processes

Article

Supporting Management Disciplines for Research and Development in Public Organizations

Zeeshan Asim [1,2] and Shahryar Sorooshian [3,4,5,*]

[1] College of Business, University of Buraimi, P.O. Box 890, Al Buraimi 512, Oman
[2] Institute of Business and Management, Karachi 75190, Pakistan
[3] Department of Business Administration, University of Gothenburg, 405 30 Gothenburg, Sweden
[4] Department of Management, Apadana Institute of Higher Education, Shiraz 7187985443, Iran
[5] Prime School of Logistics, Saito University College, Petaling Jaya 46200, Malaysia
* Correspondence: shahryar.sorooshian@gu.se

Abstract: In practice, R&D in public organizations in developing countries is confronted with a variety of failures related to supporting management disciplines. The primary goal of this study is to address this issue through multiple-criteria decision making, which includes the DANP (DEMATEL-based ANP) approach. The DANP approach helps to resolve the classification issue that arises as a result of interdependence and feedback characteristics among the capabilities related to supporting management disciplines, allowing weak capabilities to be prioritized based on their interdependence. In the case of criteria weighting, the empirical result in terms of the degree of the net causal relationship had a greater influence on other criteria; however, in terms of dimensions, the technology management process capability had a greater significance on other dimensions, while the innovation management process capability had the least significance on other dimensions. The studies were based on relevant capabilities under a generic perspective so as to oppose country-specific reviews. However, for empirical testing, the proposed framework needs to fit into a country-specific context. According to specific conditions, Pakistan is considered as a case of empirical testing, providing the experts from the multidisciplinary field of science and technology with robust professional credentials in managing multi-mission R&D from public organizations.

Keywords: knowledge management (KM); innovation management (IM); technology management (TM)

check for updates

Citation: Asim, Z.; Sorooshian, S. Supporting Management Disciplines for Research and Development in Public Organizations. *Processes* **2022**, *10*, 2542. https://doi.org/10.3390/pr10122542

Academic Editor: Jorge Cunha

Received: 29 September 2022
Accepted: 16 November 2022
Published: 29 November 2022

1. Introduction

The global economy has shifted as a result of technical, regulatory, and economic considerations which stem from industrial revelations. Systems have often struggled to adequately deal with such rapid changes, especially when it comes to dealing with rapid growth and the need to transfer [1]. Over the next few years, these trends will exert considerable pressure on the global economy, posing a serious challenge for unprepared systems. The only way to deal with the current challenges and prepare for the upcoming industrial revolutions is to invest in research and development (R&D). Yet, there is certainly less priority on implementing R&D as a significant tool within developing economics, in order to oppose the emerging threats due to dynamic technological diversification at a large industrial spectrum [2]. However, numerous developing countries are still confronting various technological obstacles due to decelerating advancements towards their R&D [3]. OECD [4] shows the majority of governmental policies among developing countries used to support the possible sources for R&D in governmental firms, but the outcome has remained fragmented and disarticulated, making them ineffective [5]. The majority of developing economies spend less than 0.5% of their GDP on R&D [6]. According to the global innovation index (GII), developing countries rely on less spending which may confront various deficiencies in relation to supporting management disciplines (SMDs), [7–9]. Almost 60%

of public R&D efforts undertaken by the majority of developing economics have failed to classify capabilities related to knowledge management, innovation management, and technology management, given that SMDs, with respect to their process functionalities, potentially influence R&D [10,11].

Supporting management disciplines are potentially used to supplement the progressive R&D with respect to dynamic market trends [12]. These activities are designed to improve organizational productivity and profitability by reinforcing effective communication among organizational functions. Within the organizational domain, the supporting management disciplines are defined as a collection of activities related to knowledge, innovation, and technology management. As a result, SMDs have a significant impact on research and development in public organizations. The majority of processes related to supporting management disciplines are strictly controlled and stimulated by the R&D department. When it comes to classifying resources related to SMD drive capabilities, the process of managing R&D performance is heavily reliant on process capabilities related to knowledge, innovation, and technology management, and thus has a high degree of uncertainty. Process capabilities related to the knowledge management discipline include knowledge acquisition, knowledge sharing, knowledge implementation, knowledge creation, knowledge utilization, knowledge transfer, knowledge protection, affective commitment, and intellectual knowledge portfolio. Similarly, the ability to share knowledge internally and externally, project management (control and monitoring), innovative compatibility, and the rate of new product development/service introduction per year are all process capabilities related to the innovation management discipline. The capabilities associated with the technology management discipline are technology acquisition, technology exploitation, technology identification, technology learning, technology protection, and technology selection.

Any modernization program must have R&D. Examining previous research on how R&D departments can determine the interrelated influence of these capabilities as well as their resources on R&D performance is not only interesting but also important in terms of evaluating overall organizational performance. The dynamic relationship between R&D performance; process capabilities related to knowledge, innovation, and technology management as an R&D supporting management discipline (SMD); and their resources is the primary focus of this research study. The objectives of the study are as follows: (a) to investigate the significant resources that drive process capabilities across three disciplines; (b) to investigate the dynamic relationship between SMD capabilities and R&D; and (c) to establish effective remedies and suggest feasible techniques to determine the direct and indirect relationship between SMD capabilities and R&D.

There is no reservation regarding the significance of R&D among developing countries as a potential instrument to confront growing challenges due to exponential technological development on a large industrial scale. However, many developing countries still face several technical barriers due to the slowing progress in their R&D. In such context, this study highlights studies which address multi-disciplinary R&D in public organizations, allow researchers to include all the studies based on relevant capabilities under a generic perspective so as to oppose country-specific review; and sketch conclusions on the significance of supporting management disciplines (SMDs) that share their boundaries with R&D under a general context. However, for empirical testing, proposed frameworks need to fit into a country-specific context by merely emphasizing the need to rectify capabilities, according to specific conditions. Unrestricted access to public organizations is also an essential factor to pursue this study. Hence, Pakistan is used as a case study of empirical testing. The focus group panel comprises of experts from the multidisciplinary field of science and technology along with robust professional credentials in managing multi-mission R&D from public organization were invited for data collection.

2. Literature Review

Scientific innovation, advanced technologies, and supporting management disciplines diffuse slowly [13]. These disciplines have convoluted as part of the substantial contributor in R&D progression over last five decades [14]. However throughout such a period, the supporting management disciplines (SMDs) were more advanced to thrust functional alignment, as the majority of developing economics primary focused on R&D [14]. Most of the R&D in governmental organizations between developing economies depends on three sets of supporting management disciplines (SMDs) that were recognize among a variety of efficient entities across public organizations based on 'knowledge management'(KM), 'innovation management'(IM) (to articulate creative products), and 'technology management'(TM) (to boost the technology assimilation presented in Figure 1) [15,16].

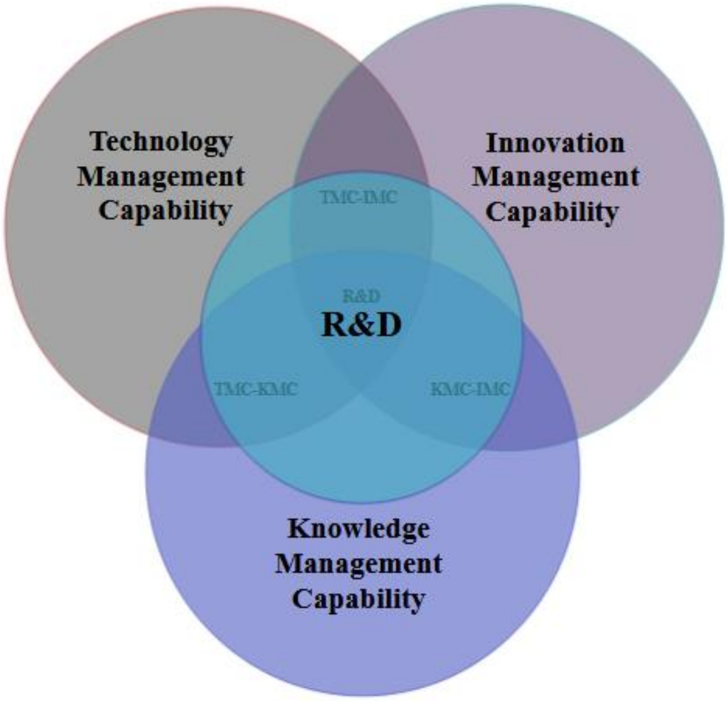

Figure 1. Frontiers between (KM), (IM), and (TM) within R&D. Sources: [15–17].

As shown Figure 1, theoretical interpretation allows researchers to highlight the capability based view on behalf of R&D perspective and describes the concepts of capabilities which gained traction in the fields of strategic management along with the peripheral contributions of supporting management disciplines (SMDs) [18]. This view appears to go beyond 'production function' and recognizes the significance of how R&D firms may consider and orchestrate functions that sustain national competitiveness [19]. This range of functionalities allows firms to accomplish full integrations in the development of un-priced assets. This discrete un-priced trait enables firms to capture value from R&D [18]. Therefore, a capability-based view allows researchers to explore the management of innovation, knowledge, and technology as supporting management tools which, though unexpected benefits, can be somewhat associated with R&D [11,18,20]. In this way, capability-views endeavors can help to classify heterogeneity among capabilities in relation to R&D supporting management disciplines. Such a classification based on concepts from knowledge management, innovation management, and technology management disciplines [15] is shown in Figure 2, and historical evidence is shown in Table 1.

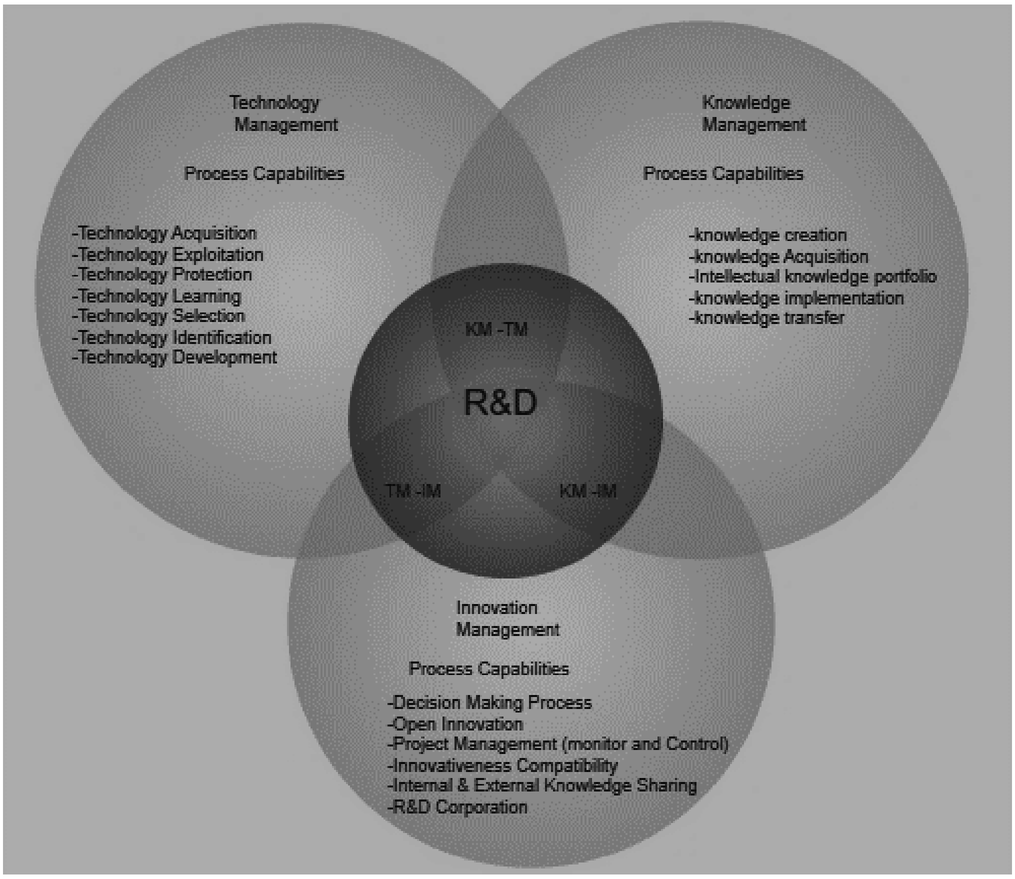

Figure 2. Detailed dimensions at capability frontiers related to SMD that influence R&D. Sources: [10,15,17,21].

Table 1. Dimensions and criteria.

Dimensions	Criteria	Measurement Items Reference
Knowledge management process capability	Knowledge sharing	[22–27]
	Knowledge creation	[28–32]
	Intellectual knowledge	[33–36]
	Knowledge transfer	[37–39]
	Knowledge acquisition	[40–42]
	Knowledge implementation	[43–45]
Innovation management process capability	Technology transfer	[46–52]
	Decision-making process	[53–56]
	Rate of introduction new product	[57–67]
	Open innovation	[68–75]
	Project management	[76–78]
	Innovativeness compatibility	[36,79–83]
	Internal and external knowledge sharing ability	[84–87]
	R&D cooperation	[88–91]

Table 1. *Cont.*

Dimensions	Criteria	Measurement Items Reference
Technology management process capability	Technology acquisition	[92–96]
	Technology exploitation	[97–99]
	Technology learning	[95,100,101]
	Technology development	[21,102–104]
	Technology selection	[105–108]
	Technology protection	[97,109,110]

From the recent findings shown in Table 1, some of emerging trends drawn within the R&D context allows process capabilities related to KM to be addressed, including (knowledge sharing, knowledge implementation, knowledge transfer, knowledge creation, intellectual knowledge, knowledge protection, knowledge identification, and knowledge acquisition). Similarly, findings also include some of trends that were focused on enabling technologies conceived as a potential resource for innovation management process capabilities, which include technology transfer, project management, decision-making process, open innovation, internal and external knowledge-sharing ability, innovativeness compatibility, introduction rates of new products, and R&D cooperation. The technology management process capability consists of numerous processes within functional units of an organization. The basic scope of technology management is far wider than the aspects that directly interface processes related to technology management that influence R&D. These processes include technology acquisition, technology exploitation, technology learning, technology development, technology selection, and technology protection.

3. Methodology

Generally, a decision making and trial evaluation laboratory (DEMATAL)-based analytic network process (ANP) is used to explore the sufficient features to optimize overall system by translating the characteristics of factors in the form of matrices.

Due to interrelating characteristics among the capabilities belonging to supporting management discipline, researchers can adapt to the DANP (DEMATEL-based ANP) approach. Based on the DANP approach, pairwise comparison questionnaires have been distributed to experts to rectify the capabilities within a country-specific context [111]. The DANP approach allows researchers to determine the relationship and criteria weight. The DANP method has also been recognized in several fields such as brand marketing [112], project portfolio [113], and expatriate assignment evaluations. The theoretical model is certified by the DANP technique to regulate the potential association between the dimensions and criteria among relevant capabilities related to supporting management discipline, as shown in Figure 1. The DANP approach does not need the perquisite; therefore, utilizing DANP is significant for interrelation. The DEMATL-based ANP (DANP) technique is split into two sections: (1) DEMATEL used to construct the IRM and (2) ANP used to conclude the criteria weights, as shown in Figure 3.

