TECHNOLOGY MANAGEMENT CAPABILITY ASSESMENT AN EMPIRICAL STUDY IN IZMIR TURKEY FOR MODEL DEVELOPMENT

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Abstract
Technology Management Capability measurement is being emphasized as an important research field in the Technology Management discipline which continues to be developed by interdisciplinary interactions. Companies which improve technology management capabilities and become mature in this sense may improve their competitive powers and in turn their performances. To test these hypothesis; which defines the technology management capabilities of the companies in relation with the Project, Innovation and Knowledge Management capabilities, process based draft evaluation model has been developed. A survey has been performed via face to face structured interviews with the upper management of the 75 selected İzmir city based companies all of which were performing in Defense area as part of the defense clustering project. Findings as a result of the evaluation of the data gathered are supporting the hypothesis. The only exception is the cause and effect relationship between technology management and knowledge management processes. This should be analyzed further been order to deepen the research.

Keywords: technology management, technology management capability, strategic management, knowledge management, innovation management, project management.

1. INTRODUCTION

The overwhelming novel scientific information production; which reaches up to yotta bytes ($10^{24} = 2^{80}$) per year, continuously helps to the creation of value and/or wealth through various applications and innovations under the very competitive and thus be very turbulent conditions of our current business environment. Competition is much tougher in this technology era and the management of technology becomes one of the major drivers for the competitive advantage. Competition could be among the supply chains of multinational companies or among nations at the macro level and among companies at the micro level. Regardless of the level, under the rapid changing environments, in order to have sustainable performance and sustainable competitive advantage, together with the knowledge and innovation, technology should also be managed. Both in the application areas and in the academic research environments, the knowledge requirements for the competitive advantage through rapidly developing technology have established the base for the evolving scientific discipline of technology management. Today, technology management discipline continues to develop by the interdisciplinary interactions and the contributions to science are going on.

National Research Council Task Force on the Management of Technology (1987) has defined Technology Management as "an interdisciplinary field of knowledge integrating science, engineering and management knowledge and practices to plan, develop and implement technological capabilities to shape and accomplish the strategic and operational objectives of an organization". Several conceptual and empirical studies contributed a lot to the field and conceptual map has become much more clear today.

The global competition, puts the technology, knowledge, and innovation management activities or processes in the heart of competition. In this study, among the several key areas of competitive advantage and sustainable performance, technology management capability assesment of companies is investigated.

The basic goal of this study is to develop a company level technology management capability assesment model proposal and to test the proposed model in the field which is in the span of control of the Agean Region Chamber of Industry, Izmir, Turkey. At the end of the study, assesment model will be further improved and presented to the user companies as a self assesment tool.

Secondary goals in this study are, to identify the components (elements) of the technology management capability, to identify the most and least effective components among others over the competitive advantage and performance parameters, to identify the relationship among the major variables namely technology management capability, competitive advantage, performance, innovation management processes, knowledge management processes and other major processes. Hence two major research questions are put forward:

Research Question 1 : What are the technology management capability levels of the firms in Izmir region?

Research Question 2 : Are there any correlations among technology management capabilities of the firms and their competitive advantages, their performances, and their major processes?

As a first step in this study, a draft assesment model was developed referencing the similar very few models which were presented in the literature (Gregory, 1995; Panda & Ramanathan, 1996; Skilbeck and Crickshank, 1997; Tschirky, 1997; Ozgur, 1999; Yuksel, 2000; Phaal et. al., 2001; Phaal et. al., 2004; Rush et. al., 2007; Levin & Barnard, 2008; Arasti et. al., 2009; Cetindamar et. al., 2009; Unsal, 2009). The proposed model was pilot tested and improved slightly, then new version was utilised in the field (and, this part of the study is supported by Izmir Development Agency-IZKA). In order to test the developed model a questionnaire was prepared. This is used as an instrument for the face to face structured interviews with the upper echelons of the selected 75 companies. These selected companies are treated as candiates for potential defense cluster in the region that has been taking place since the last four to five years. Following the completion of the interviews, information obtained from the field is statistically analyzed, evaluated and further actions are listed for the conclusions of the multiple objectives behind the study.

