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IPMS Implementation Efficiency Study Based on Chinese IPMS Standard GB/T 29490

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Abstract

Intellectual property management system (IPMS) standard GB/T 29490-2013 which aims at creating a culture of intellectual property management and improving intellectual management level for enterprises was published by Chinese government in 2013. The main objective of this research is constructing a method to calculate the relative efficiency of IPMS implementation according to the audit result of IPMS standard in order to help manager and IPMS training & consultant body to improve the system to be more efficient and more compliant to IPMS standard. Two evaluation models have been developed so as to achieve the valuation of inputs and outputs which are used in calculating the relative efficiency of IPMS implementation efficiency using Data envelop analysis. The case study indicates the method developed in the research can be effectively applied in benchmarking to find out the deficiency of IPMS practices and enhance the IP management level of efficient companies and to help certification body to figure out the limitation of the audit and improve the audit skill.

Key words: Intellectual property management system; Efficiency evaluation; Standard implementation comparison; DEA

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INTRODUCTION

Innovation is the process of value creation and the impetus for forming competitive advantages. Meanwhile intellectual property is regarded as the powerful tool for protecting innovation and profiting from innovation. Innovation and intellectual property culture need to be propagated by effective measures. Since quality culture spread all over the whole value chain of industry through the implementation of IS0 9000 series in 1990s (De Casanove, Morel, & Negny, 2017), we assume innovation management and IP management system standard could have the same affection as them.

In recent years, different kinds of standards for innovation management, intellectual capital management and intellectual property management have been published or proposed (Clausen & Alvestad, 2015) including DIN SPEC 91281, implementation of process-oriented knowledge management in small and medium-sized enterprises; DIN 77100 :2010, patent valuation-general principle for monetary patent valuation; FD X50-146:2010, innovation management-intellectual property management. European committee for standardization published innovation management series CEN/TS 16555, the 4th part of which is intellectual property management. In the same year, a national standard GB/T29490 which sets out the requirements for an intellectual property management is published by standardization administration of China. This standard is promoted by government aiming at creating intellectual property management culture and improving intellectual management level for enterprises. Meanwhile, as a member of technical committee ISO/TC 279, whose purpose is to develop, maintain and promote standards of innovation management, standardization administration of China put forward the proposal based on GB/T29490 to set up intellectual property management standard as one of the standards in the innovation management standard ISO 50500 series at the 4th plenary of ISO/TC 279. This

standard known as ISO/AWI 50505 is approved as new project in Feb. 2017 and under the development now.

By the end of 2017, 180,000 companies obtain the certification of GB/T29490 in China. It is no doubt most of the company has realized the importance of intellectual property and enhanced the ability to management intellectual property through the implementation of this national standard. But either for companies who implemented or will implement the standard or for the IPMS training & consultant body, even for IPMS certification body, to know the extent to which the efficiency of IPMS implementation based on the standard the company achieve is very important. Especially for an IPMS training & consultant body, which is the key point for the successful implementation of IPMS from the perspective of the complexity of the IPMS and specialization of IP, to have a tool which can measure the efficiency of IPMS implementation of their clients quantitatively is primary for helping their clients improve their performance on IPMS.

1. CONCEPTUAL FRAMEWORK

GB/T 29490 was originally proposed to help company fulfill total IP management not just for supporting innovation. IP strategy, recourse management, organizational design, communication for internal and external, R&D, purchasing, marketing and production are all to be concerned by the requirements of the standard for the purpose of improving the total management skill of IP. As a generic standard, it contains the minimum requirements which help company establish and maintain a documented intellectual property management system. The main requirements of it are comprised of Intellectual Property Management System; Management responsibility; Resource Management; Resource Management; IP life-circle management; implementation and operation; review and improvement and each of them are detailed. The basic IPMS requirements of GB/T 29490 are listed in table1.

Considering that the main purpose of the proposal of the standard shares commons with ISO 9001-2008 which, at least to some extent, belongs to total quality management (Mo & Chan, 1997; Taylor, 1995; Ho, 1997) and it is more easier to facilitate the integration with different management systems, the framework of the standard is constructed based on ISO 9001-2008. The same as ISO 9001, when developing, implementing and improving intellectual property management system, the companies are required by this national standard GB/T29490 to adopt prosses approach to make sure the implementation of their IPMS enable them to enhance innovation capability and develop new competitive advantages. Process approach can also help companies achieve continuous improvement by dynamic circulation. By optimizing IP resources configuration and enhancing effectiveness of IP management, this approach makes it possible for companies to control the interrelationships and interdependencies among the processes of whole system.

From the definition of process approach (I.O.f., 2015) we can see an organization can achieve value-adding by planning and carrying out processes under control (Cianfrani, Tsiakals, & West, 2002). We also can view the process approach as a powerful way of organizing and managing work activities to add value through IPMS implementation. In other words, IPMS practices which is in line with the standard can lead positive effects, for instance, competitive advantage, innovation advantage. So, from this perspective, we created IPMS practices compliance evaluation model and IPMS effectiveness evaluation model to achieve the evaluation of inputs and outputs for further IPMS implementation efficiency calculation.

Table 1
The basic requirements of GB/T 29490

Basic requirements	Contents
Management Responsibility	Management Commitment; IPR policy; Planning; Responsibility, authority and communication; Management Review
Resource Management	HR; Infrastructure; Financial Resources; Information Resources
IP life-circle Management	Maintenance; Application; Protection; Contract Management; Secrecy management
Implementation and Operation	project approval; Research and development; Purchasing; Production; Sales and after-sales
Review and Improvement	Internal Audit; Analysis and Improvement

1.1 Intellectual Property Management System (IPMS) Practices Compliance Evaluation Model

For evaluating the extent to which the company IPMS practices conforming to the requirements in standard GB/T 29490 through the implementation of IPMS, this model was developed according to both GB/29490 and previous studies of intellectual property management.

Since this model is original in many respects, in-depth interviews with 5 experts from certification body and training & consultant body were conducted to find feasibility for model design and to refine the measurement items for the model. The final IPMS practices compliance evaluation model consists of five main-criteria tiers (Management responsibility; Resource Management; IP life-circle management; implementation and operation; review and improvement) and corresponding sub-criteria tiers with 40 measurement items in all. The model is shown in Table 2.

