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Using AHP in patent valuation

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Abstract

As the knowledge economy rapidly increases, intangible assets are more valuable to businesses and valuing them attracts much research from the field of technology management. Intangible assets include intellectual capital and intellectual property. Intellectual property is often protected by patents. Since the enterprise is willing to pay the patent costs to guarantee a sustainable competence, it would be useful to be able to determine when it is worthwhile. We propose an objective scoring system for intellectual property patents from the licensor side in this study using the AHP. We used it to value the patents for new products being developed by an actual enterprise.

Keywords: Intangible assets; Intellectual property rights; Patent valuation; AHP; SAW

1. Introduction

Intellectual Property Rights (IPRs) can be highly valuable and play a key role in many fields of business. The first IPR evaluation was concerned with Brand Valuation. Recently, the concern about IPR has broadened to include all Intangible Assets [1]. There has been much research based on an accounting perspective. In this study, we take a multi-dimensional perspective for valuing IPRs. Intellectual Property Rights include brand valuation, trademark rights, patent rights, copyrights and so on; but in this paper, we only focus on patent rights.

A patent can be described as an exclusive right of limited duration over a new, non-obvious invention capable of industrial application, where the right to sue others for infringement is granted in return for publication of the invention. There is a distinction between the underlying invention which might be called the underlying intellectual asset and the intellectual property right which confers exclusive rights over that invention as defined in the claims of the relevant patent [2]. Patents can be obtained for any new and useful process, new machine, manufacture or composition of matter, or anything *new*, *useful*, and *non-obvious* (three requirements for a patent), in relation to the prior art. However, a patent cannot be obtained for a system of doing business, an arrangement of printed matter, a mental process, computer applications, and product configurations [3].

For those managing both patent applications and already granted patents, it is essential to know the value of each sufficiently and accurately if one is to make well-founded decisions about their management. Since only a small

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proportion of patents turn out to be of extraordinary value in the long run and IP department budgets are always limited it is important to be able to value them. Any methods that lead to a better understanding of the value of given patent applications or patents should be welcomed [2]. Maskus [4] also pointed out that the statistical correlation between IPRs and economic growth is positive only under some circumstances. Patents are a major force in the world economy, and their value is one of only a few metrics commonly employed to gauge the tides of new ideas and innovation that are driving our economy. Even with the present declining rates of R&D investment, leading nations spend over $1 billion dollars each day to generate intellectual property. There are over 7 million patents in force worldwide, and the number is growing at 12% to 14% per year. Patent licensing revenues are growing at 25% to 35% per year, generating global revenues in excess of $150 billion. For example, in the US, the leading patent generating nation in the world, annual patent issuances have nearly doubled from 96,727 in 1990 to 187,822 in 2001. And, during 2002, 45% to 75% of the market capitalization of the Fortune 500 companies consisted of intangible, intellectual capital assets such as brands, patents and knowledge [5].

The most fundamental task supporting empirical analysis is to measure the strength of IPRs on a consistent basis that is applicable internationally. This is an especially difficult task, and any numerical measures that claim to capture IPRs accurately are subject to sharp criticism. IPRs may be compared in importance to other underlying characteristics that govern economic structures such as factor endowments, infrastructure, and the judicial system. Unlike tariffs, IPRs are not readily measurable, nor do they have an obvious impact on prices. This also means over-emphasizing the quantitative tool for IPRs is not appropriate. Complicating the picture is the fact that identical laws may have different effects in countries that vary in market structures and preferences [4]. It is impossible to account fully for the magnitude and strength of IPRs on a comparative basis across countries. Instead, economists develop qualitative rankings, based on laws, of IPRs as measures of inputs into economic and social production [4].