This paper is organised in sequence as follows : 'Process Approach: Technology Management Capability' that is explained in the light of the related literature review, 'Methodology' of the empirical study including the proposed model which is also presented and finally, the 'Results', 'Discussions' and 'References' are provided.

2. PROCESS APPROACH: TECHNOLOGY MANAGEMENT CAPABILITY

Technology plays a key role for the companies to obtain sustainable competitive advantage at the global level. From that perspective, effective management of the technology becomes important and therefore the companies should develop the technology management capability, adopt their capabilities based on the rapid changing conditions and continously improve the processes which constitute these capabilities. This study is important from the perspectives of the capability development for the technology management, gaining of competitive advantage and obtaining superior performance through these capabilities, and to create awareness for the Capabilities and Technology Management in the fields of application.

Technology Management Capability measurement is being emphasised as an important research area in the developing field of technology management. Several studies performed in the developed countries share the common ground of research and development (R&D). Basic, applied researches and experimental developments are seen as the basis for the technology development and knowledge accumulation. From this perspective, the technology management, knowledge management and innovation management may establish the base for the framework for the technology management capability studies.

Technology management capability has been viewed as the combination of resources and processes which can be developed, deployed and protected for managing technology (Weiwei Wu, et al. 2010). In this study, the Technology Management Capability is defined as the capability to manage and continuously improve Technology Management Processes (Activities/Routines). In the literature; process, activity and routine terms are used interchangeably for the same meaning. Scientific Management (Taylor, 1911) can be accepted as the historical beginning of the efficiency and productivity studies. Following his studies, several academic studies can be observed which may also be defined as "Process Based Organisational studies" (Nordsieck, 1934; Kosiol, 1962; Gaitinades, 1983; Davenport, 1993; Hammer and Champy, 1993). Although these studies were much more comprehensive, Porter's Value Chain Approach is very much known in the area of competitive advantage (Porter, 1985). The review of technology management capability literature shows that the value chain approach of Porter (1985) and five main processes approach of Gregory (1995) seem to be the core concepts. Many of the recent studies and the measurement models have been affected from Porter's value chain model and from the contributions of Gregory to the dynamic capabilities theory. Porter has defined the value activities as primary and support activities and emphesized that they are the building blocks for a firm. Gregory (1995) in his process approach has developed technology management process framework. Figure 1 shows Gregor's 5 processes model. In the system context, Skilbeck and Crickshank (1997) have approached the technology management by interrelating the business activities with technology management processes by identifying three levels namely corporate level, business or strategic level and operational level. Tschirky (1997) also approached the technology management with three levels in his "Integrated Management Concept". Ozgur (1999) and Yuksel (2000), in their studies have taken the Gregory's model and added a new process, namely "termination".

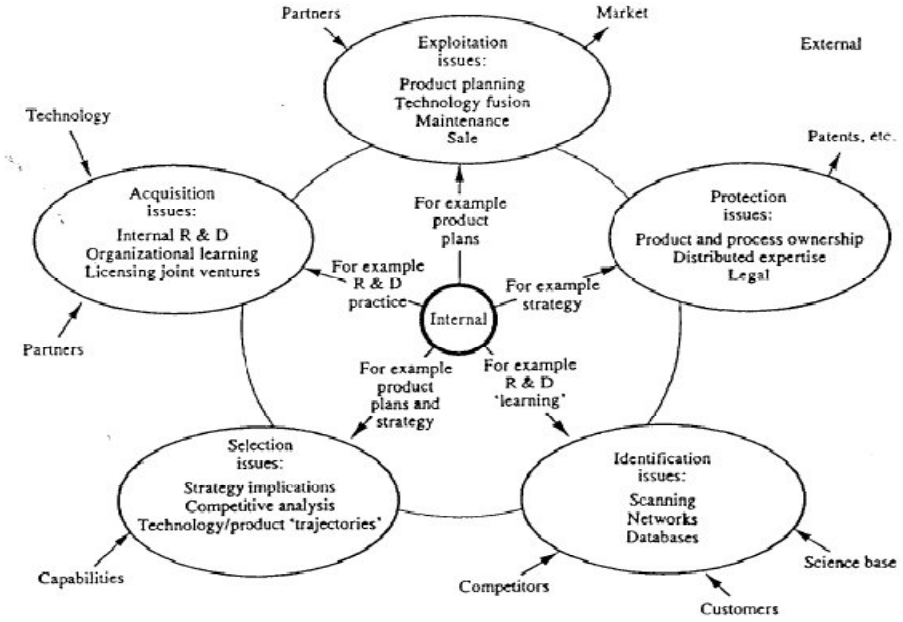

Figure 1 Technology Management Process Framework (Gregory, 1995).

