Summer 2014

A Quantitative Framework Of Skill Evaluation of IT Workforce

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Graduate School ETD Form 9
(Revised 01/14)

PURDUE UNIVERSITY
GRADUATE SCHOOL
Thesis/Dissertation Acceptance

This is to certify that the thesis/dissertation prepared

By O Hyun Hwang

Entitled
A QUANTITATIVE FRAMEWORK OF SKILL EVALUATION OF IT WORKFORCE

For the degree of Master of Science

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Head of the Department Graduate Program Date

A QUANTITATIVE FRAMEWORK OF SKILL EVALUATION OF IT WORKFORCE

A Thesis

Submitted to the Faculty

of

Purdue University

by

O Hyun Hwang

In Partial Fulfillment of the

Requirements for the Degree

of

Master of Science

August 2014

Purdue University

West Lafayette, Indiana

ACKNOWLEDGEMENTS

Many people have helped me from the beginning to the end of this work. First, I would like to convey my sincerest thanks to the members of my committee. I am grateful to Prof. Jeffrey L. Brewer and Dr. John A. Springer for their approvals as committee members even though my research topic is not general to the CIT research area. Their thoughtful insights and experience provided important guidance and support to complete this work.

I would like to express my heartfelt gratitude to Dr. Alejandra J. Magana as my chair and major professor. She always respected my opinion and gave me great ideas and advice from the beginning of writing my thesis to the end. Her brilliant ideas and critical expertise in research were essential and invaluable helps in finishing my thesis.

I am also grateful to all the faculty and staff who supported me and taught me important lessons. I could not have completed this work without their invisible support in the form of their knowledge and experience.

Finally, to my greatest supporter, I thank my beloved wife Seulgi and our precious son and daughter, Jihu and Yeonhu for constantly cheering me with their lovely smiles and hugs. I cannot express the depth of my thanks to Seulgi in words for her tender, loving care of our kids.

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GLOSSARY

competency – "The capability of applying or using knowledge, skills, abilities, behaviors, and personal characteristics to successfully perform critical work tasks, specific functions, or operate in a given role or position" (Ennis, 2008, p. 4).

competency model – "a descriptive tool that identifies the competencies needed to operate in a specific role within a job, occupation, organization, or industry" (Ennis, 2008, p.5).

experience – "the culmination of context-based events that an individual perceives, and the accumulated knowledge of specific jobs derived from action, practice, and perception of the tasks" (Sturman, 2001, p.5).

performance appraisal – "a periodic evaluation of the output of an individual measured against certain expectations" (Abu-Doleh, & Weir, 2007, p.76).

LIST OF ABBREVIATIONS

IT – Information Technology.

ETA – Employment and Training Administration.

ITWCA – Information Technology Workforce Capability Assessment.

COCOMO – Constructive Cost Model.

EM – Effort Multiplier.

PC – Personal Computer.

OS – Operating System.

HR – Human Resource.

GUI – Graphical User Interface.

E-R Model – Entity Relationship Model.

SQL – Structured Query Language.

ABSTRACT

Hwang, O Hyun. M.S., Purdue University, August 2014. A Quantitative Framework of Skill Evaluation of IT Workforce. Major Professor: Alejandra J. Magana.

Every employee has different abilities as well as experience, leading to different results in terms of skills and job performance. In order to improve employee IT skills, organizations should evaluate their employees' skills to understand the current levels of skills and knowledge and to figure out areas where skills are currently lacking.

This study used a different approach than other existing methods to evaluate the IT skills of employees. The research used quantitative empirical data that represents the work experience of employees based on their task history and job positions. The suggested method defines the relationship between IT skills and IT task activities and between IT skills and job positions. The numerical analysis method was made and used to calculate scores that express the level of work experience and skills of employees. A tool was developed with computer programming in order to embody the method and make the best use of the method, and case studies were performed in order to test the validity of the method with three cases. According to results of the case study, the same or similar skills were estimated in accordance with the same or similar work experience.

CHAPTER 1. INTRODUCTION

This chapter provides the information about motivation and significance of this study. Also, this chapter establishes the scope of study through the research question, assumptions, limitations, and delimitations.

1.1 Statement of the Problem

Today, most companies use a vast amount of information that allows them to adapt to the rapidly changing market environment. As such, information processing capabilities of companies now are an important element of competitiveness, and the productivity of IT departments and employees are the basis of such capabilities. The competitiveness of the employees has become important in IT companies and departments as well as in any other business field. In order to increase productivity and quality, IT organizations need to ensure that their employees have a high level of expertise. IT organizations should identify the necessary skills for their workforces and measure the current capability of their employees in order to determine how to improve them. That is, companies need to not only measure the job performance of their people, but also they need to measure their capabilities specifically and objectively.

IT professionals can perform many jobs, such as project managers, software engineers, hardware engineers, database engineers, network engineers, and so on.

Each position requires different skills and abilities. Tools that can evaluate employees' level of skills objectively and quantitatively are needed. It is hard to measure their actual skill levels with only the number of working years, certifications, or paper test results. Assessment models and tools should be based on quantitative evidence that accurately represents a worker's level of professional knowledge and experience.

1.2 Research Question

How can IT workforce skills be measured in terms of individual task activities and work experience?

1.3 Significance

How to increase the competency of employees is always a concern for managers of IT companies (Munro, Huff, Marcolin, & Compeau, 1997). They likely need to ask the following questions: how can organizations evaluate the competency of employees and how can their job skills be improved? Also, how can their competency for specific jobs be measured, and what skills are needed for each employee to improve? Employees, even those in the same jobs, have different levels of competence with regard to skills, knowledge, and experience (Quiñones, Ford, & Teachout, 1995). If the competence of employees can be evaluated, managers can then easily find appropriate staff for a specific job or business. Also, companies can improve their employees' abilities and provide proper training for a more specific educational program if they know which levels of skills or knowledge are required by employers. In addition, trainers or managers can focus on the very specific levels of skills or knowledge that their employees need to improve within their current job or any job they may work in the near future. However, it is difficult for companies and managers to have a great deal of detailed data on the capabilities of their employees. Furthermore, their evaluation systems sometimes tend not to be dependent on objective or quantitative methods, but rely on subjective evaluation by examiners such as managers, HR personnel or external consultants (Marcolin et al., 2000).

Most evaluation or assessment methods rely on surveys, interviews, paper tests, certification, or personal evaluation (Marcolin et al., 2000). The evaluation data may need to be based on specific and factual data in order that positions of trust can be effectively allocated to managers and employees. In particular, levels of professional skill need to be assessed objectively using reliable methods, and the results need to be expressed quantitatively and objectively.

The abilities of most of the professional workforce can only be vaguely estimated with regard to the length of their work experience and the job positions that they have had during their careers. Also, the professional skills of employees are hard to estimate with regard to the results of paper tests or certificates, because job ability cannot be assessed only with regard to the knowledge in their brains. In practice, the estimated result can be different with regard to their actual skills, depending on the amount and number of their experiences (Quiñones et al., 1995). Results can vary with regard to how long, how often and what tasks they perform (Quiñones et al., 1995). In other words, employee careers make it difficult to represent their actual work experience. It is difficult to assemble detailed information about the work experience of employees if one only has their resume or a personal evaluation by managers or a certification. Therefore, IT organizations need to have methods to collect information about the employee experience and to evaluate their skills based on specific performance.

1.4 Scope

Knowledge about financial and customer relationships, analytical thinking, interpersonal skills, and professional IT skills can be included in employee capabilities. However, this research study focuses on how to evaluate professional IT skills quantitatively. It suggests a method to estimate the level of workforce skill based on actual work experience and shows how this method can be applied in a real work environment through the tools developed in this study. In order to do this, this study defines the required skills for IT workforce roles that is defined by the Chief Information Officers Council (2011), and prepared a task list and categories for the IT work area. These tasks were specifically connected with IT skills.

This study developed a method that defines and measures the skill levels and abilities of employees based on their job experience. The method includes using not only technical knowledge but also non-technical knowledge such as management skills, knowledge of finance and project management. The technical skills required include advanced skills such as planning, analysis, and architecture as well as basic skills such as installation, configuration, and operating of systems or software.

The data of work experience in this study includes information about the amount of time and number of times in which each employee performed a specific job. This research provides a framework to gather data and evaluate employees' skills, and develops a software program as a tool to embody the framework. Through the framework, this study presents a method to change the amount of time and number of times of an employee's work experience into one integrated value for each job. In addition, this value can be compared to the value of other employees. The tool shows how information about the experience that employees have in their jobs can be accumulated and analyzed. The data extracted from the tool will be the objective reference data required to evaluate the employees' skills and job experiences.

1.5 Assumptions

The assumptions for this study include:

1. The collected sample data will reflects unbiased information about the job history of the employees.
2. The task list and categories encompass a full range of activities for the job required of the participants.
3. The role of each IT employee can be classified into one or more job specialties that has been defined in this study – such as a programmer, business analyst, system engineer or database engineer.
4. The IT workforce in organizations have professional IT knowledge and skills, and these abilities are used actively in their jobs.
5. IT work experiences improve the IT knowledge and skills of employees.
6. Each employee reports the work performed by themselves periodically to their manager.

1.6 Limitations

The limitations of this study include:

1. The sample data only contains information about IT professional employees in a particular IT service provider, which does not represent the information of employees in the whole IT companies or organizations.
2. The sample data contains information about employees in a few job positions - database engineer, system engineer, and manager, so it does not represent the overall jobs of the IT work area.
3. The sample data includes a period of four months of job history of IT employees, which does not reflect the total work experience of each employee.
4. In this study, the proposed framework is based on time-based work experience, so does not consider other factors, such as the age of employees, job complexity and task difficulty.
5. The proposed evaluation method is based on the accumulated task history, so is not suitable for evaluating new employees. Therefore, additional methods such as interviewing or testing should be considered to assess new employees.

1.7 Delimitations

The delimitations for this study include:

1. The skill list is associated with jobs mainly representing professional skills, but it does not include academic competencies such as analytical thinking, writing, leadership, communication, and interpersonal skills.

2. The task list used in this study is optimized for the jobs of employees in IT service providers in order to use sample data, so this study does not provide a standardized task list to represent the job activities of the whole IT industry. The task list should be modified and optimized depending on the type of business or organization.
3. The sample data in this study is used as an example of the proposed method and an evaluation of the results and effects of the method, but is not used to validate a particular hypothesis.
4. The difference in personal learning ability with regard to work experience is not considered in this study, because it estimates skill levels depending on job experience. For example, this method does not include the fact that the people who have outstanding learning ability may have a higher skill level than other people who have had the same experiences.

1.8 Summary

Many existing evaluation methods use subjective and qualitative approaches. However, the framework proposed in this study presents an objective evaluation method for the IT work area, and the tool provides quantitative results based on accumulated experience data. In addition, the data generated by the activities of the employees are related to IT skills and analyzed from various perspectives. The task activities, skills, occupations, and the relationships among them included in the tools reflect the actual working environment in IT companies or organizations.

CHAPTER 2. LITERATURE REVIEW

Studies of competence have been conducted in a variety of fields such as education, business and technology (e.g., Bassellier, Reich, & Benbasat, 2001; Blancero, Boroski, & Dyer, 1996; Dowsing, & Long, 2000; Goles, Hawk, & Kaiser, 2008; Marcolin, Compeau, Munro, & Huff, 2000; Munro, Huff, Marcolin, & Compeau, 1997; Rothwell, & Lindhoil, 1999; Owlia, & Aspinwall, 1998). These studies involve analyzing the abilities of organizations and individuals, particularly in terms of how well they are able to manage and develop their abilities to meet the goals of an organization. The following study is concerned with introducing the relevant information about competency measurements, IT workforce skills, and the relationship between job experience and performance.

2.1 General viewpoint of competency in the work area

Efforts to improve employee competency have been performed in a variety of fields for a long time. These studies have not only been performed for the purpose of job evaluation in order to compensate the employees but also to improve the employee levels of expertise. Also, many researchers have focused on improving educational outcomes for students. Such studies have been performed for a variety of purposes and in various fields of research. Many companies utilize a performance appraisal system in order to manage human resources effectively. Abu-Doleh and Weir (2007) defined a performance appraisal as “a periodic evaluation of the output of an individual measured against certain expectations” (p. 76). A performance appraisal can be a motivational tool to communicate with employees about their performance expectations and to give them feedback (Thomas, & Bretz, 1994). A performance appraisal is usually performed annually or more often in order to assess and observe the performance of employees. Thomas and Bretz (1994) stated several purposes of a performance appraisal:

> Improving work performance, administering merit pay, advising employees of work expectations, counseling employees, making promotion decisions, motivating employees, assessing employee potential, identifying training needs, better working relationships, assigning work more efficiently, making transfer decisions, making decisions about layoffs and terminations, and so on (p. 30).

The results of performance appraisals have become important means of identifying the training needs of employees and improving their work abilities. The studies of development and evaluation of the employee abilities are needed to utilize the results of performance appraisals productively. Competency and performance are likely to be perceived as the same concept. However, Klemp (1979) distinguished between the two terms in that competency is the enabler that provides the means to a better performance. The concept of competency is used in various ways in the literature, and it can be grouped in the following ways: competency as a skill, competency as a personality trait, and competency as knowledge (Bassellier, Reich, & Benbasat, 2001). Many researchers have tried to find an effective way to measure and develop human competency.

Most IT organizations are struggling to acquire employees who have enough skills for their business, and also have difficulty in the consistent and systematic development of competence due to the high turnover of IT staff (Luftman, Bullen, Liao, Nash, & Neumann, 2004). So, I believe that managers in organizations are expecting researchers to present them with methods that help to define the required competency for their employees and provide appropriate training opportunities for them.

2.2 Competency Model

The term, 'Competence' began to be widely used in David McClelland's article *Testing for Competence Rather than for Intelligence* in 1973. Ennis (2008) defined competency as “The capability of applying or using knowledge, skills, abilities, behaviors, and personal characteristics to successfully perform critical work tasks, specific functions, or operate in a given role or position” (p. 4). Competency can also be defined as “the knowledge, skills, abilities, and other attributes required to perform desired future behaviors” (Blancero, Boroski, & Dyer, 1996, p. 387). In other words, personal competency consists of knowledge, skills, and attitudes that are held by members of organizations. Each organization should be capable to define the required jobs and the related skills for their jobs systematically in order to achieve their objectives.

A competency model is used as a tool to develop and measure competencies systematically. A competency model can be defined as “a descriptive tool that identifies the competencies needed to operate in a specific role within a job, occupation, organization, or industry” (Ennis, 2008, p.5). A competency model is usually developed to meet an organization's business needs and objectives on the basis of a generic framework.

The Employment and Training Administration (ETA) has recently developed a competency model that can be found in the ETA Competency Model Clearinghouse (Ennis, 2008). This model has layered competency tiers, such as industry-wide technical competencies, occupation-specific competencies, work place competencies, academic competencies and personal effective competencies. Table 2.1 shows the seven tiers. The top tier, Occupation-Specific Requirements, can be divided into three tiers. The lower tiers describe the foundational competencies that can be broadly applied to many industries or occupations (Ennis, 2008).

Table 2.1 *ETA Competency Model Clearinghouse's General Competency Model Framework*

Tiers	Competencies
Management Competencies	Staffing, Informing, Delegating, Networking, Monitoring Work, Entrepreneurship, Supporting Others, Motivating & Inspiring, Developing & Mentoring, Strategic Planning/Acting, Preparing & Evaluating Budgets, Clarifying Roles & Objectives, Managing Conflict & Team Building, Developing an Organizational Vision, Monitoring & Controlling Resources
Occupation-Specific Requirements	Competencies to be specified by occupation
Industry-Sector Technical Competencies	Competencies to be specified by industry sector representatives
Industry-Wide Technical Competencies	Competencies to be specified by industry representatives
Workplace Competencies	Teamwork, Adaptability/Flexibility, Customer Focus, Planning & Organizing, Creative Thinking, Problem Solving & Decision Making, Working with Tools & Technology, Workplace Computer Applications, Scheduling & Coordinating, Examining & Recording, Business Fundamentals

Table 2.1 Continued.

Academic Competencies	Reading, Writing, Mathematics, Science & Technology, Communication-Listening & Speaking, Critical & Analytic Thinking, Active Learning, Basic Computer Skills
Personal Effectiveness Competencies	Interpersonal Skills, Integrity, Professionalism, Initiative, Dependability & Reliability, Willingness To Learn

Note. Referred from "Industry Competency Models" by U.S. Department of Labor, Employment and Training Administration, 2013.

These foundational competencies consist of personal effectiveness competencies, academic competencies, and workplace competencies in the lower tiers. The upper tiers describe more specific competencies of an industry and an occupation than the lower tiers (Ennis, 2008). As shown in Table 2.1, the upper tiers represent management competencies and occupation-specific requirements competencies including occupation-specific knowledge competencies and occupation-specific technical competencies.

The ETA has optimized this comprehensive competency model for the IT industry with the Office of Disability Employment Policy (ODEP) and experts from industry, business, and education. The industry wide technical competencies in the middle tiers were optimized with identifying the knowledge and skills needed for workers to perform successfully in the field of IT. Table 2.2 shows the optimized information technology competency model.

Table 2.2 *ETA Information Technology Competency Model*

Tier	Competencies
Industry-Wide Technical Competencies	Principles of Information Technology, Databases and Applications, Networks,/Telecom/Wireless & Mobility, Software Development & Management, User & Customer Support, Digital Media and Visualization, Compliance, Risk Mgmt./Security & Info Assurance

Note. Referred from "Industry Competency Models" by U.S. Department of Labor, Employment and Training Administration, 2013.