For example, some analysts count the number of World Intellectual Property Organization (WIPO) conventions of which nations are members as a measure of commitment to minimal global standards. However, because these conventions cannot be enforced, membership reflects a “best-efforts” commitment without much meaning. Thus, economists have found little correlation between membership and international economic activity [6]. In a word, intellectual property rights are very hard to measure [4]. We can’t value IPRs by a single dimension: it is necessary to know the value of patents from multiple dimensions such as [7] financial accounting (purchase price allocation, impairment testing), tax purposes (change of ownership, licensing in or out), merger and acquisition (M&A) purposes (influence on purchase price determination, single patent transactions) and financial and securitization purposes (refinancing costs, start-up financing). Therefore numerous researchers have tried to measure patent values or price patents from various aspects. Parr and Smith [8] divide all possible types of valuation of individual patents into Cost, Market, and Income based methods. The latter includes simple discounted cash-flow (DCF) methods [8]. A report from Arthur Andersen has divided valuation approaches into Cost, Market Value and Economic Value methods [1]. We summarize the valuation methods for individual patents for the purpose of discussion as follows:

(1) Costs: Cost based methods
(2) Market conditions: Market based methods
(3) Income: Methods based on projected cash-flows
(4) Time: DCF Methods allowing for the time value of money
(5) Uncertainty: DCF Methods allowing for the friskiness’ cash-flows
(6) Flexibility: DCF based Decision Tree Analysis (DTA) methods
(7) Changing risk: Option Pricing Theory (OPT) based methods
  (a) Discrete time: Binomial Model (B-M) based methods
  (b) Continuous time: Black–Scholes (B–S) option pricing model based methods.

The categorization above is not comprehensive because its development from the Black and Scholes [9] equation has been adjusted in numerous ways to take account of extra features such as dividends, changing underlying asset volatility and changing interest rates. However, even the most sophisticated adjustments cannot take all factors into account. Option pricing theory concerning share options, for example, assumes that competition will abolish arbitrage opportunities and yet whilst substantially correct, small differences in transaction costs, trading practices and information flows may give rise to apparent arbitrage opportunities when prices are compared with their theoretical values [10]. It needs to be remembered therefore that any valuation method is merely a starting point or a small step towards better decision making [2]. The above-mentioned methods consider only the quantitative viewpoint, not the qualitative perspective. Cromley [11] provided 20 steps for pricing a patent from different perspectives. The 20 steps are: (1) check whether the patent is in force, (2) identify the context, (3) gather information, (4) assemble a valuation team, (5) read the patent, (6) investigate the patent's scope, (7) talk with a patent attorney, (8) inquire about the patent's validity, (9) inquire into blocking patents, (10) consider synergies among patents, (11) investigate foreign patent protection, (12) consider the remaining life of the patent, (13) analyze any prior royalties paid for the patent, (14) inquire into any actual or threatened litigation involving the patent, (15) identify the next-best alternative technologies, (16) estimate a demand curve for the patented item, (17) determine the patented product's point of profit maximization, (18) consider the applicability of traditional valuation approaches, (19) do an income-approach valuation, and (20) write the patent valuation report [11]. In this paper, we propose a measurement system that includes both quantitative and qualitative perspectives from multiple dimensions.

The aim of valuing patents is to enable enterprises to know their value sufficiently accurately and objectively so they can make well-founded management decisions. Since the enterprise is willing to pay to have a patent to assure its sustainable growth, we propose an objective scoring system using AHP for patent valuation and apply it to an actual enterprise. The purpose of this paper is to lay out the important criteria and their weights for patent valuation. These criteria include qualitative and quantitative factors. We use four main dimensions to value a patent; they are technology essence, cost dimension, product market and technology market. First, technology essence includes four subcriteria: refinement, application scope, compatibility and complexity. Second, the cost dimension includes three subcriteria: R&D cost, transfer cost and reference cost. Third, the product market dimension includes four subcriteria: product life cycle stage, potential market share, market size and utility/advantage. Fourth and last, the technology market includes three subcriteria: number of supplier, number of demander and commercial level. Our results show product market is the most important dimension and its most important subcriterion is utility/advantage. We used this scoring system on an empirical case to test its usefulness.

This paper is organized as follows. Section 2 includes important criteria for valuing a patent or intellectual property. The model construction and implementation are shown in Section 3. Section 4 is the application of the method to an actual case. Finally, conclusions and recommendations are presented in Section 5.