Phaal, Farrukh, & Probert (2001) developed technology management assessment procedure based on Gregory's model. Rush, Besant, & Hobday (2007) presented a tool having nine dimensions to evaluate and measure technology management capabilities of a firm. Levin & Barnard (2008) have identified 27 routines as technology management activities. Cetindamar, Phaal & Probert (2009) have proposed a new framework by adding "learning activities" under technology management and combining knowledge management, innovation management and project management activities as support activities with the Gregory' s model. Unsal (2009) has added strategic management activities on top of this model. Parallel to the studies in the western world, there have been similar studies in the eastern world based on the Porter' s value chain; two reference studies were done in the electricity sector (Panda & Ramathan, 1995-1996). Arasti, Nayaeri & Zenouz (2009) have proposed a four dimensional model for measurement. Starting from the resource based view and continuing with the dynamic capabilities theory, resources and capabilities continuously reevaluated, regenerated and reordered (Wang and Ahmed, 2007). In the center of the dynamic capabilities theory approach; the routines, processes and activities or a group of activities have appeared (Teece, 2007). Looking for the interrelations among the technology management, innovation and knowledge management processes, arguments and debates are going on. One important discussion concept is the "Productivity Dilemma" focusing on the incompatibility of the short term efficiency versus long term adaptability (Albernathy, 1978). The other and much more recent discussion is the debate which takes into account the dynamics of the environmental changes of the today's world which focuses on the concepts of exploitation and exploration, states the necessity of ambidexterity (Adler et al., 2009). These debates are very helpful and effective to shape the research model by defining the interrelations among the business processes including the knowledge, innovation and technology management processes.

3. METHODOLOGY

In this study, the measurement models cited in literature have been analyzed and it has been noted that there is no single model that was widely accepted. While analyzing the measurement models, nested nature of the three disciplines Technology Management, Knowledge Management and Innovation Management and differentiation trends of viewpoints of each have been taken into account. In this context, an assessment

model is proposed which takes the Technology Management as a base but tries to integrate the other two disciplines at the level of main processes. The assessment model is designed such that technology management capabilities can be measured and the correlations between the levels of capabilities and the organizational performance can be identified. Then, it is pilot tested with a questionnaire having three sections. The answers are collected from the companies operating in Defense sector in Izmir, and they are also the members of the Aegean Region Chamber of Industry. First pilot test was run to cover first 10 firms from the list in alphabetic order. After conducting the interviews with the first 10 firms, minor adjustments were made on some questions, and the managers of remaining 65 firms are interviewed within the next three months. Structured and face to face interviews have been performed with the top management of the firms. Interviewees were knowledgeable about the subject of technology management and about their companies; in case they felt that they did not have the appropriate information they called the expert to answer the related questions. The questionnaire used has three main sections: First section, (20 questions) focuses on general company information like employment figures, financial structure, customers, sectors serviced, quality documents, annual sales, R&D budgets, exports, imports etc. Second section, (30 questions) is designed for technology management capability assessment using a liker-scale 1-5 having a lowest rating of 1 and the highest 5 to identify the maturity level of the process. Third section (20 questions) focuses on the competitive advantage, performances, output and the outcome of the firm.