The ETA also explains each component of their technical competencies. The component of principles of information technology means knowledge of information technology industry such as systems, platforms, tools, and technologies. This includes platform technologies like system administration and architecture as well as support for business solution and business process management. The component of databases and applications is related to data management and database administration. The user and customer support services are those that are required to provide technical support to users with regard to the implementation of computer technology and solving related problems. Communicating with users, creating inventories and auditing content assets, along with establishing helpdesk functions such as application support, incident and problem management and computing infrastructures and networks are the main functions required in this area. The component of compliance manages standards, processes, and procedures to make their products comply with regulatory requirements. The important topics in this area are intellectual property, professional ethics, and safeguarding confidential data. Risk management security and information assurance involves protecting information and information systems from unauthorized access and use. This component includes policy development and operational issues as well as security and data integrity issues.

A competency model can be used widely in such areas of recruitment, promotion, evaluation, and training. At first, it can provide the standard of knowledge and skills required for a specific job during the recruiting of new workers. Secondly, it can provide information about such knowledge and skills when organizations wish to develop training programs. Also, it can support the evaluation process for promotion and job performance with the criteria of core competencies that is necessary for their job. At last, the organizations can prepare the competencies that may be needed in the near future by identifying the lack of capacities of current staff.

In the process of assessing IT skills, the ETA Information Technology Competency Model can be the guidance in order to get appropriate evaluation criteria and items that fit into the IT working area.

2.3 Competency Measurement

Marcolin, Compeau, Munro, and Huff (2000) reviewed the various types of measurement methods found in the literature, and found that self-reports, hands-on-tests, paper-and-pencil tests and observer assessments can be included in these measurement types. Individuals assess their own abilities with self-report measures by themselves (Marcolin et al., 2000). This method is probably based on the survey methods that are most common and easy. However, it may be difficult to obtain objective results through using the method, because it depends on the subjective judgment of the individual. Hands-on tests require individuals to deal with specific problem-based evaluations by interacting with tools (Marcolin et al., 2000).

Paper-and-pencil tests that involve multiple choice questions include computer-based tests. Paper-and-pencil tests tend to focus on questions about what can be done and what procedures can be used, but hands-on tests evaluate the actual performance of tasks (Marcolin et al., 2000). While a paper-and-pencil test is commonly used for the ease of administering and scoring, a hands-on test requires observation and responses by the observer. In regard to observer assessments, skills are rated by independent observers such as researchers, managers, and external staff, and a variety of methods such as interviews and behavior observation can be used (Marcolin et al., 2000). These methods can gather data quickly and easily, but may be recognized as inefficient due to the not inconsiderable costs involved.

These methods can be trusted in terms of the confidence required to assess the skills of candidates accurately so that the result is valid and reliable. Dowsing and Long (2002) suggest the following conditions to achieve trust in terms of measurement.

1. "The qualification is relevant to the required skills in practice, and this approximates to validity" (p. 90).
2. "The examination is fair; that is, it tests those skills it is meant to test and only those skills, and this approximates to reliability" (p. 90).
3. "The results of the examination accurately reflect the performance of the candidate, that is, the assessment of performance is correct" (p. 90).
4. "The environment of the examination is controlled so that candidates are not allowed to cheat" (p. 90).

Many of today's research teams use electronic surveys to gather data and measure the development of web-based survey tools and customize them for participants. Dillman (2000) suggests that the advantages of web-based surveys are that paper, mail out, and data entry costs can be almost eliminated and that implementation time can be reduced. Also, the developed electronic system can be reused that saves on the cost of surveying additional respondents. However, Dillman (2000) also mentions the limitations of web-based surveys in that not everyone can be involved in the survey, so this may not work with the total populations, and even if connected, the respondents will not necessarily be equally literate in terms of computer usage.

Many existing studies have focused on the elements of process and design required to measure job performance. These researches are concerned with the measurement and evaluation of employee work performed. Even though these to some extent involve the measuring of capabilities, they are based on subjective and non-specific methods. Moreover, studies that assess the skill level of competency are hard to find. Most companies have a tool to assess the achievements and capabilities of their employees. However, they only usually measure job performance or subjective and conceptual competencies such as leadership, communication capability and creativity. A company's human resource representatives or managers can roughly guess employee professional skills by examining their certification or the accounts of their careers in their resumes. Thus, it is very difficult to find tools or research that evaluates the skills and capabilities of employees quantitatively.

2.4 Information technology workforce skills

Generally, the term 'skill' indicates a basic level of proficiency, such as how to handle or apply a specific tool and method. In addition, capabilities are related to the proficiency of skill adaption, and then competencies are aggregations of capabilities (Abraham, Beath, Bullen, Gallagher, Goles, & Kaiser, 2006).

IT organizations need to identify the current proficiency of the workforce and their skill needs in the near future. To do this, the skill requirements for IT professionals should be identified and classified as part of workforce research (Ang, & Slaughter, 2000). Furthermore, an assessment of employee capabilities and skill proficiency is critical to develop their competency and ultimately to meet the demands of business.

Davis and Olson (1985) described the required jobs in the area of information technology as analysis, design, development, implementation, support, and management of computer-based information systems, composed of software, hardware, people, procedures, and data.

In previous studies, the broad categories of skills included non-technical abilities such as business skills, management skills, and interpersonal skills as well as technical skills such as hardware, systems and, software. However, today some government organizations try to gather information about their employee skill capabilities by means of surveys.

The Federal Chief Information Officers Council (CIOC) carried out the 2011 Information Technology Workforce Capability Assessment Survey (ITWCA) by targeting federal civilian employees in the U.S. Office of Personnel Management (OPM). The survey (ITWCA) was administered to the 17,662 federal workforce in a set of 77 technical IT Skills (Chief Information Officers Council, 2011). They categorized the job titles as follows: customer support, security, IT project management, systems administration, applications software, policy and planning, systems analysis, network services, data management, enterprise architecture, internet, operating systems and others.

They found that respondents spent much of their time in their normal work on a number of job activities - such as customer/end user support, IT project management, applications software, systems analysis, and IT security/cyber-security/information assurance. Also, respondents most frequently rated themselves as having the following skills to some degree - desktop applications, Microsoft Windows desktop operating systems, systems support and helpdesks, client-server, information management, testing, requirements management, continuity of operations planning, system analysis and design, and network operating systems.

Goles, Hawk and Kaiser (2008) examined the current and future employee skill sets through a survey of IT software and service providers. The survey included questions about 38 capabilities and skill types – technical, business domain, project management, managing customers, and managing suppliers.

As the literature review indicates, researchers tried to find the necessary skills for employees to achieve a successful career in their job area. However, the skills required for the IT workforce are changing along with the technology and business environment, so organizations need to keep working with educational institutions to identify changing skill requirements. (Goles, Hawk, & Kaiser, 2008).

2.5 Relation between job performance and job experience

IT skill and job experience are expected to have a close relationship, but it is hard to find studies that are directly related to this. There have, however, been some examinations of the relationship between work experience and job performance, and which types of work experience have a high correlation with job performance. Through these studies, the nature of the relationship between job experience and skill improvement can be estimated. Experience can be defined as "the culmination of context-based events that an individual perceives" (Sturman, 2001, p.5). It can also be described as the accumulated knowledge of specific jobs derived from action, practice, and perception of the tasks (Sturman, 2001).

Quiñones, Ford and Teachout (1995) have identified the relationship between work experience and job performance by using a meta-analytic review method. Also, Sturman (2001) has suggested that job experience, organizational tenure and age have a non-linear relationship with performance. These researchers have demonstrated that job experience has a positive effect on work performance. Also, Sturman (2001) argues that job experience influences job knowledge and task proficiency, and thus eventually affects job performance. Job experience can be estimated as the amount of time spent by employees in their job (Quiñones et al., 1995).

In addition, number or time as the unit of measurement for the estimation can be considered. The results of the meta-analyses showed that job performance and work experience have a positive relationship (Quiñones et al., 1995). Also, the results show that the amount of task-level experience that a person has accumulated has the strongest relationship with job performance (Quiñones et al., 1995).

In comparing studies that have examined the relationship between job performance and experience with measuring at a job or organizational level of specificity, the study showed that job experience and performance have the strongest relationship in measuring at the task level of specificity (Quiñones et al., 1995). Also, it was demonstrated that time based measurements are unreliable for actual experiences. For example, the expectation of job performance for employees who have 10 years of job experience cannot be trusted because the time based measures are not reliable for estimating actual experience. The information about the number of times, the amount of times, and the specific tasks required are needed in order to predict their job performance. As a result, it is important to find out the amount and number of times and the tasks required to estimate an employee's experience, which infers information about their knowledge and skills. This is very important for this study, because this study used the measures - amount of time and number of times, and specific tasks to estimate work experience of employees.

2.6 Software cost and schedule estimation model

The reliable estimation of cost and schedule is one of the important factors in a successful software project (Musilek, Pedrycz, Sun, & Succi, 2002). The Constructive Cost Model (COCOMO) was developed by Boehm to estimate costs and schedules and was published in his book 'Software Engineering Economics' in 1981 (Musilek et al., 2002). COCOMO Ⅱ, as an improved version of COCOMO, was developed and published by Boehm and Southern California students in 2000. COCOMOⅡ provides three model series according to the steps of the project life cycle (Boehm, Clark, Horowitz, Westland, Madachy, & Selby, 1995). At first, an application composition model can be applied to develop the initial prototype in the very early stages of the project. Secondly, an early estimation model can be applied in the state in which requirements for the product development have already been made and an exploration of architectural alternatives requires support. The last model is applied to the stage of development in which more accurate information about software size and cost driver inputs can be provided.

The COCOMOⅡ model provides the following formula to estimate the effort required to develop a software system (Boehm et al., 1995). Effort is defined as person-months (PM), while a person-month represents the amount of effort for a one man operation in one month in a software development project.

$$\mathrm{PM} = 2.94 * Size^{E} * \prod_{i=1}^{17} EM_i \text{ , } \mathrm{E} = 0.91 + 0.01 * \sum_{j=1}^{5} SF_j$$

(Size: Size of software project, EM: Effort multiplier, SF: Exponent scale factors)

Source lines of code and function points are used to calculate the Size factor. The source lines of code means the size of the source program and expressed as the number of thousands of lines of code, and function points method is to quantify the amount of functions provided to the users based on the logical design.

Effort multipliers (EM) consist of 17 factors affecting the cost of the software projects and cab be categorized as Product factor, Platform factors, Personnel factors, and Project factors. Weigh values are assigned to the 17 factors according to the rating level - very low, low, nominal, high, very high, and extra high. For instance, personnel factors, one of the EM categories, consist of analyst capability, programmer capability, personnel continuity, application experience, platform experience, and language and tool experience. If the rating level of programmer capability is nominal, the weight value is 1.0, but if the rating level is very low, the weight value is 1.34. The lower rating level of programmer capability means that bigger efforts to develop software are needed, due to the lower capability of programmers.

Exponent scale factors have five elements - precedentedness, development flexibility, architecture/risk resolution, team cohesion, and process maturity. They also have different values depending on the rating of factors - very low, low, nominal, high, very high, and extra high, and the higher rating level needs the lower costs.

All the cost factors of COCOMO Ⅱ are assigned to a qualitative rating that represents the efforts to develop a software system. Each rating can range from very low to extra high, and all qualitative ratings are converted into a quantitative value to be applied to the model with weight values. All nominal rating has 1.0 value, and if the rating of a particular factor raises the cost of software development, the rating value is greater than 1.0. On the contrary, if the rating of a factor decreases the cost, the value is less than 1.0.

This approach can be considered to quantify the factors that affect IT skill estimation pursued in this study. For example, if the factors that are difficult to be quantified such as learning ability or working environment for IT skill evaluation can be rated in the same way in COCOMO Ⅱ. For example, if the rating level of the working environment can be decided, the weight value of the rating level can be applied to the result of IT skill estimation additionally. In this study, work experience is only considered to make methods and tools. However, a complementary method is used in order to take into account factors that are difficult to be measured can be considered.

2.7 Summary

This review includes explanations of a competency model, of information technology skill sets and the relationship between job experience and job performance. Organizations and industries use competency models to identify the competencies required for roles in their work area, and this competency model is utilized to estimate and develop competencies as a tool. The Employment and Training Administration has updated the comprehensive competency model to fit with information technology industry. The optimized model explains the knowledge and skills needed for workers to perform successfully in the field of IT.

Hands-on-tests, paper-and-pencil tests, observer assessments, and self-reports including electronic surveys can be one of the methods required to measure the competencies. Most of the competency measurements in the previous research studies were based on estimating non-technical competencies. It can be difficult to find research reports that assess professional skills and capabilities in the work area in quantitative and objective ways.

Several studies have shown that there is a strong relationship between job experience and job performance (Quinones, Ford, & Teachout, 1995; Sturman, 2001). The results of these studies revealed that amount of experience and task-level experience have the strongest relationship with job performance (Quinones et al., 1995). This suggests that time based measures are unreliable with regard to actual experiences (Quinones et al., 1995). As a result, the amount of time and number of times required to perform specific tasks should be found out in order to assess each individual's experience effectively.

CHAPTER 3. METHODOLOGY

This chapter describes the framework that guided the design of the tool and then its use to conduct the investigation. As part of the methodology, this study also describes detailed information about data collection, sample data, and procedures to analyze it. This study visualized and gave shape to the study results by not only suggesting a methodology but also developing a tool applying that methodology. It also provides a description of the range of skills that a set of IT employees poses. As a result, this chapter describes the quantitative measurements of skills in an IT work area.

3.1 Framework

The purpose of this study is to create a reliable model for an IT skills assessment and grasp its availability and utility. For this, based on work experience information of employees, a model that can evaluate their professional IT skills was designed, and sample data was applied to the study. The methodology suggested in this study was embodied through database and computer programming, and enabled the results to be more easily confirmed visually. Figure 3.1 shows the general outline of this study.

The framework of this study has a structure to analyze work experiences of employees based on predefined IT skills, task activities, and analyzing rules, and then the results show evaluation of the employee skills.

In this study, measures needed to estimate work experiences of employees were examined through a literature review.

IT skills and task activities that can be typically used in the IT work area were suggested, and their interrelationship was examined. In addition, a methodology to estimate and analyze work experiences of employees based on the collected task history data of employees was suggested.

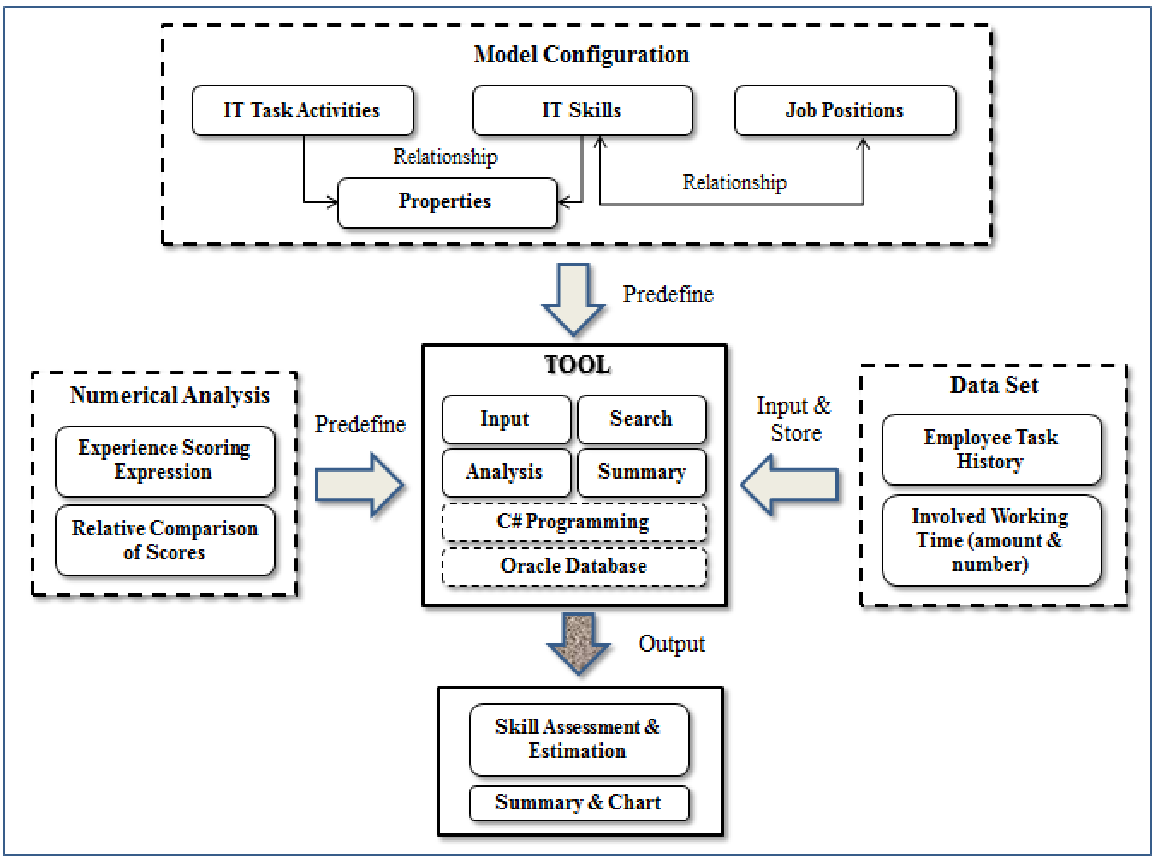

Figure 3.1 Framework Diagram

This framework is largely classified to the parts of the predefined rule, input, output, and tool. Information about the definition and relation and numerical method is included in the rule part, and the task history related to work experiences of employees belongs to the input part. After input data is analyzed by the tool, results of the IT skill assessment come out. Each area that makes up the framework is explained more in detail through the methodology description below. Information about the tool and output is described more in depth, being separated to Chapter 4.

