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A dynamic manpower forecasting model for the information security industry

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Abstract

Purpose – The purpose of this paper is to develop an integrated model for manpower forecasting for the information security (IS) industry, one of the fastest growing IT-related industries. The proposed model incorporates three critical factors (feedback structure, time lags, and a flexible saturation point) in a system dynamics (SD) simulation frame.

Design/methodology/approach – A simulation model using SD is developed for a dynamic manpower forecasting by decomposing complex processes of manpower planning into a set of feedback loops with a causal-loop diagram. Data gathered from a Korean Government agency were utilized in the simulation for forecasting the manpower demand and supply in the context of the IS industry.

Findings – The simulation results showed an overall IS manpower shortage in the IS industry. Policy alternatives were proposed based on the simulation results. The simulation model was rerun to reflect the various alternatives to achieve a stable manpower balance between demand and supply.

Originality/value – The research provides insights into the development of effective manpower planning at the industry level (macro level), and policies to increase its efficiency and effectiveness. The research model was developed and verified using SD.

Keywords Manpower planning, Systems analysis, Simulation, Information systems, South Korea

Paper type Research paper

1. Introduction

"Computing is becoming ubiquitous" (Yoo and Lyytinen, 2005). This statement is about the emerging integration of computing and the physical space by embedding computers into objects and places (Weiser, 1991, 1993). In this age of embedded and invisible computing, computers operate silently and autonomously, requiring no or very little human intervention or complicated manipulations (Mattern, 2001; Saha and Mukherjee, 2003; Wong and Whitten, 2006). Ubiquitous computing, based on networks made up of massive quantities of chip sensors that are interlinked through wireless

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connections and accessible through mobile devices from virtually anywhere and at any time, is expected to bring major changes to our lifestyle from e-commerce to ubiquitous life (Gershman and Fano, 2005; Jessup and Robey, 2002).

This paradigm change in information and communication technology (ICT) is also expected to result in major changes in the information security (IS) environment. Below are some of the most important ramifications of ubiquitous networking for IS: first, a computing environment centered on portable devices would reveal various previously unknown IS vulnerabilities. Also, due to the reliance on batteries as the power source, mobile devices and sensor devices have more moderate CPU processing capabilities than traditional PCs, which undercut the performance of hardware-based encryption in these devices (Perrig *et al.*, 2004). Second, it is more difficult to guarantee confidentiality and integrity of data within a wireless network environment (Cam-Winget *et al.*, 2003; Housley and Arbaugh, 2003). Data communicated over a wireless network are more vulnerable to interception (Smith, 2007). Therefore, policy alternatives should be prepared for resolving vulnerability and privacy issues and improving users' trust in ubiquitous computing, especially u-commerce. Third, advances in digital technologies and growing capacities of data transmission, coupled with the wide penetration of mobile devices make it possible to digitize various types of analog information such as text, audio, and video. Such digitization may include contextual information on a real time basis, and increase the risk of confidential information disclosure vulnerability and invasion of privacy over the network (Lahlou *et al.*, 2005).

In addition, the effect of these changes in ICT on the IS environment is expected to create new demand for IS manpower. Not only are technological developments important, but effective forecasting and planning for the manpower supply and demand also are necessary to prepare for major changes in ubiquitous computing. Manpower forecasting is an important practice for the government as well as business organizations because effective forecasting techniques can lead to better business or governmental strategies (Flores *et al.*, 2007). Therefore, this study focuses on the development of a dynamic manpower forecasting model for IS industry with the system dynamics (SD) methodology.

Various modeling and forecasting techniques have been developed for either demand or supply needs of manpower (O'Brien-Pallas *et al.*, 2001). Much of the literature on demand analysis is devoted to manpower forecasting at the corporate level (micro level), yet manpower forecasting at the industry level (macro level) is equally important, especially for economic development of a country (Kao and Lee, 1998). In addition, many factors have been identified and incorporated into the manpower forecasting models so as to improve their accuracy involving time lags (e.g. hiring lead time, delays in training manpower, etc.) (Grinold, 1976; Kwak *et al.*, 1977) and fixed or variable saturation points (Osaki *et al.*, 2001; Sharif and Ramanathan, 1981).

Considering the dynamic nature of demand and supply, where demand triggers supply and vice versa, feedback is also an important factor for manpower forecasting. Therefore, the purpose of this study is to develop an integrated model for the IS industry, which focuses on the combination of the demand and supply of manpower based on SD. The proposed manpower forecasting model incorporates three factors (the feedback structure, time lags, and a flexible saturation point) for the IS industry.