2. Factors of technology valuation

There has been much research into the criteria that should be used for the valuation of technology. Bidault [12] provides four factors for technology pricing which include "profitability of a technology", "cost of research and development", "transfer cost" and "other costs". The profitability of a technology includes four sub-factors: potential market and future market share, total production cost, investment turnover rate before licensee pays royalty, the apportioned cost ratio between licensor and licensee and the method of payment by licensee. The cost of research and development includes two sub-factors: on the licensor side they are think about the saving cost, time and risk; on the licensee side, it depends on R&D cost alone. Transfer cost is the only factor that can be estimated currently. According to Teece [13], the definition of transfer cost means the cost of transferring and absorbing specific knowledge about enterprises, systems and industry to make the technology transferred effective. Four factors influence the transfer cost: they are characteristics of technology provider, characteristics of technology, application ability of technology by licensee and economic conditions of licensee. Other factors are industry standards and tort cost. According to Arnold [14], the factors of technology value are: essentialness of technology, cost factors, product market factors, competitive factors, protection of intellectual property rights, resources of the licensee, law and political affairs and contract factors. These eight kinds of factors all affect technology pricing; however, a patent (one kind of intellectual property rights) is concretely related to the present technology value. With patents increasingly sharing the spotlight with brands in the world of intellectual capital assets and market capitalization analyses, it has become essential that patents join brands in lining up against traditional approaches to setting asset values [5].

As a matter of fact, despite the diversity of articles from industrial organizations or legal scholars on value-related issues of intellectual property rights, there is a lack of scientific papers that present the knowledge on the evaluation of patent rights from a corporate perspective. Reitzig [15] provides the evaluation of patent rights from a corporate perspective by building on earlier works by Pakes [16] and Harhoff et al. [17]. It turns out that valuation approaches using patent indicators seem especially convenient for the assessment of patent portfolios comprising a large number of intellectual property rights [15].

Table 1
Indicators of patent value

Patent age	Number of claims
Market value of corporation	Patenting strategy
Backward citations	Number of applicants
Forward citations	Number of trans-boarder research co-operations
Family size	Key inventors
Scope	Legal disputes (opposition in particular)
Ownership	

Source: Reitzig [15].

Table 2
Scientific-based indicators of patent quality

Indicators	Definitions
Current Impact Index (CII)	Number of citations generated by a company's most recent 5 years of patents, divided by the expected number of citations for similar high-tech companies.
Science Linkage (SL)	Average number of "other references cited" on the front page of the patent, including academic journal articles and papers presented at scientific meetings.
Technology Cycle Time (TCT)	Median age (in years) of earlier US patents referenced on the front page of a US patent.

The value of individual intellectual assets is rarely observable. Harhoff et al. [17] show in a formalized fashion that for a corporation involved in technological competition, the value of a patent is best defined as its asset value. To determine a patent's value, it is therefore necessary to consider its effects on prices, costs and sold quantities of patent-protected products by the owner and its simultaneous effects on the proprietor's competitors. As Reitzig [18] shows in a survey of the theoretical literature, counterfactual effects should become assessable when quantifying the patent's following latent value determinants: state of the art (of existing technology), novelty, inventive step, breadth, difficulty of inventing around, disclosure and dependence on complementary assets.

A variety of variables have been tested as indicators of patent value in empirical surveys. Reitzig [15] analyzes the appropriateness of the 13 best-known indicator variables for business purposes by 23 empirical studies related to patent indicators and value. Table 1 shows known patent value indicators.

Forward citations, family size and the ownership variable show the highest degree of theoretical and empirical validation. However market value also seems to be a good indicator for a company's intellectual property assets. Pioneering work on analyzing the relation between backward citations and patent value has been carried out by Narin et al. [19]. Forward citations were introduced by Trajtenberg [20] and were validated as indicators of patent value in numerous subsequent surveys, e.g. by Albert et al. [21], Harhoff et al. [17], Lanjouw and Schankerman [22] and Harhoff and Reitzig [23]. Family size, and other indicators known from earlier work of Grefermann et al. [24], were introduced as a value indicator by Putnam [25] and re-validated by Lanjouw and Schankerman [22], Harhoff and Reitzig [23] and Guellec and van Pottelsberghe de la Potterie [26]. The correlation between market value and patents has been examined by Griliches [27], Conolly and Hirschey [28], Megna and Klock [29] and Hall et al. [30]. All the studies mentioned above differ with respect to the quality of the research design, the sample sizes and the kinds of patents.