3.2 Method

This study suggests a model that performs skill assessment based on the work experience data, not like methods usually used in other studies such as surveying, interviewing, or testing. And it tries to verify the benefits and validity of this model by applying data collected from the working environment of an actual IT company to this study. Theories and methods of important elements of the methodology suggested by this study are explained below.

3.2.1 Model Configuration

In order to assess IT skills based on work experiences, first, the skill list and task list that can describe IT jobs is defined. Thus, this study investigated skills needed to conduct IT jobs and tasks performed by IT employees. It grasps the relationship between IT skills and tasks needed for skill assessment based on the task history.

The Chief Information Officers Council defined 77 IT skills and used them for an Information Technology Workforce Capability Assessment Survey (ITWCA) in 2011 (Chief Information Officers Council, and U.S. Office of Personnel Management, 2011).

This study modified some of their IT skill list, and used 80 IT skills, because some skills are only related to the government works and not common in IT working area. These IT skills are classified to the general competency area, industry skill area, and professional skill area. The general competency area contains 10 skills that are not related to the industry, yet are commonly needed for employees, such as contracting, customer service, and managing human resources. The industry skill area includes seven skills that are commonly needed for IT industry, such as IT governance, client-server, Microsoft Windows desktop operating systems. The professional skill area includes 63 technical skills needed for an IT workforce, such as network security, system analysis and design, performance testing, data modeling, and development languages. The IT skills can be identified in the Appendix A.

One hundred thirty task activities that are generally performed in the IT work area were made in this study, and these activities are classified into eight categories, that is, security, project management, problem management, performance, PC support, operation, customer support, and change management. However, this study does not suggest standard tasks that can be applied to all IT businesses. In other words, the task lists should be modified and optimized to fit for each IT business and the job type of each organization. The task activities used for the sample data analysis are different from those suggested in this study, because the sample data was collected from the task history of employees of an IT outsourcing company.

The relationship between each skill and task can be grasped through eight job attributes: Planning & Design, Testing Analysis, Implementation, Maintenance & Operation, Trouble Shooting, Finance Management Planning & Design, Testing Analysis, Implementation, Maintenance & Operation, Trouble Shooting, and Finance Management. First, job attributes related to each skill should be determined to create the relationship. Job attributes related to each task list should be decided in the same way. As a result, if all the skills and tasks have direct relationships with job attributes, each job attribute plays a role of a mediator that makes the relationships between skills and tasks.

Table 3.1 and Table 3.2 show these examples. In the tables, '1' represents that there is a relationship, and '0' means there is little or no relationship.

Table 3.1 *Example for Relationship between Skills and Job Properties*

Skill	Job Property							
	Planning /Design	Testing	Analysis	Implementation	Maintenance /Operation	Trouble Shooting	Finance	Management
Systems Support and Helpdesk	0	0	0	0	1	1	0	0
System Analysis and Design	1	0	1	1	0	0	0	0
Test Plan Development	0	1	0	0	0	0	0	0

In Table 3.1, the 'Systems Support and Helpdesk' skill is related to 'Maintenance & Operation' or 'Trouble Shooting' among the job attributes. And in the task list shown in Table 3.2, 'Problem Management' is related to 'Trouble Shooting' among the job attributes. Thus, it can be assumed that there would be a relationship between the 'Problem Management' task and the 'Systems Support and Helpdesk' skill.

Table 3.2 *Example for Relationship between Tasks and Job Properties*

IT Task	Job Property							
	Planning /Design	Testing	Analysis	Implementati on	Maintenance /Operation	Trouble Shooting	Finance	Management
Problem Management	0	0	0	0	0	1	0	1
Documentation & Reporting	0	0	0	0	1	0	0	1

Table 3.3 *Example for Relationship between Skills and Job Positions*

Skill	Job Position								
	Software Application	System Administration	Network & Telecommunic ation	Database Management	Security	Operating Systems	Customer Support	Project Management	Enterprise Architecture
Network Operating Systems	0	1	1	0	1	0	0	0	0
Data Analysis and Reporting	0	0	0	1	0	0	0	0	1

In addition, relationships between IT skills and IT jobs were grasped in the same way as suggested above in this study. Nine IT jobs were used for this study, that is, Software Application, System Administration, Network & Telecommunication, Database Management, Security, Operating Systems, Customer Support, Project Management, and Enterprise Architecture. These job lists also should be modified and optimized to fit for the work type of each organization and business, like the task activities.

3.2.2 Numerical Analysis

In order to assume or assess skills of employees based on their task history, a method and a criterion for interpreting the task history are needed. For this, the model first expressed the amount and the number of job experiences of employees with one integrated score. In other words, a formula was made to represent the amount and the number of times that employees spent for each task.

The total amount of time that one employee spent for a specific task was represented as X_i, the total number of performing the task as Y_i, and the total number of employees who performed the task more than once as n. The average number that employees performed the specific task per hour can be represented as Formula 4 below. And by using the value of Formula 4, the relative value of frequency that one employee performed the task can be calculated with Formula 5 below. By adding the result value of Formula 5 to the amount of time value of Formula 1, the experience value of each employee for a task can be calculated as show in Formula 6.

1. Amount of time spent for a specific task j by employee i = X_{ij}
2. Number of times spent for a specific task j by employee i = Y_{ij}
3. Number of people who performed a specific task j = n_j
4. Average number of times per hour that performed by all employees for the task j

$$= \alpha_j = \sum_{i=1}^{n} \left(\frac{Y_{ij}}{X_{ij}}\right) \Big/ n_j$$

5. Value for number of times for the task j by employee i = $\beta_{ij} = {}^{Y_{ij}}\!/_{\alpha_j}$

6. Time value of work experience for the task j by employee i =

$$\frac{{}^{Y_{ij}}\!/_{X_{ij}}}{\alpha_j} \cdot X_{ij} + X_{ij} = {}^{Y_{ij}}\!/_{\alpha_j} + X_{ij} = \beta_{ij} + X_{ij}$$

Conclusively, in the formulas above, the value of the number of times was converted to the relative value of amount of time. Then it was added with the real value of the amount of time.

Table 3.4 *Example of the numerical method that represents amount of job experience*

People	Amount of time (X_{ij})	Number of times (Y_{ij})	Number of time per hour	Average number of time per hour (α_j)	Value for number of times (β_{ij})	Final Value
	1)	2)	3) = 2) / 1)	4) = Sum of 3) / 7	5) = 2) / 4)	6) = 5) + 1)
Employee1	10	3	0.30	0.43	7.00	17.00
Employee2	10	6	0.60		14.00	24.00
Employee3	20	3	0.15		7.00	27.00
Employee4	20	6	0.30		14.00	34.00
Employee5	40	13	0.33		30.33	70.33
Employee6	50	50	1.00		116.67	166.67
Employee7	100	40	0.40		93.33	193.33

Table 3.4 above explains the suggested method with examples. Although Employee 1 and Employee 2 have the same ‘Amount of time’ values, Employee 2 have more ‘Number of times’ value. This means Employee 2 performed the task more frequently. As a result, Employee 2 will have a higher value for number of time, and

thereby have higher final value. In conclusion, for that task, it is shown that Employee 2 has more experience than Employee 1. Employee 6 has half the ‘Amount of time’ value compared to Employee 7, but has more number of experience for that task (50 times: 40 times). Accordingly, Employee 6 has higher ‘Index for number of times’ value, and as a result, the difference between the final values of the two employees is not as large as that seen between the ‘Amount of time’ values. Employee 3 has spent more amount of time than Employee 1 even though they have worked the same number of times for the task. Employee 3 might have worked more complicated jobs or jobs that needed more time. For example, if employee 3 has installed operating systems on more servers than employee 1, employee 3 would have spent more time than employee 1, even they have worked the same number of times for their tasks.

After obtaining index values of each employee for all tasks performed by them, the experience level of the skill of each employee can be assessed by comparing their index values. In other words, a skill level of an employee can be relatively determined by comparing the values with the index value of the other employees after calculating maximum and average index values of employees for the task. Table 3.5 below shows the results of comparing index values of employees based on the information of Table 3.4 presented as examples above.

Employee 7 has the maximum experience value (193.3), and compared to this, the total average value (76.0) has a percentage of 39.3%. And the experience value of Employee 1 has a percentage value of as low as 8.8% compared to that of the maximum value. This indicates that, for that task, Employee 1 has only 8.8% of the experience level of Employee 7. And it can be assumed that this employee has the same experience level of the skills used for performing the task.

Table 3.5 *Example of comparison index values among employees*

People	Experience Value	Percentage
Employee1	17.0	8.8%
Employee2	24.0	12.4%
Employee3	27.0	14.0%
Employee4	34.0	17.6%
Employee5	70.3	36.4%
Employee6	166.7	86.2%
Employee7	193.3	100.0%
Average	76.0	39.3%
Max	193.3	100.0%

3.2.3 Data Set, Participants, and Procedures

Work details can be recorded into the HR systems by each employee, or employees can report their work details to managers through simple ways such as emails or paper. These records can be important data from which work experiences of IT employees can be inferred.

The tool developed in this study shows a way to record and manage work experiences of employees. As explained in Chapter 2, the work experience information that is the most closely related to the job performance is specific tasks performed by employees, and the amount and the number of time demanded for the tasks (Quiñones, Ford, & Teachout, 1995). Users of the tool can record information shown in Table 3.6 in the database. Based on the accumulated data, managers can grasp work experiences of employees, and as a result, can assume or assess IT skills of employees.

Table 3.6 *Example of Input of Task History*

Name	Date	Category	Task Name	Amount of Time (Hr)	Note
Employee3	09/30/2013	Project Management	Planning & Proposal	1.5	Discussion with customer
Employee3	09/30/2013	Security	Security Auditing	1	---

In order to confirm validity and utility of the methodology and the tool, this study collected actual work details of employees working for an IT company. This company, SK C&C, has its head office in South Korea, and many branches in several countries including the U.S. This company is specializing in Information Technology that is equipped with specialized infrastructure such as Data Center and Disaster Recovery Center, which carries out system integration, information technology outsourcing and a consulting business. This company retains approximately 4,000 employees and generates approximately $2 billion in sales every year.

The data collected from the company includes the task history of the 50 employees, that is, names of them, working dates, task categories, task names, and the amount of working time. In addition, for more comprehensive data analysis, the number of years of experience of the employees, occupations, and job positions were collected together. Data of the names of the employees was changed to an artificial identifier due to confidentiality reasons. The 50 employees have various work experiences ranging from 1 to 13 years, and they mainly have occupations such as the system engineer, database engineer, and manager. The data contains all the task history performed by the employees from July to December, 2013, and was extracted as 15,000 excel records. The collected data went through loading, transformation, and mapping processes via Oracle database to fit for the tool developed in this study.

3.3 Output

Results of the skill assessment can be calculated with both index scores of each skill and task category. And these results can be visually expressed through charts – radar chart, bar graph, pie chart, etc. The analysis results provide results of analyzing the whole employees as well as skill assessment results of each employee. With these results, managers of organizations can estimate skill levels of employees and easily search those who retain skills needed for current and new jobs. Moreover, organizations can develop training programs optimized to improve skills of employees.

In order to verify the validity of the methodology and the tool, this study analyzed data and assessed skills based on the task history of IT unit employees working for an actual IT company. The results provided by the tool show skill levels of each employee through relative comparisons among them. And by comparing employees who have different job positions, the difference of skills accumulated depending on the job position can be grasped.

3.4 Validity and Reliability

In order to enhance reliability of the model suggested in this study, the tool was embodied with the actual working history of the IT company employees. The analyzed data represents consistent results. The results show very similar skill assessment with similar work experience data derived from employees in same job position, and very different skill assessment with different work experience data derived from employees in different job positions. It means that skill assessment has a positive relationship with work experience, and can be based on work experience data.

To reduce bias of the sample data, the long-term task history of the employees having various experience periods was collected. It tried to produce useful information needed for company activities by analyzing the collected data from various points of view. And it raised objectivity and reliability of the skill definition by using IT skills suggested by Chief Information Officers Council in the study.

3.5 Modified Numerical Method

The numerical method suggested earlier cannot be used to evaluate IT skills of new workers, because they don't have information of accumulated task history that prove the level of their work experience. A modified method including an initial value that expresses work experience held by new career employees should be considered for this case. A modified method might be expressed as follows.

1. Value for work experience for task j by employee i $= \beta_{ij} + X_{ij}$
2. Initial value for work experience for task j for new employee i $= I_{ij}$
3. Modified value for work experience for task j by employee i $= I_{ij} + \beta_{ij} + X_{ij}$

The initial values for the new career employees can be determined by the manager by using other methods such as interviews, and reviews of certification. The initial value decided by managers should be relative values that are compared with the skill values of all employees. For example, one new career employee skill level can be assigned as 70% of the average skill values of all employees or 30% of the max skill value of all employees.

The original numerical method was used for tool development and case studies using sample data, because the initial values of employees in the sample data cannot be identified. Only work experience was considered in evaluating IT employee skills in this study. But if the other factors - learning ability, the work environment, training opportunities and working attitude can be measured in the future study, weight values like the effort multipliers in COCOMOⅡ can be applied to the method in this study.

1. Index for skill j by employee i $= I_{ij} + \beta_{ij} + X_{ij} = S_{ij}$
2. Modified index for skill j by employee i = $S_{ij} * \prod_{i=1}^{n} AF_i$

(AF: Additional factors affecting skill improvement, n: Number of factors)

However, with the limited range of this study, work experience was only considered in terms of the results and tool development, because additional factors cannot be defined and the scale values of the factors cannot be determined to be applied into numerical method at this present.

3.6 Summary

The framework suggested in this study includes information about the predefined model configuration, and the numerical analysis. And the tool that can accumulate and analyze the task history was provided. IT skills and task activities that can be generally applied to IT works were used, and the relationship between skills and task activities and that between skills and job positions were grasped through the job property.

The method that can express the number of times and the amount of time that employees spent for a specific task with an integrated index was suggested. Also, the method that can express experience levels of employees was suggested. By comparing experience values of employees, the method to estimate skills that each employee retains was suggested.

This study increased reliability of the study results and confirmed utility of them by collecting experience data of actual IT company employees and applying this data to the embodied tool.

CHAPTER 4. TOOL DESIGN

The developed tool provides a means to evaluate IT employees' skills using the history of tasks performed by the employees. The tool embodies the framework and method of this study. With this tool, organizations can evaluate the IT skills of their employees quickly, easily, and frequently. It is designed to provide an intuitive and simple user interface.

4.1 Software Overview

This tool was developed with the C# programming language and Oracle database based on the Windows OS platform. The data generated by users can be easily stored in the Oracle database through the interface developed into the tool. The Oracle database provides high-speed processing and analysis for complex data, while having excellent compatibility with the Visual C# programming. Figure 4.1 shows the overview of the developed tool in this study.

This tool has been developed using a Windows Form, so the graphical user interface is familiar to most users. All data inputs and outputs by the users are handled through the Windows Form, and the results can be displayed with visualized charts – bar graph, radar chart, and pie chart.

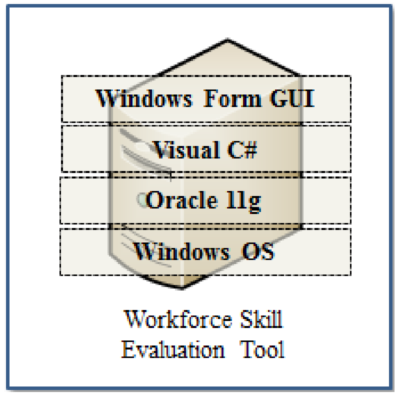

Figure 4.1 Software Overview

4.2 Design Considerations

There are some limits and restrictions on development of this tool. The constraints and development environment were described below.

4.2.1 Constraints

The employee information in this tool has been implemented with a minimal configuration to support the main features, because the employee information is stored in the HR systems in the real business environment. In addition, the inputting and updating of employee data, regarded as the role of the HR system, are not implemented in this tool.

Security features for the logging and personal data management such as encryption should be included in most commercialized programs. However, it is not a major feature of this tool, and some complexity of implementation was expected, so the features are not implemented in this tool. This tool is dependent on client environments and does not provide high accessibility for the anonymous client machine through the web browser.

4.2.2 Software Development Environment

This Tool was developed using Microsoft Visual C# programming based on the Windows operating system. The Oracle database is used to store the data, and ODP.NET was used as the .NET data provider optimized for the Oracle database. The GUI of this tool was implemented with the Windows form application.

Table 4.1 *Software Development Environment*

Component	Product Name	Version	Note
Database	Oracle Database 11g	11.2.0.1	Personal edition (It has same features with enterprise edition except license policy.)
Development Tool	Microsoft Visual Studio	2010	C# module
.Net Data Provider	ODP.NET	11.2.0.3	Oracle Data Provider for .NET
GUI	Windows Form		Supporting Windows Platform

4.3 Architecture

This tool has four main modules - Input Task History, Approval Processing, Skill Analysis, and Search/Summary. The architecture and features of main modules were described below.

4.3.1 Overview

The Input Task History module is used to enter employee work details such as tasks performed and the amount of time taken to perform each task. Also, it asks approval for storing the requested task history in the database from managers. Managers can accept or reject the requests through the Approval Processing module.

Employees are able to analyze their skill level, and check their task and skill history through the Skill analysis module. Finally, managers can check the status of employee skills, and easily find employees who have the skills needed for a new job through the Search and Summary module. Figure 4.2 shows the main modules and summarizes the features of the modules.

