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Identifying Target for Technology Mergers and Acquisitions Using Patent Information and Semantic Analysis

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***Abstract*--Technology plays an increasingly important role in today's enterprise competition. Technology mergers and acquisitions (Tech M&A), as an effective way to acquire external technology resources rapidly, have attracted attention from researchers because of their potential realization of value through synergy. A big challenge that faces corporate managers and government policy makers is how to identify the appropriate target to support effective technology integration. In this study, we develop a model of target selection of Tech M&A from the perspective of technology relatedness and R&D capability. We present the results relating to M&A in the field of cloud computing in China.**

I. INTRODUCTION

Rapid technological change and diverse customer needs make firms face increasing pressure of innovation. When enhancing the innovative capabilities, even the largest and most technologically self-sufficient firms do not always have the time to build their own new technologies from scratch[1]. Getting external technology resources to enhance existing technology portfolios has been a preferred choice for firms[2].

Technology mergers and acquisitions (Tech M&A), as an effective way to get external technology resources, have been a hot topic since the 1980s. Tech M&A can enable a firm to gain contact at the research frontier in the field of competence[3]. On the other hand, firms can enter a new technology area by Tech M&A aiming at reducing risk through technology technological diversification[4]. The research on Tech M&A can be divided into three stages:

In the first stage, scholars found that the some firms could develop significantly faster after acquiring some small technology-based firms. Granstrand et. Al [5] summed up 5 key factors to Tech M&A success based on 13 M&A events in high tech industries.

In the second stage, researchers began to explore motivations of Tech M&A and evaluate performance, especially from the perspective of finance. Scholars used multi-dimensional indexes and chose various time frames to evaluate acquisition performance[6].

Now, in the third stage, research on Tech M&A tends to be diversified, including Tech M&A integration, Tech M&A mode, and Tech M&A target selection. Paruchuri [7] analyze the relationship between the research personnel and innovation output during Tech M&A integration. Tian and Xin [8] identify attributes of target companies and propose a theory to support the decision making of acquiring companies through four in-depth case studies conducted across three primary sectors in the Medical Technology Industry. Lin [9] tests an acquisition–learning–innovation framework and finds that unrelated acquisitions also enhance exploration in an era of technology fermentation. Research at this stage mainly focuses on performance evaluation after Tech M&A. Few studies have been conducted on target selection pre-acquisition.

The volume of Tech M&A events has been steadily increasing in recent years. However successful Tech M&A is not easy. Some studies point out that the failure rate of Tech M&A is pretty high -- between 70% and 90%[10]. Taking account of the $2 trillion transactions of M&A every year, the failures are extremely costly. Tech M&A success or failure can be determined by many factors, like strategy formulation, technology relatedness, and financial status. But the most fundamentally important step to increase the success of M&A projects is to select the right target companies, which are well matched to the strategic purpose of a given M&A action[11].

Existing studies on identifying M&A targets concentrate primarily on development or application of financial and managerial variables such as firm size, cash flow, and debt-to-equity ratio as indicators for pricing and valuation, but do not consider the technological perspective[12][13]. The main purpose of Tech M&A is to gain technological synergy to enhance innovation capability. Technology relatedness as a main factor effecting technological synergy should be carefully considered in the pre-acquisition stage.

In this paper, we seek to devise new measurement methods from the perspective of semantic analysis and patent IPCs to analyze technology relatedness, including technology similarity and technology complementarity of Tech M&A. We take into account R&D capability as well to propose a systematic framework for target selection. We present results for a firm in China, Huawei Technologies Co. Ltd (Huawei), in the field of cloud computing.

II. CHALLENGES

Tech M&A, by its very nature, is a method to get external technology resources. The primary factor in target selection of Tech M&A is technical relatedness. However few methods have been proposed to analyse it. A big challenge that faces corporate managers and government policy makers is how to confirm a methodological architecture to help them identify

the appropriate target to support effective technology integration.

Our research is based on the following driving questions:

1. How do we use a quantitative method to measure technology relatedness?
2. What factors should be considered for effective technology integration based on the analysis of technology relatedness?
3. How to devise a comprehensive method from the perspective of technology relatedness and technology integration on post-acquisition stage?