Hirschey and Richardson [31] provide three scientific-based dimensions of patent quality. These are listed with their definitions in Table 2. In addition, McMillan and Thomas [32] developed a valuation of companies based on the quality of their patent portfolios where patent quality was measured using a number of patent citation indicators. The underlying assumption in patent citation analysis is that a patent which is highly cited is an important and valuable one. McMillan and Thomas [32] presented some indicators of patent quality. They are CII, SL, TCT and R&D intensity (R&D expenditure/sales).
A patent, as distinct from any underlying invention, is valued by how much the returns from all possible modes of exploitation of the patented invention are greater than those that would be obtained in the absence of the patent.

Making such a distinction is difficult even when the returns from the patented invention are well defined. However in the early life of the patent or application many other types of uncertainty are also involved such as uncertainties about both the technical and commercial success in competitive markets of the underlying invention as well as uncertainties about the legal challenges the application and subsequent patent may have to face during its life.

According to Razgaitis [33], the AHP, used as the evaluating method in this paper, is a rating/ranking method. There has been little research to date on patent valuation using AHP.

3. Evaluation structure

The purpose of this section is to describe the patent valuation hierarchical structure we used. The AHP, developed by Saaty [34], is a robust and flexible multi-criteria decision analysis methodology. Formulating the decision problem in a hierarchical structure is the first and probably the most important step. Once the hierarchy has been constructed, the decision maker begins the prioritization procedure to determine the relative importance of the element in each level of the hierarchy. Then, based on the results of interviews with experts, we determined the licensees' and licensors' preference weights for each criterion in our evaluation structure.

We established our evaluation hierarchy shown in Fig. 1 by studying the literature in Section 2 and conducting interviews with experts. The goal is in level 1. In the second level are the four main criteria including essence of technology, cost dimension, product market and competitive dimension. In the third level are the sub-criteria: four for essence of technology, three for cost dimension, four for product market and three for competitive dimension.

The four subcriteria for essence of technology are refinement, application scope, compatibility and complexity. Refinement means that complete technology or a ripe technology is more valuable than a technology needing sustained developing or improving. A technology that has more scope for application is more valuable. Compatibility means the degree to which it advances existing technology. Complexity means the level of the licensee's technology, or the relative support for the technology afforded by the licensor. The four sub-criteria under the cost dimension are R&D cost, transfer cost and reference cost. The R&D cost is the cost of the research and development process. The transfer cost includes the cost of pre-engineering technological exchange, engineering costs, cost of R&D personnel, pre-start-up training costs and excess manufacturing costs. Reference cost includes industry standards for the price of the technology, the price of competitive or similar technology, investment return rate and tort cost. The four sub-criteria for product market are product life cycle, potential market share, market size and utility/advantage. The utility/advantage factor means that if a new technology can create a new market, its value is higher than any of the existing market technologies. The technology market dimension has three sub-criteria: number of technology providers, number of technology demanders and commercial level. Commercial level means technology that is likely to advance commercial success is more valuable than the technology for non-commercial areas or for uncertain markets. All the criteria were evaluated using the AHP pairwise comparison process by experts from the academic field or business field having various viewpoints.

The case we studied is that of C Company, a small enterprise in Taiwan. Because the iPod, an MP3-MPEG (Movie Picture Experts Group) 1 Layer 3 player made by Apple Co., is currently a hot trend the owner of C Company wants to produce an MP3 player to capitalize on this hot trend. We want to help the owner of C Company find the most suitable technology to make an MP3 player. From the United States Patent Office's PTO Patent Full-Text and Image Database, we found 24 patents related to MP3 players. We sifted four alternatives that seemed to have the most promise from the 24. These four alternatives are described as follows:

Alternative A is an MP3 player with an integrated camera. Its inventor is Deok-Joon Yang from the Republic of Korea. The ornamental design for this MP3 player integrated camera is its most distinguishing feature. Its patent number is D512,404 filed December 6, 2005.

Alternative B is another MP3 player with the same inventor and filing date as alternative A having patent number D512,403.