Table 2
IPMS practices compliance evaluation model

Main-criteria tiers	Sub-criteria tiers
Management Responsibility (Kaynak, 2003; Sıtkı İlkay, Aslan, 2012; Reitzig, 2007)	top management has been committed to IPM. (u_{11}) IP policy and objectives has been developed properly by top management. (u_{12}) Top management can ensure the allocation of the resources needed by IPM. (u_{13}) Top management's review can effectively evaluate the whole IPMS periodically. (u_{14}) IP policy and objectives are understood by the employees. (u_{15}) IP-related law and regulations are comprehended by staff in the whole company. (u_{16}) In-house and inter-company coordination and communication are effectively conducted under IP management representative. (u_{17}) There is enough direct interaction between IP management representative and top management on IP-related issue. (u_{18})
Resource Management (Kaynak, 2003; Davis, Harrison, 2002; Poltorak, Lerner, 2011)	The employees are trained periodically according IPM requirements to their section. (u_{21}) Enough IP-related training given to managers and supervisors throughout the company. (u_{22}) Noncompetition agreements and confidential disclosure agreements are well used to protect trade secret. (u_{23}) Incentive mechanism is conducted well on encouraging employee to create, protect, use intellectual property. (u_{24}) Financial resources and infrastructures are guaranteed for running the IPMS. (u_{25}) IP information management mechanism can be used well for decision-making in important field of technology management, acquiring external technology sources and commercialization technology. (u_{26}) Disclosure of information is well controlled. (u_{27})
IP life-circle Management	IP acquisition is aligned with our IP policy and objectives. (u_{31}) Adequate retrieval and analysis are conducted before IP acquiring. (u_{32}) IP review and assessment are well conducted during the IP maintenance. (u_{33}) Docketing system has been established for IP maintenance. (u_{34}) Viable proposition and IP assessment are made before licensing and assignment. (u_{35}) Due diligence is made thoroughly before merge and acquisition. (u_{36}) IP monitoring mechanism is established to help prevent our company from infringing other's IP. (u_{37}) IP monitoring mechanism is established to help provide information about infringement of our IPR in time. (u_{38}) Contingency plan has been made to deal with IP dispute. (u_{39}) IP-related contract can be made properly to reduce IP risk. (u_{310}) Confidential information, zone, employee has been identified to protect trade secret. (u_{311})
Implementation and Operation	Enough investigation can be made before project starting in order to avoid spending time and money where a blocking IP is hold by competitors. (u_{41}) IP risk assessment can be made according to which project proposition will be established. (u_{42}) Identifying the partner in the value chain and competitor in the market through the combination of IP and marketing analysis. (u_{43}) Enough IP investigation is made through the product development according to which research trajectory can be adjusted in time. (u_{44}) Research records are kept well. (u_{45}) Researchers can report the invents of which they can seek for legal protection during the product development in time. (u_{46}) The reports wrote by researchers can be assessed in time to make decision to apply for legal protection. (u_{47}) Enough investigation for IP background of product purchased is made to reduce IP dispute. (u_{48}) Innovation of product and process in production can be assessed and identified in time to pursue IP protection. (u_{49}) Marketing monitor mechanism can discover infringement of our IP at the very first time. (u_{410}) Before launching the new product to the market, IP investigation are made thoroughly in order to make IP protection and risk aversion plan. (u_{411}) We got enough IP protection through advertising and exhibition. (u_{412})
Review and Improvement	Internal audit is conducted periodically to make sure the system is consistent with the standard. (u_{51}) Improvement of the IPMS and IPM practices has been made according to the result of the internal audit. (u_{52})

To be continued

Continued

1.2 IPMS Effectiveness Evaluation Model

GB/T29490 is designed as a framework to improve the effectiveness of intellectual property management system(IPMS). (AÖztaş, Güzelsoy, & Tekinkuş, 2007; Neely, Gregory, & Platts, 1995) defined the effectiveness as the extent to which outputs or results meet the goals. From the perspective of quality management, some study describes effectiveness of quality management system as the extent to which the quality objectives are achieved (Van der Spiegel, et al, 2007; Al-Nakeeb, et al, 1998). As quality management system GB/T19000-2008 (A.O.C., 2008), the counterpart of ISO 9001-2005 (A.O.C., 2005) in China, is one of the normative references of GB/T29490, the terms and definitions in ISO 9001-2005 and GB/T19000-2008 is applicable to GB/T29490. So the 'IPMS effectiveness' can be defined as the extent to which planned results are achieved according to (A.O.C., 2008 & 2005) and (Van der Spiegel, et al, 2007; Al-Nakeeb, et al, 1998). Hence, in order to develop the IPMS effectiveness evaluation model, the objectives of the standard and the measurement items should be identified firstly. As described in the standard GB/T29490, through the

implementation and continual improvement of IPMS, the outputs include promoting innovation ability, improving market position, supporting continual improvement, enhancing competitive advantage. Based on the premise that market position is relative to the degree and nature of product differentiation of the market and publics' perceptions and evaluation of productions and firms (Wind, 1977; Botha, Crompton, & Kim, 1999), we regard the market position as part of the competitive advantage and discussed them together.

1.2.1 Competitive Advantage

Competitive advantage is a series of traits which contributes to the owner outperforming their competitors. (Porter, 1985) defined it as an advantage gained by creating more customers value than competitors by lowering price or by achieving the same goal at a comparable cost but in a unique way to gain a higher price. It means you can win the game either by being cheaper (low cost) or by being different(differentiation). According to Porter's Competitive Advantage model (Porter, 1985), players using offensive or defensive strategy, for instance, product quality strategy, cost leadership strategy, differentiation strategy, in order to seek for defensible position over their competitors and gain ROI (Return on Investment).

IP strategy can be deployed to optimize the financial return by using different IP tactics to gain competitive advantage. IP strategy should be used to make sure new technology is protected to obtain sustainable competitive advantage and minimizes re-invention to save money and time during development (Cronin, 2010). Three most important ways intellectual property rights can help a company gain competitive advantage are providing a temporary technological lead (incumbency), protecting brand names and helping form an industry standard. According to survey, prevention of copying, creating a monopoly in the market, gaining negotiation advantage, earning of license revenue, prevention of infringement suit and enhance company's reputation are the most mentioned benefits by managing IP (Hall & Ziedonis, 2001; Cohen, Nelson, & Walsh, 2000; Barton, 1998).

Based on Porter's model (Porter, 1985) and literature review (Li & Zhou, 2010; Molina-Azorín, Tarí, & Pereira-Moliner, 2015; Teo & Pian, 2003; Salavou & Halikias, 2009), we intend to use differentiation advantage, cost advantage and institutional advantage scales to measure the competitive advantage gained by company managing their IP (see Table 3).