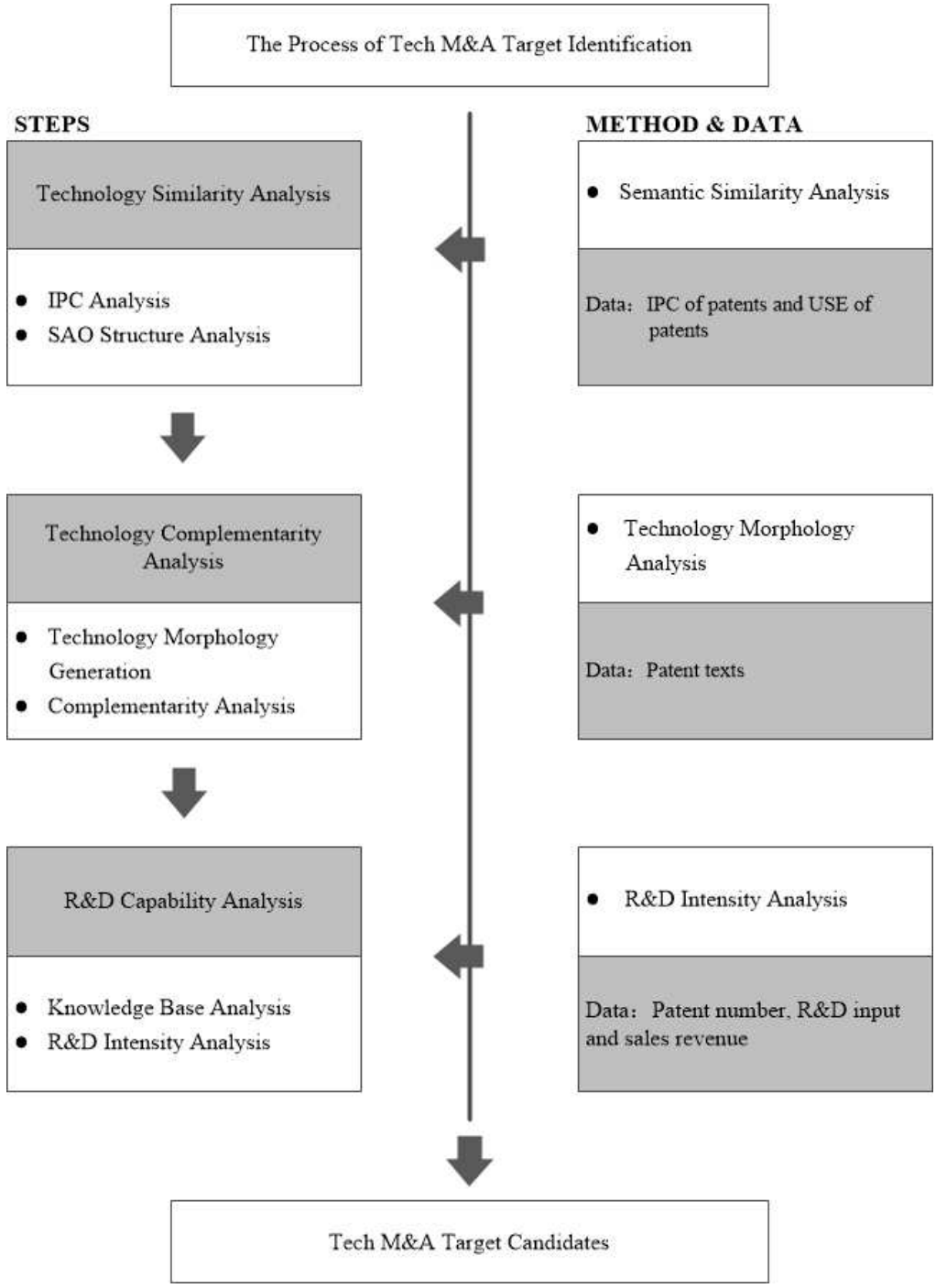

Fig. 1.Tech M&A Target Identification Process

In this study, we divide the method of Tech M&A target selection into three steps based on patent analysis. Figure 1 shows the process.

Step 1: Technology Similarity Analysis—— The purpose of this step is to calculate the technology similarity of the acquirer and target to reduce the scope for step 2. First, IPC of each patent will be extracted and the degree of overlap will be regarded as the preliminary evaluation of consistency of technology area. Second, we measure technology similarity through Subject – Action – Objective (SAO) analysis of USE in the abstract of patents after choosing the potential candidates of high consistency with the acquirer.

Step 2: Technology Complementarity Analysis—— This step is based on results of Step 1. Technology morphology analysis is introduced to help with the complementarity analysis. First, we extract keywords from patent texts and arrange them according to the related technology. Second, we calculate the complementarity of each technology combination with the help of expert experience.