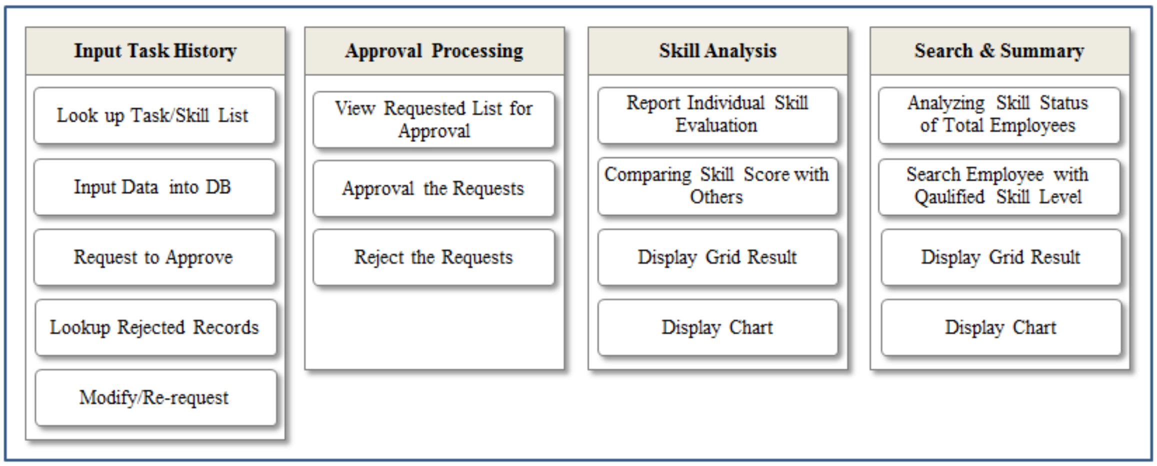

Figure 4.2 Main Modules

4.3.2 Data Flow for Modules

Functions and process flows implemented in each module are shown in Figure 4.3 and Figure 4.4.

4.3.2.1 <u>Loading program</u>

Users must enter their own username and password to run the program, but if this information does not match with the username and password stored in the database, the program will be terminated without proceeding further.

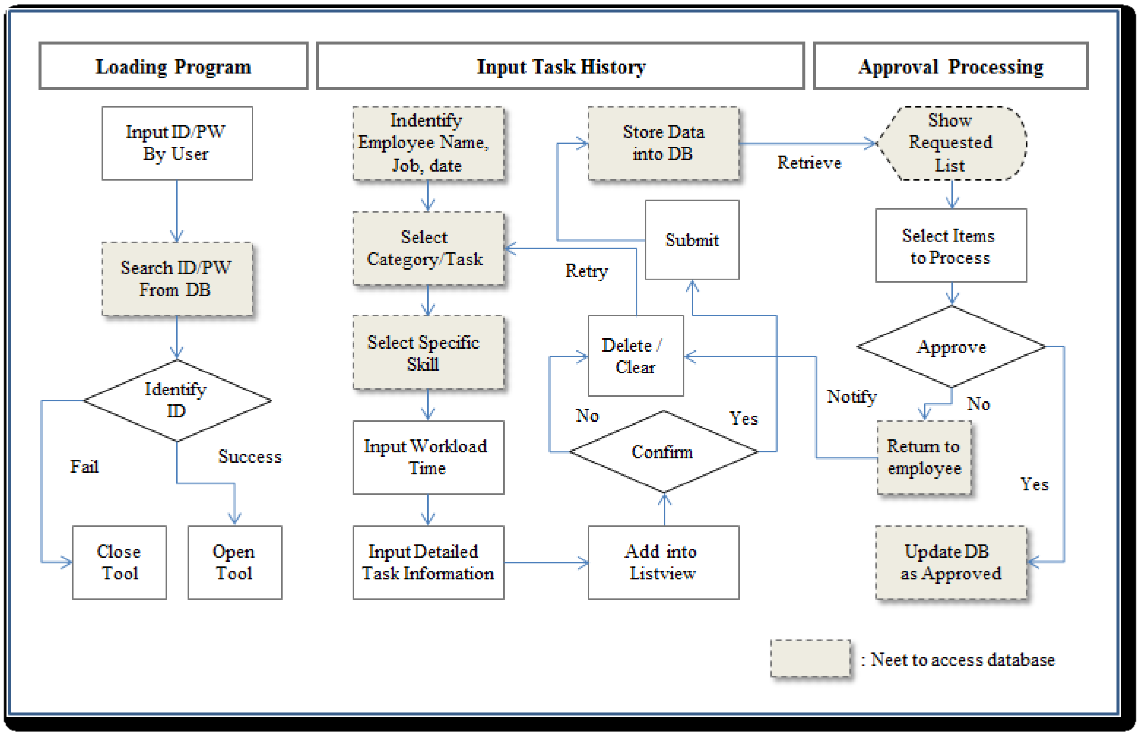

Figure 4.3 Data Flow for Loading Program, Input Task History, and Approval Processing

4.3.2.2 Input task history

Once the program is run, the personal information entered in the Loading module is transferred to the Input Workload module. So, username, manager name, current date, and job list can be assigned automatically to the module in this process. First, users should select the category of task and a task name that are displayed through the combo box. And then the tool displays the skills associated with the selected task on the other combo box. After selecting the most relevant skills, users can add information on the grid form of the tool. Once all input operations are finished, users can request approval from their managers and store the data in the database.

4.3.2.3 Approval processing

Managers can check the list that is entered by employees, then they need to decide to approve or reject for each item or all items that displayed on the module. The rejected items are notified and transferred back to the employees through the Input Task History module. Employees are able to request approval of the rejected items again after modifying them through the Input Task History module.

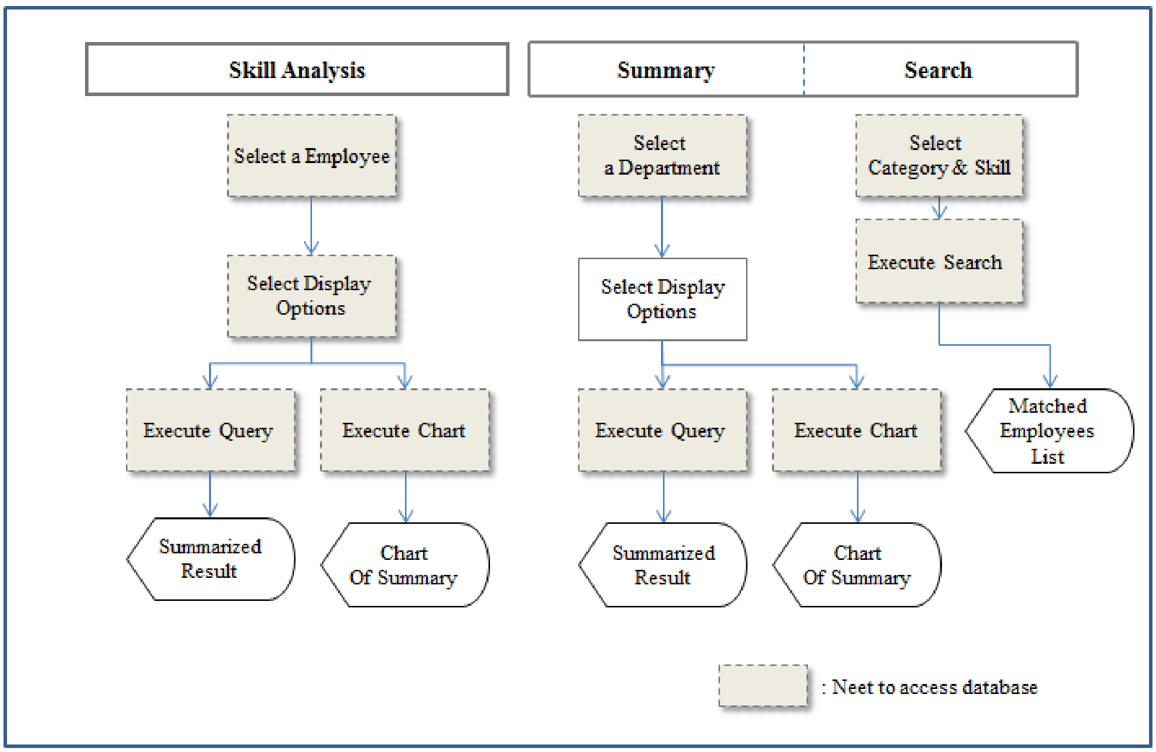

Figure 4.4 Data Flow for Skill analysis, and Search & Summary

4.3.2.4 Skill analysis

Employees can view only the history of their own tasks and skills, but managers can retrieve the information of employees. Employees' data stored in the database can be analyzed in accordance with the display options. Analyzed results are displayed visually through the chart - radar chart and bar graph, or on the grid forms. Through this module, managers can figure out current employees' skill level, and identify skills that employees need to develop.

4.3.2.5 Search & Summary

Managers can check the status of each skill set held by employees. The information provided for the status includes the skill or category name, the average value of these skills, the maximum value of these skills, and so on. The results can be displayed on the grid form or charts such as bar graph and pie chart. This module also provides an additional search function with which managers can find employees who have the skills needed for current or new jobs.

4.3.3 Logical Model

The following Entity-Relationship Model (E-R Model) shows the entities that contain information and the logical relationships among the entities. Each entity can represent a table in the database, and the relationships among the entities can represent processes and functions in the program. This logical model is designed to create effectively the relationship between task activities and skills, and to store the information of task history simply. Figure 4.5 shows Entity-Relationship Diagram describing main entities and their relationships.

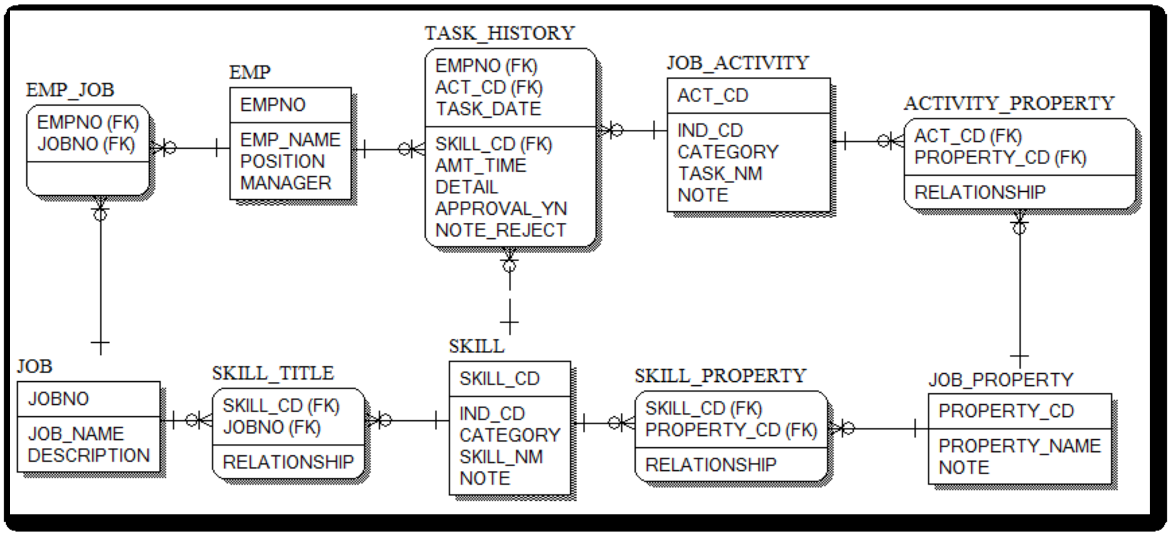

Figure 4.5 Database Entity Relationship Diagram (Main Entities)

4.3.4 Main Entities

The contents contained in the main entities and their roles have been described briefly below.

- SKILL: The information on skills-related industry, category, and skill name is stored in this entity. This is an essential entity in order to provide information on skills for users.
- SKILL_TITLE: This entity contains the information on the relationship between skills and occupations - database engineer, network engineer, system engineer, software application, security, operating system, customer service, project management, and architecture. The relationship field has the value ‘1’ or ‘0’. The value ‘1’ indicates that there is a relationship between the skill and the job occupation, and the value ‘0’ indicates that there is no relationship.

- SKILL_PROPERTY: This entity includes information that is essential to make the relationship between skills and properties. These properties – planning/design, analysis, testing, implementation, trouble shooting, financial management, maintenance/operation, and management were explained in Chapter Three. The relationship field has the value '1' or '0'. The value '1' indicates that there is a relationship between the skill and the property, and the value '0' indicates that there is no relationship.
- JOB_ACTIVITY: This entity is necessary to provide information on tasks for users. It contains tasks list and classification.
- ACTIVITY_PROPERTY: This entity includes information that is essential to make the relationship between tasks and properties. This entity also has the PROPERTY_CD and RELATIONSHIP fields that have same roles with the fields of SKILL_PROPERTY entity.
- TASK_HISTORY: This entity contains the history of tasks performed by employees. It contains employee ID, performed tasks, and the amount of time spent on the tasks. The tool accumulates large amounts of important information that is needed to evaluate skill competencies of employees in this entity.

CHAPTER 5. RESULTS

The developed tool that embodies the method suggested in this study is explained in this chapter and several case studies using the collected sample data performed. Consistent results are described and the reliability and validity of the study tested.

5.1 Tool Implementation

As explained in chapter four, the developed tool has four main components: Input Task History, Approval Processing, Skill Analysis, and Summary and Search. Visual interfaces such as charts, graphs, and windows interface were developed with C# programming language while processes for handling and analyzing data were implemented in a relational database Structured Query Language (SQL). The database structure is described in the Appendix B and Appendix C. Interfaces have fast response times as well as accurate results sets. Advanced SQL and database skills and chart control features included in Windows .NET platform were used. For example, SQL is used to analyze data and calculate values, and C# programming is used to display the results and charts in the tool. The SQL queries used to analyze and calculate data can be identified in the Appendix D and programming source codes used to draw chart were given in Appendix E.

The major components are shown below in screen shots captured from the tool. Figure 5.1 shows how task history can be input by employees and managed systematically. Considering Figure 5.1, in 1 and 2, the tool displays the related task names when a task category was selected by the user. In 3, the related skill names were also displayed when a task name was selected by the user. Input of used skills is optional. If the information of used skills related with performed task can be stored and managed, employee skill ability can be estimated more precisely, but if the skill information is not stored and managed, employee skill can be estimated from task history data with the method suggested in this study.

The task history stored in a database system by employees can be approved or rejected by managers. In 4, Figure 5.1 shows task history rejected by a manager. It can be resubmitted for manager's approval after modification.

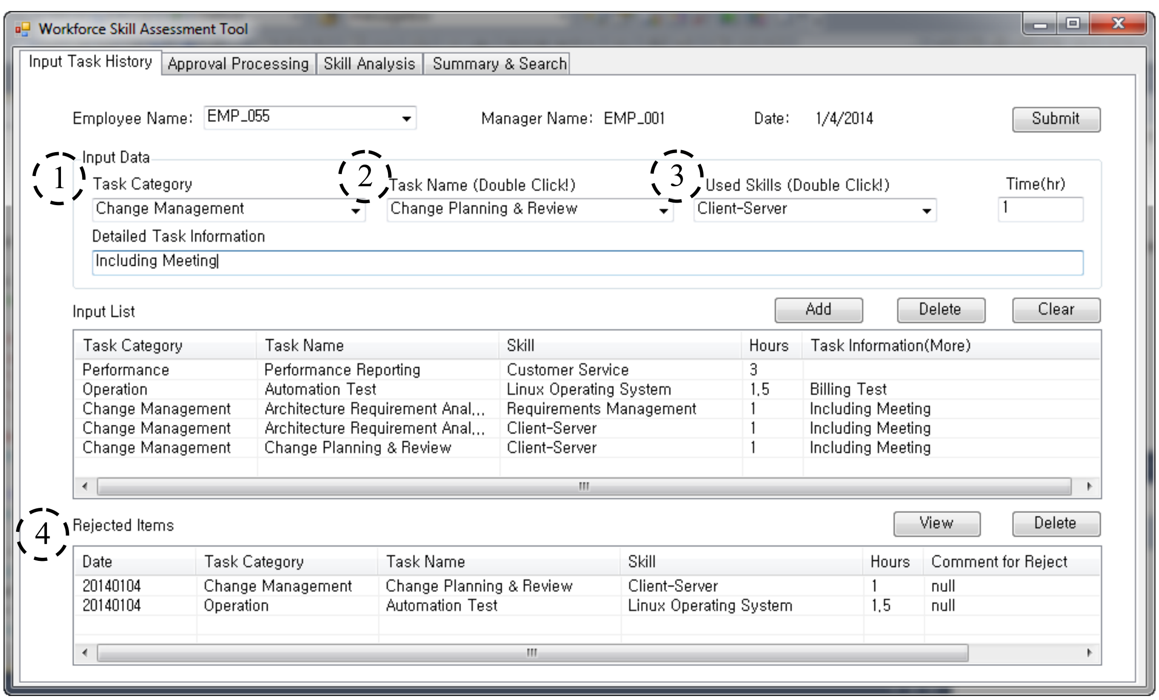

Figure 5.1 Tool Image – Input Task History

Figure 5.2 shows how the task history requested by employees can be managed by managers. Managers can approve or reject the requested task history, and the employees who submitted the task history are notified of the rejected items. This tool only uses task history approved by managers to estimate the skill of employees.