Table 3
Competitive advantage measurement criterion

Differentiation advantage ($\mathbf{u_{61}}$)
Our trademarks and brands we built makes it difficult for our competitors to copy. ($\mathbf{u_{611}}$)
The protection of our innovation by IP makes it difficult for our competitor to imitate. ($\mathbf{u_{612}}$)

To be continued

Continued

Our protection of trade secret and HR management help us embody our advantages not in individuals but in the company. ($\mathbf{u_{613}}$)
Using combination of different kinds of IP to keep vertical differentiation and horizonal differentiation of our products to make them unique. ($\mathbf{u_{614}}$)
Able to use design patent to differentiate product in the market. ($\mathbf{u_{615}}$)
Cost advantage ($\mathbf{u_{62}}$)
IP management helps us minimize re-invention to save time and money in development. ($\mathbf{u_{621}}$)
By lowering budget of infringement suit we can invest more into innovation. ($\mathbf{u_{622}}$)
Our IP help us attract more venture capital and private equity investors. ($\mathbf{u_{623}}$)
Our products or services have more competitive price than our competitors. ($\mathbf{u_{624}}$)
Use of IP in vertical relations with suppliers and customers to sustain low cost. ($\mathbf{u_{625}}$)
Institutional advantage ($\mathbf{u_{63}}$)
Our early-warning mechanism established by running IPMS can provide us enough IP information to make tactical decision and reduce the potential damage. ($\mathbf{u_{631}}$)
Our IP emergency-respond system established by running IPMS enables us to work out contingency dispute, conflicts or emergency situation timely. ($\mathbf{u_{632}}$)

1.2.2 Innovation

As defined by Schumpeter, "innovation is the market introduction of technical or organizational novelty, not just its invention". It means an idea or invention must be replicable and introduced to the market to satisfy customer's specific need. Innovation process has been divided into four dimensions: invention, innovation, diffusion and imitation (Burton-Jones, 2001). Dealing the big challenge of innovation is not just how to creating the value from it but how to capture that value you created. Implementation of intellectual property management system properly is the key point to insure company to enhance innovation capacity and appropriate from innovation through all these four parts mentioned above. Creating suitable intellectual property environment can help build protective barriers around innovation to proffer the innovator a better market share. Owning either the invention which has strong IP protection or natural barriers or owning the complementary technology or/and assets are two vital points to a successful innovation (Teece, 1986; Teece, 2000; Teece, 2006). By managing your IP effectively, many tactics can be used to restructure your IP environment (Peters, Thiel, & Tucci, 2013). For instance, for incumbent, making your patented technology being recognized by a standard-setting organization can reduce the probability of reverse engineering. For new entrants, acquiring enough "defensive" patents enable you cross-license your competitors to insure your design freedom (Reitzig, 2004; Fisher III & Oberholzer-Gee, 2013). Along with the benefits and forces behind increased open innovation, the role of IP in interfirm cooperation in R&D has been discussed intensively. For radical product innovation is evidently less achieved by company their own, boundaries of enterprises must be opened (Gassmann & Bader, 2006). The challenges come along with it is how

to manage IP generated during the open innovation process. Firms even find IP is more important when they engage in open innovation than in closed innovation (Chesbrough, 2003; Holgersson & Granstrand, 2017).

Many measurement indicators have been developed for innovation capability.(Chen, Zhu & Yuan Xie, 2004; Kleinschmidt, & Cooper, 1991; Al-RefaieGhnaimat, & Ko, 2011; Prajogo & Hong, 2008; Lew, & Sinkovics, 2013; Subramaniam & Youndt, 2005). We developed three basic scales measurement model for innovation capability based on the literature review.

Table 4
Innovation

Innovation achievement ($\mathbf{u}_{71}$)
Number of patent applications (last year) ($\mathbf{u}_{711}$)
Percentage of new developed product sales in total sales (last year) ($\mathbf{u}_{712}$)
Number of new developed technologies has introduced to the market (last year). ($\mathbf{u}_{713}$)
Number of intellectual property rights issued (last year) ($\mathbf{u}_{714}$)
Innovation mechanism ($\mathbf{u}_{72}$)
Ability of monitoring technology resources in the market by patent information management ($\mathbf{u}_{721}$)
Ability of integrating new technology resources in open innovation safely under the cooperation agreement management. ($\mathbf{u}_{722}$)
Ability of keeping design freedom by IP management. ($\mathbf{u}_{723}$)
Seek IP protection in time in order to introduce new products quickly to the market ($\mathbf{u}_{724}$)
Multiple IP tactics are used to secure innovation in the market. ($\mathbf{u}_{725}$)
Employees get more incentives in innovation by IP incentive program. ($\mathbf{u}_{726}$)
Innovation culture ($\mathbf{u}_{73}$)
Innovation atmosphere has been enhanced by IP management ($\mathbf{u}_{731}$)
Awareness for supporting innovation of top management is enhanced by implement of IP management system. ($\mathbf{u}_{732}$)

1.2.3 Continuous Improvement

Deming described continuous improvement as "improvement initiatives that increase success and reduce failures" (Juergensen, 2000). Another more practical definition is from the work of (Boer, et al, 2017), the author defined it as a planned, organized and systematic process which aims at improving company performance. As continuous improvement requirements are fully embedded in ISO9001 (Gotzamani, 2005), to fulfill the continual improvement an organization should understand and evaluate its current situation in order to identify the areas which should be improved in the QMS (Tsim, Yeung, & Leung, 2002), especially after the certification the requirements give the organization the opportunities to improve the effectiveness which has been achieved. Continuous improvement has the equal importance for IPMS as for QMS, the objective of continuous improvement of GB/T29490 is to enhance an organization's ability to ensure the IPMS to be consistent with the internal and external business environment and to keep it effective. Through reviewing IPMS policy and objectives, monitoring the whole management process, observing the output satisfaction degree to the expected goal, organization can ensure their whole business process satisfying the requirements of the GB/T29490. As alike as ISO 9001, an effective business plan, an organization structure supporting the continuous improvement also could be the measurement variables. We developed the measurement model adapted from the work of (Psomas, Kafetzopoulos, & Fotopoulos, 2012).