Step 3: R&D capability analysis—— We use knowledge base and R&D intensity as indicators to make further selection of potential targets after the first two steps.

III. METHOD

In this study, we try to provide detailed guidance for identifying potential Tech M&A targets from a technological perspective based on patent information. Patents have long been considered to be up-to-date and valuable information sources in technology, and careful analysis of patents could provide information of not only technological competitiveness, but also overall technological opportunity in the specific technology areas. Therefore, the technological capabilities of a corporation can be represented by its set of patents[14]. Rapid technology renewal keeps emerging technology a hotspot in Tech M&A for years, and we choose a representative one -- cloud computing technology, focusing on opportunities within China.

Patents for cloud computing are collected from the Derwent Innovations Index (DII), employing the search strategy by Owens [15], from 2000 to 2012. We get 621 patents on cloud computing of China after data cleaning.

For technology similarity analysis, we extract the IPCs of every patent and measure the consistency of technology area with the method of Makri [16]. After that, NLP tools are used to extract the SAO structures from the patents collected with the help of open API. In order to identify the semantic similarity of SAO structures, a semantic knowledge base, *WordNet*, is introduced to calculate the similarity between two words or phrases in the SAO structures.

We conduct technology complementarity analysis based on the theory of technology morphology. First, we extract the keywords from patents and map them into their associated morphology. Second, we evaluate the technology complementarity level with the help of experts and calculate the technology complementarity by the extension of common technology complementarity.

We analyze the R&D capability from the view of knowledge base and R&D intensity of potential targets. Knowledge base of a firm is measured by the related number of patents, and R&D intensity is measured by the a firm's ratio of expenditures on R&D to the firm's sales.

V. RESULTS

A. Patent Collection

The patent database consists of 621 DII patent abstract records chosen with the search strategy by Owens. Table 1 lists the top 10 assignees. According to technology development strategy and the layout of the cloud computing technology area, we choose Huawei Corp (Huawei) as an acquirer to search for Tech M&A targets. Huawei is a global leading provider of Information Communication Technology solutions, and is also the most professional one-stop cloud service provider in China. Huawei has been expanding the layout of cloud computing since 2010, and in the year 2011, Huawei acquired Huasy for 5,300 million dollars to enhance the security of cloud platforms. Tech M&A is regarded as an important way to achieve rapid development of related technologies on cloud computing for Huawei.

TABLE 1. TOP 10 ASSIGNEES IN CLOUD COMPUTING

Assignee Names	Patent Number	Percentage
ZTE Corp	52	8.4%
Microsoft Corp	41	6.6%
Inspur electronic information co ltd	33	5.3%
LI Z (Individual)	24	3.9%
Huawei Crop	23	3.7%
IBM Corp	21	2.7%
Univ Qinghua	19	2.1%
Hon Hai Precision Ind Co Ltd	19	1.9%
Guangdong Electronics Ind Inst Co Ltd	17	1.4%
Univ Beijing Aeronautics & Astronautics	15	1.4%

B. Technology Similarity Analysis

Literature on Tech M&A suggests that the maximum benefits from an acquisition can be realized when technology portfolios of both firms are related[17]. Technology similarity as a part of technology relatedness describes the degree to which the technological problem solving of two companies focuses on similar, narrowly defined areas of knowledge. It could promote technology integration and reduce non-novel R&D projects to achieve economies of scale[18]. We apply Makri's theory to make a preliminary assessment of technology similarity between the Acquirer and the Target (A&T) with the help of IPC analysis. IPC of patents show the distribution of technology area. Technology similarity of firms with high consistency of technology distribution will probably be higher than the others'. The measure of technology similarity is described below. The Total Patent A&T in the formula means the total number of patents of both the acquirer and the target.

$$Technology\ Similarity = \frac{Overlap\ All\ Patent\ Class}{Total\ Patent\ A\&T} \times \frac{Total\ Acquirer\ Patent\ In\ Common\ Classes}{Total\ Acquirer\ Patent} \quad (1)$$

We extract IPC information from the patents collected to illustrate technology similarity. We refine the data first. Individual assignees and firms whose total number of cloud patents are fewer than 6 are excluded. Second, we define the degree of "common classes." For example, there are three patents P_1, P_2, P_3 with the IPC H04L29/08, H04L29/06, H04H60/72. P_1 and P_2 represent similarity because they are under the same subcategory H04L29, and the combination with P_3 does not. In this way, we calculate the technology similarity between the acquirer and the potential target for each of the leading Chinese firms in the domain. The results are shown in Table 2. The left part of the table is the potential target list and the right part is the evaluation of technology area. We can find that GCI SCI&Technology Co Ltd (GCI), Shanghai Hechen Information Technology (Hechen), ZTE Corp (ZTE), and Shuguang Cloud Computing Technology Co (Shuguang) offer high consistency in technology area. The IPC distribution is densely located in H40L29 and G06F09.