2. Review of relevant literature

Many previous studies are based on either demand or supply forecasting of manpower, and there is a paucity of studies that deal with a combination of the two (also known as an integrated model). The modeling and forecasting techniques used for either demand or supply are well documented in Bechet and Maki (1987) and O'Brien-Pallas *et al.* (2001). For example, the Markov model has been the most important manpower forecasting technique available to organizations to date as an ideal method in situations where manpower flow must be studied for each year of a multiple year planning period (Bechet and Maki, 1987).

The need for an integrated model has been suggested by many researchers. They argue that the general approach to modeling requirements for manpower needs industrial-wide views with interactions accounting for all factors that would influence supply, demand, utilization, and wages (Lomas *et al.*, 1985; O'Brien-Pallas *et al.*, 2001; Prescott, 1991). Manpower forecasts at various industry levels include the manufacturing industry in Taiwan (Kao and Lee, 1998), health care industry in Canada (O'Brien-Pallas *et al.*, 2001), and construction industry in Hong Kong (Chan *et al.*, 2006). Decision making on policy alternatives, for example, for establishing new departments in academic institutions or increasing the number of enrollments in the related departments, would usually require industry level manpower demand forecasts. For a more accurate forecasting of manpower demand and supply, a comprehensive, integrated model is needed that considers the demand and supply simultaneously from multiple perspectives over the entire process of the forecasting, from inflow to stock and outflow (Prescott, 1991).

Understanding and modeling complex systems require a mastery of such concepts as stocks and flows, feedback, time lags, and non-linearity (Sterman, 2002). Most previous research on manpower forecasting implicitly involves the concept of stocks and flows and a combination of other concepts. In this section, a review of previous literature on the three important concepts is provided: feedback, time lags, and saturation points.

2.1 Feedback structure

Feedback structure reveals how complex environments behave over time (Goodman, 1989). From the dynamic behavior perspective of manpower, supply and demand for manpower have their own feedbacks, forming closed loops with an intersection of a variable, called "demand and supply gap." Demand-supply behavior, through two negative feedback loops, converges to equilibrium, a stable state of the system (Figure 1).

Previous studies treated the demand and supply side as two separate systems and developed manpower models (as shown in the red box in Figure 1, consisting of only manpower supply, manpower demand, and the demand-supply gap) from an open loop perspective without considering the feedback effect of the two. Demand for workforce in one industry, however, triggers inflow of manpower into the industry, stimulating its supply. The supply can either suppress the creation of new demand in manpower by becoming a restrictive factor *vis-à-vis* operational capability or creating new demand by enhancing the operational capability. In the open global market, manpower forecasting models need to consider global manpower flows, outsourcing, and outward-oriented foreign direct investments. Of course, national policies, such as immigration laws and international trade agreements, affect cross-border manpower flows.

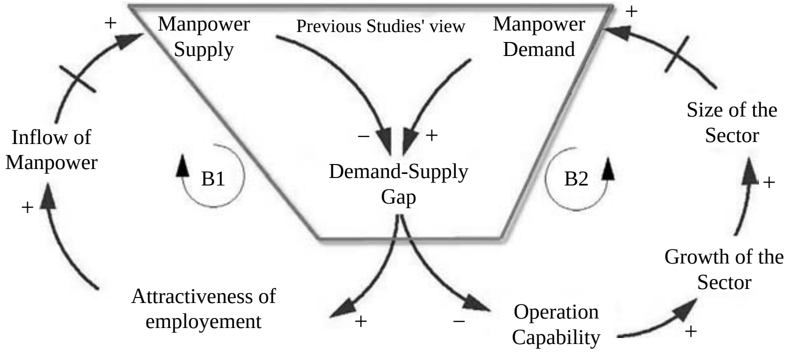


Figure 1.
Casual loop diagram of dynamic manpower demand-supply model

2.2 Time lags

Making effective manpower decisions (e.g. the number of workers to be hired, transferred, or laid off) requires considerable lead time (Kwak *et al.*, 1977). A critical shortage of the labor-market supply in some skill groups may require a hiring lead time of several months. Grinold (1976) emphasizes the existence of time lags in the qualification of inputs into the system in a situation where the demand for the manpower is uncertain. This implies time lags should be a variable to be considered in manpower forecasting model (Grinold, 1976; Kwak *et al.*, 1977). Freeman (1976) includes a fixed time lag in the cobweb model of supply in a context of labor market, which has shown marked cyclical fluctuations, to explain the supply of new engineers. Time lags have a significant influence on dynamic behavior in most social systems, creating instability and the tendency for the system to oscillate (Sterman, 2001).