3.1 Proposed Model:

Focusing on the management theories, starting from the "Scientific Management", continuing with the systems, organizational theories and at the same time focusing on the productivity, efficiency, affectivity, value creation and competition concepts, it may be said that "Process Approach" has been used most widely in several management disciplines The majority of the management disciplines can be defined through the processes by referring to the advancements in pure and/or applied academic cycles. For example Project Management focuses on the set of processes; innovation and knowledge management follow the same pattern. While some of them clearly address the processes; some other of them refers to routines and yet still some of them to activities. From the simplicity standpoint we use the term process(es) in this study. Towards the end of 20th century, process approach with the help of information and communication technologies move to the front line. TQM, BPM and BPR were developed and become widespread. Several frameworks and models are developed with the help of process based approaches. Business processes are defined and redefined with some minor changes and improvements. Processes are grouped and regrouped with different associated names. Boundaries of the processes are redrawn in several applications. Taking the business processes as a whole, we can say that technology management is also a subset like knowledge, innovation and project management processes. The technology management subset is defined with 5 processes by Gregory (1995) and widely used by several researchers. After careful analysis of the models developed so far, technology management capability assessment model developed in this study focuses on multi-level processes management structure. Although technology management processes is the subset of the overall business processes, model takes the complete business processes into consideration in multi-level due to the strong interrelation among almost all business processes. Please see Figure-2 for the visual representation of the proposed model which shows the multi-level management processes including specifically:

1. Corporate Upper Structure Processes
2. Strategic Upper Structure / Planning Processes
3. Operational Processes
4. Support Processes
5. Technology Management Processes

6. Innovation Management Processes
7. Knowledge Management Processes.

3.1.1 Corporate Upper Structure Processes

These processes are the ones which are closely related to the owners and the public among the other major stakeholders. Processes are named as "Mission and Values Definitions", "Vision Development and Update", "Policy Development and Deployment", "Stakeholders Relations", "Technology Foresight". They are treated at the first level.

3.1.2 Strategic Upper Structure / Planning Processes

Taking basic inputs from Corporate Upper Structure Processes these processes create and manage the strategic decisions and directions. These groups of processes are namely "Strategic Planning", "Strategic Marketing (Market Pull)", "Technology Strategy Development (Technology Push)", "Business Planning and Budgeting" and "Project Management". They all are treated at the second level.

3.1.3 Operational Processes

These are the third level processes which are taking inputs from second level processes and the guiding principles from the first level. Processes are "Marketing and Sales", "Product and/or Services Design and Development", "Product and/or Service Realizations", "After Sales Services and Customer Relations".

3.1.4 Support Processes

These are the third level processes which are taking inputs from second level processes and the guiding principles from the first level. The processes are as follows: "Human Resources Management", "Facilities and Material Management", "IT Resources Management", "Financial Resources Management", "External Relations Management" and "Continuous Improvement and Change Management".

3.1.5 Technology Management Processes

These are the third level processes which are taking inputs from second level processes and the guiding principles from the first level. Processes are "Identification", "Selection", "Acquisition", "Exploitation", and "Protection".

3.1.6 Innovation Management Processes

These are the third level processes which are taking inputs from second level processes and the guiding principles from the first level. Processes are "Idea Generation", "Idea Evaluation", "Project Selection" and "Innovation Application/Realization". Innovation application may be a project and/or may be inserted into the related part of the routines as an improvement.

3.1.7 Knowledge Management Processes.

These are the third level processes which are taking inputs from second level processes and the guiding principles from the first level. Processes are "Knowledge Discovery", "Knowledge Capturing", "Knowledge Sharing" and "Knowledge Application".

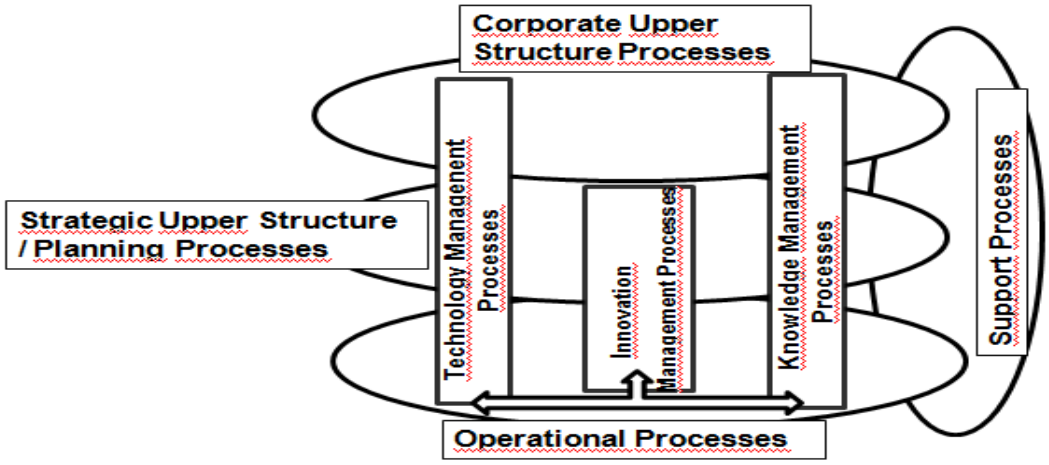

Figure-2. Proposed Technology Management Capability Assessment Model.