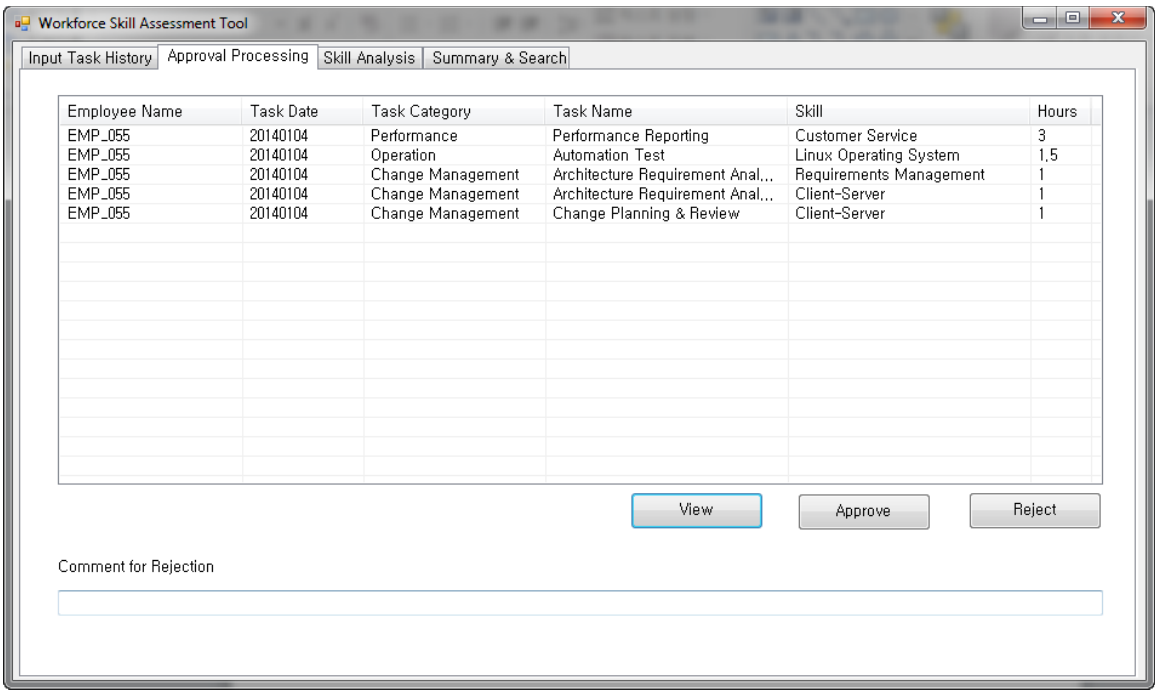

Figure 5.2 Tool Image – Approval Processing

Figure 5.3 shows the analyzed skill information of an employee classified according to task category. The estimated skill value can be displayed with a relative percentage value derived from comparison with all other employees as well as an absolute value calculated with only the employee skill value. Additionally, visual information through a radar chart can be provided by the tool. The analyzed skill can be displayed for each task category, as shown in Figure 5.3, as well as for each skill level, as shown in Figure 5.4.

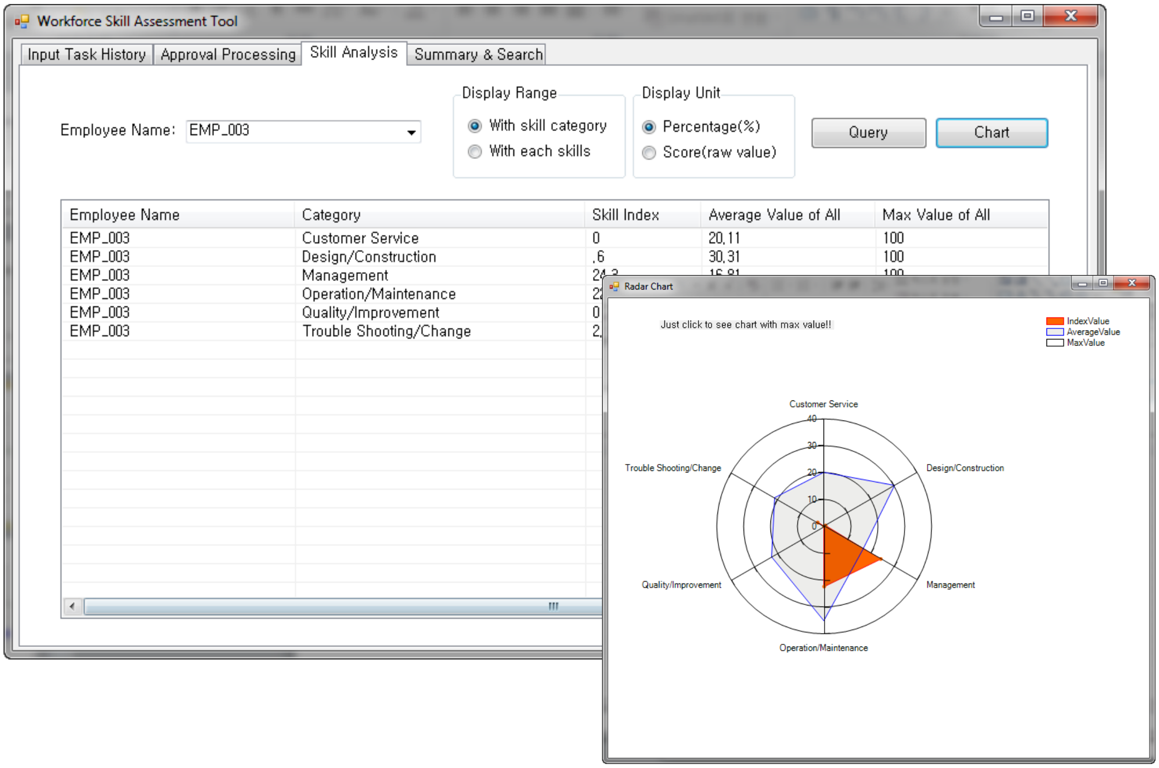

Figure 5.3 Tool Image – Skill Analysis (For Category)

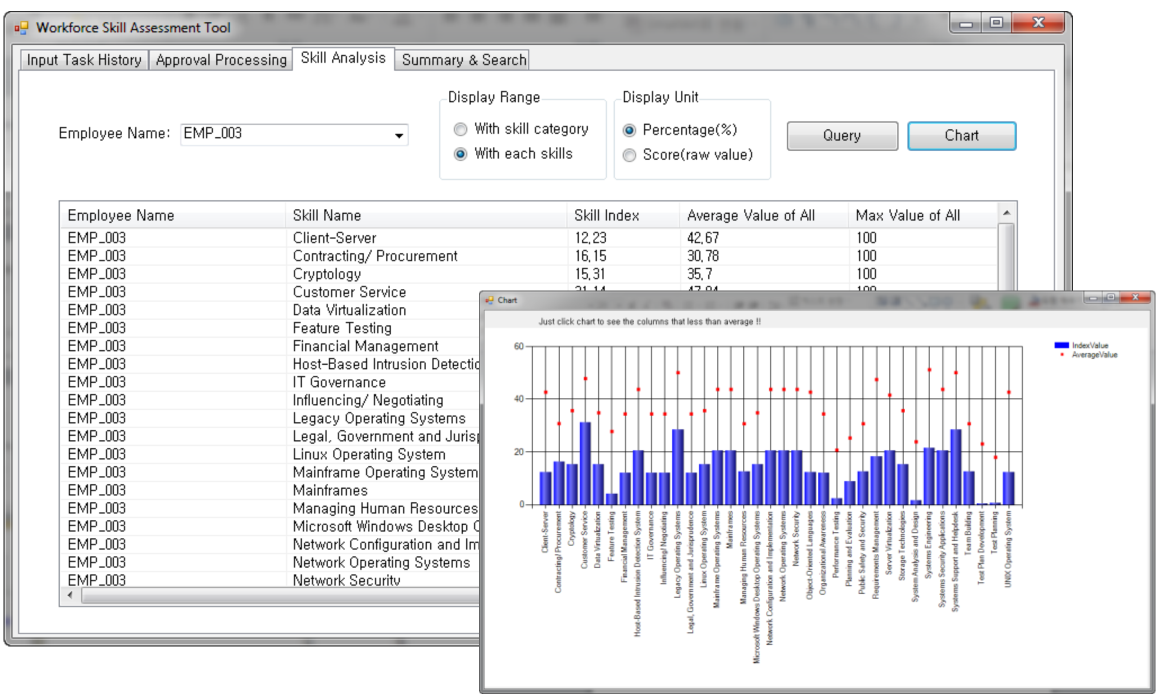

Figure 5.4 Tool Image – Skill Analysis (For Each Skill)

The employee skill level can be recognized easily by comparison with the average and maximum values of all employee skill values. Moreover, the tool provides intuitive information through the bar graph. The tool also provides the skill list and values that have less than the average skill value of all employees, so each employee can identify the skills that need to be improved compared with other employees' skills.

The analyzed skill information for all employees of departments can be obtained through the summary and search component as shown in Figure 5.5. Managers can analyze employee skill level from various perspectives. The department skill information is provided for each category, each task, and each skill. The information can also be displayed visually in pie charts and bar graphs.

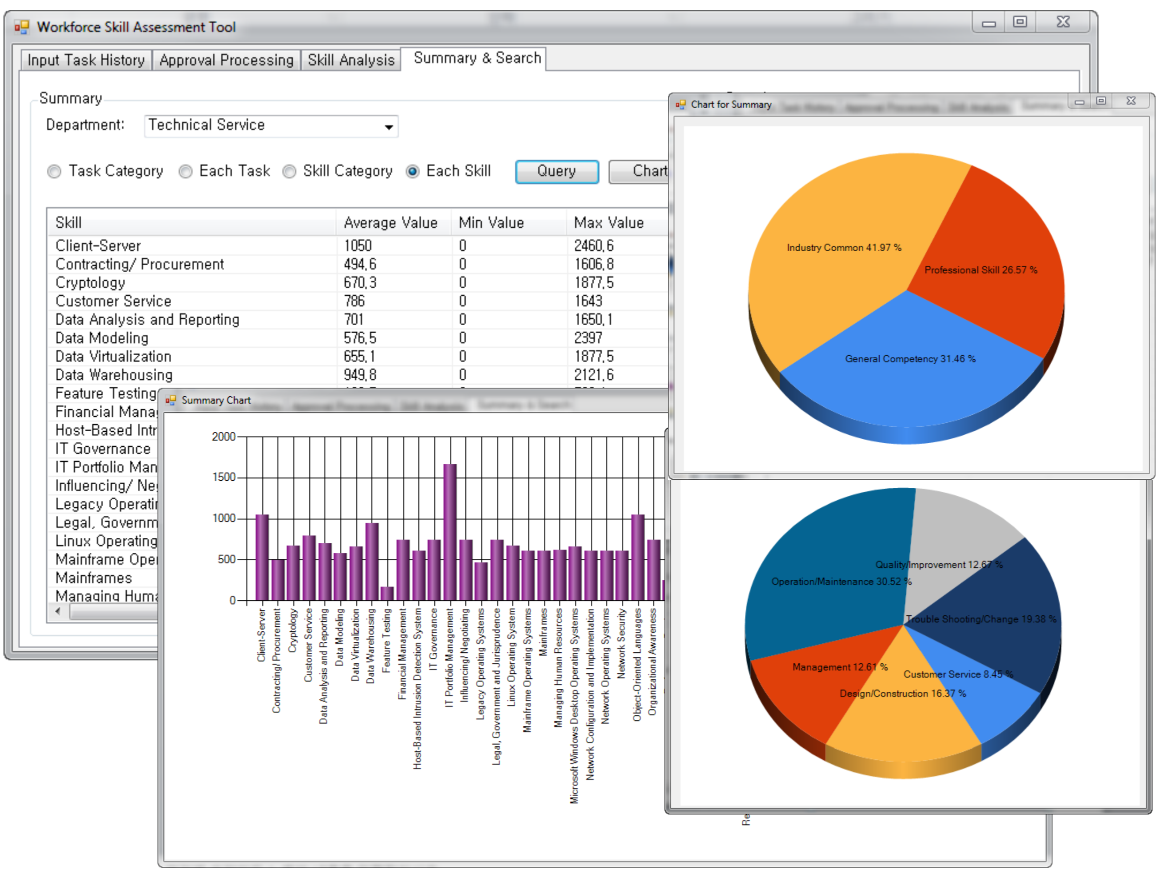

Figure 5.5 Tool Image – Summary and Search (For Skill Analysis)

Employees who have specific skills can be searched for through the summary and search component as shown in 1 on Figure 5.6. If a user selects a desired skill to search for and clicks the search button, the tool shows the name of employees who have bigger values than the average skill value of all employees. Managers can find employees who have skills needed for new jobs and business through this feature.

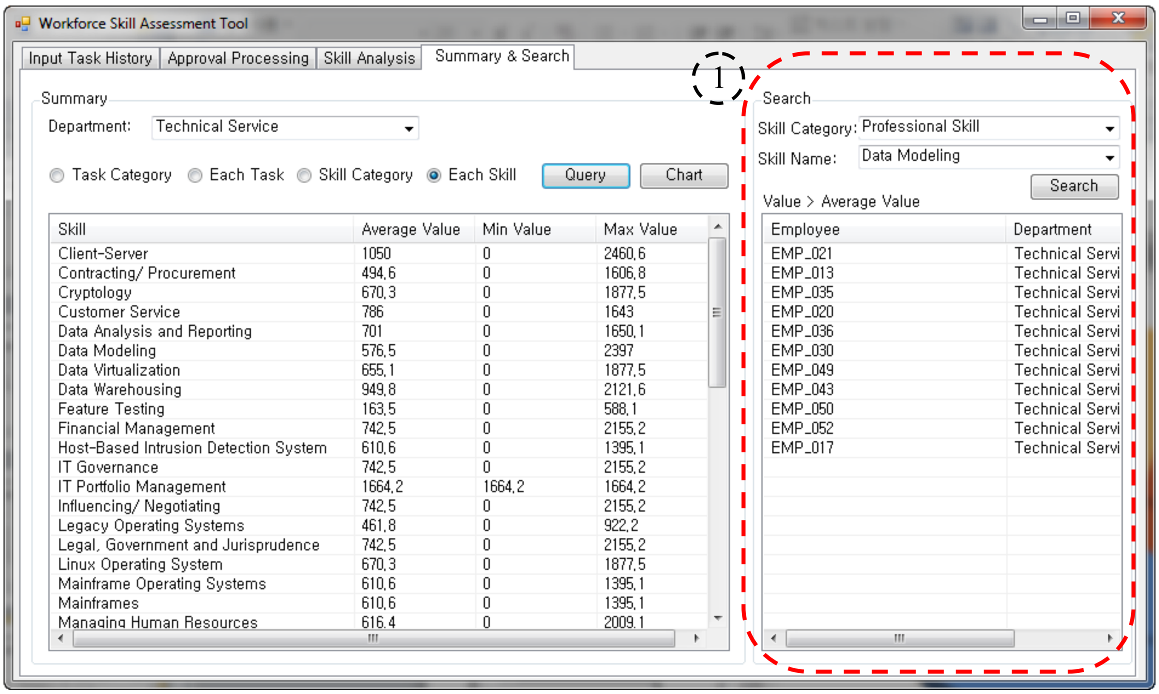

Figure 5.6 Tool Image – Summary and Search (Search Function)

5.2 Case Study

Several case studies using the sample data were carried out to test validity and reliability of results of the method presented in this study. Employee groups were created from the collected sample data and then actual task history and skill evaluation results were compared with each group. In each case study, the employee groups had similar or clearly different results in terms of skill evaluation. In this study, three cases (discriminative case, consistent case, diverse case) were based on the method suggested, and the contents and results of each case are described below in detail.

5.2.1 Discriminative Case

The estimated experience and skill levels were compared between two employee groups who had different job experiences and different job positions. Each group was composed of 12 employees with varying years of experience. The employees in the first group were database engineers and the employees in second group were in system engineers. In order to include a variety of work experience, each group consisted of four employees with three years of experience, four employees who had between four and eight years of experience, and four employees who had between nine and thirteen years of experience. As many employees as possible were included in the same group in order to increase the reliability of the results. Employees with the same years of experience performed the same task, but they had different work experience because of their different positions. The two groups were not expected to accumulate the same skills according to the method employed in this study. Table 5.1 shows the summarized information of employee groups.

Table 5.1 *Generation of Employee Group for Discriminative Case*

Group	**Subject (experience*number of employees)**	**Job Position**	**Value Type**
Group_DB	12 employees = (1 ~ 3 years * 4+ 4 ~ 8 years * 4+ 9 ~ 13 years * 4)	Database engineering	Sum of accumulated values
Group_Server		Server engineering	

The analyzed outcomes of job experience and skill for the two groups are displayed below. Figure 5.7 shows that the two groups generated from the sample data had performed the same or similar tasks. Both groups mainly performed operation and maintenance tasks rather than quality and improvement tasks. Consequently, the chart shows the same pattern of task history for both groups. Even if the two groups performed the same task, however, the used knowledge and skills were not expected to be identical because the employees had different positions. For example, database engineers mainly used knowledge and skills about database administration for the installation task, but server engineers mainly used knowledge and skills related to server administration. The skills used for the same task can differ depending on the job.