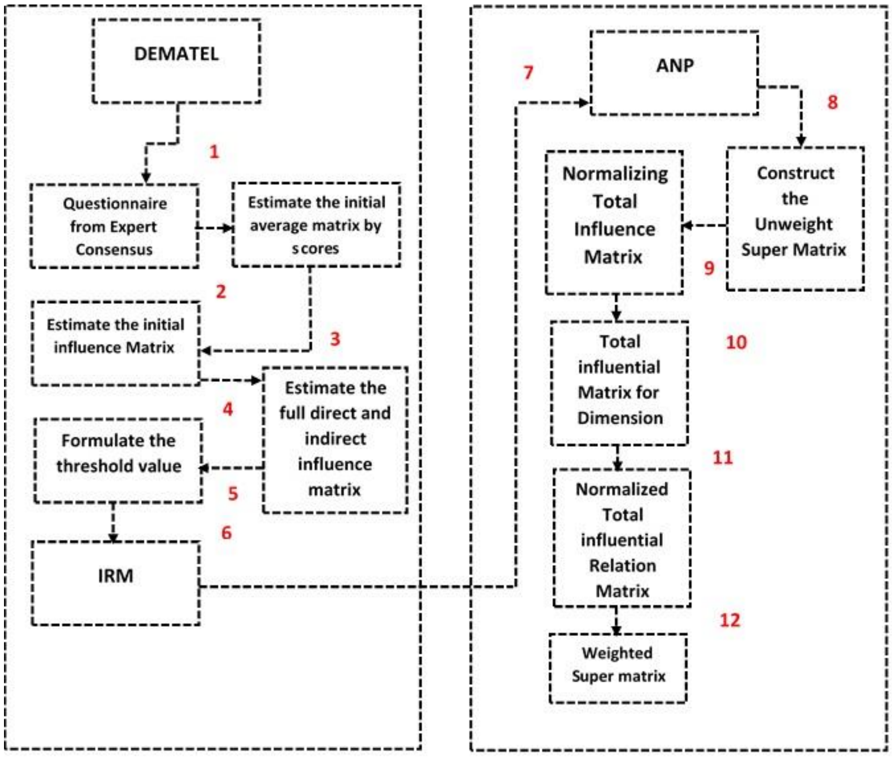

Figure 3. The DANP (DEMATEL-based ANP) approach.

3.1. The Dematel-Based ANP (DANP) Approach

The DEMATEL is used to state the better working link and robustly illustrate the practical solution for any cascaded cluster problem [114]. The DEMATEL enables some of the sufficient features used to optimize the overall system by translating the characteristics of factors in the form of matrices. These factors allow decision makers to understand direct and indirect effects among them. This study aims to highlight the bidirectional relationships among capabilities with respect to their dependency on certain dimensions and criteria. This study follows a complete range of mathematical steps presented by [114]. The fundamental steps of DANP techniques, adopted from Chen and Hsu [115], are as follows. At the first stage, the ANP is estimated by simply applying the traditional DEMATEL techniques after measuring the threshold value "α", presented by İlkerGölcük and AdilBaykasoğlu [116]. After that, an unweighted super matrix of overall system is assembled, as shown in Figure 4.

To understand a full picture shown in Figure 4, the first step is used to estimate the average matrix. In second step, the initial influence matrix were estimated. Third, a comprehensive picture is drawn with a direct and indirect influence on the matrix, which includes the need to develop the interface with indirect effects in order to address the relevant problem along with the power of $X^1, X^2,\ X^3, X^4,\ \ldots, X^k\ and\ \lim_{k\to\infty} X^k = [0]_{n\times x}$, when $X = \left[x_{ij}\right]_{n\times n},\ 0 \le x_{ij} < 1\ and\ 0 \le \sum X_{ij}\ or \sum X_{ij} < 1$. Here, only one column or one row sum equals 1. As result of this, the total influence matrix is used for illustration purposes. To develop the interface with the indirect effects in order to address relevant problems along with the power of $X^1, X^2,\ X^3, X^4,\ \ldots, X^k\ and\ \lim_{k\to\infty} X^k = [0]_{n\times x}$, when $X = \left[x_{ij}\right]_{n\times n},\ 0 \le x_{ij} < 1\ and\ 0 \le \sum X_{ij}\ or \sum X_{ij} < 1$, only one column or one row sum equals 1. As a result, the total influence matrix is used to illustrate the following: $T = X^1 + X^2 + X^3 + X^4 + \ldots + X^k = T = X\left(1 + X^1 + X^2 + X^3 + X^4 + \ldots + X^k\right)$. The complete mathematical steps are represented in Equation $T = X\left(I - X^k\right)(I - X)^{-1}\ T = X(I - X)^{-1}$ when $\lim_{k\to\infty} X^k = [0]_{n\times x}$, where $T = \left[t_{ij}\right]_{n\times n}, i, j = 1, 2, \ldots, n$. In addition, the selected techniques represent each row sum and column sum of matrix ***T***, $r = (r_i)_{n\times1} = \left[\sum_{j=1}^{n} t_{ij}\right]_{n\times1}$ $c = (c_i)_{n\times1} = \left[\sum_{i=1}^{n} t_{ij}\right]_{n\times1}$. This helps to formulates the threshold value $\propto = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} t_{ij}}{N}$, essential for network relation map for ANP. We adopt the ANP technique in order to perform steps 6–8. Steps 6 and 7 advise how to formulate the normalized weighted matrix. As shown in Figure 4, the results allow the normalized total criteria relationship matrix and the normalized total dimensions relationship matrix to be drawn, respectively. Step 7 is shown in Figure 4 with the weighted super matrix ***W***. In Step 8, the ***W**** super matrix is multiplied by itself ($\lim_{n\to\infty}(W^*)^n$) to create a converged stable matrix.

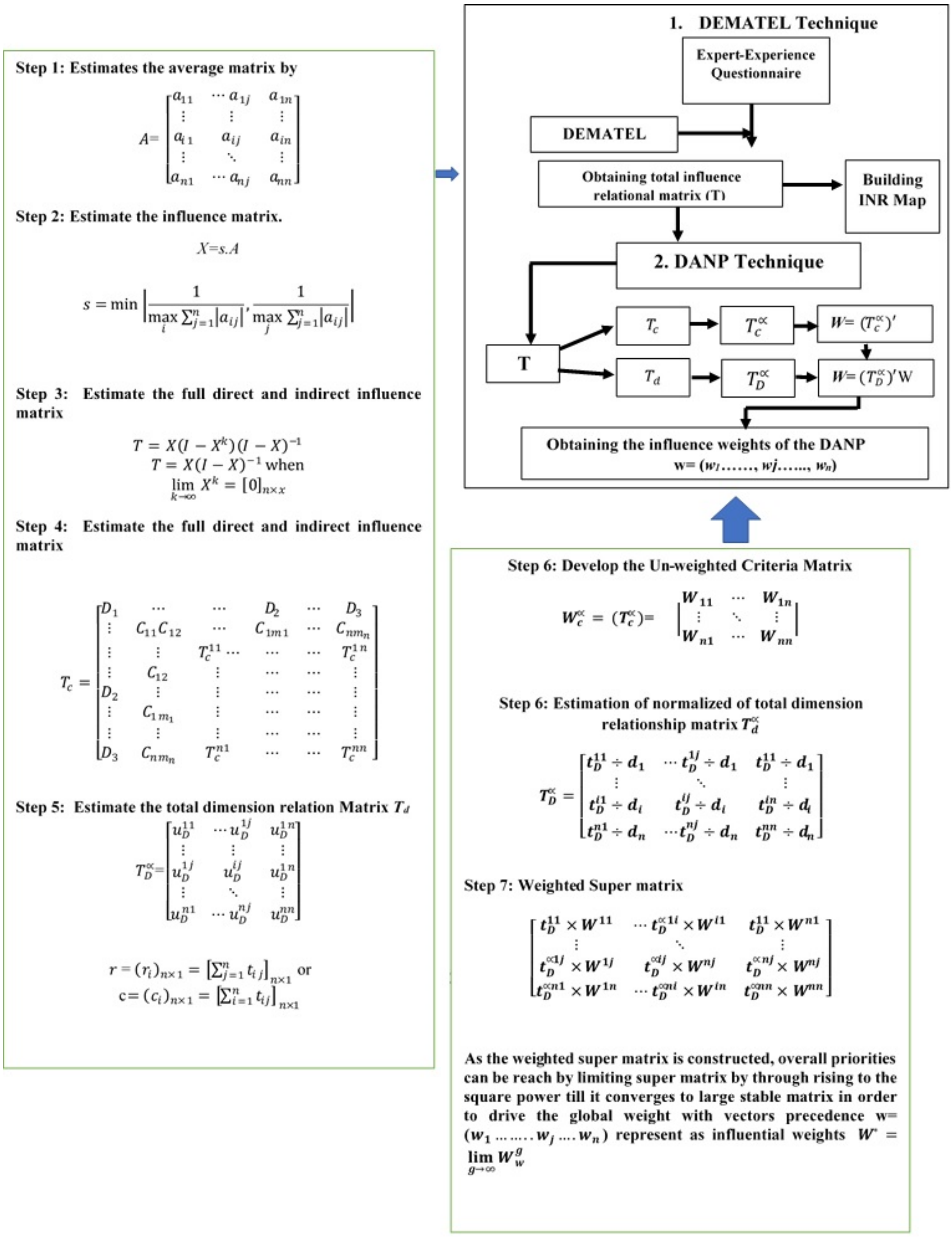

Figure 4. Complete steps of DANP methods.

3.2. Research Framework

The role of R&D has been regarded as one of the most significant strategies to create knowledge-based culture similarly, among developing economics [117]. For radical economic transformation, most low- and middle-income developing economies consider R&D as a creative ability on the national level which drives the systematic foundation to enhance the knowledge stock. This systematic ability enables knowledge culture in order to create new applications [10]. The potential spending on knowledge resources at public firms may increase the possibility of accomplishing high-standard R&D at national and regional levels, thus allowing policymakers to introduce more investment on advanced capabilities across public firms. Resulting in more added value in relation to capital and economic development [118]. However, the role of R&D at the public organization level faces various challenges, such as the % of GDP spending on R&D, especially imbalance income [119,120]. The situation never less different in case of Pakistan, which remains at the bottom investing approximately 0.30% of their GDP on R&D, as compared to other developing economies.

In several developed countries, the potential spending on private R&D firms is much higher than public R&D firms [10]. In the case of low-income developing economies, the majority of R&D is carried out using public funds. Therefore, the majority of R&D-related activities are performed in public organizational settings [10]. The current R&D system at the public organization level in Pakistan is based on large research centers owned by public organizations spread across various sectors. For example, 59% belongs to the agricultural and textile sectors; 12% belongs to the health sector; and the other 28% is spread across 15 different sectors including engineering, automobiles, chemicals, petroleum products, fertilizers, cement, steel, leather products, livestock, non-metallic minerals, food and beverage, tobacco, and electricity gas [121,122].

The literature driven theoretical model for supporting management discipline required has to be discussed within country specific context. In this study, researchers take the specific example of R&D in Pakistani public organization [10,111], The questionnaire based on dimension and criteria were derived research framework shown in Figure 5.

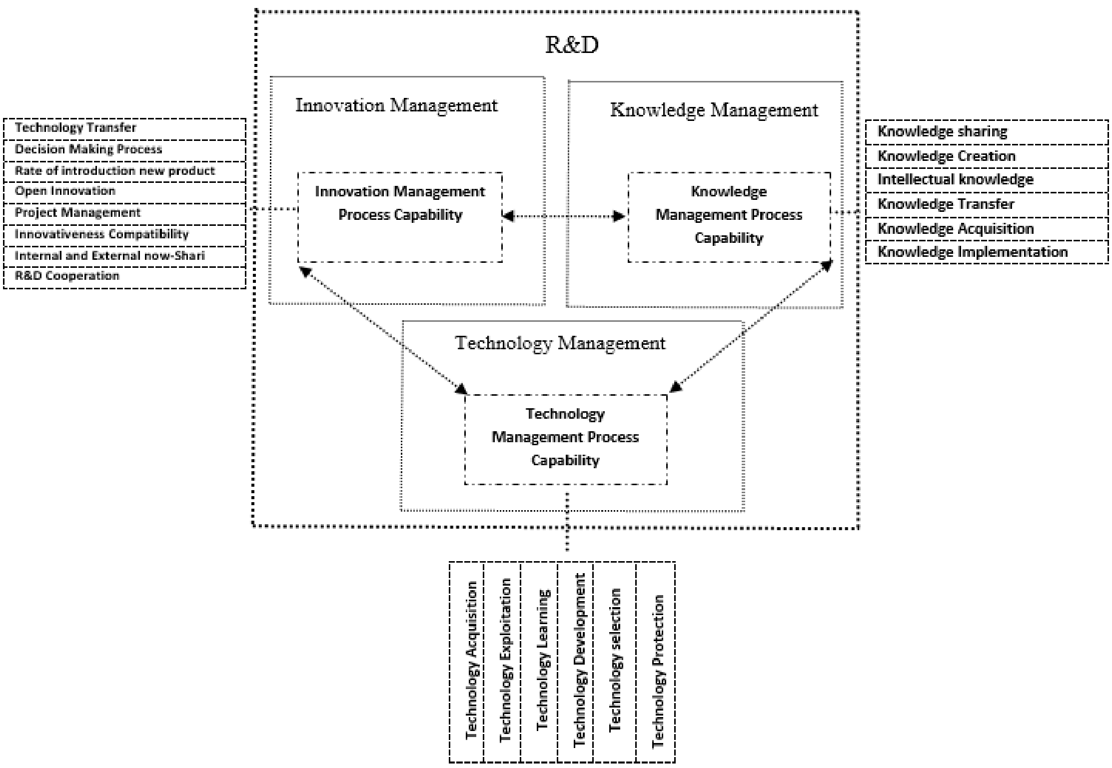

Figure 5. The study framework.

3.3. Research Design

In order to measure the interrelationships among the capabilities related to knowledge, innovation, and technology management, a set of pairwise questionnaires were distributed among experts across 41 focus groups. The outcome of focus-group discussions were then analyzed using the hybrid multicriteria decision-making algorithm known as DANP [123,124]. The framework includes both DEMATEL as well ANP techniques which help to analyze the interrelationship among various dimensions and criteria related to knowledge, innovation, and technology management as supporting management disciplines that influence R&D. The expert-approved model based on the following research design is shown in Figure 6.