In some cases, lags, which can result from abrupt changes within a system, must be filtered out or buffered to maintain its stability. As a result, decision makers often need to intervene to correct apparent discrepancies between the desired and actual state of the system to restore the system to equilibrium (Sterman, 2001). Lag effects, in spite of their decisive roles within decision-making models, including manpower planning models, have not been integrated into their models primarily because of the static nature of estimation techniques, whether mathematical or statistical.

There are two types of lags in time: physical lag and information lag. In Figure 1, the straight lines, cutting across the arrows connecting one variable to another, mark the presence of lag effects. In a manpower demand-supply system, physical lags occur on the supply side due to the time required to develop the workforce. Information lags occur on the demand side due to the time elapsed before coming to the realization of the need for additional workforce arising from the growth of an industry. In other words, even if a demand-supply gap triggers the inflow of manpower in an industry, it takes a considerable amount of time to actually fill the demand and reduce the gap. On the other hand, information lags occur because either manpower planning relies on past years' data to assess the size of current demand or additional labor force is requested on an as-needed basis.

To sum, while a shortage of manpower sparks up supply, the demand-supply gap is only filled gradually. During this lag, the market continues to feel that the supply of manpower is insufficient. At times, this perception could persist even after a sufficient supply of manpower may actually cause an oversupply. Meanwhile, the market can also excessively reduce the supply based on the perception of oversupply, which persists even after a reduction by an adequate size, causing a labor shortage.

2.3 A flexible saturation point

Estimates of the potential market growth of an industry provide a basis of planning manpower demand and supply. A more accurate estimation of market growth plays a critical role in preventing serious strategic errors made by many companies (e.g. US electric utilities in the 1970s, the US petroleum industry in the 1980s, etc.) (Barnett, 1988). There has been much research on the market growth based on diffusion theory, such as the Bass model and its variations. The Bass (1969) model, the origin of the diffusion model with relatively high power of forecasting than other diffusion models (Lee *et al.*, 2006), has been used for demand forecasting and market growth. It is a function of a fixed market potential (the total number of people who will eventually use the product) to predict the number of adopters at a given time period along with the coefficients of innovation (external influence factor) and imitation (internal influence factor).

In these models, there are common assumptions that potential markets are always constant, and that relationships driving demand in the past would continue unaltered (Barnett, 1988; Osaki *et al.*, 2001). In other words, the ceiling of the market does not change from the start of the market growth to the end (a fixed saturation point). Problems of over- or under-estimation of the market growth posed by fixing the market's saturation point have indicated by many researchers, who propose a double logistic model where potential market size increases with time continuously (Osaki *et al.*, 2001; Sharif and Ramanathan, 1981). They argue that a market's saturation point for products is subject to change by new value additions to or new use creations to the product (Osaki *et al.*, 2001). A lack of understanding about the market's saturation point or mistakenly shared fundamental assumptions can cause inaccurate industry-wide forecasting (Barnett, 1988). A saturation point set too low implies slow growth speed of the industry until it reaches the point and eventually results in an underestimation of manpower demand. Contrarily, one being set too high implies fast growth of the industry and results in an oversupply of manpower. In addition to the fixed saturation point problems, the Bass model has certain limitations posed by the lack of available data in forecasting the demand for new products not yet in the market (Lee *et al.*, 2006).

This study introduces a flexible saturation point, the same concept used for the variable saturation points, but differs in its variation relating to market size of other closely related industries. A flexible saturation point is expressed as a function of multiplication of the total amount of the increase of market size of closely related other industries and the fixed growth rate (percentage) of the estimated size of the industry. Accordingly, the saturation point in the industry changes proportionally as the potential market size of the related industries changes. The rationale for the introduction of flexible saturation points is based on the fact of two or more industries' interdependence, where one industry cannot exist without the other industries. For example, the growth of the IS industry relies on the ICT industry, which has matured enough to show its growth patterns (e.g. growth and size of the industry). Furthermore, the introduction of ubiquitous computing further increases the risk of overestimation or underestimation for manpower demand forecasting-based exclusively on the size of the IS industry, as this new growth engine for the ICT industry is bound to produce huge spillover effects.

3. A dynamic manpower forecasting model

3.1 Overview of the SD methodology

SD, originated from the work of Forrester (1961), is a methodology for understanding complex problems with dynamic behavior affected by a certain set of feedback mechanisms (Goodman, 1974; Sterman, 1994). SD has been used to investigate various systems including industrial dynamics (Forrester, 1961), urban dynamics (Forrester, 1969), population growth, growth and a selection process of new technologies (Mohapatra and Saha, 1993), and business dynamics (Sterman, 2000). SD modeling focuses on the feedback structure of a system, rather than its parameters to trace the driving forces of system evolution.