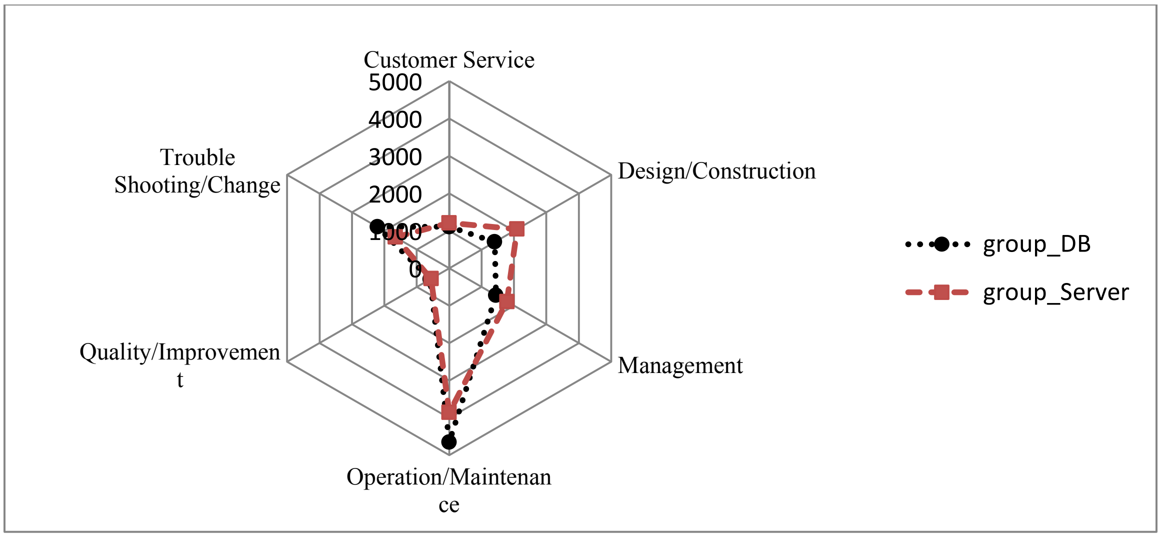

Figure 5.7 Job Experience Chart for Discriminative Case

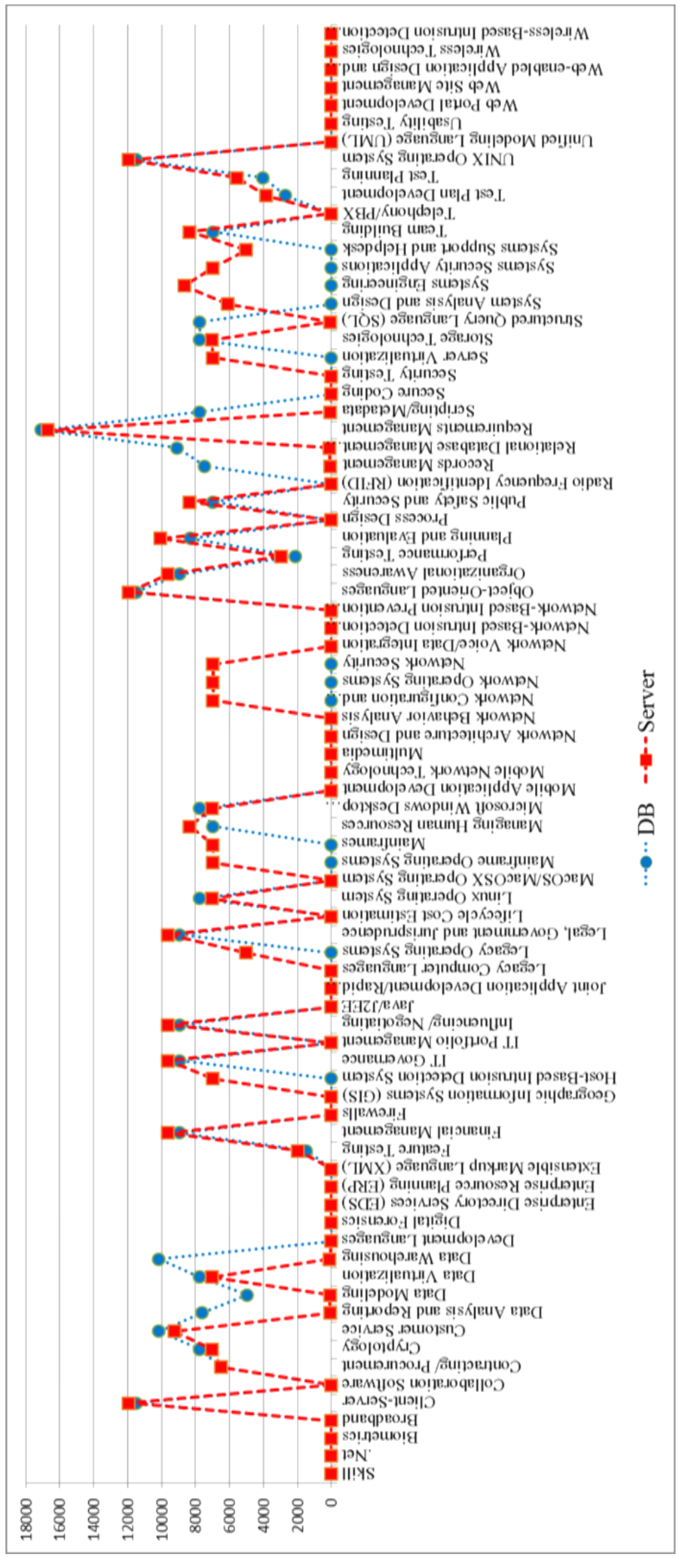

Figure 5.8 Estimated Skill Graph for Discriminative Case

Figure 5.8 shows results for the estimated skills of the groups. It shows that the two groups have different accumulated skills, even though they have performed the same tasks. They have accumulated different work experience because of their different positions. The chart presents the result forecast by the method used in this study. In other words, employee skills can be estimated based on work experience, and work experience of employees is determined according to task history and job.

5.2.2 Consistent Case

This case was performed to identify the consistent skill improvements in accordance with years of employee experience in the same job position. In other words, it tried to see if the estimated skill increases consistently in accordance with accumulating work experience. One employee with one year's experience, one with five years of experience, and one with ten years of experience who held server engineering jobs were created from the sample data. Then their accumulated task history and skill information were analyzed and compared. Information about how the employee data were generated is detailed below and Table 5.2 shows a summary.

- Period of task history of sample data : four months
- Average skill score of employees with experience between one and three years : S_1
- Average skill score of employees with experience between four and eight years : S_2

- Average skill score of employees with experience between nine and thirteen years : S_3

⇨ Skill score of employee with one year's experience: S_1*3 (12 months)

⇨ Skill score of employee with five years' experience: S_1*9 (three years) + S_2*6 (two years)

⇨ Skill score of employee with ten years' experience: S_1*9 (three years) + S_2*15 (5 years) + S_3*6 (two years)

Table 5.2 *Generation of Employee Group for Consistent Case*

Group	Subject (experience*number of employees)	Job Position	Value Type
1 year of experience	1 ~ 3 years * 8	Server engineering	Accumulated average values (shown above in detail)
5 years of experience	1 ~ 3 years * 8 4 ~ 8 years * 8		
10 years of experience	1 ~ 3 years * 8 4 ~ 8 years * 8 9 ~ 13 years * 2		

According to the method suggested in this study, employee skill scores can be expected to increase consistently as their work experience increases if they perform the similar or same tasks in the same job positions. Job experience and skills for the three employees are shown in the following charts.

Figure 5.9 shows the task history of the three made-up employees who perform the same task. The three chart lines of each employee show the same pattern, but the value increases with increasing years of experience. As a result, the accumulated work experience also increases as years of experience of employees who work in server engineering job increase.

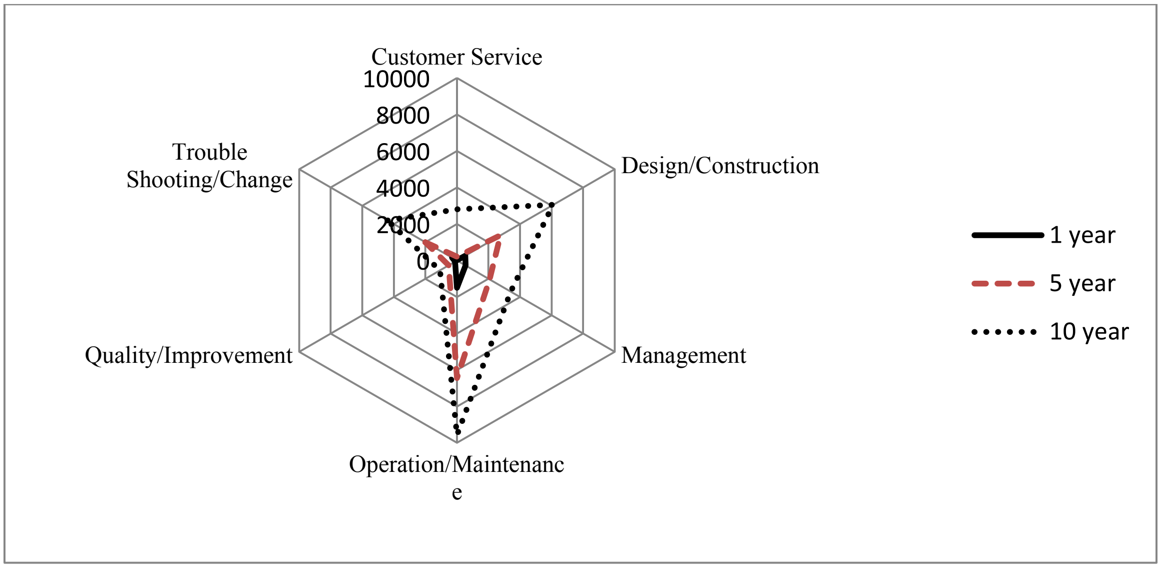

Figure 5.9 Job Experience Chart for Consistent Case

Figure 5.10 shows that the estimated skills of three employees are increased consistently. As shown in Figure 5.9, their accumulated skill levels do not differ, because the employees have the same job positions and the same task history. In conclusion, this case shows that the same skills are accumulated from the same work experience.

Like the former case, this case shows the expected results. The former case showed that different skills are accumulated depending on different work experience, but in this case the same skills are accumulated as the same work experience increases.

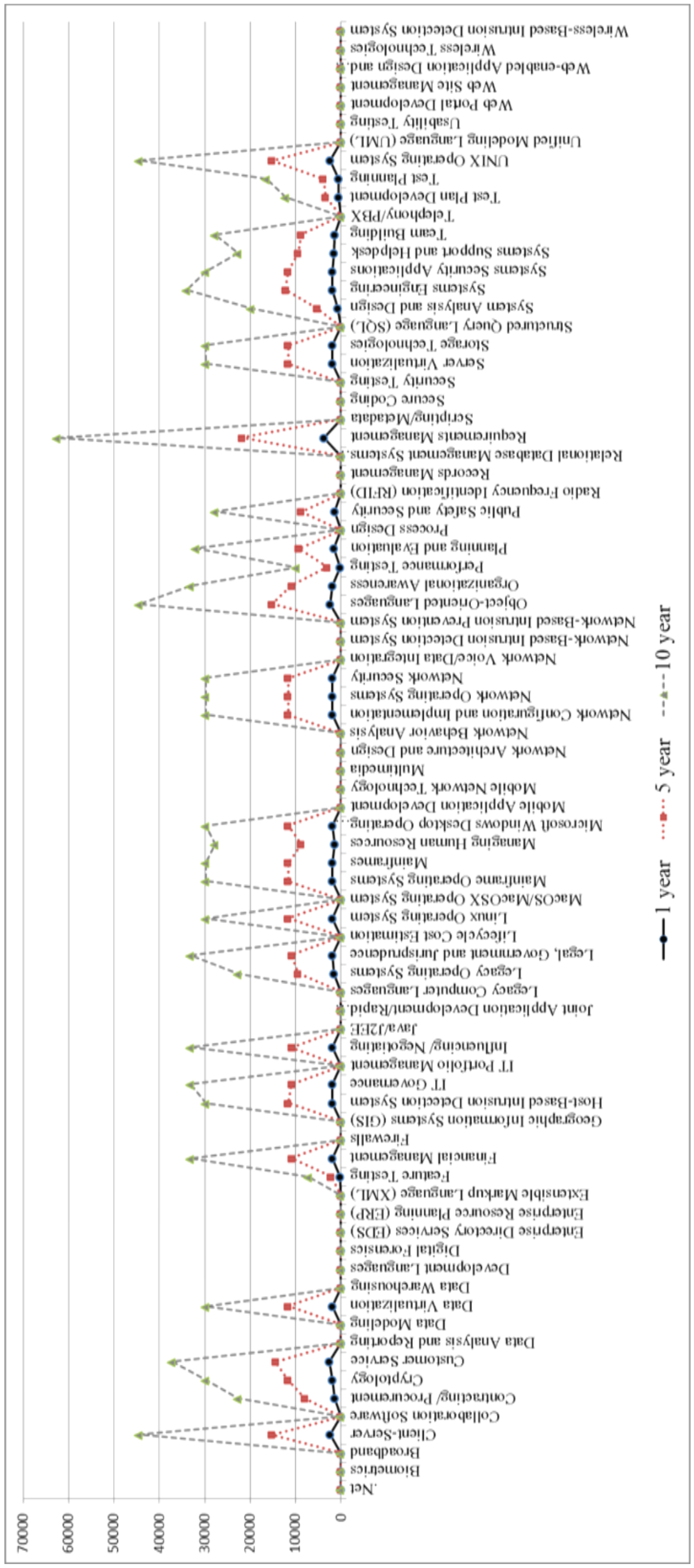

Figure 5.10 Estimated Skill Graph for Consistent Case

5.2.3 Diverse Case

This case tried to identify the difference of accumulated skills and experience between senior employees and junior employees. To do this, three employee groups with diverse years of experience were created. Data for the first employee were generated from the average experience value of employees with between one and three years of experience. Data for the second employee were generated from the average experience value of employees with between four and eight years of experience. Finally, data for the third employee were generated from the average experience value of employees with between nine and thirteen years of experience. Table 5.3 summarizes the information for employee groups.

Table 5.3 *Generation of Employee Group for Diverse Case*

Group	**Subject (experience*number of employees)**	**Job Position**	**Value Type**
1 ~ 3 years of experience	1 ~ 3 years * 8	Server engineering	Average values
4 ~ 8 years of experience	4 ~ 8 years * 8		
9 ~ 13 years of experience	9 ~ 13 years * 2		

The accumulated skill values for particular years of experience were used in the consistent case, but the average skill value of employees with one to three, four to eight, and nine to thirteen years of experience was used in this case. For example, the accumulated skill value of employees with one to ten years of experience was used to calculate the skill value of an employee with ten years of experience in the consistent case study, but the average experience value of employees with experience between nine and thirteen years was used in this case study. This case study was intended to identify the difference in task history accumulated among new, junior, and senior employees. This case study shows that senior employees with the same job position accumulate different skills because they perform different tasks with new and junior employees. The analyzed results of job experience and skill for three employees are shown in the chart below.

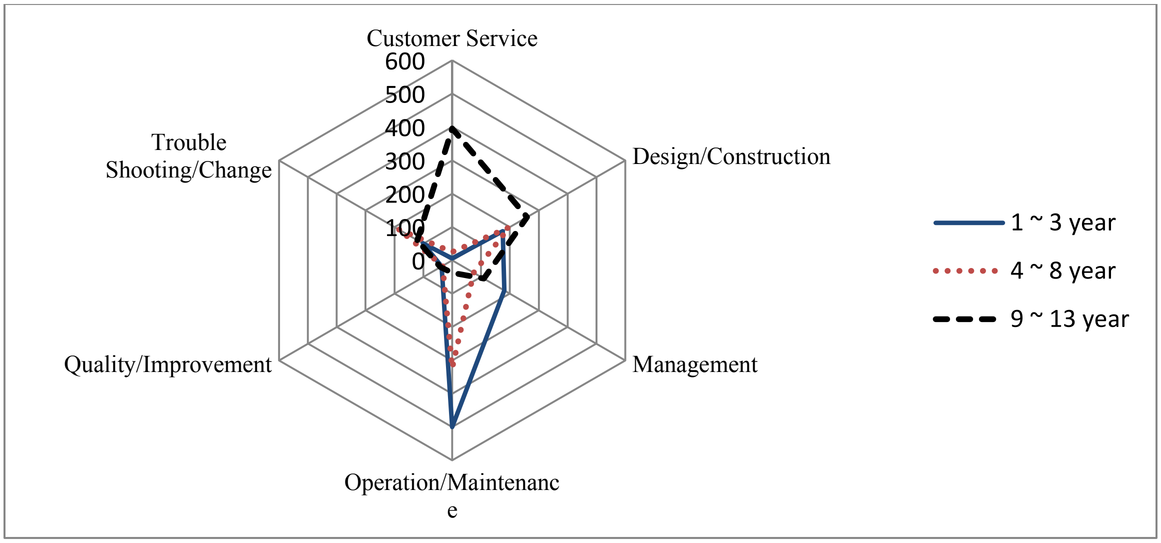

Figure 5.12 Job Experience Chart for Diverse Case

Figure 5.11 shows that employees with nine to thirteen years of experience perform different tasks from other employees with different years of experience. Employees with one to eight years of experience perform mainly operation and maintenance tasks, whereas employees with nine to thirteen years of experience perform customer service tasks more often. Consequently, employees with nine to thirteen years of experience are expected to accumulate more skills related to customer service tasks. On the other hand, other employees are expected to accumulate more skills related to operation and maintenance tasks.