Table 5
Continuous improvement

We set up business plan which is effective enough for continuous improvement of IPMS. ($\mathbf{u}_{81}$)
Individual groups use company's strategic goals and objectives to focus and prioritize their improvement activities. ($\mathbf{u}_{82}$)
The enabling mechanisms used effectively to encourage involvement in continuous improvement are monitored and developed. ($\mathbf{u}_{83}$)
We develop the organization structure to support the continuous improvement of IPMS($\mathbf{u}_{84}$)
Our IPMS is consistent with external and internal environment well no matter how they change. ($\mathbf{u}_{85}$)
The improvement area of the IPMS are identified. ($\mathbf{u}_{86}$)
The improvements of the IPMS are confirmed through the internal audits. ($\mathbf{u}_{87}$)
The implementation process of IPMS can be continuously corrected through the monitoring and reviewing by explicit assessment. ($\mathbf{u}_{88}$)
The IP strategy can be modified properly according to result of the internal audit and management review. ($\mathbf{u}_{89}$)

1.3 The Methodological Framework

An IPMS certification body usually audit a certain number of organizations in a relative narrow time window. Similarly, an IPMS training & consultant body usually have a certain kind of clients in the same industry at a certain time period. For these auditees or the clients of training & consultant body, they usually have the similar starting-up time for IPMS implementation, similar initial certification audit time and surveillance audit time. We choose 5 companies in access control industry which are the clients of one training & consultant body in Xiamen Fujian province, China. Two of these companies are Xiamen IP advantage company and China high technic company. These five company have almost the same start-up time and initial certification audit time. We collected the data in the period of the first surveillance audit one year after the initial certification audit. Firstly, we use GEM (group eigenvalue method) to find out the weight of every measurement items. The fuzzy comprehensive evaluation method is used to evaluate the degree of IPMS practices conformation to the requirements in the standard and effectiveness of IPMS implementation. Letting the evaluation score of the IPMS practices conformation to be the input and evaluation of effectiveness of IPMS implementation to be the output we use Data Envelopment Analysis to calculate the overall relative efficiency of IPMS implementation based on standard GB/T 29490. The companies with the relative lower efficiency can be found and the improvement method can be identified.

1.3.1 Data envelopment Analysis

DEA was first put forward by (Charnes, Cooper, & Rhodes, 1978), which mainly uses the mathematic method to evaluate relative efficiency of multiple decision making units(DMU). Generally, the efficiency value of DMU is defined as the weighted outputs divided the weighted inputs. Setting weights of inputs and outputs to be variable and making the efficiency value of the most effective DMU equal to 1 while other DMUs less than 1 under the same weight, it ingeniously avoids assigning the weights by real people. The basic DMU model is known as CCR, this model is a typical model to analyze the efficiency of DMU with multiple inputs and outputs. The Fractional Programming of input-oriented CCR (CCR-I) is given by (Charnes, Cooper, & Rhodes, 1978) as follow:

$$\begin{cases} \max h_{J_0} = \dfrac{\sum_{k=1}^{s} u_k y_{kj_0}}{\sum_{i=1}^{m} v_i x_{ij_0}} \\ s.t. \dfrac{\sum_{k=1}^{s} u_k y_{kj}}{\sum_{i=1}^{m} v_i x_{ij}} \le 1 \; j = 1,2,\cdots,n \\ u \ge 0 \\ v \ge 0 \end{cases} \quad (1)$$

$$k = 1,2,\cdots,s \quad i = 1,2,\cdots,m$$

where x_{ij} is the amount of input i of DMU j; y_{kj} is the amount of output k of DMU j; is the weight for input i, u_k is the weight for output k, m is the number of input, s is the number of output; n is the number of DMUs. Under the constraint sets we try to find a set of weights to maximize h_{j0}. If the result of the objective function (1) is efficiency score 1, the DMU_{j0} is considered efficient, otherwise it is considered inefficient. The dual of equivalent linear programming of (1) is used to calculate which is written as follow:

$$\begin{cases} min\theta - \varepsilon(e_s^T S^- + e_m^T S^+) \\ s.t. \quad \sum_{j=1}^{n} X_j \lambda_j + S^+ = \theta X_0 \\ \sum_{j=1}^{n} Y_j \lambda_j - S^- = Y_0 \\ S^+ \ge 0, S^- \ge 0, j = 1,2,\cdots,n \end{cases} \quad (2)$$

Where X_0 and Y_0 are input and output vector for j_0, $X_0 = (x_{1j0}, x_{2j0}, \cdots, x_{mj0})^T$; $Y_0 = (y_{1j0}, y_{2j0}, \cdots, y_{sj0})^T$; $X_j = (x_{1j}, x_{2j}, \cdots, x_{mj})^T$; $Y_j = (y_{1j}, y_{2j}, \cdots, y_{sj})^T$; slacks $S^- = (s_{1j}^-, s_{2j}^-, \cdots, s_{mj}^-)^T$ and $S^+ = (s_{1j}^+, s_{2j}^+, \cdots, s_{sj}^+)^T$ imply the surpluses and slacks of inputs and deficiency of outputs; ε is a small positive number; $e_s = (1,1,\cdots 1)^T \in R^S$; $e_m = (1,1,\cdots 1)^T \in R^m$.

λ_0^*, s_0^{*-}, s_0^{*+}, θ_0^* are the optimal solution of (2). When $\theta_0^* = 1$, $s_0^{*-} = 0$, $s_0^{*+} = 0$ DMU j_0 is efficient, it lies on the efficient frontier. From technology perspective, it implies the optimal combination of inputs has been made to achieve the best output. If $\theta_0^* < 1$, DMU j_0 is inefficient. The value of θ_0^* is also the proportional reduction of input needed for unit DMU j_0 to be efficient. If we let $\overline{X_0} = \theta_0^* X_0 - s_0^{*-}$, $\overline{Y_0} = Y_0 + s_0^{*+}$, then $(\overline{X_0}, \overline{Y_0})$ is the projection of (X_0, Y_0) onto efficient frontier. The projection is the reference for us to improve the inefficient DMU.

As we discussed in section 2, process approach is a value-adding process, so we assume IPMS effectiveness are raising partly when IP management level is improving. Also, the main objectives of this study is finding out the deficiency of IPMS practices and enhancing the IP management, so we chose IPMS practices as inputs and IPMS effectiveness as outputs to assess the technical efficiency of IPMS implementation based on GB/T 29490 by using DEA CCR-I model. Since most of measurement items in the measurement model of IPMS implement efficiency is qualitative, in the sake of achieving quantifiable degree of expert judgements of measurement items and reducing the number of dimensionalities of input and output based on the model we use fuzzy comprehensive evaluation method to get the assessment value of input and output.

1.3.2 Fuzzy Comprehensive Evaluation Method

Fuzzy comprehensive evaluation method is a comprehensive evaluation method aim at derive quantitative evaluation value from qualitative evaluation based on fuzzy set theory (Wang, 1983). It can be used to achieve a comprehensive evaluation value for objectives restricted by several criteria. The procedures of Fuzzy comprehensive evaluation method can be described by the following steps.