Alternative C is a single button MP3 player. Its inventors are Michael M.Austin (Lilburn, GA), Kevin K. Maggert (Lilburn, GA) and Lori D. Perry (Lawrenceville, GA). Their device includes an electronic accessory having a single button that actuates all of its control features. In one embodiment, the accessory is an MP3 player with songs stored on a multimedia card. Once the card has been loaded with songs and inserted, the MP3 player is coupled to an energy source with the energy source preferably being a cellular telephone. After coupling, all of the functions of the MP3 player are controlled with its single button. When using the cellular telephone as a power source, power is actuated by pushing the button for one second. Volume is adjusted by toggling the button laterally. Tracks are selected by pushing

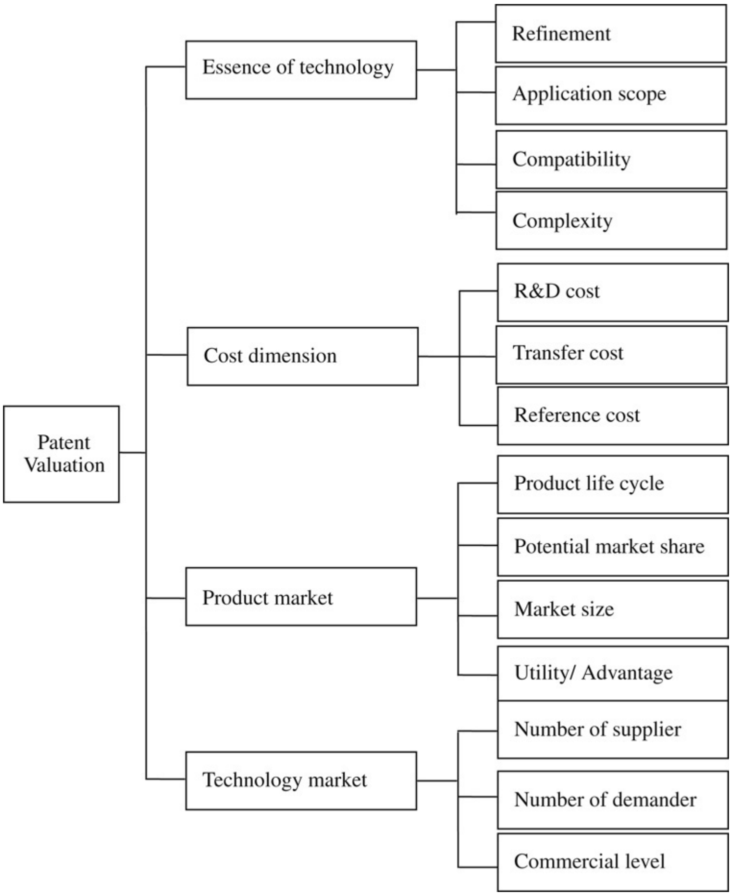

Fig. 1. Patent valuation hierarchy structure.

the button quickly while power is applied. Power is turned off by depressing the button for two seconds or more. Its patent number is 6,590,303 and the filing date is July 8, 2003.

Alternative D is a dual-mode MP3 player. Its inventors are Chin-Yao Chang (Taipei, Taiwan) and Wen-Hwa Chou (Taipei, Taiwan). Its patent number is 6,631,098 and the filing date is October 7, 2003. This portable MP3 player has two operation modes. In the first mode, the portable MP3 player operates independently. A controller in the MP3 player first reads MP3 files from internal memory then uses an MP3 decoder to decode the MP3 files. In addition, the audio data are output to an earphone or a speaker. In the second mode, a docking station is provided for the MP3 player which has an extended memory device, e.g. a CD-ROM, for storing a second group of MP3 files. The controller of the portable MP3 player accesses the second group of MP3 files via interfaces that are connected when the portable MP3 player is placed in the docking station. The MP3 decoder of the portable player is also used to decode the second set of MP3 files and the corresponding audio data are output through the docking station.