We further analyze technology similarity from the perspective of SAO structure of patent text. The SAO structure can express the precise meaning and can thus represent technological key-concepts and key-findings in the patent[19]. Moehrle et al. [20] proposed a method of using patent-based inventor profiles to guide human resource decisions. Park et al. [21] used semantic patent maps to identify technological competition trends for R&D planning.We extract the USE from the abstract of patents and then transform the content to SAO structures (Table 3). After filtering out some duplicated SAO structures using a set of stopwords (STOPWORDS, 2011)[22], we get the data ready for semantic analysis.

TABLE 2. PRELIMINARY TECHNOLOGY SIMILARITY ANALYSIS

Potential Targets	**Preliminary Technology Similarity Analysis**
GCI SCI&Technology Co Ltd	0.064
Shanghai Hechen Information Technology	0.061
ZTE Corp	0.058
Shuguang Cloud Computing Technology Co	0.053
Inspur Electronic Information Co Ltd	0.048
Hon Hai Precision Ind Co Ltd	0.036
Microsoft Corp	0.024
IBM Corp	0.014
Beijing Z & W Technology Consulting Co. Ltd.	0.011
Yulong Computer Telecom Technology	0.009
Shenzhen Zidong Technology Co Ltd	0.008

TABLE 3 SAMPLE OF EXTRACTED SAO STRUCTURE FROM PATENTS

S (Subject)	**A** (Action)	**O** (Object)
Method	Execute	Software application e.g. batch application and user-interactive application, on a computer system, according to a SLA
System for creating a composite public cloud	Delivery	Hosted services
Method	Schedule	Cloud computing open platform
Virtualized desktop application display platform	Used	Cooperative computing of an electric power system
System	Control	Quantum microscopy instrument
Issuing network invoice	Based	Cloud computing and data asynchronous transmission technology
Method	Protect	Data and privacy of user in cloud environment
Multi-tenant service providers	Request	Dynamic platform reconfiguration
Distributed systems on a set of computer processors	Perform	Coordinated upgrades
Experiment cloud platform system	Manage	Computer calculation and software resources

WordNet-based semantic similarity between two SAO structures is computed by using the C# library [23]. We set a threshold value as 0.7 to determine if the two SAO structures are the same according to semantic similarity calculation results and the advice of experts. If the result is more than s, the two structures can be considered the same. For any two SAO structures (SAO_i and SAO_j), we determine the Similarity (SIM) between them as:

$$SIM(SAO_i, SAO_j) = \begin{cases} 1, & if\ (Measure(SAO_i, SAO_j)) \geq s \\ 0, & otherwise \end{cases} \quad (2)$$

The USE of a patent may include more than one SAO structure. We define the semantic similarity between the patents as the basis of how many SAO structures the two patents share. Suppose that there are two patents P_1 and P_2, and we denote that $Num_{SAO}(P_1)$ is the number of SAO structures in patent P_1, $Num_{SAO}(P_2)$ is the number of SAO structures in patent P_2, and $Num_{SAO}(P_1, P_2)$ is the number of the semantically identical SAO structures shared by patents P_1 and P_2. The Patent Similarity (PSIM) can be described as:

$$PSIM(P_1, P_2) = \frac{2 \times Num_{SAO}(P_1, P_2)}{Num_{SAO}(P_1) + Num_{SAO}(P_2)} \quad (3)$$

After measuring the similarity between patents, we take the pairwise average similarity of patents owned by two different firms as the technology similarity. For any two firms (F_1, F_2), Firm Technology Similarity (FSIM) could be measured as:

$$FSIM(F_1, F_2) = \frac{\sum_{i=1}^{i=PN(F_1)} \left(\sum_{j=1}^{j=PN(F_2)} PSIM(P_i, P_j) \right)}{PN(F_1) \times PN(F_2)} \quad (4)$$

Here, $PN(F_1)$ and $PN(F_2)$ are the patents of the two firms (F_1 and F_2) respectively, and the $PSIM(P_i, P_j)$ means the patent similarity of the two firms. We list results in Table 4. We find that the top 3 firms with highest technology similarity with Huawei are GCI, ZTE, and Hechen. The result agrees with the IPC analysis that technology similarity of firms with high consistency of technology distribution is higher. We choose the firms whose technology similarity with Huawei is not less than 0.7 for technology complementarity.