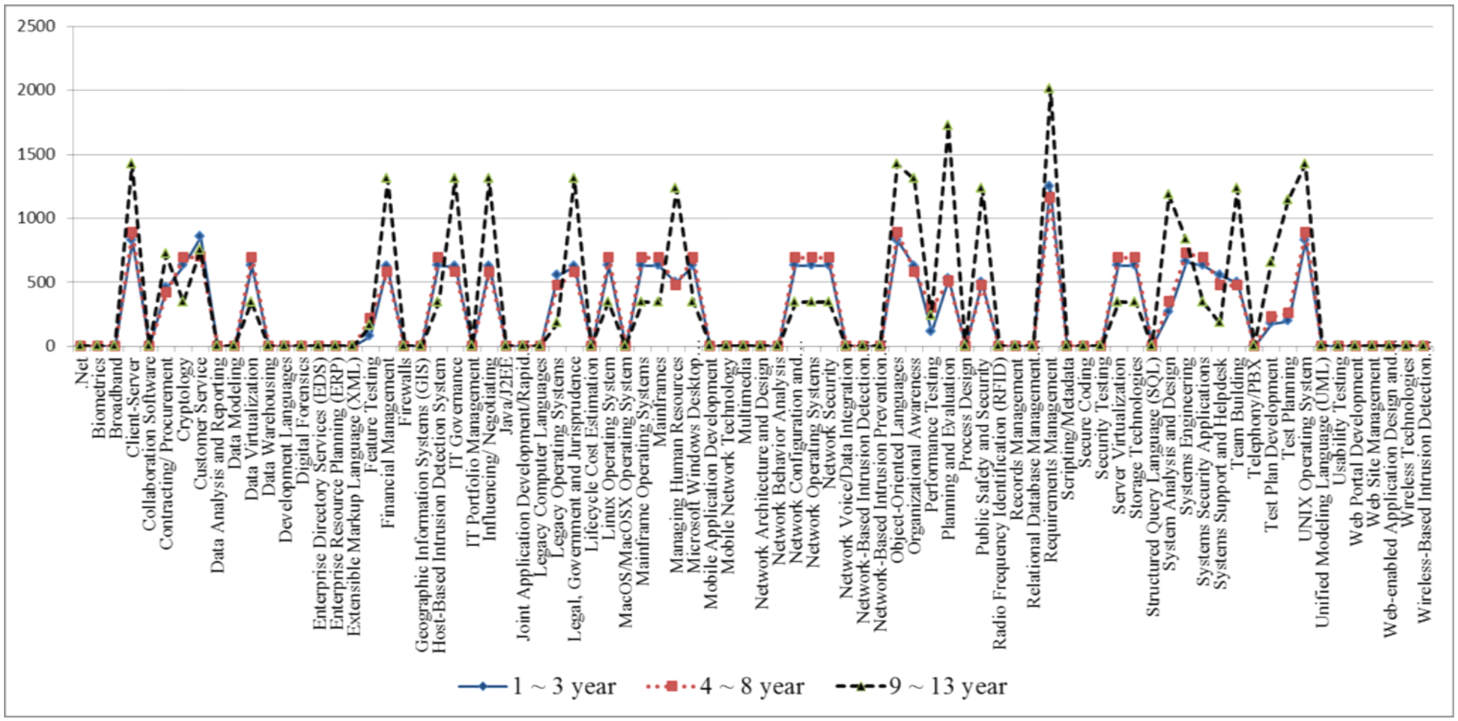

Figure 5.12 Estimated Skill Graph for Diverse Case

Figure 5.12 shows that there is a difference in the estimated skills of three employee groups. The estimated skills for employees with one to three years of experience and employees with four to eight years of experience are almost the same, but the result for employees with nine to thirteen years of experience shows a different pattern. The difference between the patterns as shown in Figure 5.11 derives from the fact that employees with nine to thirteen years of experience have performed different tasks even though they have the same job position as other employees. As a result, these employees have accumulated different work experience, and so they have accumulated different skills. Like the former cases, this case also shows the results expected by the method and tool presented in this study. This case study shows that accumulated skills can differ depending on employees' different work experience.

So far, the three case studies have shown consistently that skills can vary, depending on the work experience. The same or similar skills are estimated in accordance with the same or similar work experience, and different skills can be derived depending on different work experience. As a result, these case studies show that the estimation results for employee skills depend on work experience of task history and job position.

CHAPTER 6. DISCUSSION AND CONCLUSION

This chapter provides a summary of the study, with an overview and conclusion. Also, the implications and limitations of the study are discussed and future studies recommended. It concludes by explaining the findings of the study.

6.1 Summary of This Study

The purpose and motivation of this study is reviewed and its methods and results summarized below.

6.1.1 Motivation and Background

This study began with questions such as the following: how can IT skills of employees be evaluated objectively and quantitatively, and how can the results of evaluation be managed systematically and continuously?

The rapidly changing business environment means most companies use a vast amount of information in order to adjust in the market. In this environment, the productivity of IT organization has become an important element of company competitiveness, as it needs to handle vast amounts of information. Therefore, the abilities of IT employees are considered the critical factors of IT organization, and the organizations need to make efforts to improve their employees' abilities.

In order to improve employee skills, first, organizations should evaluate their employees' skills to understand the current levels of skills and knowledge and to figure out areas where skills are currently lacking. Every employee has different abilities as well as experience, leading to different results in terms of skills and job performance. Employees in the same jobs can have different levels of skills even though they have the same years of experience in their jobs.

Most methods to evaluate employee skills use surveys, interviews, paper tests, reviews of certification, and personal evaluation (Marcolin, Compeau, Munro, & Huff, 2000). Some of those methods measure knowledge of employees, and some methods depend on the subjective opinion of evaluators. It is not easy to get quantitative and objective results from IT skill evaluation of employees. Moreover, it is not easy to get results quickly when managers are seeking up-to-date evaluation results.

A different approach with existing evaluation methods was used in this study. The research question of this study was how IT workforce skills can be measured in terms of individual task activities and experience? This study suggested a method to estimate the level of workforce skill based on actual work experience data.

Quinones, Ford, and Teachout (1995) explained that job performance and work experience have a positive relationship, and the number of times and amount of time that spent by employees for their tasks are important factors to predict job performance. This study used the three measures to estimate employee skills based on their job experience.

6.1.2 Methods

This study defined the relationship between IT skills and IT task activities and between IT skills and job positions. First, the study referred to the 2011 Information Technology Workforce Capability Assessment survey (Chief Information Officers Council, 2011); 80 IT skills and eight IT job positions were then defined. IT task activities were collected from sample data and the eight job properties were suggested as a mediator to define the relationship between IT skills and IT task activities.

Sample data was collected from an IT company to test a developed tool and to check the validity and reliability of the method suggested in this study. The sample data included the task history of employees, which represents working experience for their jobs. The task history consists of employee identifiers, task categories, task names, working date, amount of time taken in the tasks, and so on. The sample data was extracted from more than 50 IT employees and contained more than 15,000 records that represent working activities of the employees over four months. The work includes database engineering, system engineering, and management.

The numerical analysis method was suggested to calculate scores that express the level of work experience and skills of employees. Relative levels of work experience and skills can be decided by comparing scores among employees. The numerical analysis considered how much time employees spent on specific tasks related to their job and how many times employees were involved in each task. The numerical method produced a single score value of each IT skill for every employee.

A tool was developed to embody the suggested method, using .NET programming and Oracle database. In this way, not only employee IT skills can be estimated quickly and easily, but also information on employees' work experience can be managed systematically and effectively with an intuitive and simple interface. The tool provides features for input data, managing task history, skill analysis, and search with visual interfaces such as charts, graphs, and windows components.

6.1.3 Results

A tool was developed with computer programming in order to embody the method and make the best use of the method, and a case study using the sample data was carried out to test the validity and reliability of results of the method presented in this study. The case study consists of a discriminative case, consistent case, and diverse case.

In the discriminative case, estimated experience and skill levels were compared between two employee groups who had different job experiences and different job positions. This case showed that employees accumulated different skills even though they performed the same tasks, because they had different job positions: database engineering and server engineering. It shows their skill levels depend on their work experience, which is based on their task history and job positions.

The consistent case was performed to identify consistent skill improvements in accordance with years of employee experience in the same job position. This case showed employees who had the same job positions and the same task history have accumulated the same level of skills.

The diverse case tried to identify differences in accumulated skills and experience among senior employees and junior employees who had different years of experience. This case showed that the senior employees have accumulated different work experience and skills because they have performed different tasks according to their years of experience, even though they had the same job position as other employees.

6.2 Discussion

This section described the findings from results, implications through this study, limitations of this study, and recommended future studies.

6.2.1 Findings and Implications

This study proposed a method for employee skill assessment, as well as the development of a tool to make the best use of the method. The tool has shown the potential for using the method in the workplace. With this tool, this study could indicate how to evaluate the IT skills of employees quickly, easily, and constantly, as well as how to manage the working history of employees systematically. This study assumed that employee skills and work experience have a positive relationship, and the case studies have shown that the results of this study reflect this assumption.

It was difficult to find existing literature that studied employee ability evaluation based on work experience, so this study couldn’t compare the effects with those of other studies. To compensate for weakness, this study used large sample data collected from actual IT employees in order to test the validity and reliability of the method through case studies. The case studies have shown that estimated results for employee skills depend on their work experience related to the task history and job position, and skill levels are increased as work experience is accumulated.

First, the discriminative case showed that employees who have different jobs accumulate different experience and skills. Second, the consistent case showed that skill levels of employees increase consistently as their job experience increases. Finally, the diverse case showed that employees can accumulate different work experience according to number of years of experience, even though they have the same job position, so that the employees accumulate different skills.

All the cases have shown the results expected by the method and tool presented in this study, because the suggested method and tool calculate skill levels of employees based on work experience levels that represent how much time employees spend on specific tasks related to their job, and how often they do so. The same or similar skills are estimated in accordance with the same or similar work experience, and different skills can be derived depending on the nature of the work experience.

Other existing evaluation methods rely on survey, interview, or personal evaluation of employees, while this study has suggested and used a different approach than other existing methods to evaluate the IT skills of employees. It tried to use quantitative empirical data that can indicate the skill abilities of employees. The study used information that represents work experience of employees based on their task history and job positions. Quantitative evaluation results were obtained through the method and tool presented in this study. Moreover, this study showed that evaluation results can be found and managed easily, quickly, and constantly.

Effective training programs optimized for each employee can be developed and recommended by organizations if the skills of employees can be evaluated continuously. Employees are able to choose their own training program and ask for better programs from their companies to improve on areas where skills are lacking. In addition, a well-managed evaluation system can help companies to more effectively find employees who have the skills required for new jobs and businesses more effectively.

Some existing skill evaluation methods, such as interviews, surveys, and personal evaluation require not inconsiderable time and costs. Manual jobs by human resources are needed for those methods and the greater the number of subjects of evaluation, the greater the costs and time. This makes it difficult to perform skill evaluations continuously and frequently. Some costs and time are required to establish the IT system necessary to use the method and tool suggested in this study. However, the costs and time for human resources necessary when evaluations are processed can be saved through an automated evaluation system. Furthermore, the human resources costs and time will not increase considerably even though the number of evaluation subjects increases significantly.

This skill evaluation system can be implemented and used independently with the existing systems, or it can be added to the existing HR system as one of its features. But it would be preferable to add this system to the existing HR system in order for it to be connected with employee information and be utilized for employee training.

This system can be helpful in checking the current status of employees' workload and predicting human resources needs for employees' jobs. Because this system provides information about employees' working time in terms of their tasks and skill abilities, it can help to predict expected human resources and skill abilities in the near future through analyzing the information in the system. For instance, the capabilities and number of employees needed for new jobs or organizations can be estimated by analyzing and comparing the skill abilities and working times of employees in current jobs.

6.2.2 Limitations of the Study

This study has tried to evaluate employee skills based on task history data; but other factors that can affect the skill improvement of employees are not considered. Learning ability, job attitudes, organizational tenure, age, characteristics of the workplace, and training and education may be considered as measures for employees' skill evaluation. Sturman (2001) studied the effect of organizational tenure and age on job performance, and DeMarco and Lister (1985) explained that characteristics of the workplace are factors which affect programmer performance. However, these factors were not included as measures for skill evaluation in this study, because it was difficult to find research about the factors' effects on skill improvement; moreover, they could not be quantified objectively at this time.

This study assumed that the rate of employee skill improvement increases with the rate of their work experience. The growth rate of employee skill can be changed with the frequency of experience in the same job. The skill level might not even increase after a certain level of work experience. This fact cannot be decided upon and applied in this study because it also depends on many other factors such as individual characteristics and the working environment. The change in skill-increasing rate over time should be identified and applied in the numerical method and tool in order to get more accurate evaluation results.

The relationships between skills and task activities and between skills and job positions are expressed with a one sign digit: '1' means that there is a relationship and '0' means no relationship. However, there can be different degrees of relationships between IT skills and task activities and job positions. For example, one of the IT skills described in this study – the Linux operating system – has a stronger relationship with system administration jobs than database management jobs, even though the skill has relationships with both jobs. Not only one sign digits such as 1 and 0 but also weight values such as 2 and 3 can be used to identify the degrees of relationship between skills and task activities and job positions, but the strength of the relationship can vary depending on the jobs and businesses of organizations and should be determined through discussion and agreements between employees, managers, and experts in the job fields. However, the relationships were expressed as simply as possible in this study, with one sign digits, in order to reduce subjective views by the author.

6.2.3 Future Study

Other evaluation methods are used commonly in this working area. Each of these methods has pros and cons in evaluating employee skills and there are no methods that provide perfect information about employees' skill abilities for managers. However, the weaknesses of each method may be complemented through using other methods together. It may be possible to increase the reliability of the evaluation results in this study in conjunction with other methods. The results derived by the method used in this study can be supplemented with reviews by managers, and personal evaluation can be applied additionally. Research combining the results from other methods can be a future study to improve the quality of this study.

In this study, sample data collected from IT employees' actual task histories was used to develop method and results, but the effect of the suggested method could not be checked through comparison with results of the various methods. The results obtained through the method suggested in this study can be compared with the results from surveys and interviews, as well as self-evaluations of employees. Also, the expected confidence level of skill evaluation results can be figured out through studying the difference among the results. The scope of application of this study can be determined after identifying the expected confidence level of this study, and future studies can allow this study to find and improve the weaknesses.

6.3 Conclusion

This study suggested a method to evaluate employees' IT skills through a different approach using existing methods. The method suggested in this study estimates skill levels of employees based on work experience that consists of employees' detailed daily work history. This study showed the developed tool can provide results of skill evaluations easily and quickly. Case studies using sample data have shown consistent skill evaluation results depending on the work experience of employees.

This study has explained that costs and time can be saved through use of the suggested method and tool due to a reduction in manual human resources processes, as some of the existing skill evaluation methods such as interview, survey, and personal evaluation require considerable time and costs to carry out the necessary process. If employee skills can be evaluated and managed continuously by organizations, the organization can develop training programs that are optimized for their employees and get useful help to manage human resources through use of the employee's working history and information on their skills and abilities.

This study has weaknesses and is not perfect for skill evaluation of employees, but can be a good complement to make up for the weaknesses of other existing methods, or a good solution if supplemented by other methods. The results of skill evaluation might not be reliable with only small amounts of data on task history and work experience, but can have high reliability with large amounts of data on employees' working history. In addition, the skill evaluation method in this study can be applied and optimized for other industry working areas and educational areas such as manufacturing, finance, and engineering.

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APPENDICES

Appendix A IT Skills List

Table A1 *IT Skill*

No.	Skill Name	Category
1	Contracting/ Procurement	General Competency
2	Customer Service	
3	Financial Management	
4	Influencing/ Negotiating	
5	Legal, Government and Jurisprudence	
6	Managing Human Resources	
7	Organizational Awareness	
8	Planning and Evaluation	
9	Public Safety and Security	
10	Team Building	
11	Microsoft Windows Desktop Operating Systems	IT Industry Skill
12	Client-Server	
13	Requirements Management	
14	UNIX Operating System	
15	Object-Oriented Languages	
16	Test Planning	
17	IT Governance	
18	Systems Support and Helpdesk	Professional IT Skill
19	System Analysis and Design	
20	Test Plan Development	
21	Network Operating Systems	
22	Data Analysis and Reporting	
23	Systems Engineering	
24	Network Security	
25	Broadband	
26	Collaboration Software	
27	Relational Database Management Systems (RDBMS)	
28	IT Portfolio Management	
29	Performance Testing	
30	Feature Testing	
31	Network Architecture and Design	
32	Network Configuration and Implementation	
33	Legacy Computer Languages	
34	Multimedia	
35	Development Languages	

Note. Referred from " Information Technology Workforce Capability Assessment Survey (ITWCA) " by Chief Information Officers Council, and U.S. Office of Personnel Management, 2011.

Table A1 Continued.

36	Structured Query Language (SQL)	
37	Systems Security Applications	
38	Data Modeling	
39	Process Design	
40	Legacy Operating Systems	
41	Lifecycle Cost Estimation	
42	Usability Testing	
43	Wireless Technologies	
44	Records Management	
45	Cryptology	
46	Enterprise Directory Services (EDS)	
47	Web Site Management	
48	Data Virtualization	
49	Firewalls	
50	Network-Based Intrusion Detection System	
51	Data Warehousing	
52	Security Testing	
53	Storage Technologies (SAN, NFS, RAID, SCSI, IP Storage)	
54	Web-enabled Application Design and Development	Professional IT Skill
55	Mainframe Operating Systems	
56	Mainframes	
57	Host-Based Intrusion Detection System	
58	Network-Based Intrusion Prevention System	
59	.Net	
60	Mobile Network Technology	
61	Server Virtualization	
62	Enterprise Resource Planning (ERP)	
63	Linux Operating System	
64	Telephony/PBX	
65	Network Voice/Data Integration	
66	Network Behavior Analysis	
67	Scripting/Metadata	
68	Web Portal Development	
69	Joint Application Development/Rapid Application Development (JAD/RAD)/Agile	
70	Wireless-Based Intrusion Detection System	
71	Extensible Markup Language (XML)	
72	Digital Forensics	
73	MacOS/MacOSX Operating System	

Note. Referred from " Information Technology Workforce Capability Assessment Survey (ITWCA) " by Chief Information Officers Council, and U.S. Office of Personnel Management, 2011.

Table A1 Continued.

74	Secure Coding	Professional IT Skill
75	Unified Modeling Language (UML)	
76	Biometrics	
77	Geographic Information Systems (GIS)	
78	Mobile Application Development	
79	Java/J2EE	
80	Radio Frequency Identification (RFID)	

Note. Referred from " Information Technology Workforce Capability Assessment Survey (ITWCA) " by Chief Information Officers Council, and U.S. Office of Personnel Management, 2011.