Step 1. Setting up the set of evaluation criteria for objective

We use m evaluation criterion to describe object. The set of evaluation criteria can be written as U = $\{u_1, u_2, \cdots, u_m\}$, where is the evaluation criterion i, m is the number of all evaluation criteria which are used to describe the objective.

Step 2. Setting up appraisal set

Appraisal set is defined as a set of the possible evaluation result given by evaluators. It could be written as V = $\{v_1, v_2, \cdots, v_k, \cdots, v_n\}$, where v_k is the evaluation result i, n is the number of all possible evaluation result.

Step 3. Single factor evaluation and fuzzy evaluation matrix setting up

To achieve the fuzzy membership degree of U to V we can start from valuating the single evaluation factor u_i $(i = 1,2, \cdots, m)$, it is defined as single factor evaluation and can be written as *f:* $U \rightarrow f(V)$. The appraisal set of the evaluation criterion *i* is the subset of $R_i = (r_{i1}, r_{i2}, \cdots, r_{ik}, \cdots, r_{in})$, r_{ik} is the fuzzy membership degree of evaluation criterion *i* to grade according to v_k. Then the fuzzy evaluation matrix R with m evaluation criteria and n levels of evaluation result can be set up as follow:

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & & r_{2n} \\ \vdots & & \ddots & \vdots \\ r_{m1} & r_{n1} & \cdots & r_{mn} \end{bmatrix}$$

Step 4 calculate the weight of each evaluation criterion.

The weight of each evaluation factor should be determined in order to obtain a comprehensive evaluation. The weight vector $W = (w_1, w_2, \ldots w_m)$ can be determined by GEM group eigenvalue method.

Step 5 calculating the comprehensive evaluation result

The comprehensive evaluation vector is $B = (b_1, b_2, \ldots, b_n)$. B can be calculated as follow:

$$B = W^{\circ}R = (w_1, w_2, \cdots w_m)\begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & & \ddots & \vdots \\ r_{m1} & r_{n1} & \cdots & r_{mn} \end{bmatrix} = (b_1, b_2, \cdots, b_n)$$

Where $^{\circ}$ is composition operator $M(\wedge, \oplus)$, $b_j = min\{1, \sum_{j=1}^{m} min(w_i, r_{ij})\}$. Then we can use fuzzy weighted average operation to gain comprehensive evaluation result for each object (Pavlacka and Talašová, 2006):

$$A = \frac{\sum_{j=1}^{n} b_j^k \cdot \mu(v_i)}{\sum_{j=1}^{n} b_j^k}$$

Where $\mu(v_i)$ is the valuation to . We assume IPMS practices main-criterion and IPMS effectiveness main-criterion are the objectives that will be evaluated. The comprehensive evaluation result A for each criterion can be obtain using this method. Then we use comprehensive evaluation results of IPMS practices compliance criterion to be the input and comprehensive evaluation results of IPMS effectiveness criterion to be the outputs for further technical effectiveness assessment of DMU by DEA method.

1.3.3 Group Eigenvalue Method

GEM is an eigenvalue method which is used for group decision which was first put forward by (Qiu, 1997). To solve the group decision problem, using GEM can gain the optimal order of items waiting for being evaluated without non-consistence when constructing the judgement matrix using AHP method.

N objects B1, B2, …, Bn are evaluated by group decision support system G which is comprised of M experts S1, S2, …, S_m. The value of B_j which is evaluated by Expert S_i is $X_{i,j} \in [i,j](i=1,2,..,m; j=1,2\ldots n)$. The importance of the objectives is determined by the value of $X_{i,j}$, the higher the value is , the more important the object is. The values of B_j evaluated be group decision support system G constitute m×n-order matrix:

$$x = (x_{ij})_{m\times n} = \begin{pmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{pmatrix}$$

In the real world, there is no expert can make a completely accurate decision with 100% reliability, so an ideal expert S_* is constructed who has the most consistent opinion with the group decision support system G, in another word, the differences between ideal expert and every other expert in the group should be as small as possible. As defined (Qiu, 1997), if there is an expert, the sum of intersection angles between whose evaluation vector and the evaluation vectors of experts in the group decision support system is the smallest, then this expert is the ideal expert. The evaluation vector of the ideal expert S_* is: $x_* = (x_{*1}, x_{*2}, \ldots x_{**})^T \in E^n$. So x_* is the vector which can make f= $\sum_{i=1}^{m}(b^T x_i)^2$ reach the maximum value $\forall b=(b_1, b_2, \cdots, b_n)^T \in E^n$, we could let $\|b\|_2 = 1$, then we get the following equation:

$$\max_{\|b\|_2=1,} \sum_{i=1}^{\cdots} (b^T x_i)^2 = \sum_{i=1}^{\cdots} (x_*^T x_i)^2$$

In order to obtain vector , the following Theorem is given by (Qiu, 1997):

As for $\forall b=(b_1, b_2, \cdots, b_n)^T \in E^n$

$$\max_{\|b\|_2=1,} \sum_{i=1}^{m} (b^T x_i)^2 = \sum_{i=1}^{m} (x_*^T x_i)^2 = \rho_{max}$$

ρ_{max} is the maximum positive eigenvalue of $F=x^T x$, and is eigenvector corresponding to , which has all positive components in it and $\|x_*\|_2 = 1$.

When we achieve x_* , which is the evaluation vector of the ideal expert for measurement items, in other words, it is the order of importance of measurement items. Then we normalized this evaluation vector to achieve the weights of the measurement items

2. A CASE STUDY OF IPMS IMPLEMENTATION EFFICIENCY BASED ON STANDARD GB/T 29490

2.1 Calculation Example

We choose 5 companies in access control industry located in Xiamen special economic zone, China. Two of them are entitled Xiamen IP advantage companies (an award granted by Xiamen Intellectual property administration for achievement in IP management) and China High-New Technology Enterprise (a status certificated by China's Ministry of Finance, State Administration of Taxation and Ministry of Science and Technology jointly). And all of these 5 companies are the clients belong to the same training & consultant body in Xiamen. Company A and B started their IPMS in March 2016 and company B, C and D started in April 2016. The certification audit time for these 5 companies are all at May 2017. In order to make sure all the companies could have enough time to run the new management system smoothly and the continuous improvement can be evaluated sufficiently we conduct our evaluation for all 5 companies at the first surveillance audit on May 2018.