C. Technology Complementarity Analysis

Analysis of technology complementarity is based on the result of the technology similarity analysis. Technology complementarity is considered as an important driver of invention[24]. Acquiring complementary technologies can promote exploratory learning within the organization, which may accelerate the process of innovation[25]. Different from technology similarity, complementary technology contributes to post-merger invention performance by stimulating higher quality and more novel inventions[26]. Sparse research has been conducted on the measurement of technology complementarity at the pre-acquisition stage. In this paper, we introduce morphology analysis for this. Technology Morphology Analysis was introduced to patent assessment by Yoon[27] and now is widely used for technology opportunity analysis. technology complementarity before Tech M&A can be evaluated by analyzing different technology morphological combinations with the help of expert experience.

First, we convert the patents into structured data using keyword vectors according to their frequency of occurrence and with reference to technology dictionaries. Second, we set words associated with a specific technology and appearing frequently as keywords. Then, we map the patent keywords into their associated morphology and get Table 5, which shows the main technologies, subdivision technologies, and the corresponding keywords of cloud computing from the patents.

TABLE 4. TECHNOLOGY SIMILARITY EVALUATION OF POTENTIAL TARGETS

Potential Targets	Technology Similarity
GCI SCI&Technology Co Ltd	0.75
ZTE Corp	0.73
Shanghai Hechen Information Technology	0.72
Shuguang Cloud Computing Technology Co	0.69
Inspur electronic information co ltd	0.69
IBM Corp	0.68
Microsoft Corp	0.66
Hon Hai Precision Ind Co Ltd	0.64
Beijing Z & W Technology Consulting Co. Ltd.	0.62
Yulong Computer Telecom Technology	0.58
Shenzhen Zidong Technology Co Ltd	0.57

TABLE 5. TECHNOLOGY MORPHOLOGY OF CLOUD COMPUTING

Main Technology composition		Sample Keywords
Display Technology	Based on plug-in	Flash, Silverlight, JavaFX
	Based on browser	HTML5, Ajax, CSS3
Multi-tenancy	Shared nothing	Separate database, Separate schema
	Shared hardware	Shared Database, separated data storage, Additional storage subsystems
	Shared everything	Shared schema, network monitoring, Shared schema
Virtualization	Platform virtualization	Virtual Machine Monitor, Hypervisor, Host OS
	Resource virtualization	Load balancing, Monitoring Resources
	Application virtualization	Virtual terminal, remote Access，application Access
Security	Application security	Anti-virus services, Network security monitoring, DDoS attack warning
	Platform security	Access control management, Security API, Network security
	Infrastructure security	Secure Hypervisor, Full Disk Encryption, Secure Virtual Machine
Distributed Storage		Horizontal scalability, area network storage, secret sharing

After that, we generate a table of subdivision technology complementarity according to experts' assessment for complementarity between Huawei and the potential targets. If the firms have related patents, we add a group of lines to indicate that they have related technologies. The groups of vertical lines and horizontal lines reflect the technology distribution of Huawei and the target respectively. The depth of background colour of each cell shows the complementarity level, which is divided into 3 layers and the white background means the two technologies have no complementarity. The crossing lines with red background mean the two firms have complementary technologies. The table is symmetrical, so we take the lower triangular region for analysis. We set the degree of complementarity to three levels marked by the depth of colour and the three levels are set as 1, 2 and 3 for calculation. To measure the technology complementarity, we just need to take the cells with crossing lines and background into consideration. Again we suppose there are two firms F_1 and F_2. We denote the related patent number of F_1 and F_2 in the *i*th cell with crossing lines and red background as $F_1PN(i)$ and $F_2PN(i)$. The complementarity formula between the two firms is below:

$$Complementarity = \sum_{i \in D} (F_1PN(i) \times F_2PN(i) \times complementarity\ level) \quad (5)$$

where the D means the technology areas in which the technologies of the two firms are complementary. After calculating the complementarity of all the potential targets with the acquirer, we normalize the result by calculating the percentage of each complementarity result in the sum of all the complementarity results.