Appendix B Physical Entity Relationship Diagram

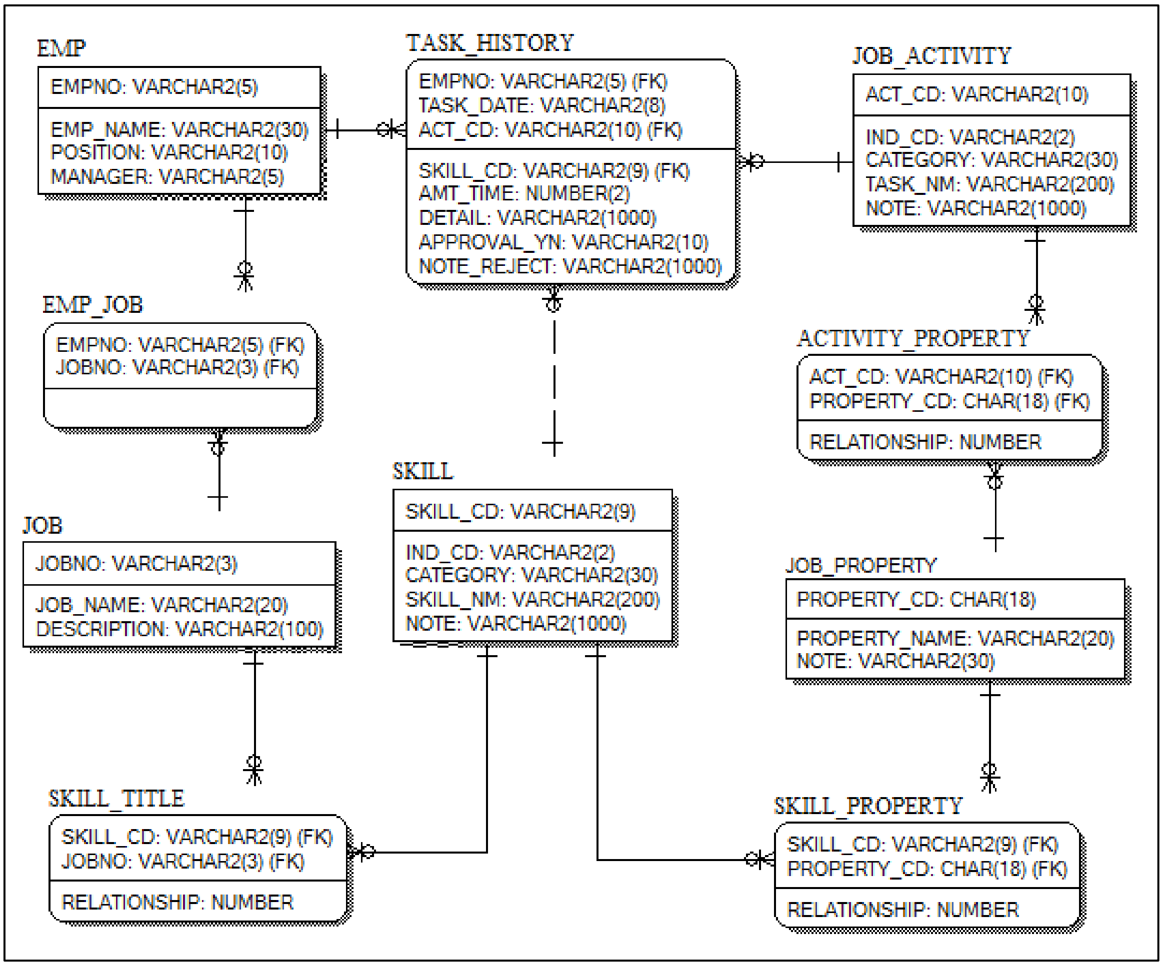

Figure B1 Physical Entity Relationship Diagram

Appendix C Database Table Definitions

Table Name: SKILL			Estimated Rows Count: 10 ~ 200		
Table Definition: IT skills list					
Column Definition					
Column Name	Data Type	Primary Key	Null	Index	Column Comment
SKILL_CD	VARCHAR2(9)	PK1	NO		Skill Code Ex) IT_GC_001
IND_CD	VARCHAR2(2)				Industry Code Ex) IT
CATEGORY	VARCHAR2(30)				General Competency, Industry Common, Professional Skill
SKILL_NM	VARHCHAR2(200)		NO		Skill Name
NOTE	VARHCHAR2(1000)				

Table Name: JOB_ACTIVITY			Estimated Rows Count: 10 ~ 200		
Table Definition: IT task activities list					
Column Definition					
Column Name	Data Type	Primary Key	Null	Index	Column Comment
ACT_CD	VARCHAR2(10)	PK1	NO	PK1	Activity Code Ex) IT_SEC_001
IND_CD	VARCHAR2(2)				Industry Code Ex) IT
CATEGORY	VARCHAR2(30)				Security, Project Management, …
TASK_NM	VARHCHAR2(200)		NO		Activity Name
NOTE	VARHCHAR2(1000)				

Table Name: JOB_PROPERTY			Estimated Rows Count: 1 ~ 10		
Table Definition: Properties to define the relationship between skills and activities					
Column Definition					
Column Name	Data Type	Primary Key	Null	Index	Column Comment
PROPERTY_CD	CHAR(18)	PK1	NO	PK1	Property Code Ex) 001, 002, …
PROPERTY_N	VARCHAR2(20)				Ex) Analysis,

AME					Finance, Testing, Plan & design …
NOTE	VARHCHAR2(50)				

Table Name: EMP_JOB			Estimated Rows Count: 10 ~ 100,000		
Table Definition: Define jobs of employees					
Column Definition					
Column Name	Data Type	Primary Key	Null	Index	Column Comment
EMPNO	VARCHAR2(5)	PK1	NO	PK1	Employee ID
JOBNO	VARCHAR2(3)	PK2	NO	PK1	Job Position Code

Table Name: SKILL_TITLE			Estimated Rows Count: 100 ~ 2,000		
Table Definition: Define the relationship between skills and job positions					
Column Definition					
Column Name	Data Type	Primary Key	Null	Index	Column Comment
SKILL_CD	VARCHAR2(9)	PK1	NO	PK1	Skill Code
JOBNO	VARCHAR2(3)	PK2	NO	PK1	Job Position Code
RELATIONSHIP	NUMBER(1)		NO		‘0’ or ‘1’

Table Name: SKILL_PROPERTY			Estimated Rows Count: 100 ~ 2,000		
Table Definition: Define the relationship between skills and properties					
Column Definition					
Column Name	Data Type	Primary Key	Null	Index	Column Comment
SKILL_CD	VARCHAR2(9)	PK1	NO	PK1	Skill Code
PROPERTY_CD	CHAR(18)	PK2	NO	PK1	Property Code
RELATIONSHIP	NUMBER(1)		NO		‘0’ or ‘1’

Table Name: ACTIVITY_PROPERTY			Estimated Rows Count: 100 ~ 2,000		
Table Definition: Define the relationship between task activities and properties					
Column Definition					
Column Name	Data Type	Primary Key	Null	Index	Column Comment
ACT_CD	VARCHAR2(10)	PK1	NO	PK1	Activity Code
PROPERTY_CD	CHAR(18)	PK2	NO	PK1	Property Code
RELATIONSHIP	NUMBER(1)		NO		‘0’ or ‘1’

Table Name: TASK_HISTORY			Estimated Rows Count: 10 ~ 10,000,000		
Table Definition: This stores task history of employees					
Column Definition					
Column Name	Data Type	Primary Key	Null	Index	Column Comment
EMPNO	VARCHAR2(5)	PK1	NO	PK1	Employee ID
TASK_DATE	VARCHAR2(8)	PK2	NO	PK2	Working date Ex) 09262013
ACT_CD	VARCHAR2(10)	PK3	NO	PK3	Task activity code
SKILL_CD	VARHCHAR2(9)				Related skill code
AMT_TIME	NUMBER(2)		NO		Working time (Hours) Ex) 0.5, 1, 2, …
DETAIL	VARHCHAR2(1000)				Job explanation
APPROVAL_YN	VARCHAR2(10)				Ex) null, Approved, Rejected
NOTE_REJECT	VARHCHAR2(1000)				Reasons of rejection

Appendix D Analysis database SQLs

SQL 1: This calculates experience scores of each task activity for every employee, and this query created as the view object, V_CALC_INDEX, in database.

```
SELECT empno,act_cd,index_value,
      MAX(index_value) OVER (PARTITION BY act_cd) max_value,
      AVG(index_value) OVER (PARTITION BY act_cd) avg_value
FROM (
     SELECT empno,act_cd,ROUND(cnt_act_cd/(SUM_YbyX/N)+sum_amt_time,2) index_value
     FROM (
          SELECT empno,act_cd,sum_amt_time,cnt_act_cd,    -- find average time per a number of
task
                sum(cnt_act_cd/sum_amt_time) over(partition by act_cd) SUM_YbyX,
                count(empno) over(partition by act_cd) N
          FROM (
                 SELECT empno,act_cd,sum(amt_time) sum_amt_time,count(act_cd) cnt_act_cd
                 from task_history
                 group by empno,act_cd
                 ORDER BY 1,2
                   )
              )
           )
ORDER BY 1,2
;
```

SQL 2: This calculates experience scores of each task category for every employee, and this query created as the view object, V_INDEX_CATEGORY, in database.

```
SELECT empno,category,
      value_category,
      max(value_category) over (partition by category) max_value,
      ROUND(avg(value_category) over (partition by category),2) avg_value
FROM (
         SELECT empno,category, sum(index_value) value_category
         FROM (
                  SELECT a.empno, b.category, b.task_nm,
                            ROUND(cnt_act_cd/(SUM_YbyX/N)+sum_amt_time,2) index_value
                  FROM (
                           SELECT empno, act_cd, sum_amt_time, cnt_act_cd,
                            sum(cnt_act_cd/sum_amt_time) over (partition by act_cd) SUM_YbyX,
                            count(empno) over(partition by act_cd) N
                           FROM (
                                    SELECT empno, act_cd, sum(amt_time) sum_amt_time,
                                              count(act_cd) cnt_act_cd
                                    FROM task_history
                                    group by empno,act_cd
                                    ORDER BY 1,2
                                    )
                           ) a, job_activity b
                  WHERE a.act_cd=b.act_cd
                   )
          GROUP BY empno, category
         )
ORDER BY 1,2
;
```

SQL 3: This calculates percentage experience scores of each category for every employee to display radar charts, and this query created as the view object, V_INDEX_RADAR, in database.

```
SELECT emp_name, CATEGORY,
        NVL(round(value_category/max_value*100,1),0) pct_value,
        ROUND(NVL(avg_value/max_value*100, def_avg/def_max*100),2) pct_avg,
        100 pct_max
FROM (
        SELECT emp_name, CATEGORY, value_category, max_value, avg_value,
                max(max_value) OVER (PARTITION BY category) def_max,
                 MAX(avg_value) OVER (PARTITION BY category) def_avg
        FROM (
                SELECT c.emp_name,c.CATEGORY,NVL(d.value_category,0) value_category,
                        max_value,
                        avg_value
                FROM (SELECT a.empno,a.emp_name, B.CATEGORY
                        FROM EMP a,
                        (SELECT distinct CATEGORY
                          FROM JOB_ACTIVITY
                          WHERE CATEGORY != 'Others') b
                        ) c,
                V_INDEX_CATEGORY d
                WHERE d.empno(+)=c.empno
                AND d.CATEGORY(+)=C.CATEGORY
                )
         )
ORDER BY 1,2
;
```

SQL 4: This calculates percentage scores of each skill for every employee to display bar graph, and this query created as the view object, V_SKILL_INDEX_PERSON_PCT, in database.

```
SELECT emp_name,skill_nm,ROUND(skill_index/max_index*100,2) skill_index_pct,
          ROUND(avg_index/max_index*100,2) avg_index_pct,
           100 max_index_pct
FROM (
          SELECT emp_name,skill_nm,skill_index,
                    max(skill_index) OVER (PARTITION BY skill_nm) max_index,
                    AVG(skill_index) OVER (PARTITION BY skill_nm) avg_index
          FROM (
                    SELECT v2.emp_name,v2.skill_nm, SUM(NVL(v1.index_value,0)) skill_index
                    FROM (SELECT a.EMPNO,a.ACT_CD,b.skill_cd,a.INDEX_VALUE
                               FROM V_CALC_INDEX a,
                                        (SELECT ar.act_cd, sr.skill_cd
                                           FROM ACTIVITY_PROPERTY ar,
                                                     SKILL_PROPERTY sr
                                        WHERE ar.PROPERTY=sr.PROPERTY
                                        AND ar.VALUE=1
                                        AND sr.VALUE=1
                                        ) b
                              WHERE a.ACT_CD=b.act_cd) v1,
                             (SELECT ep.EMPNO, ep.EMP_NAME, sk.SKILL_CD, sk.skill_nm
                              FROM SKILL sk, SKILL_TITLE_REL st, EMP_JOB ej, EMP ep
                              WHERE ep.EMPNO=ej.EMPNO
                              AND ej.JOBNO=st.JOB_TITLE
                              AND st.VALUE=1 AND sk.SKILL_CD=st.SKILL_CD
                              ) v2
                    WHERE v1.empno(+)=v2.empno
                    AND v1.skill_cd(+)=v2.skill_cd
                    GROUP BY v2.emp_name,v2.skill_nm
                     )
          )
WHERE  max_index != 0
ORDER BY 1,2
;
```

Appendix E Programming Source Codes

Code 1 : Drawing radar chart displaying skill scores of task categories.

```
private void Form3_Load(object sender, EventArgs e)
{
            string oradb = "Data Source=(DESCRIPTION=(ADDRESS_LIST="
          + "(ADDRESS=(PROTOCOL=TCP)(HOST=localhost)(PORT=1521)))"
          + "(CONNECT_DATA=(SERVER=DEDICATED)(SERVICE_NAME=ohyun)));"
          + "User Id=ohyun;Password=ohyun;";

            conn = new OracleConnection(oradb); // C#
            conn.Open();
            cmd = new OracleCommand();
            cmd.Connection = conn;
            cmd.CommandText =
                 "SELECT * FROM V_INDEX_RADAR WHERE emp_name=:ename";
                 // execute the analysis query in database
            cmd.CommandType = CommandType.Text;
            OracleParameter p_emp_no = new OracleParameter();
            p_emp_no.OracleDbType = OracleDbType.Varchar2;
            p_emp_no.Value = ename;
            cmd.Parameters.Clear();
            cmd.Parameters.Add(p_emp_no);

            OracleDataReader drOracle = cmd.ExecuteReader();

        while (drOracle.Read())
        {
        chart1.Series["IndexValue"].Points.AddXY(drOracle.GetOracleValue(1).ToString(),
        drOracle.GetOracleValue(2).ToString());

        chart1.Series["AverageValue"].Points.AddY(drOracle.GetOracleValue(3).ToString());
        }
        chart1.Series["IndexValue"].ChartType = SeriesChartType.Radar;
        chart1.Series["IndexValue"].Color = Color.FromArgb(255, 255, 100, 0) ;
        chart1.Series["IndexValue"].BorderColor = Color.Red;
        chart1.Series["AverageValue"].ChartType = SeriesChartType.Radar;
        chart1.Series["AverageValue"].Color = Color.FromArgb(20, 20, 20, 0);
        chart1.Series["AverageValue"].BorderColor = Color.Blue;
        chart1.Series["MaxValue"].ChartType = SeriesChartType.Radar;
        chart1.Series["MaxValue"].Color = Color.FromArgb(0, 0, 0, 0);
        chart1.Series["MaxValue"].BorderColor = Color.Black;

        chart1.ChartAreas[0].AxisX.LabelStyle.Angle = -90;
        chart1.ChartAreas[0].AxisX.Interval = 1;
}
```

Code 2 : Drawing bar graph displaying skill values of employees.

```
private void Form2_Load_1(object sender, EventArgs e)
{
            string oradb = "Data Source=(DESCRIPTION=(ADDRESS_LIST="
          + "(ADDRESS=(PROTOCOL=TCP)(HOST=localhost)(PORT=1521)))"
          + "(CONNECT_DATA=(SERVER=DEDICATED)(SERVICE_NAME=ohyun)));"
          + "User Id=ohyun;Password=ohyun;";

            conn = new OracleConnection(oradb);
            conn.Open();
            cmd = new OracleCommand();
            cmd.Connection = conn;
            cmd.CommandText =
                 "SELECT * FROM V_SKILL_INDEX_PERSON_PCT WHERE emp_name=:ename";
                 // execute the analysis query in database
            cmd.CommandType = CommandType.Text;
            OracleParameter p_emp_no = new OracleParameter();
            p_emp_no.OracleDbType = OracleDbType.Varchar2;
            p_emp_no.Value = ename;
            cmd.Parameters.Clear();
            cmd.Parameters.Add(p_emp_no);

            OracleDataReader drOracle = cmd.ExecuteReader();

        while (drOracle.Read())
        {
         chart1.Series["IndexValue"].Points.AddXY(drOracle.GetOracleValue(1).ToString(),
        drOracle.GetOracleValue(2).ToString());
         chart1.Series["AverageValue"].Points.AddY(drOracle.GetOracleValue(3).ToString());
        }
        chart1.Series["IndexValue"].ChartType = SeriesChartType.Column;
        chart1.Series["IndexValue"].Color = Color.Blue;
        chart1.Series["AverageValue"].ChartType = SeriesChartType.Point;
        chart1.Series["AverageValue"].Color = Color.Red;

        chart1.Series["IndexValue"]["ShowMarkerLines"] = "true";
        chart1.Series["IndexValue"]["BarLabelStyle"] = "Center";
        chart1.Series["IndexValue"]["DrawingStyle"] = "Cylinder";

        chart1.ChartAreas[0].AxisX.LabelStyle.Angle = -90;
        chart1.ChartAreas[0].AxisX.Interval = 1;
}
```