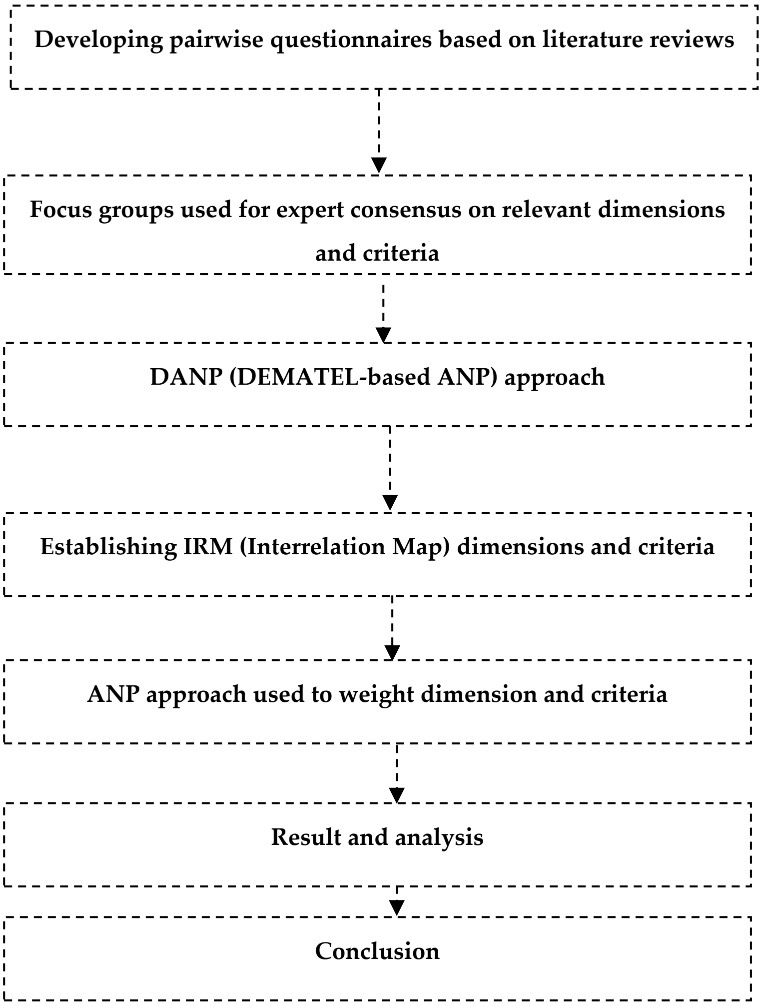

Figure 6. Flowchart of the proposed research design.

3.4. Data Collection

This section includes a comprehensive description of the expert's involvement during the focus-group discussions, from the introduction of the research participants to the research theme dimensions and criteria.

(1) *Selection criteria for R&D*: According to the findings of Meesapawong [125], all active R&D in public organization missions related to 'Knowledge Management', 'Innovation Management', and 'Technology management' as supporting management disciplines were carefully screened. Out of 58 active public R&D organizations, 58 were acknowledged and the rest of them were discarded on the bases of three significant

criteria ('Organization mission', 'Source of funding', and 'Number of Existing R&D projects').

(2) *Experts:* Experts from 58 active R&D in public organizations from Pakistan were arranged across 41 focus groups. The selection criteria of experts were based on comprehensive guidelines presented by Meesapawong [125]: (1) those holding a position of a chief scientific officer, a consultant, a professional engineer, an academician, a technical research officer, an R&D manager, or a senior researcher; (2) those involved in R&D management, knowledge management, technology management, and innovation management; and (3) those who responded to invitation letters and agreed to participate. These multidisciplinary background R&D experts developed their consensus based on similar expertise related to knowledge, innovation, and technology management experiences. According to the findings proposed by Meesapawong [125], The focus group was comprise on five experts and accepted if: (1) they had a rich understanding and experience about research theme; (2) they could present their research ideas during the focus-group discussions; (3) homogeneous groups were separate; (4) there was excellent teamwork during the discussion, i.e., not being overlay assertive or too anxious to express opinions.

(3) *Research Theme:* Experts with similar research knowledge on innovation, knowledge, and technology management in R&D context were invited to participate in the focus-group discussion to develop a group consensus, and the pairwise questionnaire based on DANP technique was used to identified relationship in between dimensions and criteria.

(4) *Dimension and Criteria*: With respect to the literature review, the dynamic interdependencies in between the dimension and criterion are shown in Table 1.

3.5. Analysis

A complete range of 195 experts, who composed thirty-nine focus group, with five participants in each group, is shown in Table 1. This included chief scientific officers, R&D managers, consultants, professional engineers, technical research officers, government chief research officers, and academicians. The same panel experts were involved in both focus-group discussions and DANP (DEMATEL-based ANP) techniques. Initially, almost forty-one focus groups were invited to participate in order to cover the maximum reliability of the instrument. Out of the 41, only 39 groups were chosen as valid discussion groups with a potential response rate. These thirty-nine multidisciplinary focus groups fully participated in both sessions. The demographic information of the surveyed experts is shown in Table 2.

Table 2. Demographic information of the surveyed experts.

Orientation	Categorize	N	%
Positions	Chief research officers	32	16.4
	Professional engineers	30	15.3
	R&D managers	32	16.4
	Consultants	33	16.9
	Technical research officers	35	17.9
	Academicians	33	16.9
	Total	*195 (39)*	*100*
Gender	Male	130	66.6
	Female	65	33.3
	Total	*195 (39)*	*100%*
Age	31–41	28	13.8
	41–51	89	45.6
	51–above 60	78	40
	Total	195	100

Table 2. *Cont.*

Orientation	Categorize	N	%
Education	Bachelor	48	24.6
	Masters	79	40.5
	PhD degree	68	34.8
	Total	*195*	
	Average (Research Publication)	*Journal/experts*	
Industrial and academic experience	Chief scientific officers	264 years	18.9
	Professional engineers	250 years	17.9
	R&D managers	196 years	14.0
	Consultants	366 years	26.2
	Technical research officers	336 years	24.1
	Total (Industrial Experience)	*1392 years*	*100*

4. Results

From DANP technique, First, we were able to address the impact relationships with respect to their significance and examine the degree of importance among dimensions in this study.

Tables 3 and 4 show the group consensus among experts concerning the impact of each criterion. The error gap ratio in Table 4 was 3.43% less than 5%, which specifies a significant confidence level of 96.57. Therefore, the total average matrix can be obtained from Table 3 and these data can be used for the DEMATEL technique. Based on DEMATEL techniques, Steps 1–3, as initially discussed in Figure 4 in Section 3.1, were used, which are as follows. (1) Step 1: The total average matrix was normalized to obtain matrix $\mathbf{T}_{\mathbf{(Criteria)}}$, as shown in Table 5. (2) Step 2: The total criteria relation matrix $\mathbf{T}_{\mathbf{(Criteria)}}$ and the total dimension relation $\mathbf{T}_{\mathbf{(Dimension)}}$ were calculated through matrix X, as shown in Tables 6 and 7, respectively. (3) Lastly, the degree to which each criterion and dimension influenced and was influenced by all others, as shown in Table 8. After performing steps 1–3, based on three steps, we were able to develop the IRM for both dimensions and criteria, respectively, as shown in Figures 7–10

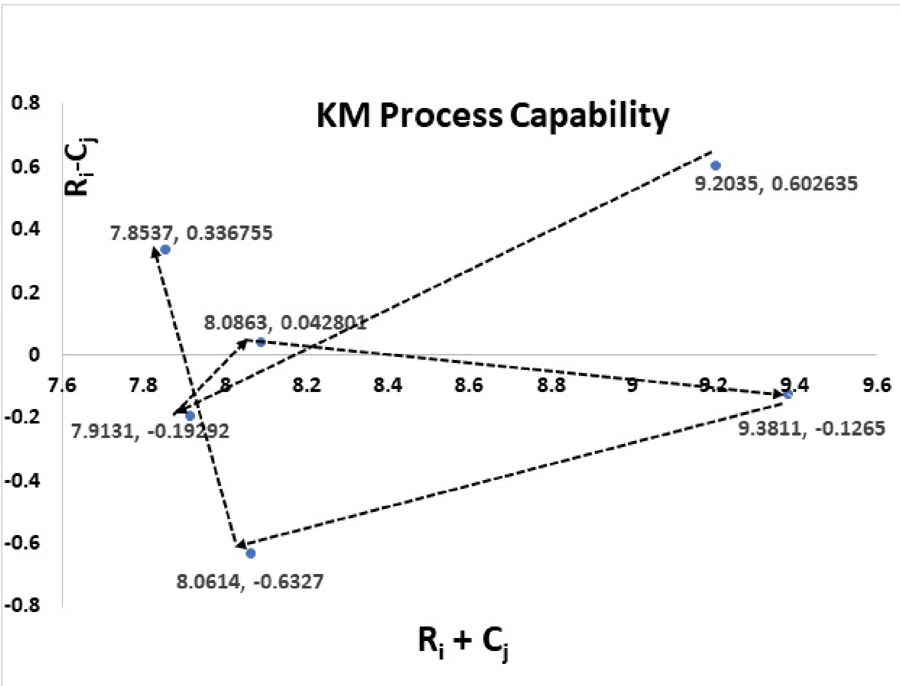

Figure 7. The IRM for the KM process capability ($T_{Criteria}$).

Table 3. The total average matrix T $_{(Criteria)}$ across 39 groups.

Focus Group (39)	(K. cre)	(K. Acq)	(Int Kno Port)	(K.Shar)	(K.Imp)	(K.tran)	(Tech. Tran)	(Dec.Mak)	(In. Op Inn)	(Proj. mang)	(Inn. com)	(Rate Int)	(Int & Ext Kno)	(R&D.Corp)	(Tech. Acq)	(Tech. Expo)	(Tech. Pro)	(Tech. lear)	(Tech. Sele)	(Tech. Iden)	(Tech Deve)
(K.cre)	0	2.12	1.9	2.9	3.36	1.1	3.36	1.4	3.17	2.11	2.19	2.36	2	1.4	2.1	2.2	2.36	2	1.367	1.88	2.87
(K.Acq)	1.86	0	2.6	2.6	1.81	1.3	1.84	1.4	1.38	2.78	1.35	1.13	1.6	1.4	2.5	1.4	1.13	1.5	1.351	1.12	1.98
(Int Kno Port)	2	2.7	0	3.35	1.86	1.4	1.86	1.4	1.49	2.79	1.51	1.12	1.5	1.5	2.9	1.5	1.11	1.5	1.59	1.21	1.63
(K.shar)	3.12	3.59	3.1	0	1.88	1.3	1.85	1.4	1.71	3.12	2	1.54	1.6	1.4	3.2	2	1.49	1.6	1.368	1.2	2.62
(K.Imp)	2.12	1.86	1.6	1.86	0	2.8	0	2.7	2.19	1.49	1.13	1.49	1.2	1.2	1.5	1.1	1.49	1.2	1.212	1.49	2.71
(K.tran)	1.18	1.67	2.1	2.12	2.86	0	2.87	0	2	1.72	1.74	1.75	2	1.7	1.8	1.8	1.75	2	1.75	1.88	2.13
(Tech. Tran)	1.19	1.87	1.6	1.86	0	2.7	0	2.7	2.18	1.49	1.12	1.49	1.2	1.3	1.5	1.1	1.48	1.2	1.214	1.47	2.73
(Dec.Mak)	3.12	1.65	2.1	2.16	2.87	0	2.84	0	2	1.72	1.74	1.72	2	1.7	1.7	1.7	1.72	2	1.72	1.87	2.12
(In. Op Inn)	2	1.21	1.2	2	2.51	1.4	2.49	1.4	0	1.47	1.37	2.43	1.2	1.2	1.5	1.4	2.49	1.2	1.22	1.49	2.61
(Proj. mang)	1.67	3	2.7	3	2	1.6	1.9	1.6	1.76	0	2.12	1.62	1.7	1.1	0	2.1	1.62	1.7	1.122	1.37	1.62
(Inn. com)	2	1.21	1.5	1.62	1.69	1.6	1.71	1.6	2	1.62	0	2.69	1.9	1.7	1.6	0	2.65	1.9	1.69	2.19	1.62
(Rate Int)	1.69	1.13	1.2	1.67	1.49	2.2	1.5	2.2	3	1.24	2.87	0	1.4	1.9	1.2	2.9	0	1.4	1.872	2.13	1.62
(Int & Ext Kno)	1.25	1.37	1.1	1.62	1.23	1.6	1.25	1.6	1.48	1.47	1.62	1.62	0	1.4	1.5	1.6	1.62	0	1.367	1.13	1.35
(R&D.Corp)	1.48	1.12	1.4	1.48	1.62	1.6	1.64	1.6	1.2	1.25	3.12	2.17	1.2	0	1.2	3.1	2.25	1.2	0	3.47	2.12
(Tech. Acq)	2	3	2.7	3	2	1.4	1.9	1.6	0	0	2.12	1.65	1.7	1.1	0	2.2	1.62	1.7	1.119	1.37	1.62
(Tech. Expo)	1.71	1.21	1.5	1.62	1.7	1.6	1.71	1.6	1.76	1.62	0	2.7	1.9	1.7	1.6	0	2.65	1.9	1.67	2.23	1.62
(Tech. Pro)	1.25	1.13	1.2	1.65	1.49	1.6	1.5	2.2	2	1.23	2.87	0	1.4	1.9	1.2	2.9	0	1.4	1.872	2.12	1.62
(Tech. lear)	1.51	1.37	1.1	1.65	1.21	2.2	1.25	1.6	3	1.48	1.62	1.62	0	1.4	1.5	1.6	1.62	0	1.367	1.12	1.33
(Tech. Sele)	3	1.15	1.4	1.46	1.62	1.6	1.64	1.6	1.47	1.23	3.12	2.18	1.2	0	1.2	3.1	2.25	1.2	0	3.47	2.12
(Tech. Iden)	1.87	1.19	1.2	1.46	2.21	1.6	2.29	2.4	1.2	1.36	3.12	2.67	1	2.9	1.4	3.1	2.65	1	2.869	0	1.87
(Tech Deve)	2	2	2	3.12	3	2.4	2.8	2.5	1.7	1.45	1.37	1.62	0.9	1.5	1.5	1.4	1.62	0.9	1.49	1.71	0

Table 4. The total average matrix T $_{(Criteria)}$ across 38 groups.