Step 1: Base on the primitive IPMS effectiveness evaluation model, we use GEM to calculate the weight of each sub-criteria to their main-criteria. 15 experts (8 experts are senior auditors came from two different certification bodies, others are from two training & consultant bodies who have been working in IP management area over ten years.) evaluated the sub-criterion for each main-criteria to assess the importance of each sub-criteria (using a 5-point Likert format where 1=least important to 5=most important). We use the main-criteria "management responsibility" of company A for example to show how to achieve the weights of the measurement items. Score value matrix of management responsibility measurement items is given by 15 experts as below.

$$X_{mr} = \begin{pmatrix} 5 & 4 & 3 & 4 & 4 & 2 & 4 & 1 \\ 4 & 3 & 2 & 5 & 4 & 2 & 3 & 3 \\ 4 & 3 & 2 & 5 & 3 & 2 & 4 & 2 \\ 3 & 5 & 3 & 4 & 4 & 1 & 5 & 2 \\ 4 & 5 & 4 & 4 & 4 & 1 & 4 & 1 \\ 5 & 5 & 2 & 3 & 3 & 3 & 3 & 2 \\ 3 & 4 & 3 & 5 & 4 & 2 & 4 & 2 \\ 4 & 4 & 2 & 4 & 3 & 2 & 4 & 3 \\ 5 & 4 & 3 & 4 & 4 & 2 & 5 & 2 \\ 5 & 4 & 3 & 3 & 4 & 2 & 3 & 2 \\ 4 & 4 & 2 & 3 & 4 & 4 & 4 & 2 \\ 3 & 3 & 2 & 3 & 3 & 2 & 3 & 1 \\ 4 & 3 & 3 & 4 & 5 & 2 & 3 & 2 \\ 4 & 3 & 2 & 5 & 5 & 1 & 4 & 3 \\ 4 & 4 & 2 & 2 & 3 & 2 & 3 & 2 \end{pmatrix}$$

We can calculate the eigenvector by MATLAB, x_{*mr}= (0.4283,0.4072,0.2683,0.4096,0.4016,0.2084,0.4023,0.2108), when ε = 0.0003 x_{*mr} is the evaluation vector of the ideal expert for management responsibility measurement items, in other words, it is the order of importance of the management responsibility measurement items. Then we normalized this evaluation vector to achieve the weights of the measurement items, W_{mr} = (0.156,0.149.0.098,0.150.0.147.0.076,0.147,0.077).

Step 2 We use fuzzy comprehensive evaluation method to calculate the evaluation value for each main-criteria of Intellectual Property Management System practices compliance evaluation model and IPMS effectiveness evaluation model. According the method in section2, the appraisal set is determined as V=$\{v_1,v_2,v_3,v_4,v_5\}$ = {*excellent, good, average, fair, poor*}, the valuation of can be determined as $\mu(v_i)$ =(10,8,6,4,2).

Experts for evaluation in this step are divided into 2 groups. One group is assigned to evaluate the IPMS practices activities, which consists of 6 experts, all of them are the auditor in the surveillance audit (in fact, all surveillance audit for these 5 companies need less than 6 auditors, this research funded the superfluous auditors), they all come from the same certification body. The rest of experts are in another group, 3 of them come from the same training & consultant body who served for these 5 companies, the others all come from these 5 companies. We chose 3 experts from senior management respectively in each company to evaluate the IPMS effectiveness evaluation model in their own company with 3 experts we mentioned above from training & consultant body.

The main-criteria "management responsibility" of Intellectual Property Management System practices compliance evaluation model is also used to be the example for calculation. Following the method in section 2, based on the evaluated score experts made, the fuzzy evaluation matrix of U_{mr} of company A is obtained as follow:

$$R_{mr} = \begin{pmatrix} \frac{1}{6} & \frac{1}{2} & \frac{1}{3} & 0 & 0 \\ 0 & \frac{2}{3} & \frac{1}{3} & 0 & 0 \\ \frac{1}{3} & \frac{1}{2} & \frac{1}{6} & 0 & 0 \\ \frac{1}{3} & \frac{1}{6} & \frac{1}{2} & 0 & 0 \\ \frac{1}{6} & \frac{1}{3} & \frac{1}{2} & 0 & 0 \\ \frac{1}{3} & \frac{1}{3} & \frac{1}{6} & \frac{1}{6} & 0 \\ \frac{1}{6} & \frac{1}{2} & \frac{1}{3} & 0 & 0 \\ \frac{1}{6} & \frac{1}{3} & \frac{1}{6} & \frac{1}{3} & 0 \end{pmatrix}$$

According to section 2 $B_{mr} = W_{mr} \circ R_{mr}$ = (0.851,1,1,0.153,0). Then we can use fuzzy weighted average operation to gain comprehensive evaluation result A_{mr} for U_{mr}.

$$A_{mr} = \frac{\sum_{j=1}^{n} b_j^k . \mu(v_i)}{\sum_{j=1}^{n} b_j^k} = 6.45$$

For quantitative main-criteria ($\mathbf{u_{71}}$), the valuation is made by Table 6

Table 6
Quantitative main-criteria evaluation

Sub-criterion	Valuation				
	Excellent	Good	Average	Fair	Poor
	10	8	6	4	2
u_{711}	30 & above	20-30	10-20	5-10	5 & below
u_{712}	20% & above	15%-20%	10%-15%	5%-10%	5% & below
u_{713}	20 & above	15-20	10-15	5-10	5 & below
u_{714}	50& above	40-50	20-40	10-20	10 & below

Table 7 shows the comprehensive evaluation results of both IPMS practices compliance main-criterion and IPMS effectiveness main-criterion for all 5 companies.

Table 7
Comprehensive evaluation results

	Inputs					Outputs		
	A_{mr}	A_{rm}	A_{lc}	A_{io}	A_{ri}	A_{ca}	A_{in}	A_{ci}
A	6.45	7.78	7.67	6.67	6.78	5.31	6.03	6.98
B	6.90	6.69	7.01	7.54	7.89	6.56	6.34	6.70
C	7.34	7.67	7.98	6.99	7.23	7.98	8.33	8.67
D	7.65	7.45	6.89	6.78	6.98	6.44	6.01	6.76
E	7.69	6.78	6.54	7.07	6.93	7.09	6.94	8.01

Step3 We use comprehensive evaluation results of IPMS practices compliance main-criterion to be the input and comprehensive evaluation result of IPMS effectiveness criterion to be the output, as shown in Table 7, for further technical effectiveness assessment of 5 DMUs using DEA-solver.