Our proposed model in this study covers all above given business processes which are needed to effectively manage and run any company. Several institutes, specifically like American Productivity and Quality Center (APQC) focus on to the similar frameworks in the industrial applications. And, as aforementioned, our basic goal in this study is to develop a model to measure the maturity levels of the processes to run the business. This in turn can be used to make a gap analysis to continuously improve all the business activities collectively.

Proposed model concentrates on Technology, Innovation and Knowledge Management processes as in the similar studies in the literature (Cetindamar et. al., 2009; Unsal 2009). As stated above, a 1-5 likert scale is used to measure the level of maturity of the processes which is taken from the well-known CMMI model. Measurement levels of any process stated in this study are:

1. Process is Undefined
2. Process is Partially Repeatable
3. Process is Defined
4. Process is Managed(output is measured)
5. Process is Continuously Improved

4. RESULTS

Interview results of the 75 firms were statistically analyzed, with the help of SPSS software PASW 18. Analysis results are presented below. Data gathered from 75 firms are tested for normality by using One-Sample Kolmogorov-Simirnov Test and found to be normally distributed. Please refer to Table -1.

Table -1 One-Sample Kolmogorov-Simirnov Test for 75 Firms

One-Sample Kolmogorov-Smirnov Test

		TECHNOLOGY MANAGEMENT PROCESSES	PERFORMANCE	COMPETITIVE ADVANTAGE
N		75	75	75
Normal Parameters[a],b	Mean	3,8287	3,7489	4,1600
	Std. Deviation	,61929	,61229	,52616
Most Extreme Differences	Absolute	,082	,074	,121
	Positive	,050	,074	,081
	Negative	-,082	-,072	-,121
Kolmogorov-Smirnov Z		,706	,642	1,050
Asymp. Sig. (2-tailed)		,701	,804	,220

a. Test distribution is Normal.
b. Calculated from data.

Recalling the research question 1, which is searching for the technology management capability level of the firms in Izmir, descriptive statistics are presented in Table-2.

Table-2 Technology Management Processes Descriptives

Descriptive Statistics for Technology Management Processes					
	N	Minimum	Maximum	Average	Std. Deviation
IDENTIFICATION	75	2,00	5,00	3,7533	,82353
SELECTION	75	1,50	5,00	3,9467	,75146
ACQUISITION	75	1,00	5,00	3,4133	,96431
EXPLOITATION	75	2,75	5,00	4,0900	,54624
PROTECTION	75	1,50	5,00	3,9400	,79253

Concerning the technology management processes of the 75 firms' averages, minimum value is seen as 1 in acquisition process and maximum value is seen as 5 in all 5 processes. The lowest average and the highest standard deviation occur in acquisition process as 3.41 and 0.96 respectively. The highest average value and the lowest standard deviation occur in exploitation process as 4.09 and 0.55 respectively. Overall average of the all five processes of the 75 firms is 3.8, out of 5 in other words on the average process maturity levels of the firms is close to the "managed" level.

In this study, we are also searching for any correlations among all major processes, between processes maturity and competitive advantage, between processes maturity and the performance (Research Question 2 : Are there any correlations among technology management capabilities of the firms and their competitive advantages, their performances, and their major processes?). As the results of the analysis, correlations are presented in Table -3. It is found that all correlations are significant at 0.01 levels, concerning not only the technology management processes but also the other main processes, performance and competitive advantage. This means that all processes closely related and interlinked to each other. They covary depending on the maturity levels of the processes. Similarly, correlations exist between the processes and competitive advantage and the performance.

Table-3 Correlation Matrix for the Main Processes, Competitive Advantage and Performance.