Focus Group (38)	(K. cre)	(K. Acq)	(Int Kno Port)	(K.Shar)	(K.Imp)	(K.tran)	(Tech. Tran)	(Dec.Mak)	(In. Op Inn)	(Proj. mang)	(Inn. com)	(Rate Int)	(Int & Ext Kno)	(R&D.Corp)	(Tech. Acq)	(Tech. Expo)	(Tech. Pro)	(Tech. lear)	(Tech. Sele)	(Tech. Iden)	(Tech Deve)
(K.cre)	0	2	1.8	2.8	3	1.1	3.2	1.3	3.1	2	2.1	2.3	2	1.8	2	2.1	2.3	1.9	1.32	1.81	2.77
(K.Acq)	1.8	0	2.5	2.5	2	1.3	1.8	1.3	1.3	2.7	1.3	1.1	0	2.5	2.4	1.3	1.1	1.5	1.3	1.08	1.91
(Int Kno Port)	1.9	3	0	3.2	2	1.3	1.8	1.3	1.4	2.7	1.5	1.1	2.6	0	2.8	1.5	1.1	1.4	1.54	1.17	1.58
(K.shar)	3	3	3	0	2	1.3	1.8	1.3	1.7	3	1.9	1.5	3.5	3	3.1	1.9	1.4	1.6	1.32	1.17	2.53
(K.Imp)	2	2	1.6	1.8	0	2.7	0	2.6	2.1	1.4	1.1	1.4	1.8	1.6	1.4	1.1	1.4	1.2	1.17	1.44	2.62
(K.tran)	1.1	2	2	2	3	0	2.8	0	1.9	1.7	1.7	1.7	1.7	2.1	1.7	1.7	1.7	1.9	1.69	1.81	2.05
(Tech. Tran)	1.2	2	1.6	1.8	0	2.6	0	2.6	2.1	1.4	1.1	1.4	1.8	1.6	1.4	1.1	1.4	1.2	1.17	1.42	2.64
(Dec.Mak)	3	2	2	2.1	3	0	2.7	0	1.9	1.7	1.7	1.7	1.7	2.1	1.7	1.7	1.7	1.9	1.66	1.81	2.05
(In. Op Inn)	1.9	1	1.2	1.9	2	1.3	2.4	1.3	0	1.4	1.3	2.3	1.2	1.2	1.4	1.3	2.4	1.2	1.18	1.44	2.52
(Proj. mang)	1.6	3	2.6	2.9	2	1.6	1.8	1.6	1.7	0	2	1.6	2.8	2.6	0	2	1.6	1.6	1.08	1.32	1.56
(Inn. com)	1.9	1	1.4	1.6	2	1.6	1.7	1.6	1.9	1.6	0	2.6	1.1	1.4	1.6	0	2.6	1.8	1.63	2.12	1.56
(Rate Int)	1.6	1	1.2	1.6	1	2.1	1.5	2.1	2.9	1.2	2.8	0	1.1	1.1	1.2	2.8	0	1.3	1.81	2.06	1.57
(Int & Ext Kno)	3	0	2.6	2.5	2	1.2	1.8	1.3	3.1	2.6	1.3	1.1	0	2.5	2.4	1.3	1.2	1.5	1.31	1.08	1.91
(R&D.Corp)	2	3	0	3.2	2	1.3	1.7	1.3	1.3	2.7	1.4	1.1	2.6	0	2.8	1.4	1.1	1.4	1.52	1.19	1.57
(Tech. Acq)	1.9	3	2.6	2.9	2	1.3	1.8	1.6	0	0	2	1.6	2.9	2.6	0	2.1	1.6	1.6	1.08	1.32	1.57
(Tech. Expo)	1.7	1	1.5	1.6	2	1.6	1.7	1.5	1.7	1.6	0	2.6	1.1	1.4	1.6	0	2.6	1.8	1.61	2.15	1.56
(Tech. Pro)	1.2	1	1.2	1.6	1	1.6	1.5	2.2	1.9	1.2	2.8	0	1.1	1.1	1.2	2.8	0	1.3	1.81	2.05	1.57
(Tech. lear)	1.5	1	1.1	1.6	1	2.1	1.2	1.6	2.9	1.4	1.6	1.6	1.3	1.1	1.4	1.6	1.6	0	1.32	1.08	1.29
(Tech. Sele)	2.9	1	1.3	1.4	2	1.6	1.6	1.6	1.4	1.2	3	2.1	1.1	1.3	1.2	3	2.2	1.2	0	3.35	2.05
(Tech. Iden)	1.8	1	1.2	1.4	2	1.6	2.2	2.3	1.2	1.3	3	2.6	1.2	1.1	1.3	3	2.6	1	2.77	0	1.8
(Tech Deve)	1.9	2	1.9	3	3	2.3	2.7	2.4	1.7	1.4	1.3	1.6	1.9	1.9	1.4	1.3	1.6	0.8	1.44	1.65	0

Table 5. Normalized initial direct-relation $T_{(Criteria)}$.

	(K. cre)	(K. Acq)	(Int Kno Port)	(K.Shar)	(K.Imp)	(K.tran)	(Tech. Tran)	(Dec.Mak)	(In. Op Inn)	(Proj. mang)	(Inn. com)	(Rate Int)	(Int & Ext Kno)	(R&D.Corp)	(Tech. Acq)	(Tech. Expo)	(Tech. Pro)	(Tech. lear)	(Tech. Sele)	(Tech. Iden)	(Tech Deve)
(K.cre)	0	0.048	0.042	0.066	0.0763	0.026	0.076	0.031	0.072	0.048	0.0497	0.054	0.045	0.031	0.048	0.0495	0.05	0.046	0.031	0.0427	0.065
(K.Acq)	0.042	0	0.0593	0.059	0.0412	0.031	0.042	0.031	0.031	0.063	0.0307	0.026	0.037	0.0307	0.057	0.0316	0.03	0.035	0.031	0.0254	0.045
(Int Kno Port)	0.045	0.061	0	0.076	0.0423	0.031	0.042	0.031	0.034	0.063	0.0343	0.025	0.035	0.0343	0.065	0.0341	0.03	0.034	0.036	0.0275	0.037
(K.shar)	0.071	0.082	0.0711	0	0.0427	0.03	0.042	0.031	0.039	0.071	0.0454	0.035	0.037	0.0309	0.072	0.0454	0.03	0.037	0.031	0.0272	0.059
(K.Imp)	0.048	0.042	0.0367	0.042	0	0.062	0	0.061	0.05	0.034	0.0255	0.034	0.027	0.0272	0.034	0.0254	0.03	0.028	0.028	0.0338	0.062
(K.tran)	0.027	0.038	0.0481	0.048	0.065	0	0.065	0	0.045	0.039	0.0395	0.04	0.045	0.039	0.04	0.0397	0.04	0.045	0.04	0.0426	0.048
(Tech. Tran)	0.027	0.042	0.0367	0.042	0	0.062	0	0.061	0.049	0.034	0.0254	0.034	0.027	0.0284	0.033	0.0257	0.03	0.028	0.028	0.0334	0.062
(Dec.Mak)	0.071	0.037	0.0481	0.049	0.0651	0	0.065	0	0.045	0.039	0.0396	0.039	0.045	0.039	0.039	0.0393	0.04	0.045	0.039	0.0425	0.048
(In. Op Inn)	0.045	0.028	0.0282	0.045	0.057	0.031	0.057	0.031	0	0.033	0.031	0.055	0.028	0.027	0.034	0.0312	0.06	0.028	0.028	0.0339	0.059
(Proj. mang)	0.038	0.068	0.0611	0.068	0.0454	0.037	0.043	0.037	0.04	0	0.0481	0.037	0.039	0.0254	0	0.0479	0.04	0.038	0.025	0.031	0.037
(Inn. com)	0.045	0.028	0.034	0.037	0.0384	0.037	0.039	0.037	0.045	0.037	0	0.061	0.042	0.0383	0.037	0	0.06	0.042	0.038	0.0497	0.037
(Rate Int)	0.038	0.026	0.0273	0.038	0.0338	0.05	0.034	0.05	0.068	0.028	0.0653	0	0.031	0.0425	0.028	0.0647	0	0.031	0.043	0.0484	0.037
(Int & Ext Kno)	0.028	0.031	0.0254	0.037	0.0279	0.037	0.028	0.037	0.034	0.033	0.0368	0.037	0	0.0311	0.033	0.0368	0.04	0	0.031	0.0257	0.031
(R&D.Corp)	0.034	0.025	0.0311	0.034	0.0368	0.037	0.037	0.037	0.027	0.028	0.0709	0.049	0.028	0	0.028	0.0709	0.05	0.028	0	0.0788	0.048
(Tech. Acq)	0.045	0.068	0.0618	0.068	0.0454	0.032	0.043	0.037	0	0	0.048	0.037	0.039	0.0254	0	0.0493	0.04	0.038	0.025	0.031	0.037
(Tech. Expo)	0.039	0.027	0.0343	0.037	0.0386	0.037	0.039	0.036	0.04	0.037	0	0.061	0.042	0.0384	0.037	0	0.06	0.042	0.038	0.0506	0.037
(Tech. Pro)	0.028	0.026	0.0275	0.037	0.0339	0.037	0.034	0.051	0.045	0.028	0.0652	0	0.031	0.0425	0.028	0.0652	0	0.031	0.043	0.0482	0.037
(Tech. lear)	0.034	0.031	0.0254	0.037	0.0275	0.05	0.028	0.037	0.068	0.034	0.0368	0.037	0	0.031	0.033	0.0368	0.04	0	0.031	0.0254	0.03
(Tech. Sele)	0.068	0.026	0.0311	0.033	0.0368	0.037	0.037	0.037	0.033	0.028	0.0708	0.049	0.028	0	0.028	0.0709	0.05	0.028	0	0.0788	0.048
(Tech. Iden)	0.042	0.027	0.0277	0.033	0.0502	0.037	0.052	0.054	0.027	0.031	0.0709	0.061	0.023	0.0647	0.031	0.0706	0.06	0.023	0.065	0	0.042
(Tech Deve)	0.045	0.045	0.0454	0.071	0.0681	0.054	0.064	0.056	0.039	0.033	0.0311	0.037	0.02	0.0329	0.034	0.0311	0.04	0.02	0.034	0.0388	0

Table 6. Total relation matrix $T_{(Criteria)}$.

	(K. cre)	(K. Acq)	(Int Kno Port)	(K. Shar)	(K. Imp)	(K. tran)	(Tech. Tran)	(Dec.Mak)	(In. Op Inn)	(Proj. mang)	(Inn. com)	(Rate Int)	(Int & Ext Kno)	(R&D. Corp)	(Tech. Acq)	(Tech. Expo)	(Tech. Pro)	(Tech. lear)	(Tech. Sele)	(Tech. Iden)	(Tech Deve)	
(K.cre)	0.204	0.239	0.2315	0.288	0.2772	0.205	0.276	0.217	0.266	0.224	0.2462	0.241	0.198	0.1875	0.223	0.2462	0.24	0.198	0.188	0.2295	0.277	4.903
(K. Acq)	0.202	0.155	0.209	0.236	0.2022	0.17	0.201	0.176	0.185	0.201	0.1869	0.174	0.158	0.153	0.195	0.1879	0.17	0.156	0.154	0.1729	0.212	3.86
(Int Kno Port)	0.214	0.222	0.1615	0.261	0.2117	0.177	0.21	0.183	0.195	0.209	0.1988	0.182	0.163	0.1626	0.21	0.1988	0.18	0.162	0.165	0.1828	0.214	4.065
(K. shar)	0.26	0.262	0.25	0.217	0.2366	0.197	0.235	0.205	0.222	0.236	0.2311	0.212	0.183	0.1778	0.237	0.2314	0.21	0.183	0.179	0.204	0.259	4.627
(K. Imp)	0.202	0.187	0.1813	0.213	0.1601	0.193	0.159	0.197	0.197	0.168	0.177	0.177	0.144	0.1463	0.168	0.177	0.18	0.146	0.147	0.1763	0.221	3.714
(K. tran)	0.196	0.198	0.205	0.234	0.232	0.152	0.231	0.157	0.208	0.186	0.2048	0.197	0.172	0.1688	0.186	0.2052	0.2	0.172	0.17	0.199	0.226	4.095
(Tech. Tran)	0.176	0.182	0.1762	0.207	0.154	0.188	0.153	0.192	0.191	0.163	0.1714	0.171	0.14	0.1432	0.163	0.1718	0.17	0.141	0.143	0.1709	0.216	3.585
(Dec.Mak)	0.248	0.207	0.2147	0.247	0.2437	0.16	0.242	0.166	0.219	0.195	0.215	0.206	0.18	0.1765	0.195	0.2149	0.21	0.18	0.177	0.2084	0.237	4.34
(In. Op Inn)	0.202	0.177	0.1764	0.22	0.215	0.171	0.213	0.177	0.155	0.17	0.1865	0.2	0.148	0.1495	0.171	0.1868	0.2	0.148	0.151	0.1809	0.225	3.823
(Proj. mang)	0.204	0.223	0.2147	0.249	0.2115	0.181	0.208	0.187	0.201	0.148	0.2077	0.19	0.164	0.1536	0.148	0.2077	0.19	0.164	0.155	0.1838	0.211	4.001
(Inn. com)	0.205	0.179	0.1833	0.214	0.2006	0.177	0.2	0.183	0.201	0.175	0.1619	0.208	0.163	0.1624	0.175	0.162	0.21	0.163	0.163	0.1986	0.206	3.889
(Rate Int)	0.201	0.177	0.1785	0.216	0.1989	0.19	0.198	0.196	0.222	0.169	0.2211	0.156	0.155	0.1671	0.169	0.2207	0.16	0.155	0.168	0.1995	0.208	3.92
(Int & Ext Kno)	0.157	0.152	0.1466	0.179	0.1586	0.148	0.158	0.153	0.157	0.145	0.163	0.156	0.1	0.1302	0.145	0.1631	0.16	0.1	0.131	0.1464	0.166	3.111
(R&D. Corp)	0.193	0.176	0.1805	0.21	0.1994	0.177	0.199	0.184	0.183	0.168	0.226	0.199	0.15	0.1281	0.168	0.2262	0.2	0.151	0.129	0.2259	0.216	3.891
(Tech. Acq)	0.204	0.217	0.2094	0.242	0.2043	0.17	0.201	0.181	0.156	0.143	0.2014	0.184	0.159	0.1486	0.143	0.2028	0.18	0.159	0.149	0.1777	0.204	3.838
(Tech. Expo)	0.196	0.176	0.1813	0.211	0.198	0.175	0.197	0.181	0.193	0.173	0.1594	0.206	0.161	0.1606	0.173	0.1596	0.2	0.161	0.161	0.1972	0.203	3.828
(Tech. Pro)	0.182	0.168	0.1697	0.204	0.1883	0.169	0.187	0.188	0.191	0.16	0.2117	0.146	0.147	0.1597	0.16	0.2118	0.15	0.147	0.16	0.1903	0.197	3.685
(Tech. lear)	0.174	0.163	0.1567	0.192	0.1702	0.17	0.17	0.162	0.201	0.155	0.1736	0.167	0.108	0.1386	0.154	0.1737	0.17	0.108	0.139	0.1564	0.178	3.378
(Tech. Sele)	0.236	0.186	0.1895	0.221	0.2103	0.186	0.21	0.193	0.2	0.176	0.2356	0.209	0.158	0.1355	0.177	0.2357	0.21	0.159	0.136	0.2349	0.226	4.124
(Tech. Iden)	0.225	0.197	0.1977	0.234	0.2333	0.197	0.234	0.22	0.205	0.189	0.2492	0.23	0.163	0.2039	0.189	0.249	0.23	0.163	0.205	0.1754	0.234	4.424
(Tech Deve)	0.219	0.21	0.2082	0.26	0.2412	0.204	0.236	0.212	0.206	0.185	0.2008	0.197	0.153	0.1664	0.186	0.2009	0.2	0.153	0.168	0.199	0.185	4.187
	4.3	4.053	4.0218	4.754	4.347	3.758	4.318	3.909	4.152	3.739	4.2292	4.009	3.266	3.32	3.736	4.2332	4	3.267	3.34	4.0101	4.52	

Table 7. Total relation matrix T $_{(Dimension)}$.

