507245
	MU	2.005714091	4	2.039565569	3	4.04527966	2	-0.033851478
	EU	1.224465532	5	2.815569194	1	4.040034726	3	-1.591103662
	MR	0.593190809	6	2.232220656	2	2.825411465	6	-1.639029848
	CT	2.630234157	1	1.773559598	4	4.403793755	1	0.856674559
	JT	2.007001265	3	0.909198082	6	2.916199348	5	1.097803183
Managerial and strategic issues (MS)	SI	5.428504096	3	5.270811357	3	10.69931545	2	0.157692739
	PR	5.489776681	2	5.274312647	2	10.76408933	1	0.215464033
	TD	5.834115139	1	4.486522276	4	10.32063741	3	1.347592863
	CM	4.088721805	4	5.326832005	1	9.41555381	4	-1.238110201
Regulatory concerns (RC)	GA	1.984496124	1	0.736434109	2	2.720930233	1	1.248062016
	EC	0.736434109	3	1.76744186	1	2.503875969	3	-1.031007752
	IB	1.170542636	2	1.387596899	3	2.558139535	2	-0.217054264
Relative advantage in economic terms (RA)	CE	3.464566929	3	4.511811024	2	7.976377953	2	-1.047244094
	HM	4.511811024	2	3.464566929	3	7.976377953	2	1.047244094
	ES	5.062992126	1	5.062992126	1	10.12598425	1	8.88178E-16

The results for the five main dimensions of critical actors shows the dimension “Marketing related benefits and forces (MB)” according to R criterion, has the greatest influence on other dimensions; also according to D criterion, the dimension “Managerial and strategic issues (MS)” most affected from other dimensions; it also according to R+D, has the most interaction with the other dimensions, which these demonstrate great importance of this dimension in TT. Also according to the R-D criterion, the dimensions “Marketing related benefits and forces (MB)” and “Relative advantage in economic terms (RA)” are the causal factors (positive), and the dimensions “Technical features (TF)”, “Managerial and strategic issues (MS)”, and “Regulatory concerns (RC)” are the effect factors (negative).

In the first main dimension "Technical features (TF)", the factor "SC" (Scientific Changes) according to R criterion, has the greatest influence on other factors; according to D criterion, the factor "CP" (Compatibility) most affected from other factors; and according to R+D, the factor "RL" (Reliability) has the most interaction with the other factors which this demonstrate great importance of this factor in this dimension. Also according to the R-D criterion, the factors "SC", "TS", and "OB" are causal factors (positive), and the factors "LS", "CP", "FS", "RL", and "TA" are effect factors (negative) in this dimension.

In the second main dimension "Marketing related benefits and forces (MB)", the factor "CT" (Competition) according to R criterion, has the greatest influence on other factors; it also according to R+D, has the most interaction with the other factors which demonstrate great importance of this factor in this dimension. Besides, according to D criterion, the factor "EU" (End users support) most affected from other factors. Also according to the R-D criterion, the factors "PA", "CT", and "JT" are causal factors (positive), and the factors "MU", "EU", and "MR" are effect factors (negative) in this dimension.

In the third main dimension "Managerial and strategic issues (MS)", the factor "TD" (Training and development support) according to R criterion, has the greatest influence on other factors; according to D criterion, the factor "CM" (Commitment) most affected from other factors; and according to R+D, the factor "PR" (Personnel resources) has the most interaction with the other factors which demonstrate great importance of this factor in this dimension. Also according to the R-D criterion, the factors "SI", "PR", and "TD" are causal factors (positive), and the factor "CM" is an effect factor (negative) in this dimension.

In the forth main dimension "Regulatory concerns (RC)", the factor "GA" (Government authorities) according to R criterion, has the greatest influence on other factors; it also according to R+D, has the most interaction with the other factors which demonstrate great importance of this factor in this dimension. Besides, according to D criterion, the factor "EC" (Environmental concerns) most affected from other factors. Also according to the R-D criterion, the factors "GA", and "EC" are causal factors (positive), and the factor "IB" is an effect factors (negative) in this dimension.

In the fifth main dimension "Relative advantage in economic terms (RA)", the factor "ES" (Government authorities) according to R criterion, has the greatest influence on other factors; according to D criterion, most affected from other factors; and consequently, according to R+D, has the most interaction with the other factors which demonstrate great importance of this factor in this dimension. Also according to the R-D criterion, the factor "CE" is a causal factor (positive), and the factors "HM" and "ES" are effect factors (negative) in this dimension.

Conclusion:

In this paper, applied the Grey-based DEMATEL analysis to prioritizing and determining interactional relationships of the critical factors to successful technology transfer in which the entrance data consider in the range of uncertain numbers (Grey numbers), is the special characteristic of this method. In other words, the application of Grey theory system makes it possible to consider the uncertainty of decision system structure and inputs of decision system. Besides, the utilization of DEMATEL method helps the decision maker to identify causal dimension(s) and factor(s) within each other and understand the relative cause-effect relationships between dimensions and factors. Therefore, this research provides another point of view to implement technology transfer without assuming dimensions and factors are mutually

independent. Each actions taken on net causes (dimension/factor) will have direct/indirect effects on the corresponding net receivers (dimension/factor). Hence, the decision maker can pay more attention and allocate resources to cause dimension(s) and factor(s) to effectively implement successful technology transfer.

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