2.2 data analysis and Managerial Implication

The results of IPMS implementation efficiency for all 5 companies are summarized in Table 8. The overall technical efficiency scores of all the 5 companies and their peer company (reference set) are shown in table 8. From table 8, it can be seen the overall efficiency scores of C and E equals to 1, which means these 2 companies lay onto the efficient frontier. The result is performing as expected for both these 2 companies being entitled Xiamen IP advantage companies and China High-New Technology Enterprise for the last two years before our valuation. It indicates overall efficiency are measured efficient due to input/output configuration and as well as size of scale. Whereas, the overall efficiency of company A, B and D are less than 1, which indicates these three companies are inefficient companies. For brevity, Table 8 shows projection value and slacks variable value for each main-criteria of the most inefficient company, company D, whose overall efficiency score is 89.5%. It means 10.5% of inputs are underutilized for per unit output. Table 9 shows the potential improvements for the most inefficient companies D. In the case of company D, we can find the excess in all inputs and deficiency in 2 outputs except for "competitive advantage". Regarding the frontier as an empirical standard of excellence, we use DEA as a benchmarking tool to make it possible for manager to learn better IPMS practices. As we discussed in the section 2, we can obtain the benchmarking goals by calculating the distance between a targeted DMU and the frontier. An inefficient unit can be improved to be efficient by reducing inputs or increasing outputs or combining both moving towards the frontier. The improvement target (projection value) are calculated based on θ_0^*, s_0^{*-} and θ_0^* as stated in section 2. For traditional explanation, the company D could reduce the inputs on the IPMS practices respectively by 14.98%, 17.15%, 10.50%, 10.50% and 12.80% as while as increase the outputs on "innovation achievement" and "continuous improvement" by 8.04% and 5.76% to improve the IPMS efficiency and make itself effective comparing to its reference company C. But it seems we need a diffident way to explain the excess of the inputs because we assume the IPMS implementation effectiveness will increase as the company enhance the quality of IPMS practices based on the fact that the processes in IPMS is considered as value-added. In this hypothesis, it does not make sense to reduce the IPMS practices level to some extent in order to achieve more technical efficiency for IPMS practice.

As we mentioned above, 10.5% of inputs are underutilized for per unit output in company D. The most important thing is to defined what is the underutilized input, how did this happen. As the fuzzy evaluation matrix is obtain based on the evaluated score experts made according the auditing result in the surveillance audit, to figure out this question, we have to note, ISO 19011:2011—Guidelines for auditing management systems defined an audit as a "systematic, independent and documented process for obtaining audit evidence (records, statements of fact or other information which are relevant and verifiable) and evaluating it objectively to determine the extent to which the audit criterion (set of policies, procedures or requirements) are fulfilled." , which is also adopted by GB/T 29490. Basically, audit performances are conducted, including meeting with the auditee, understanding the process and system, to verify if IPMS practices of the auditee are in compliance with audit criterion in GB/T 29490. In another words, audits which determine compliance and conformance are not focused on the deep inside of the good or poor performances.

Table 8
Relative IPMS implementation efficiency

DMU	Overall Technical Efficiency Score (%)	Rank	Reference Set
A	91.6	4	C
B	94.1	3	C
C	1	1	C
D	89.5	5	C
E	1	1	E

Table 9
Projection value and slacks variable value

DMU I/O	Score Data	Projection value	Difference	Slack Variable	%
D	0.895				
(I)mr	7.65	6.504	-1.146	0.343	-14.98%
(I)rm	7.45	6.173	-1.277	0.495	-17.15%
(I)lc	6.89	6.167	-0.723	0	-10.50%
(I)io	6.78	6.068	-0.712	0	-10.50%
(I)ri	6.98	6.086	-0.894	0.161	-12.80%
(O)ca	6.44	6.44	0	0	0.00%
(O)in	6.01	6.493	0.483	0.483	8.04%
(O)ci	6.76	7.149	0.389	0.389	5.76%

As we stated above, company C has been entitled Xiamen IP advantage companies and China High-New Technology Enterprise for the last two years before our valuation. And we ascertain that IP management of company C is more mature than companies who have not earn these titles. We investigated deeply in the company A, B, D and their conference set C though semi-structured interviews hoping to find out the reason behind the result we obtained in Table 8. Table10 shows the main differences between the most ineffective company D and its reference in IPMS practices.

Table 10
The main difference between the most ineffective company D and it's reference in IPMS practices

Ipms practices	Company C	Company D
Company profile	C big enterprise has 1000 employees, 200 of them are in the R&D center, IP apartment has been established for 5 years before starting to establish IPMS base on GB/T 29490. Five staffs in IP apartment, two of them are patent agents.	Medium-size company has 100 employees. Two staffs in the R&D apartment assigned by president doubles in IP apartment.
Management responsibility	The leader of this apartment is vice president of the company. And we found several intellectual property litigations have given the president a deep understanding of the importance of IP management, made the president fully committed to the IPM(u_{11}). Cooperating with a qualified IP Agency. All patent documents are fulfilled by patent agent. (u_{13}) (u_{17}) IP policy is understood thoroughly by employees. (u_{15})	President do not have enough consciousness for the importance of the IPM. This makes the situation that they can't fully commit to the IPM(u_{11}). Part of responsibility for IP apartment is to write the patent documents for patent agency to filing the application directly to SIPO. (u_{13}) (u_{17}) IP policy is understood incompletely by employees. (u_{15})
Resource management	associated the innovation with promotion and performance assessment for their staffs, especially they honor the inventor every year for their contribution to make others realize the importance of innovation and honor the inventor for their contribution. (u_{24}) sophisticated retrieval skills make it can be fully used by R&D. (u_{26}).	Incentive policy all about material reward. (u_{24}) Though there are enough IP information retrieval records, the retrieval capability of the staffs is not professional (u_{26}).
IP life-circle management	Retrieval result is highly correlative with the IP will be acquiring of which patentability is guaranteed. (u_{32}) Not only have a complete monitoring mechanism but also have competent stuff to support it. (u_{37}) (u_{38})	The retrieval result is not qualified to the IP will be acquiring though the quantity is enough. (u_{32}) Procedure documents for IP monitoring mechanism is perfect, but the legal counsel is overconfident and non-professional. (u_{37}) (u_{38})
Implementation and operation	The staffs in IP department is well trained for information retrieval. They are familiar with patent, trade mark and copy right and coordinate well with other department in-house and IP agent out-house to deal with the problems they face. (u_{41}) (u_{43}) (u_{44}) (u_{411})	For the shortage of professional skills and the inadequate coordination with the R&D staffs, the investigation and retrieval can't help find the blocking patent which lead to the invalidation of patent. (u_{41}) The same problem is in IP investigation in research trajectory adjustment (u_{44}) and identifying partners and competitors. (u_{43})
Review and improvement	Persist adjusting the IP management system periodically according to the result of the. (u_{52})	Due to the lack of real president commitment and consciousness of staff, the improvement of the IPMS is not satisfied. (u52)

We found out company C is a big enterprise which has 1000 employees, 200 of them are in the R&D center, IP apartment has been established for 8 years before starting to establish IPMS based on GB/T 29490. There are five staff in this apartment, two of them are patent agents. The leader of this apartment is vice president of the company. And we found several intellectual property litigations have given the president a deep understanding of the importance of IP management before they start to establish IPMS. This made the president fully committed to the IPM.