	KM Proc Cap	IM Proc Cap	TM Proc Cap	
KM process cap	1	1	1	3
IM process cap	1.3	1	1	3.3
TM process cap	1.3	1	1	3.3
	3.6	3	3	

Table 8. Overall effects (given and received) of the total average matrix on T $_{(Dimension)}$ and T $_{(Criteria)}$.

	T $_{(Dimension)}$ and T $_{(Criteria)}$	$R_{(row)}$	$C_{(Column)}$	$R_{(row)} + C_{(Column)}$	$R_{(row)} - C_{(Column)}$
KM process cap	KM process capability T $_{(Dimension)}$	14.8	14.9	29.6	−0.1142
K.cre	Knowledge creation	4.9031	4.3	9.2035	0.602635
K.Acq	Knowledge acquisition	3.8601	4.053	7.9131	−0.19292
Int Kno Port	Intellectual knowledge portfolio	4.0646	4.022	8.0863	0.042801
K.shar	Knowledge sharing	4.6273	4.754	9.3811	−0.1265
K.Imp	Knowledge implementation	3.7143	4.347	8.0614	−0.6327
K.tran	Knowledge transfer	4.0952	3.758	7.8537	0.336755
I.M process cap	IM process cap $\mathbf{T}_{(Dimension)}$	15.3	16.1	31.5	−0.80577
Tech. Tran	Technology transfer	3.5848	4.318	7.9033	−0.73361
Dec.Mak	Decision-making process	4.3397	3.909	8.2489	0.430509
In. Op Inn	Open innovation	3.8232	4.152	7.9755	−0.32906
Proj. mang	Project management	4.0012	3.739	7.7404	0.261937
Inn. com	Innovativeness compatibility	3.8895	4.229	8.1187	−0.33971
Rate Int	Rate of introduction new product	3.9201	4.009	7.9295	−0.08936
Int & Ext Kno	Internal and external knowledge sharing	3.1109	3.266	6.3766	−0.15486
R&D.Corp	R&D corporation	3.891	3.32	7.2109	0.571005
TM process Cap	TM process capability $\mathbf{T}_{(Dimension)}$	16.2	15	31.6	0.919972
Tech. Acq	Technology acquisition	3.8378	3.736	7.5738	0.101692
Tech. Expo	Technology exploitation	3.8285	4.233	8.0617	−0.40473
Tech. Pro	Technology protection	3.6852	4.004	7.6896	−0.31915
Tech. lear	Technology learning	3.3781	3.267	6.6447	0.111499
Tech. Sele	Technology selection	4.1241	3.34	7.4644	0.783744
Tech. Iden	Technology identification	4.4235	4.01	8.4336	0.413427
Tech Deve	Technology development	4.1871	4.52	8.7075	−0.3334

The ANP technique, involving steps 6–8. (1) Step 6 was completed to find the normalized weighted matrix. Tables 9 and 10 show the results of normalized total criteria relationship matrix and the normalized total-dimensional relationship matrix, respectively. (2) Step 7 was then completed. Table 9 shows the weighted super matrix $\boldsymbol{W}$. In Step 8, the $\boldsymbol{W}$* super matrix multiplied by itself ($\lim_{n\to\infty} (W^*)^n$) to create the converged stable matrix, as shown in Tables 10–12.

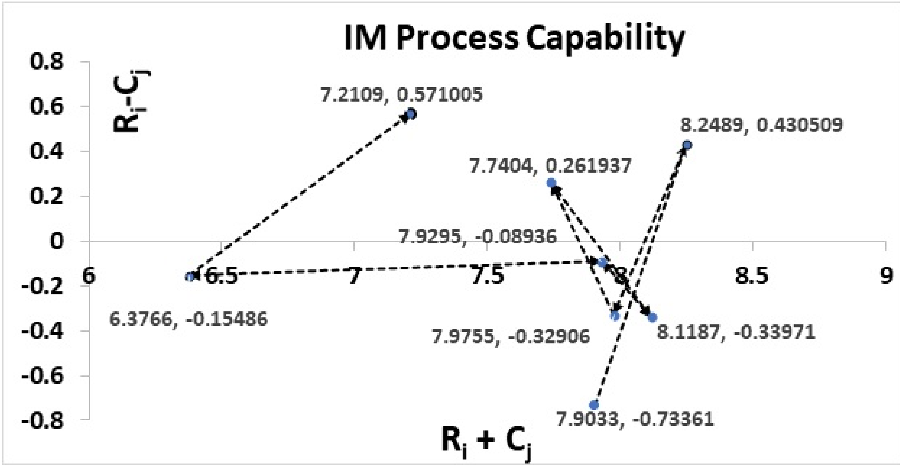

Figure 8. The IRM for the IM process capability ($T_{Criteria}$).

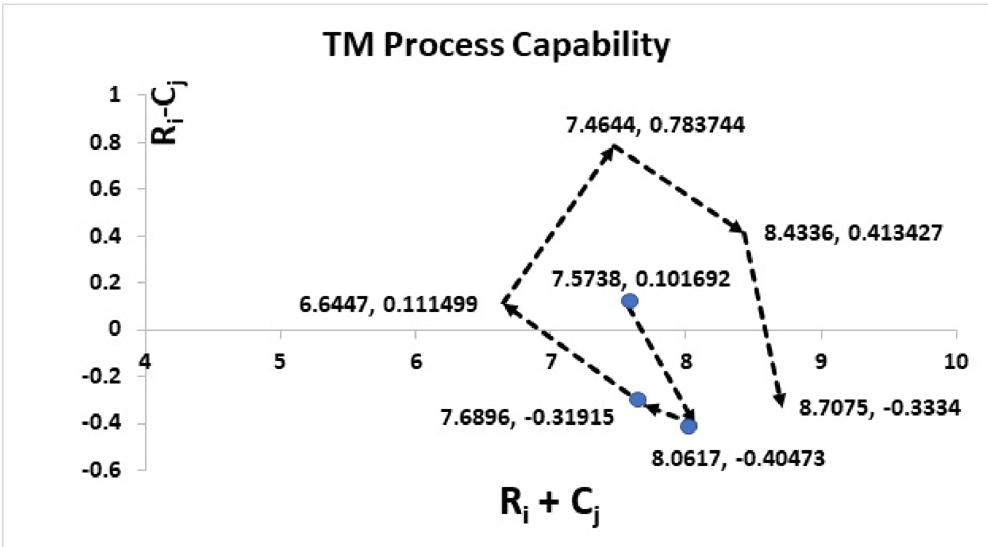

Figure 9. The IRM for the TM process capability ($T_{Criteria}$).

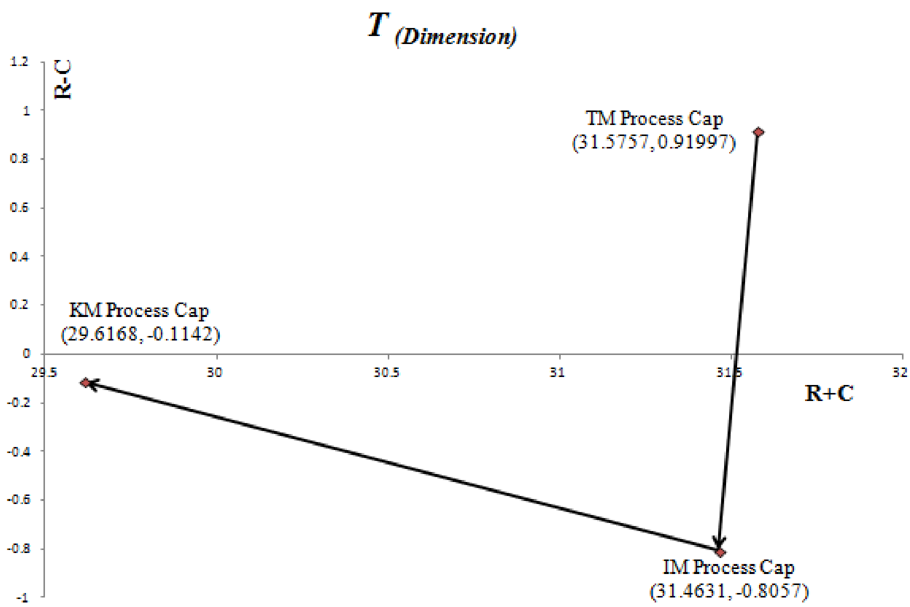

Figure 10. The IRM of dimensions.

Table 9. Normalized relation matrix T^{α} (Dimension).

	KM Proc Cap	IM Proc Cap	TM Process Cap
KM process cap	0.333	0.333	0.33
IM process cap	0.394	0.303	0.3
TM process cap	0.394	0.303	0.3

For further clarification, in case of criteria, the outcome was based on pair-wise questionnaires resulting the total average matrix T (Criteria) to be calculated from 39 focus groups. To ensure reliability, errors of the gap ratio (%) = $\frac{1}{n(n-1)}\sum_{i=1}^{n}\sum_{j=1}^{n}\frac{\left|g_c^{ijp}-g_c^{ij(p-1)}\right|}{g_c^{ijp}}$ = 3.43% were less than 5%, i.e., showing a significant confidence of 96.57%, where p = 39 denotes the number of experts and t_{ij}^{p} is the average influence of criterion *i* on criterion *j*, thus denoting the number of criteria. Here, in order to formulate the direct and indirect influences, a pre-normalized method was required to take the further steps forward. Therefore, a normalized initial direct-relation T (Criteria) is shown in Table 5. The full direct and indirect influence matrix was estimated by employing the following equation: $T = X\left(I - X^k\right)(I - X)^{-1}$, $T = X(I - X)^{-1}$ when $\lim_{k\to\infty} X^k = [0]_{n\times x}$, where $T = [t_{ij}]_{n\times n}$, $i, j = 1, 2, \ldots, n$. In addition, the method presents each row sum and column sum of matrix *T*, as shown in the following equation: $r = (r_i)_{n\times 1} = \left[\sum_{j=1}^{n} t_{ij}\right]_{n\times 1}$, $c = (c_i)_{n\times 1} = \left[\sum_{i=1}^{n} t_{ij}\right]_{n\times 1}$.

In the case of dimensions, firstly, based on consensus outcomes from 39 focus groups, the total average matrix T (Dimension) could be formulated. Then, the % of error gap was used to test the reliability of the data instrument; therefore, the total average matrix T (Dimension) was also formulated again ($n-1$) in relation to the number of focus groups. In this case, there were ($n-1$) = 38 focus groups. To formulate the direct and indirect influence, a pre-normalized method was required to take the further steps forward. After the initial direct matrix was pre-normalized, the total relational matrix for T (Dimension) can be shown in Table 7.

The r_i was used to represents the row sum of the i^{th} row of the matrix *T (Dimension)*. While c_j represents the column sum of the j^{th} column of the matrix *T (Criteria)*, *R (row)* + *C (Column)* shows that the degree of strength of influence is delivered and received. In simple words, R (row) + C (Column) represent the degree of significant control of *i* used for carrying purposes while addressing the problem. Similarly, if R (row) − C (Column) is positive in nature, then it can be used to translate as factor *i* is bound to affect other factors; however, if R (row) − C (Column) is negative in nature, then it can be used to represent factor *i* which is influenced by other factors. Therefore, the cause and effect among *T (Dimension)* is shown in Figure 10.

Table 10. Normalized total influential matrix $\mathbf{T}^{*}_{(\mathbf{Criteria})}$.

Normalized	(K. cre)	(K. Acq)	(Int Kno Port)	(K.Shar)	(K.Imp)	(K.tran)	(Tech. Tran)	(Dec.Mak)	(In. Op Inn)	(Proj. mang)	Inn. com)	(Rate Int)	(Int & Ext Kno)	(R&D.Corp)	(Tech. Acq)	(Tech. Expo)	(Tech. Pro)	(Tech. lear)	(Tech. Sele)	(Tech. Iden)	(Tech Deve)
(K.cre)	0.14	0.166	0.1601	0.199	0.192	0.142	0.125	0.117	0.1162	0.139	0.128	0.121	0.128	0.1246	0.14	0.154	0.15	0.12	0.118	0.143	0.173
(K.Acq)	0.17	0.132	0.1779	0.201	0.172	0.145	0.125	0.127	0.1266	0.145	0.127	0.1089	0.125	0.1146	0.16	0.15	0.139	0.12	0.123	0.138	0.169
(Int Kno Port)	0.17	0.178	0.1295	0.209	0.17	0.142	0.126	0.128	0.1268	0.146	0.127	0.1079	0.125	0.1135	0.16	0.151	0.138	0.12	0.126	0.139	0.163
(K.shar)	0.18	0.184	0.1758	0.152	0.166	0.139	0.126	0.112	0.117	0.138	0.13	0.1179	0.13	0.1283	0.16	0.154	0.14	0.12	0.119	0.136	0.172
(K.Imp)	0.18	0.165	0.1596	0.187	0.141	0.17	0.124	0.115	0.1128	0.14	0.125	0.1269	0.125	0.1305	0.14	0.146	0.146	0.12	0.122	0.145	0.183
(K.tran)	0.16	0.163	0.1686	0.193	0.191	0.125	0.142	0.114	0.113	0.136	0.125	0.1239	0.125	0.1206	0.14	0.151	0.145	0.13	0.126	0.147	0.167
(Tech. Tran)	0.16	0.168	0.1627	0.191	0.142	0.174	0.115	0.145	0.1441	0.123	0.129	0.1294	0.105	0.1081	0.14	0.146	0.145	0.12	0.122	0.145	0.183
(Dec.Mak)	0.19	0.157	0.1625	0.187	0.185	0.121	0.151	0.104	0.1369	0.122	0.134	0.1288	0.113	0.1103	0.14	0.151	0.145	0.13	0.125	0.147	0.167
(In. Op Inn)	0.17	0.153	0.1518	0.189	0.185	0.147	0.153	0.126	0.1107	0.122	0.133	0.1429	0.106	0.1069	0.14	0.148	0.159	0.12	0.119	0.143	0.178
(Proj. mang)	0.16	0.174	0.1674	0.194	0.165	0.141	0.143	0.128	0.1374	0.102	0.142	0.1301	0.113	0.1052	0.12	0.165	0.151	0.13	0.123	0.146	0.168
(Inn. com)	0.18	0.154	0.1582	0.185	0.173	0.153	0.137	0.126	0.138	0.121	0.111	0.1431	0.112	0.1116	0.14	0.127	0.162	0.13	0.128	0.156	0.161
(Rate Int)	0.17	0.153	0.1537	0.186	0.171	0.164	0.134	0.132	0.1499	0.114	0.149	0.1048	0.104	0.1126	0.13	0.173	0.122	0.12	0.132	0.157	0.163
(Int & Ext Kno)	0.17	0.162	0.1556	0.19	0.168	0.157	0.136	0.132	0.135	0.125	0.14	0.1346	0.086	0.1121	0.14	0.162	0.155	0.1	0.13	0.145	0.165
(R&D.Corp)	0.17	0.155	0.1587	0.185	0.175	0.156	0.138	0.128	0.1276	0.117	0.157	0.1387	0.104	0.0891	0.13	0.172	0.153	0.11	0.098	0.172	0.164
(Tech. Acq)	0.16	0.174	0.168	0.194	0.164	0.137	0.146	0.132	0.1133	0.104	0.147	0.1339	0.116	0.1081	0.12	0.167	0.15	0.13	0.123	0.146	0.167
(Tech. Expo)	0.17	0.155	0.1593	0.185	0.174	0.154	0.138	0.126	0.1348	0.121	0.111	0.1439	0.113	0.1122	0.14	0.127	0.163	0.13	0.128	0.157	0.161
(Tech. Pro)	0.17	0.156	0.157	0.189	0.174	0.156	0.135	0.135	0.1372	0.115	0.152	0.105	0.106	0.1148	0.13	0.175	0.12	0.12	0.132	0.157	0.162
(Tech. lear)	0.17	0.158	0.1528	0.187	0.166	0.166	0.133	0.127	0.1576	0.121	0.136	0.1311	0.085	0.1086	0.14	0.161	0.155	0.1	0.129	0.145	0.165
(Tech. Sele)	0.19	0.151	0.1542	0.18	0.171	0.151	0.138	0.127	0.1317	0.116	0.155	0.138	0.104	0.0894	0.13	0.171	0.153	0.12	0.099	0.17	0.164
(Tech. Iden)	0.18	0.154	0.154	0.182	0.182	0.153	0.138	0.13	0.1212	0.111	0.147	0.136	0.096	0.1204	0.13	0.172	0.159	0.11	0.142	0.121	0.162
(Tech Deve)	0.16	0.156	0.1551	0.194	0.18	0.152	0.151	0.136	0.1323	0.119	0.129	0.1268	0.098	0.107	0.14	0.156	0.153	0.12	0.13	0.154	0.144

Table 11. Weighted super matrix $W = T^*_{(Dimension)} \times (\mathbf{T}^*_{(\mathbf{Criteria})})'$.