CORRELATION COEFFICIENTS	STRU	STRA	S P	KM	IM	TM	OP	CA	P
STRUCTURAL UPPER STR. P.	1	,683**	,492**	,615**	,485**	,596**	,801**	,412**	,323**
STRATEGIC UPPER STR. P.		1	,552**	,619**	,610**	,671**	,833**	,454**	,425**
SUPPORT PROCESSES			1	,549**	,515**	,606**	,765**	,517**	,518**
KNOWLEDGE MANAGEMENT				1	,576**	,546**	,823**	,402**	,367**
INNOVATION MANAGEMENT					1	,494**	,775**	,607**	,409**
TECHNOLOGY MANAGEMENT						1	,789**	,590**	,391**
COMPETITIVE ADVANTAGE								1	,571**
PERFORMANCE									1

** *Correlation* ***is significant at 0.01 level two tails***

On the other hand, to identify cause and affect relationships between the variables multiple regression analysis is performed. The outcome is such that direct effect of the processes over the performance is not significant, but Technology Management Processes and Innovation Management Processes relationships over the competitive advantage are significant at 0.01 levels (Table-4). This means that 48 % of the variations in the dependent variable "Competitive Advantage" can be explained by the variations coming from the independent variables namely Technology Management and Innovation Management Processes.

Table-4 Multiple Regression Analysis Results

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,693[a]	,480	,465	,38481

a. Predictors: (Constant), TECHNOMGT, INOVATION

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	9,825	2	4,912	33,174	,000[a]
	Residual	10,662	72	,148		
	Total	20,487	74			

a. Predictors: (Constant), TECHNOMGT, INOVATION
b. Dependent Variable: COMPETITIVE ADVANTAGE

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1,792	,298		6,016	,000
	INOVATION	,228	,064	,346	3,558	,001
	TECHNOMGT	,387	,083	,456	4,694	,000

a. Dependent Variable: COMPETITIVE ADVANTAGE

5. DISCUSSIONS

Analysis of the data collected from 75 firms shows similarities with the studies done by Unsal (2009). Basically, a result of the field study supports the hypothesis from the correlations standpoint and positive impact of the process based management approach over competitive advantage can be observed. On the other hand, the direct relationship between the process based management approach and the performance has not been observed. Similar results have been obtained by Unsal (2009). Basic findings corresponding to the research questions can be summarized as follows:

(1) Technology management capability levels of each and every 75 firms in the sample are identified. In other words, although not provided in details here in this paper, findings related to each and every elements of the Technology Management Capability constructs which are 5 main processes referenced in Gregory's study are also the output of this study. Based on the correlation results, except the protection process, almost all of the 4 processes namely identification, selection, acquisition and exploitation has significant impacts over the competitive advantage dependent variable. As compared to others, protection process has the lowest correlation coefficient but all 5 processes are significant at 0.01 level.

Positive direct relationships have been identified between the Technology Management Capability and the Competitive Advantage of the company. Besides this relationship, there is an also positive direct relationship between innovation management and competitive advantage.

(2) Correlations among technology management capabilities of the firms and their competitive advantages, their performances, and their major processes are significant at 0.01 level. Multiple regression analysis to show the cause and effect relationship results indicate that Technology Management Processes and Innovation Management Processes relationships over the competitive advantage are significant at 0.01 levels. Similar kind of impact was also expected for Knowledge Management Processes but it did not come out as an output of the multiple regression analysis as they may be dominated by Innovation Processes. As in the Unsal's study, results related to the impact on performance are in line with our findings. Several studies in the literature show that activities related to the continuous improvement of the processes improve the output and results. In turn this has an impact on competitive advantage and with some delay over the performance too. Especially if these improvements are not supported by innovation activities, expected benefits on performance may delay. It is always good to have incremental improvements in the processes but exploratory improvements are also needed to have competitive advantage and the superior performance. This may favor the ambidexterity and balancing of all type of improvements including continuous step by step improvements and radical changes like exploratory improvements. Findings of this study which is reflected on the regression analysis as cause and effect relationship among Technology Management Processes, Innovation Processes and Competitive Advantage are in favor of this comment. On the other hand, within the performance context, only one year performance data seem to be not enough to make an evaluation especially focusing on sustainability and the randomness of success. Studies in performance focus multiple year results and the trends (Kirby, 2005; Richard et. al., 2009). Besides the performance, the study may also be enriched by focusing on the knowledge management processes considering that the term technology contains know-how and know-why. Further researches, analysis and more literature reviews may improve the assessment model structure.

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