4. Actual example and discussion

In this research, we take the licensor's perspective to value the technologies/patents. The experts' judgments were solicited by questionnaire. We used the AHP in Fig. 1 to determine the weights of the elements in each level then ranked the alternatives by the Simple Additive Weights (SAW) method. A final appraisal score A_i for each ith alternative is computed by multiplying the jth criterion importance weight w_j by the 5-point scale of the ith alternative on the jth criterion. The preference is then ordered according to the score. The alternative that has the highest score is chosen as the best. For m attributes and n alternatives, when a decision maker assigns a set of importance weights

Table 3
Weights of patent valuation system

Aspects level	Weighting value	Criteria level	Weighting value
Essence of technology	0.155	Refinement	0.021
		Application scope	0.031
		Compatibility	0.055
		Complexity	0.048
Cost dimension	0.236	R&D cost	0.079
		Transfer cost	0.078
		Reference cost	0.079
Product market	0.454	Product life cycle	0.061
		Potential market share	0.091
		Market size	0.140
		Utility/advantage	0.162
Technology market	0.155	Number of supplier	0.023
		Number of demander	0.025
		Commercial level	0.107

Table 4
Performance value of each alternative and the ranking results

Alternatives	SAW value (A_i)	Rank
A—MP3 player with integrated camera	3.805	2
B—MP3 player	3.345	4
C—single button MP3 player	3.450	3
D—dual-mode MP3 player	3.976	1

to attributes, the most preferred alternative (A^*) is selected such that

$$A^* = \left\{ A_i \,\middle|\, \max_i \sum_{j=1}^{m} w_j x_{ij} \right\}, \quad i = 1, 2, \ldots, n;\ 1 \le x_{ij} \le 5 \tag{1}$$

where x_{ij} is the rating of the jth attribute on the ith alternative. The x_{ij} rating scale [1,5] is defined in the following way: 5 means very good; 4 means good; 3 means fair; 2 means poor; 1 means very poor. We used the software "Expert Choice 2000" to calculate the weights. Expert Choice 2000 makes structuring and modifying the hierarchy simple and quick and it eliminates tedious calculations. The resulting weights are shown in Table 3. Based on the interviews with the experts and the results from the questionnaires, the weight or performance value for each alternative and their ranks are shown in Table 4.

Product market has the highest importance (0.454) followed by cost dimension (0.236). It means that having a market for the product is essential to make more profits. Profit is everything and the only thing for the survival of an enterprise. In addition, cost is more important than the other two factors: essence of technology and technology market. This result is consistent with technology pricing methods. Cost, income and market are the most popular methods for pricing technologies. Under the essence of technology level, compatibility has the highest relative importance (0.055). It means that the degree of existing technology in the company is the first concern. In this situation, the licensee will have to consider the compatibility of its existing technology with the patented technology if it wants to buy that patent. The three criteria under the cost dimension have almost the same importance. Therefore, research and development cost, transfer cost and reference cost are equally important. Both the licensee and the licensor are equally concerned with the three kinds of cost. Under the product market factor, utility/advantage has the highest relative importance (0.162). This means that the likelihood that a new technology can create a new market is very much emphasized by decision makers. Under the technology market, commercial level has the highest relative importance (0.107). This means commercial success is a key factor in technology markets. If a technology is not commercially viable, its value would be very low (no value).

The SAW value is calculated by Eq. (1). According to the rank of the four alternatives, the best choice is to license alternative D, a dual-mode MP3 player, from Chang and Chou in Taiwan. And the second choice is the alternative A, the MP3 player with integrated camera. If it proves to be hard to negotiate a license for the first alternative, C Company has a close second choice in the MP3 player with integrated camera.

5. Conclusions and recommendations

Banks, investors and insurers now have come to acknowledge that patent rights have considerable influence on the value of enterprises and on the stability of patent-based business models in the "knowledge economy" [35]. Past studies have shown that patent evaluation should be measured both by the quantitative and qualitative aspect using multiple dimensions. Therefore, we successfully established a patent valuation system from the perspective of a licensor using AHP in order to determine the importance of patent valuation indicators. Our work should provide a starting point for decision makers to evaluate patents for developing new products as they follow or extend our efforts. The C Company was satisfied with our finding that their best option was to license the dual-mode MP3 player from its Taiwanese inventors. Further, the negotiations about the royalty rate and other details for transferring the technology to C Company have begun. There are still many limitations to this study; for example, the characteristics of patents and the factors that should be included in any evaluation vary according to the industry. Consequently, one must not think the characteristics of patents are common and we need to study different industries in the near future. We hope we can extend the study as soon as possible.

Finally, the results in this study are as viewed from the licensor side. We would like to establish a patent valuation hierarchy system for both licensors and licensees in forthcoming research.

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