	(K. cre)	(K. Acq)	(Int Kno Port)	(K.Shar)	(K.Imp)	(K.tran)	(Tech. Tran)	(Dec.Mak)	(In. Op Inn)	(Proj. mang)	(Inn. com)	(Rate Int)	(Int & Ext Kno)	(R&D.Corp)	(Tech. Acq)	(Tech. Expo)	(Tech. Pro)	(Tech. lear)	(Tech. Sele)	(Tech. Iden)	(Tech Deve)
(K.cre)	0.043	0.0529	0.053	0.056	0.055	0.05	0.058	0.0665	0.062	0.056	0.0626	0.061	0.0592	0.06	0.055	0.058	0.06	0.057	0.065	0.059	0.06
(K.Acq)	0.051	0.0406	0.055	0.057	0.051	0.05	0.059	0.0555	0.054	0.061	0.0546	0.054	0.0573	0.05	0.059	0.052	0.05	0.054	0.051	0.052	0.05
(Int Kno Port)	0.049	0.0547	0.04	0.054	0.049	0.052	0.058	0.0575	0.054	0.059	0.056	0.054	0.0551	0.06	0.057	0.054	0.05	0.052	0.052	0.052	0.05
(K.shar)	0.061	0.0618	0.064	0.047	0.058	0.059	0.068	0.0662	0.067	0.069	0.0653	0.066	0.0671	0.07	0.066	0.063	0.06	0.063	0.061	0.062	0.07
(K.Imp)	0.059	0.0529	0.052	0.051	0.043	0.059	0.05	0.0653	0.066	0.058	0.0613	0.061	0.0596	0.06	0.055	0.059	0.06	0.056	0.058	0.062	0.06
(K.tran)	0.044	0.0445	0.044	0.043	0.052	0.038	0.061	0.0429	0.052	0.05	0.0542	0.058	0.0557	0.06	0.046	0.052	0.05	0.056	0.051	0.052	0.05
(Tech. Tran)	0.041	0.041	0.041	0.041	0.041	0.047	0.039	0.0505	0.051	0.048	0.0459	0.045	0.0454	0.05	0.049	0.047	0.05	0.045	0.047	0.047	0.05
(Dec.Mak)	0.038	0.0418	0.042	0.037	0.038	0.037	0.048	0.0347	0.042	0.043	0.0421	0.044	0.044	0.04	0.045	0.043	0.05	0.043	0.043	0.044	0.05
(In. Op Inn)	0.038	0.0415	0.042	0.038	0.037	0.037	0.048	0.0457	0.037	0.046	0.0461	0.05	0.0451	0.04	0.038	0.046	0.05	0.053	0.045	0.041	0.04
(Proj. mang)	0.046	0.0476	0.048	0.045	0.046	0.045	0.041	0.0407	0.041	0.034	0.0402	0.038	0.0416	0.04	0.035	0.041	0.04	0.041	0.039	0.038	0.04
(Inn. com)	0.042	0.0416	0.042	0.043	0.041	0.041	0.043	0.0449	0.045	0.048	0.0371	0.05	0.0468	0.05	0.05	0.038	0.05	0.046	0.053	0.05	0.04
(Rate Int)	0.04	0.0357	0.035	0.039	0.042	0.041	0.043	0.043	0.048	0.043	0.0478	0.035	0.0449	0.05	0.045	0.049	0.04	0.044	0.047	0.046	0.04
(Int & Ext Kno)	0.042	0.0412	0.041	0.043	0.041	0.041	0.035	0.0376	0.035	0.038	0.0374	0.035	0.0286	0.03	0.039	0.038	0.04	0.029	0.035	0.032	0.03
(R&D.Corp)	0.041	0.0376	0.037	0.042	0.043	0.04	0.036	0.0368	0.036	0.035	0.0373	0.038	0.0374	0.03	0.037	0.038	0.04	0.037	0.03	0.041	0.04
(Tech. Acq)	0.045	0.0509	0.052	0.051	0.045	0.045	0.049	0.049	0.048	0.042	0.0491	0.047	0.0513	0.05	0.037	0.044	0.04	0.046	0.041	0.041	0.05
(Tech. Expo)	0.05	0.049	0.049	0.05	0.048	0.049	0.052	0.054	0.053	0.059	0.0453	0.062	0.0578	0.06	0.053	0.04	0.06	0.051	0.054	0.055	0.05
(Tech. Pro)	0.049	0.0453	0.045	0.046	0.047	0.047	0.052	0.0517	0.057	0.054	0.0579	0.043	0.0553	0.05	0.048	0.052	0.04	0.049	0.048	0.05	0.05
(Tech. lear)	0.04	0.0406	0.04	0.04	0.039	0.041	0.043	0.0453	0.042	0.046	0.0456	0.043	0.0353	0.04	0.041	0.041	0.04	0.032	0.036	0.036	0.04
(Tech. Sele)	0.038	0.0401	0.041	0.039	0.04	0.041	0.043	0.0446	0.043	0.044	0.0457	0.047	0.0463	0.03	0.039	0.041	0.04	0.041	0.031	0.045	0.04
(Tech. Iden)	0.047	0.0451	0.045	0.044	0.047	0.048	0.052	0.0524	0.051	0.052	0.0556	0.056	0.0519	0.06	0.046	0.05	0.05	0.046	0.054	0.038	0.05
(Tech Deve)	0.056	0.0553	0.053	0.056	0.06	0.054	0.065	0.0596	0.063	0.06	0.0575	0.058	0.0589	0.06	0.053	0.051	0.05	0.052	0.052	0.051	0.05

Table 12. Weighted super matrix ***W****.

	(K. cre)	(K. Acq)	(Int Kno Port)	(K.Shar)	(K.Imp)	(K.tran)	(Tech. Tran)	(Dec.Mak)	(In. Op Inn)	(Proj. mang)	(Inn. com)	(Rate Int)	(Int & Ext Kno)	(R&D.Corp)	(Tech. Acq)	(Tech. Expo)	(Tech. Pro)	(Tech. lear)	(Tech. Sele)	(Tech. Iden)	(Tech Deve)
(K.cre)	0.055	0.0547	0.055	0.055	0.055	0.055	0.059	0.0592	0.059	0.059	0.0592	0.059	0.0593	0.06	0.056	0.056	0.06	0.056	0.056	0.056	0.06
(K.Acq)	0.052	0.0517	0.052	0.051	0.052	0.052	0.056	0.0559	0.056	0.056	0.0558	0.056	0.0558	0.06	0.053	0.053	0.05	0.053	0.053	0.053	0.05
(Int Kno Port)	0.051	0.0511	0.051	0.051	0.051	0.051	0.055	0.0554	0.055	0.055	0.0554	0.055	0.0555	0.06	0.053	0.053	0.05	0.053	0.053	0.053	0.05
(K.shar)	0.06	0.0605	0.06	0.061	0.061	0.06	0.066	0.0655	0.065	0.065	0.0655	0.065	0.0655	0.07	0.062	0.062	0.06	0.062	0.062	0.062	0.06
(K.Imp)	0.055	0.0551	0.055	0.055	0.055	0.055	0.06	0.0596	0.06	0.06	0.0598	0.06	0.0598	0.06	0.057	0.057	0.06	0.057	0.057	0.057	0.06
(K.tran)	0.048	0.048	0.048	0.048	0.048	0.048	0.052	0.0523	0.052	0.052	0.0521	0.052	0.0519	0.05	0.05	0.05	0.05	0.049	0.05	0.05	0.05
(Tech. Tran)	0.044	0.0436	0.044	0.044	0.044	0.043	0.047	0.0471	0.047	0.047	0.0472	0.047	0.0472	0.05	0.045	0.045	0.04	0.045	0.045	0.045	0.04
(Dec.Mak)	0.04	0.0403	0.04	0.04	0.04	0.04	0.044	0.0439	0.044	0.044	0.0438	0.044	0.0437	0.04	0.042	0.042	0.04	0.042	0.042	0.042	0.04
(In. Op Inn)	0.041	0.0413	0.041	0.041	0.041	0.041	0.045	0.0448	0.045	0.045	0.0448	0.045	0.0447	0.04	0.043	0.043	0.04	0.042	0.043	0.043	0.04
(Proj. mang)	0.04	0.0398	0.04	0.04	0.04	0.04	0.043	0.0435	0.043	0.044	0.0434	0.043	0.0434	0.04	0.041	0.041	0.04	0.041	0.041	0.041	0.04
(Inn. com)	0.043	0.0431	0.043	0.043	0.043	0.043	0.047	0.0467	0.047	0.047	0.0469	0.047	0.0467	0.05	0.044	0.045	0.04	0.044	0.044	0.044	0.04
(Rate Int)	0.041	0.0407	0.041	0.041	0.041	0.041	0.044	0.0441	0.044	0.044	0.0439	0.044	0.0441	0.04	0.042	0.042	0.04	0.042	0.042	0.042	0.04
(Int & Ext Kno)	0.036	0.0357	0.036	0.036	0.036	0.036	0.039	0.0388	0.039	0.039	0.0388	0.039	0.039	0.04	0.037	0.037	0.04	0.037	0.037	0.037	0.04
(R&D.Corp)	0.036	0.0361	0.036	0.036	0.036	0.036	0.039	0.0393	0.039	0.039	0.0393	0.039	0.0393	0.04	0.037	0.037	0.04	0.037	0.038	0.037	0.04
(Tech. Acq)	0.044	0.0443	0.044	0.044	0.044	0.044	0.048	0.0482	0.048	0.048	0.0481	0.048	0.0481	0.05	0.046	0.046	0.05	0.046	0.046	0.046	0.05
(Tech. Expo)	0.05	0.0499	0.05	0.05	0.05	0.05	0.054	0.054	0.054	0.054	0.0543	0.054	0.054	0.05	0.051	0.052	0.05	0.051	0.051	0.051	0.05
(Tech. Pro)	0.047	0.0474	0.047	0.047	0.047	0.047	0.051	0.0513	0.051	0.051	0.0511	0.051	0.0512	0.05	0.049	0.049	0.05	0.049	0.049	0.049	0.05
(Tech. lear)	0.039	0.0386	0.039	0.039	0.039	0.039	0.042	0.0419	0.042	0.042	0.0418	0.042	0.0421	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
(Tech. Sele)	0.04	0.0396	0.04	0.04	0.04	0.04	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.04	0.041	0.041	0.04	0.041	0.041	0.041	0.04
(Tech. Iden)	0.047	0.0473	0.047	0.047	0.047	0.047	0.051	0.0512	0.051	0.051	0.0512	0.051	0.0513	0.05	0.049	0.049	0.05	0.049	0.049	0.049	0.05
(Tech Deve)	0.053	0.0535	0.054	0.053	0.053	0.054	0.058	0.0581	0.058	0.058	0.0581	0.058	0.058	0.06	0.055	0.055	0.06	0.055	0.055	0.055	0.06

The following findings based on the analytical DANP model results are shown in Table 8.

1. *Dimensions impact relationship:* The outcomes of the relationship matrix draw three valid dimensions, as shown in Figure 1. Since the matrix does not hold any null values, it actually represents a dynamic relationship in case of a country-specific context. The experts believe that the dimension technology management process capability (TM process cap **T** $(_{\textbf{Dimension}})$) shows the highest R $_{(\text{row})}$ − C $_{(\text{Column})}$ (0.9199718); such a positive value reflects the strong influence on other dimensions. In the case of the degree of importance, the innovation management process capability reflects a very low R $_{(\text{row})}$ − C $_{(\text{Column})}$ value (−0.80576843); thus, it has been susceptible for further influence. Therefore, the improvement priorities can be taken from the technology management process capability as the highest priority, while the innovation management process capability corresponds to the low precedence for further improvement.
2. *Impact relationship of criteria under the dimension KM process capability* ***(T*** $_{\textbf{\textit{Dimension}}}$***):*** The degree of relationship knowledge creation shows the highest R $_{(\text{row})}$ − C $_{(\text{Column})}$ positive value (0.602635), which reflects the strong effects on other criteria. On the other hand, knowledge implementations have a very low R $_{(\text{row})}$ − C $_{(\text{Column})}$ value (−0.6327) with regards to the criteria, thus making it vulnerable to influence.
3. *Impact relationship of criteria under the dimension IM process capability* ***(T*** $_{\textbf{\textit{Dimension}}}$***):*** In the case of the IM process capability, R&D corporation has emerged as the highest positive value of R $_{(\text{row})}$ − C $_{(\text{Column})}$ (0.571005), demonstrating the strong influential significance on other criteria, while technology transfer shows very low R $_{(\text{row})}$ − C $_{(\text{Column})}$ (−0.73361), indicating that it is susceptible to influence. Therefore, the improvement priorities can be ordered from R&D corporation as the highest priority to improve technology transfer as a low priority for further improvement.
4. *Impact relationship of criteria under the dimension TM process capability* ***(T*** $_{\textbf{\textit{Dimension}}}$***):*** Technology selection has the highest positive value of R $_{(\text{row})}$ − C $_{(\text{Column})}$ (0.783744), which illustrates the strong influential significance on other criteria. While technology exploitation shows very low R $_{(\text{row})}$ – C $_{(\text{Column})}$ (−0.40473), it is susceptible to influence. Therefore, the improvement priorities, in terms of the degree of net interrelation, can be ordered from technology selection as the highest priority for rectification to technology exploitation as a low priority for further improvement.