Company A and B and D are medium-size company with 150, 200 and 100 employees respectively. All of them have not been experienced any real IP litigation mainly because their R&D policy is relatively conservative. In this case, their presidents could not have enough consciousness for the importance of the IPM, because they just achieved the information about the importance of IPM from the IPMS consultant in a relatively short time period (IPMS training period, about 6 month). This makes the situation that they can't fully commit to the IPM. But during the whole IPMS training, the consultant gave a whole bunch of skills help them to deal with the question the auditors asked them, making it seems like their commitment is in compliance with the criterion for management responsibility to some extent, but the practical level is lower than that.

To contrary, there are two staffs in the R&D apartment in company D assigned by president doubles in IP apartment. For the sake of cost saving, part of responsibility for them is to write the patent documents (clams and specification) for patent agency to filing the application directly to SIPO. This arrangement does not conflict with the criteria about allocation of enough human resources (u_{13}) and effective communication with patent agency (u_{17}), but the direct result of this arrangement is the poor patent quality because of the non-professionals. It is the same situation in the policy understanding by employees (u_{15}). Depending on the evidence of training record for employees and factual statement of employees from the random selection, the valuation of compliance is relatively magnified by the audit for the perfect records and skilled statement.

The similar thing happened in (u_{21}) (u_{22}) for "resource management". For the incentive mechanism, we found their incentive policy all about material reward. It is in

line with either the law or the criteria (u_{24}) of the IPMS standard, admittedly, but it has no method to motivate the internal enthusiasm for creation and innovation. Whereas, company A associated the innovation with promotion and performance assessment for their staffs, especially they honor the inventor every year for their contribution to make others realize the importance of innovation. Though there are enough IP information retrieval records for company D, the retrieval capability of the staffs is not professional, leading to poor correlation with R&D practices (u_{26}).

For the part of IP life-circle management, the most severe problem for company D is IP monitoring mechanism (u37) (u38). The procedure document for IP monitoring mechanism is perfect, the respond system is in compliance with the criteria, even there is in-house legal counsel to deal with it. We found an IP dispute after the first audit which has not been found in the surveillance audit for the surveillance audit spend less time on only some portions of the IPMS Process. One of the competitors negotiated with company D willing to license one of their patents. After the discussion, marketing manager and legal counsel decided to reject the request of their competitor for their marketing plan and confidence of their patent stability. Unexpectedly, a request of reexamination was filed by their competitor and it turned out all the claims are invalidated. The overconfidence and non-professional of legal counsel lead the tragedy. If they had negotiated properly, the lost would have been avoided, even would have achieve a win-win situation. We assume this is mainly because legal counsel is not professional for patentability. This also proved there has been enough investigation and retrieval records to support the confirmation of compliance, but in fact, for the shortage of professional skills and the inadequate coordination with the R&D staffs, the investigation and retrieval can't help find the blocking patent which lead to the invalidation of patent. (u41) They have the same problem in IP investigation in research trajectory adjustment (u44) and identifying partners and competitors. (u43) But for company C, it is totally different. Professional IP staff coordinate with other apartments in-house and different IP agency out-house to deal with the problems they face. The cooperation for all the forces in and out the company makes it feasible for them move beyond the legal- oriented and patent-focused IP management to a cross-functional IP management. For instance, before launching a product they analysis all the possibility to pursue the optimum combination of IPRS, including patent, copyright and trademark to protect the innovation and make sure the value given to customs by patent and copyright can turn into the preference of brand. (u411)

The arrangement of internal audit of company D can cover the whole IP management system and assess the suitability and effectiveness for the implementation result and they have improvement arrangement. The improvement for IPMS is a long-term and periodic procedure. Due to the lack of real president commitment and consciousness of staff, the improvement of the IPMS is not satisfied.

We found the same situation happened in inefficient company A and B through the interview. Though the details are different, the main problems embedded are almost the same.

From the above, we can see due to the limitation of audit, the issue underneath the compliance is what we need to concern. Auditee can achieve the certification by sophisticated training and perfect performance in the audit. This can directly affect the IPMS practice relative efficiency due to the real practices do not perform as well as it seems to do, whereas the valuation of effective auditee is more in line with reality. The manager of the inefficient company or the consultant body can improve the IPMS implementation efficiency according to the result of the relative efficiency comparing with efficient company as a benchmark.

3. CONCLUSION AND FUTURE WORK

In this paper, we addressed the problem of calculation of IPMS implementation efficiency based on IPMS standard of China. One of the main contributions is to using Data Envelop Analysis (DEA) to calculate the relative IPMS implementation efficiency according to the audit result of IPMS standard. And the main purpose of calculating the relative IPMS implementation efficiency is to help manager and IPMS training & consultant body to improve the system to be more compliant to the IPMS standard and more efficient.

The objectives of IPMS standard has been defined according to the definition of IPMS effectiveness and the output of implementing IPMS described in the IPMS standard GB/T 29490. IPMS practice compliance evaluation model has made as the inputs of DEA, and IPMS effectiveness evaluation model has made as the outputs of DEA to prepare for relative efficiency calculation. Group Eigenvalue Method (GEM) is used to find out the weight of every measurement items of the main-criterion of two evaluation models. Then we use fuzzy comprehensive evaluation method to evaluate the degree of IPMS practices conformation to the requirements in IPMS standard and effectiveness of IPMS implementation based on the evaluation of sub-criterion made by the experts. The two bunches of the results are then used to be the inputs and outputs in DEA in order to calculate the relative efficiency of IPMS implement based on standard GB/T 29490.

The procedure of implementing DEA to evaluate the relative efficiency of IPMS practice implementation based on IPMS standard can be applied in benchmarking to find

out the deficiency of IPMS practices and enhance the IP management level of inefficient companies. And it is also can help certification body to figure out the limitation of the audit and improve the audit skill.

For the future work, the affecting factors of IPMS implementation efficiency, for instance, the size of the company, the length of the time of system implementation will be considered and research will not just focus on the IPMS practices but will also focus on the human capital inputs and material capital inputs.

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