We take GCI (GCI SCI&Technology Co Ltd) as an example. The technology complementarity of the two firms is shown in Table 6. The two firms have complementary technologies in the area of display technology area and security technology area, of which the cells appear with crossing lines and red background. For GCI, 1 patent is on display technology of based on plug-in, 2 patents are based on browsers, and 2 patents on application virtualization. For Huawei, 3 patents are on platform security. Using (5), we calculate the technology complementarity as 39. We can compute the technology complementarity for the remaining firms in the same way. We then carry out a normalization process. Technology complementarity of other potential targets is listed in Table 7. ZTE has the highest complementarity with Huawei, the second being GCI, and the third being Hechen.

D. R&D capability analysis

Previous literature indicates that R&D capability is an important factor of technology integration and innovation after Tech M&A[.28] Acquiring firms with high R&D capability will promote technology integration and technology synergy creation after Tech M&A[29]. In this study, we use the absolute size of the knowledge base measured by the number of related patents and R&D intensity to evaluate the R&D capability of candidate acquisitions. R&D intensity is defined as the ratio of expenditures by a firm on R&D to the firm's sales. We use the average of three years' ratio. All of the three firms can be target candidates for Huawei from the perspective of Tech M&A, and ZTE is the most appropriate target. Considering the scales of the three firms, if Huawei hopes to become the leading firm through Tech M&A, ZTE Corp could be the better target; if Huawei hopes to enhance subdivision technologies in cloud computing, Shanghai Hechen and GCI would be the better choice.

TABLE 6. TECHNOLOGY COMPLEMENTARITY OF HUAWEI AND GCI

GCI / Huawei	Based on plug-in	Based on browser	Shared nothing	Shared hardware	Shared everything	Platform virtualization	Resource virtualization	Application virtualization	Application security	Platform security	Infrastructure security	Distributed Storage
Based on plug-in												
Based on browser												
Shared nothing												
Shared hardware												
Shared everything												
Platform virtualization												
Resource virtualization												
Application virtualization												
Application security												
Platform security												
Infrastructure security												
Distributed Storage												

Note: complementarity level 1 shown by complementarity level 2 shown by and complementarity level 3 shown by

TABLE 7. TECHNOLOGY COMPLEMENTARITY EVALUATION OF POTENTIAL TARGETS

Potential Targets	Technology Complementarity
ZTE Corp	0.56
GCI SCI&Technology Co Ltd	0.23
Shanghai Hechen Information Technology	0.21

TABLE 8. APPROPRIATE TARGET CANDIDATES OF TECH M&A FOR HUAWEI

Potential Targets	Knowledge Base	R&D Intensity
ZTE Corp	52	0.12
Shanghai Hechen Information Technology	13	0.06
GCI SCI&Technology Co Ltd	10	0.05

V. CONCLUSIONS

This paper presents a framework to identify and evaluate companies from the technological perspective to support M&A target selection decision-making. The paper takes technology similarity, technology complementarity, and R&D intensity as main indicators to evaluate potential targets. First, technology similarity is preliminarily evaluated according to patent IPCs. Further analysis is conducted using SAO-based semantic similarity analysis. The approach enables one to extract the technological key-concepts and key-findings in patents and can complement the IPC-based analysis. Firms with high technology similarity with the acquirer can be selected.

Second, technology morphology analysis is introduced to analyze the technology complementarity between the targets and the acquirer. Keywords are mapped into their associated morphology. Technology complementarity level is set by the experts to all the possible technology combinations. The technology complementarity can be computed according to the patent distribution and the corresponding technology complementarity level. Thus, firms are further selected.

Third, this paper uses R&D capability, including the absolute size of knowledge base and R&D intensity, to help choose the targets for an acquirer. We verified the usability and practicality of the method by applying it to patents related to cloud computing technologies, and selected Huawei Technologies Co. Ltd. as an example to assess Tech M&A in the cloud computing technology area.

During the whole analysis process, we keep in contact with department of cloud computing of Huawei. Huawei showed interest in our research results, especially the measurement of the technology similarity and technology complementarity. Huawei extended the further requests for the research including further technology similarity and complementarity analyses and the analysis of technology development trends of cloud computing, to support the firm's present work.

However, there are a few limitations in the study. Some doubt remains regarding the reliability of patent data. Sometimes patent data cannot reflect the core technology of a firm because an emerging technology is not yet allowed for patenting. The analysis based on patents does not take the tacit knowledge into account. Another limitation is to what extent the framework can be applicable to other industries. Firms in some kinds of industries may not have many patents, though they have complex knowledge. Other indicators, such as the stage of technology development and the range of multiple sector interests of the players, should be considered in further study.

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