Some pre-normalized methods required for further steps to be carried out. Therefore, the normalized initial direct-relation T^{α} $_{(\text{Dimension})}$, as shown in Table 9, demonstrates the interrelationship among dimensions; thus, it is simple to construct a relationship that replicates features with a transformative system. After measuring the interrelationship among the dimensions and criteria as shown in Table 8. the DANP techniques are then used for relative influence weights, and the ANP procedure is subsequently applied. The interrelation between the dimensions and criteria can be clarified from the unweighted supermatrix. However, in order to simultaneously assess the influence of all the criteria and dimensions, it is necessary to construct the weighted supermatrix, the limits of which can be applied to measure the global weighted matrix for all the dimensions and criteria. For the unweighted supermatrix, at first, the total influential matrices for dimension need to normalize and then transpose to consider as unweighted matrix. While on the other hand, similar steps would take for criteria matrix. At last, for weighted super-matrix the transpose of normalized sub-criteria matrix multiple with criteria normalized matrix $\boldsymbol{W}^{\propto} = \boldsymbol{T_D}^{\propto} \times (T_C{}^{\propto})'$. Some pre-normalized methods require further steps to be carried out. Therefore, the normalized initial direct-relation T $_{\textbf{(Dimension)}}$ and T $_{\textbf{(Criteria)}}$ are shown in Tables 10–12.

As show in Table 13, the innovation management process capability (IM process cap) exhibits the highest weight of 0.348171091, thus, marked as most significant dimension. On the other hand, knowledge management process capability (KM process cap) is the least significant dimension and should be assigned the lowest priority in terms of improvement because it exhibits the lowest weight (0.321123568). Hence, if the strategic target of the decision makers aims to reach the desired level in order to enhance the significance of supporting management capabilities across R&D functions, the IM process cap should be the first priority for improvement, followed by the TM process cap and the KM process cap.

Table 13. The list of weight ranks for each dimension and criterion.

Dimension T *(Dimension)*	Criteria T *(Criteria)*	Dimension		Criterion	
		Weight	Weight Rank	Weight	Weight Rank
KM process cap	(K.cre)	0.321123568	3	0.054777223	4
	(K.Acq)			0.051567816	5
	(Int Kno Port)			0.051191381	7
	(K.shar)			0.060432623	1
	(K.Imp)			0.05499844	3
	(K.tran)			0.048156086	10
IM process cap	(Tech. Tran)	0.348171091	1	0.047371391	11
	(Dec.Mak)			0.043704975	16
	(In. Op Inn)			0.044729515	14
	(Proj. mang)			0.043435665	17
	(Inn. com)			0.046747215	12
	(Rate Int)			0.044025985	15
	(Int & Ext Kno)			0.038883435	21
	(R&D.Corp)			0.039272909	20
TM process cap	(Tech. Acq)	0.331558948	2	0.046113212	13
	(Tech. Expo)			0.05139726	6
	(Tech. Pro)			0.048820136	9
	(Tech. lear)			0.03994906	19
	(Tech. Sele)			0.041017751	18
	(Tech. Iden)			0.048902412	8
	(Tech Deve)			0.055359116	2

5. Conclusions

Thus, in this study, the MCDM evaluation technique was applied to determine the effective influence of supporting management disciplines on R&D., This study found that the TM process capability (TM process cap) had the greatest impact on other dimensions, while the innovation management process capability (IM process cap) had the smallest impact on another dimensions. In case of the degree of importance for the *KM process capability* ($T_{Dimension}$), the knowledge creation (K.cre) had the highest influence on other criteria. Meanwhile, knowledge implementations (K. Imp) had the smallest impact on other criteria. While in case of the *IM process capability* ($T_{Dimension}$), R&D corporation (R&D Corp) emerged with a degree of influence on other criteria; however, technology transfer (Tech Tran) had the smallest impact on other criteria. In the *TM process capability* ($T_{Dimension}$) dimension analysis, technology selection (Tech. Sele) emerged with a degree of influence on other criteria, while technology exploitation (Tech. Expo) appeared to have the smallest impact on other criteria. In case of determining the causality and weights among each dimension, this study adopted IRM and DANP techniques. This study found that R&D corporation, technology transfer, and innovativeness compatibility are potential resources that R&D mangers requires to be able to reconfigure any instance of enhancing the R&D effectiveness across R&D firms in the public sector. This research has two limitations. First, this study is country-specific by its orientation and can prove the current situation at a specific time based on the consensus among country-specific experts. We recommend that for future research avenues, researchers extend the data collection period through longitudinal studies. Secondly, it can be argued that the identification of dimensions and criteria should be based on historical evidence or conventional literature reviews. Through systemic reviews and in-depth interviews, we can find more criteria that can be used for future research avenues. Furthermore, this study mainly focusses on supporting management disciplines and their interrelationship among capabilities related to knowledge management, innovation management, and technology management within the R&D department. Therefore, for future research, other organizational functions can be included, especially those that extend the scope of research sampling so that the research outcomes can be applied to other projects.

Author Contributions: Conceptualization, Z.A. and S.S.; methodology, Z.A. and S.S.; software, Z.A.; validation, S.S.; formal analysis, Z.A.; investigation, Z.A.; resources, S.S.; data curation, Z.A.; writing—original draft preparation, Z.A.; writing—review and editing, Z.A. and S.S.; visualization, Z.A.; supervision, S.S.; project administration, Z.A.; funding acquisition, S.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Jensen, M.C. The modern industrial revolution, exit, and the failure of internal control systems. *J. Financ.* **1993**, *48*, 831–880. [CrossRef]
2. Wang, C.-H.; Lu, Y.-H.; Huang, C.-W. R&D, productivity, and market value: An empirical study from high-technology firms. *Omega* **2013**, *41*, 143–155.
3. Mazurkiewicz, A.; Poteralska, B. Technology Transfer Barriers and Challenges Faced by R&D Organisations. *Procedia Eng.* **2017**, *182*, 457–465.
4. OECD. *Economic Outlook for Southeast Asia, China and India 2016: Enhancing Regional Ties*; OECD Publishing: Paris, France, 2016.
5. Maloney, W. Why Don't Poor Countries Do R&D? 2014. 25 July 2018. Available online: https://blogs.worldbank.org/developmenttalk/why-dont-poor-countries-do-rd (accessed on 27 July 2022).
6. WEF. *The Global Competitiveness Report 2016–2017*; World Economic Forum: Geneva, Switzerland, 2017.
7. Ali, M.; Ullah, S.; Khan, P. Managing innovation and technology in developing countries. *arXiv* **2009**, arXiv:0911.1514.
8. Dutta, S.; Lanvin, B.; Wunsch-Vincent, S. *The Global Innovation Index 2016: Winning with Global Innovation*; Cornell University, INSEAD, and WIPO: Geneva, Switzerland, 2016.
9. Wamae, W. Enhancing the role of knowledge and innovation for development. *Int. J. Technol. Manag. Sustain. Dev.* **2009**, *8*, 199–220. [CrossRef]
10. Asim, Z.; Sorooshian, S. Exploring the Role of Knowledge, Innovation and Technology Management (KNIT) Capabilities that Influence Research and Development. *J. Open Innov. Technol. Mark. Complex.* **2019**, *5*, 21. [CrossRef]
11. Aleksandras, V.R.; Jurgita Raudeliūnienė, I.R. Integral knowledge, innovation and technology cluster formation nurturing the universal development sustainability in the context of globalization. *Econ. Sociol.* **2014**, *7*, 41–58.
12. Ehigie, B.O.; McAndrew, E.B. Innovation, diffusion and adoption of total quality management (TQM). *Manag. Decis.* **2005**, *43*, 925–940. [CrossRef]
13. Chaminade, C.; Lundvall, B.-Å. Science, Technology, and Innovation Policy: Old Patterns and New Challenges. In *Oxford Research Encyclopedia of Business and Management*; Oxford University Press: Oxford, UK, 2019.
14. Galbraith, B.; McAdam, R.; Cross, S.E. The Evolution of the Incubator: Past, Present, and Future. *IEEE Trans. Eng. Manag.* **2019**, *68*, 265–271. [CrossRef]
15. Unsal, E.; Cetindamar, D. Technology management capability: Definition and its measurement. *Eur. Int. J. Sci. Technol.* **2015**, *4*, 181–196.
16. Brockhoff, K. The emergence of technology and innovation management. *Technol. Innov.* **2017**, *19*, 461–480. [CrossRef]
17. Asim, Z.; Sorooshian, S.; Ahmad, M.S. Publication Trends on Overlapping Boundaries among Capabilities related to Knowledge, Innovation and Technology Management in R&D Context. *Int. J. Recent Technol. Eng.* **2019**, *7*, 352–363.
18. Teece, D.J. Towards a capability theory of (innovating) firms: Implications for management and policy Cambridge. *J. Econ.* **2017**, *41*, 693–720. [CrossRef]
19. Bank, W. Research and Development Expenditure. 18 March 2018. Available online: https://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS?view=map (accessed on 15 April 2022).
20. Teece, D.J. Business models, business strategy and innovation. *Long Range Plan.* **2010**, *43*, 172–194. [CrossRef]
21. Cetindamar, P.; Probert, U. Technology Management as a Dynamic Capability: A Framework for Technology Management Activities. *Technovation* **2009**, *29*, 237–246. [CrossRef]

22. Selnes, F.; Sallis, J. Promoting Relationship Learning. *J. Mark.* **2003**, *67*, 80–95. [CrossRef]
23. Chang, K.-H.; Gotcher, D.F. Safeguarding Investments and Creation of Transaction Value in Asymmetric International Subcontracting Relationships: The Role of Relationship Learning and Relational Capital. *J. World Bus.* **2007**, *42*, 477–488. [CrossRef]
24. Corsaro, D.; Cantu, C.; Tunisini, A. Actors' Heterogeneity in Innovation Networks. *Ind. Mark. Manag.* **2012**, *41*, 780–789. [CrossRef]
25. Garvin, A.G. Building a Learning Organization. *Harv Bus Rev.* **1993**, *71*, 78–91.
26. Kohtamaki, M.; Bourlakis, M. Antecedents of Relationship Learning in Supplier Partnerships from the Perspective of an Industrial Customer: The Direct Effects Model. *J. Bus. Ind. Mark.* **2012**, *27*, 299–310. [CrossRef]
27. Gronroos, C.; Voima, P. Critical Service Logic: Making Sense of Value Creation and Co-Creation. *J. Acad. Mark. Sci.* **2013**, *41*, 133–150. [CrossRef]
28. Gulati, R.; Singh, H. The architecture of cooperation: Managing coordination costs and appropriation concerns in strategic alliances. *Adm. Sci. Q.* **1998**, *43*, 781–814. [CrossRef]
29. Nieto, M.; Santamaria, L. Technological Collaboration: Bridging the Innovation Gap between Small and Large Firms. *J. Small Bus. Manag. Decis.* **2010**, *48*, 44–69. [CrossRef]
30. Un, C.A.; Cuervo-Cazurra, A.; Asakawa, K. R&D Collaborations and Product Innovation. *J. Prod. Innov. Manag.* **2010**, *27*, 673–689.
31. Eisenhardt, K.M.; Martin, J.A. Dynamic capabilities: What are they? *Strateg. Manag. J.* **2000**, *21*, 1105–1121. [CrossRef]
32. Liao, C.; Wang, H.-Y.; Chuang, S.-H.; Shih, M.L.; Liu, C.-C. Enhancing knowledge management for R&D innovation and firm performance:An integrative view. *Afr. J. Bus. Manag.* **2010**, *4*, 3026–3037.
33. Carayannis, E.G.; Provance, M. Measuring firm innovativeness: Towards a composite innovation index built on firm innovative posture propensity and performance attributes. *Int. J. Innov. Reg. Dev.* **2008**, *1*, 90–107. [CrossRef]
34. Daniels, H.; Smits, M. Portfolio Optimization as a Tool for Knowledge Management. In Proceedings of the Annual International Conference of the German Operations Research Society (GOR), Bremen, Germany, 7–9 September 2005.
35. Wang, C.; Lu, I.; Chen, C. Evaluating firm technological innovation capability under uncertainty. *Technovision* **2007**, *28*, 349–363. [CrossRef]
36. Jain, K.; Siddiquee, Q.; Singal, V. Measurement of Innovativeness in an Organisation using AHP in Technology Management for Global Economic Growth (PICMET). In Proceedings of the Picmet 2010 Technology Management for Global Economic Growth, Phuket, Thailand, 18–22 July 2010.
37. Arvanitis, S.; Kubli, U.; Woerter, M. University industry knowledge and technology transfer in Switzerland: What university scientists think about cooperation with private enterprises. *Res. Policy* **2008**, *37*, 1865–1883. [CrossRef]
38. Bothma, T.J.D. Nine drivers of knowledge transfer between universities and industry R & D partners in South Africa. *South Afr. J. Inf. Manag.* **2007**, *9*.
39. Brennenraedts, R.; Bekkers, R.; Verspagen, B. The different channels of university-industry knowledge transfer: Empirical evidence from Biomedical Engineering. In *Eindhoven Centre for Innovation Studies*; Technische Universiteit Eindhoven: Eindhoven, The Netherlands, 2006; pp. 1–18.
40. Harris, P.R. Cross-cultural Management: A Knowledge Management Perspective. *Eur. Bus. Rev* **2004**, *16*, 205–206. [CrossRef]
41. Satyanarayan, S.; Azumah, G. Operationalisation of knowledge management practices in r&d activity in multinational organisations. In Proceedings of the 12th Management International Conference, Wuhan, China, 14–16 September 2011.
42. Yli-Renko, H.; Autio, E.; Sapienza, J.H. Social capital, knowledge acquisition, and knowledge exploitation in young technology-based firms. *Strateg. Manag. J.* **2001**, *22*, 587–613. [CrossRef]
43. Crossan, M.M.; Apaydin, M. A Multi-Dimensional Framework of Organizational Innovation A Systematic Review of the Literature. *J. Manag. Stud.* **2010**, *47*, 1154–1191. [CrossRef]
44. Kuwada, K. Strategic Learning: The Continuous Side of Discontinuous Strategic Change. *Organ. Sci.* **1998**, *9*, 719–736. [CrossRef]
45. Fang, S.-R.; Fang, S.-C.; Chou, C.-H.; Yang, S.-M.; Tsai, F.-S. Relationship Learning and Innovation: The Role of Relationship-Specific Memory. *Ind. Mark. Manag.* **2011**, *40*, 743–753. [CrossRef]
46. Rombach, D.A. Research Collaborations Between Academia and Industry. In Proceedings of the International Conference on Software Engineering (FOSE'7), Minneapolis, MN, USA, 23–35 May 2007; pp. 29–36.
47. Tran, T.A.K. Literature Review on Technology Transfer from Government Laboratories to Industry. In Proceedings of the Portland International Conference on Management of Engineering & Technology (PICMET 2009), Portland, OR, USA, 2–6 August 2009.
48. Allen, T.J.O.S. Introduction. In *Building Technology Transfer within Research Universities: An Entrepreneurial Approach*; Allen, T.J., O'Shea, R.P., Eds.; Cambridge University Press: Cambridge, UK, 2014.
49. Mom, T.J.M.; Oshri, I.; Volberda, H.W. The skills base of technology transfer professionals. *Technol. Anal. Strateg. Manag.* **2012**, *24*, 871–891. [CrossRef]
50. Dasgupta, P.; Taneja, N. Low Carbon Growth: An Indian Perspective on Sustainability and Technology Transfer. *Probl. Sustain. Dev.* **2011**, *6*, 65–74.
51. Morrissey, M.T.A. Rethinking technology transfer. *J. Food Eng.* **2005**, *67*, 135–145. [CrossRef]
52. Sazali, A.W.; Raduan, C.R. *The Handbook of Inter Firm Technology Transfer: An Integrated Knowledge-Based View and Organizational Learning Perspective*; LAP LAMBERT Academic Publishing: Saarbrücken, Germany, 2011.
53. GarcÃa-Granero, A.; Vega-Jurado, J.; Alegre-Vidal, J. Is R&D Enough to Take Advantage from External Knowledge? Focusing on Coordination Mechanisms. *J. Technol. Manag. Innov.* **2014**, *9*, 118–130.

54. Damanpour, Organizational innovation: A meta-analysis of effects of determinants and moderators. *Acad. Manag. J.* **1991**, *34*, 555–590. [CrossRef]
55. Song, M.; Droge, C.; Hanvanich, S. Calantone, R. Marketing and technology resource complementarity: An analysis of their interaction effect in two environmental contexts. *Strateg. Manag. J.* **2005**, *26*, 259–276. [CrossRef]
56. Rios, A.A.S.B.L.A. *The Organization of R&D within Firms: Measures, Characteristics and Consequences*; National Bureau of Economic Research: Boston, MA, USA, 2011.
57. John Hagedoorn, M.C. Measuring innovative performance: Is there an advantage in using multiple indicators. *Res. Policy* **2003**, *32*, 1365–1379. [CrossRef]
58. Freeman, C.; Soete, L. *The Economics of Industrial Innovation*; MIT Press: London, UK, 1997.
59. Acs, Z.J.; Audretsch, D.B. Patents as a measure of innovative activity. *Kyklos* **1989**, *4*, 171–180. [CrossRef]
60. Ahuja, G.; Katila, R. Technological acquisition and the innovative performance of acquiring firms: A longitudinal study. *Strateg. Manag. J.* **2001**, *22*, 197–220. [CrossRef]
61. Archibugi, D. Patenting as an indicator of technological innovation: A review. *Sci. Public Policy* **1992**, *6*, 357–358.
62. Ernst, H. Patent applications and subsequent changes of performance: Evidence from time-series cross-section analyses on the firm level. *Res. Policy* **2001**, *30*, 143–157. [CrossRef]
63. Grupp, H. The measurement of technical performance of innovations by technometrics and its impact on established technology indicators. *Res. Policy* **1994**, *23*, 175–193. [CrossRef]
64. Lanjouw, J.O.; Schankerman, M. The Quality of Ideas: Measuring Innovation with Multiple Indicators. In *NBER Working Paper 7345*; NBER: Cambridge, MA, USA, 1999.
65. Stuart, T.E. Interorganizational alliances and the performance of firms: A study of growth and innovation rates in a high-technology industry. *Strateg. Manag. J.* **2000**, *21*, 791–811. [CrossRef]
66. Trajtenberg, M. A penny for your quotes: Patent citations and the value of innovations. *Rand J. Econ.* **1990**, *21*, 172–187. [CrossRef]
67. Gunduz, M.; Alfar, M. Integration of Innovation Through Analytical Hierarchy Process (AHP) in Project Management and Planning. *Technol. Econ. Dev.* **2019**, *25*, 258–276. [CrossRef]
68. Laursen, K.S. The Role of Openness in Explaining Innovation Performance among U.K. Manufacturing Firms. *Strateg. Manag. J.* **2006**, *27*, 131–150. [CrossRef]
69. Collins, L. Opening Up the Innovation Process. *Eng. Manag. J.* **2006**, *16*, 14–17. [CrossRef]
70. Trott, P.H. Why 'Open Innovation' is Old Wine in New Bottles. *Int. J. Innov. Manag.* **2009**, *13*, 715–736. [CrossRef]
71. Dahlander, L.; Ganu, D.M. How Open is Innovation? *Res. Policy* **2010**, *39*, 699–709. [CrossRef]
72. Van De Vrande, V.; Vanhaverbeke, W.; Gassmann, O. Broadening the Scope of Open Innovation: Past Research, Current State and Future Direction. *Int. J. Technol. Manag.* **2010**, *5*, 221–235. [CrossRef]
73. Huizingh, E.R.K.E. Open Innovation: State of the Art and Future Perspective. *Technovation* **2011**, *31*, 2–9. [CrossRef]
74. Lichtenthaler, U. Open Innovation: Past Research, Current Debates and Future Directions. *Acad. Manag. Perspect.* **2011**, *25*, 75–93.
75. Chesbrough, The Era of Open Innovation. *MIT Sloan Manag. Rev.* **2003**, *44*, 35–38.
76. Kavanagh, D.N. Innovation & project management—exploring the links. *PM World Today* **2009**, *9*, 1–7.
77. Edgett, S.J. People: A Key to Innovation Capability. *Eur. Bus. Rev* **2014**, *26*, 10–12.
78. Filippov, S.; Mooi, H. Innovation project management: A research agenda. *J. Innov. Sustain. RISUS* **2010**, *1*, 2179–3565.
79. Ji, X.; Pang, C.; Bao, G. The Influence of Innovativeness Compatibility on Consumers' Online Purchase Intention on the Creative Product: A Case Study of Fashion. In Proceedings of the 2007 International Conference on Wireless Communications, Networking and Mobile Computing, Shanghai, China, 21–25 September 2007.
80. Oostrom, J.K.; van der Linden, D.; Born, M.P.; van der Molen, H.T. New technology in personnel selection: How recruiter characteristics affect the adoption of new selection technology. *Comput. Hum. Behav.* **2013**, *29*, 2404–2415. [CrossRef]
81. Hall, B.H.; Griliches, Z.; Hausman, J.A. Patents and R and D: Is there a lag? *Int. Econ. Rev.* **1986**, *27*, 265–283. [CrossRef]
82. Haner, Innovation Quality—a conceptual framework. *Int. J. Prod. Econ.* **2002**, *80*, 31–37. [CrossRef]
83. Damanpour, F.; Szabat, K.A.; Evan, W.M. The relationship between types of innovation and organizational performance. *J. Manag. Stud.* **1989**, *26*, 587–601. [CrossRef]
84. Wang, C.; Chin, Y.; Tzeng, G. Mining the R&D innovation performance processes for high-tech firms based on rough set theory. *Technovision* **2010**, *30*, 447–458.
85. Blomqvist, K.; Harkink, E.; Drongelen, I.K.; Kuittinen, O.; Ojanen, V. Measuring Innovativeness—Challenges and possibilities for knowledge-based firms. In Proceedings of the International Engineering Management Conference, Singapore, 18–21 October 2004.
86. Carayannis, E.G.; Popescu, D.; Sipp, C.; Stewart, M. Technological learning for entrepreneurial development (TL4ED) in the knowledge economy (KE): Case studies and lessons learned. *Technovation* **2006**, *26*, 419–443. [CrossRef]
87. Svetina, A.C.; Prodan, I. How Internal and External Sources of Knowledge Contribute to Firms' Innovation Performance. *Manag. Glob. Transit.* **2008**, *6*, 277–299.
88. Van Beers, C.; Zand, F. R&D Cooperation, Partner Diversity, and Innovation Performance: An Empirical Analysis. *J. Prod. Innov. Manag.* **2014**, *31*, 292–312.
89. Belderbos, R.; Carree, M.; Lokshin, B. Cooperative R&D and Firm Performance. *Res. Policy* **2004**, *33*, 1477–1492.
90. Amara, N.; landry, R. Sources of Information as Determinants of Novelty of Innovation in Manufacturing Firms: Evidence from the 1999 statistics Canada innovation Survey. *Technovation* **2005**, *25*, 245–259. [CrossRef]

91. Cho, C.; Son, J.K.; Lee, S.; Park, S. Comparative Analysis of R&D-Based Innovation Capabilities in SMEs to Design Innovation Policy. *Sci. Public Policy* **2016**, *44*, 403–416.
92. Lanctot, A.; Swan, K.S. Technology acquisition strategy in an internationally competitive environment. *J. Int. Manag.* **2000**, *6*, 187–215. [CrossRef]
93. Hung, S.W.; Tang, R.H. Factors affecting the choice of technology acquisition mode: An empirical analysis of the electronic firms of Japan, Korea and Taiwan. *Technovation* **2008**, *28*, 551–563. [CrossRef]
94. Pavitt, K. What we know about the strategic management of technology. *Calif. Manag. Rev.* **1990**, *32*, 17–26. [CrossRef]
95. Dilek Cetindamara, R.P.; Probert, D.R. Technology management as a profession and the challenges ahead. *J. Eng. Technol. Manag.* **2016**, *41*, 1–13. [CrossRef]
96. Jun, J.; Von Zedtwitz, M. Technological capability development in China's mobile phone industry. *Technovation* **2008**, *28*, 327–334. [CrossRef]
97. Asim, Z.; Sorooshian, S. Capabilities of R & D: Literature analysis. *Int. J. Mech. Eng.* **2018**, *9*, 316–324.
98. Escher, J.-P. The Process of External Technology Exploitation as Part of Technology Marketing A Conceptual Framework. In Proceedings of the PICMET '01. Portland International Conference on Management of Engineering and Technology, Proceedings Vol.1: Book of Summaries (IEEE Cat. No.01CH37199), Portland, OR, USA, 29 July–2 August 2001.
99. Levin, D.Z.; Barnard, H. Technology management routines that matter to technology managers. *Int. J. Technol. Manag.* **2008**, *41*, 22–37. [CrossRef]
100. Nordhaus, W.D. *The Perils of the Learning Model for Modeling Endogenous Technological Change*; National Bureau of Economic Research: Boston, MA, USA, 2009.
101. Gillingham, K.; Newell, R.G.; Pizer, W.A. Modeling endogenous technological change for climate policy analysis. *Energy Econ.* **2008**, *30*, 2734–2753. [CrossRef]
102. Ehrlenspiel, K.; Kiewert, A. *; Lindemann, Cost-Effective Development and Construction: Cost Management in Integrated Product Development*, 6th ed.; Springer: Berlin/Heidelberg, Germany, 2007.
103. Nazarko, J.; Glinska, U.; Kononiuk, A.; Nazarko, L. Sectoral foresight in Poland: Thematic and methodological analysis'. *Int. J. Foresight Innov. Policy* **2013**, *9*, 19–38. [CrossRef]
104. Halicka, K. Forward-looking planning of technology development. *Bus. Manag. Educ.* **2015**, *13*, 308–320. [CrossRef]
105. Kodanu. Technology Fusion and the New Research and Development. *Harv. Bus. Rev.* **1992**, *70*, 70–78.
106. Meyer, M.H.; Utterback, J.M. *The Product Family and the Dynamics of Core Capability*; Sloan Management Review; Massachusetts Institute of Technology: Cambridge, MA, USA, 1993.
107. Abetti, P.A. *Linking Technology and Business Strategy*; Presidents Association, Chief Executive Officers Division of American Management Association: New York, NY, USA, 1989.
108. Clark, K. What Strategy can do for Technology. *Harv. Bus. Rev.* **1989**, *12*, 94–98.
109. OMITI. Intellectual Asset Management for Sustainable Research. In Proceedings of the Sustainable Research and Innovation Conference, Nairobi, Kenya, 18–20 May 2011.
110. Cetindamar, D.; Phaal, R. *Technology Management: Activities and Tools*; Palgrave Macmillan: London, UK, 2016.
111. Asim, Z.; Teck, T.S.; Sorooshian, S. An Expert-Approved R&D Model. *Int. J. Eng. Adv. Technol.* **2019**, *8*, 1939–1946.
112. Wang, Y.-L.; Tzeng, G.-H. Brand marketing for creating brand value based on a MCDM model combining DEMATEL with ANP and VIKOR methods. *Expert Syst. Appl.* **2012**, *39*, 5600–5615. [CrossRef]
113. Jeng, D.J.F.; Huang, K.-H. Strategic project portfolio selection for national research institutes. *J. Bus. Res.* **2015**, *681*, 2305–2311. [CrossRef]
114. Gölcük, İ.; Baykasoğlu, A. An analysis of DEMATEL approaches for criteria interaction handling within ANP. *Expert Syst. Appl.* **2016**, *46*, 346–366. [CrossRef]
115. Chen, F.H.; Hsu, T.S.; Tzeng, G.H. A balanced scorecard approach to establish a performance evaluation and relationship model for hot spring hotels based on a hybrid MCDM model combining DEMATEL and ANP. *Int. J. Hosp. Manag.* **2011**, *30*, 908–932. [CrossRef]
116. Yang, J.L.; Tzeng, G. An integrated MCDM technique combined with DEMATEL for a novel cluster-weighted with ANP method. *Expert Syst. Appl.* **2011**, *38*, 1417–1424. [CrossRef]
117. Lizarralde, R.; Ganzarain, J.; Zubizarreta, M. Assessment and Selection of Technologies for the Sustainable Development of an R&D Center. *Sustainability.* **2020**, *12*, 2–23.
118. Asim, Z.; Sorooshian, S. Innovation Management Capabilities for R&D in Case of Pakistan: Innovation Management for R&D. In *Encyclopedia of Information Science and Technology*; Khosrow-Pour, M., Ed.; IGI Global Publisher Hershey: Hershey, PA, USA, 2019.
119. Huang, C.; Chua, P.; Chiang, Y. A fuzzy AHP application in government-sponsored R&D project selection. *Omega* **2008**, *36*, 1038–1052.
120. Meesapawong, P.; Rezgui, Y.; Li, H. Perceiving societal value as the core of innovation management in public research and development organizations. In Proceedings of the 5th International Conference on Management of Innovation and Technology, Singapore, 2–5 June 2010; pp. 312–317.
121. Shahab, M. Technology Achievement Index 2015: Mapping the Global Patterns of Technological Capacity in the Network Age. *Technol. Forecast. Soc. Chang.* **2015**, 2–35.

122. Manzoor, R.; Samad, G. *The Sustainable Green Growth Perspective of Pakistan: In the Context of Environment Friendly Technologies*; Centre for Environmental Economics and Climate Change: Islambad, Pakistan, 2013; pp. 1–13.
123. Abdel-Basset, M.; Mohamed, M.; Sangaiah, A.K. Neutrosophic AHP-Delphi group decision making model based on trapezoidal neutrosophic numbers. *J. Ambient. Intell. Humaniz. Comput.* **2017**, *9*, 1427–1443. [CrossRef]
124. Asim, Z.; Sorooshian, S.; Hasan, M. A technique to address four-layed DANP method. *Int. J. Civ. Eng. Technol.* **2018**, *9*, 281–288.
125. Meesapawong, P. *Managing Innovation in Public Research and Development Organisations Using a Combined Delphi and Analytic Hierarchy Process Approach*; School of Engineering, Cardiff University: Cardiff, UK, 2013.