In general, SD modeling proceeds from sketching a causal loop diagram, constructing a stock-flow diagram, and finally defining equations for model variables (Richardson and Pugh, 1981). The art of SD modeling lies in discovering and representing the feedback processes and other elements of complexity that determine the dynamics of a system. A causal loop diagram identifies important feedback structures embedded in a system. It consists of many causal relations between two consecutive variables. A causal relationship between two variables is positive if they vary in the same direction. It is negative if they vary in the opposite direction. A causal loop itself can be either positive or negative. A feedback loop with zero or an even number of negative causal relations is positive and is characterized by exponential growth (self-reinforcing) behavior. A feedback loop with an odd number of negative causal relations is negative and shows goal-seeking (self-balancing) behavior.

The stock-flow diagram is composed of variables and their causal relationships. Variables in the stock-flow diagram include stock variables, rate variables that change the value of stock variables, and auxiliary variables that represent intermediate variables between stock and rate variables. After constructing a stock-flow diagram, one can define equations for each variable. Although a SD model is mathematical and can be reduced to a set of differential equations, one must note that it is not used to forecast system behavior conclusively. Instead, it is used to ascertain dynamic patterns of system behavior.

3.2 Design of a manpower forecasting model

Considered the dynamic relationship between the ICT and the IS industry, a domestic manpower forecasting model is developed that integrates dynamic characteristics; feedback structures, time lags, and a flexible saturation point (Figure 2). SD modeling was chosen because it could provide more reliable forecasts of short- to mid-term than a statistical model, and thus leads to better decisions (Pardue *et al.*, 1999). In addition, SD provide a means of understanding the causes of industry behavior, which leads to better policy establishment (Lyneis, 2000). We chose the IS industry in Korea as the context of this study. Korea is a world leader in high-speed internet-based e-commerce and thus IS industry is characterized by fast growing manpower demand and being closely interrelated with other cutting-edge industries. In Korea, global manpower flow has been much more restricted as compared to the US or EU countries, primarily due to government policies. Thus, in our study, the model is developed for the domestic IS manpower forecasting.

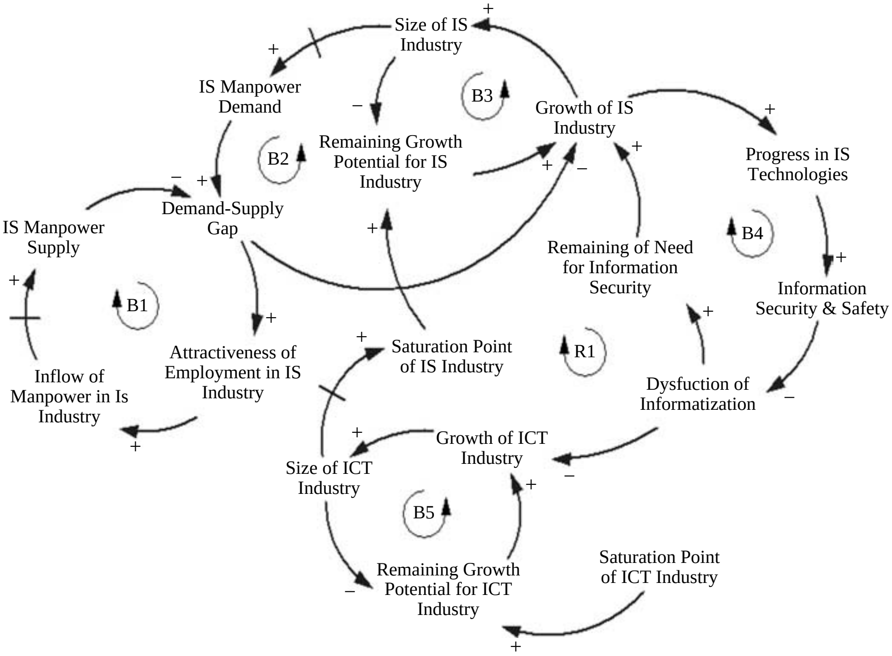


Figure 2.
Dynamic interaction between ICT and IS industries

The diffusion of ubiquitous computing provides new opportunities for growth of the ICT and IS industries. As shown in Figure 2, the growth of the ICT industry parallels that of the IS industry. The growth of the IS industry, by resolving negative side effects of informatization, provides the ICT industry with a stable basis for growth. The growth of the IS industry further creates new demand for workforce, and additional manpower will bring benefits to the industry, serving as a basis for its sustainable growth (loop B1). The ICT industry, forming a symbiotic relationship with the IS industry, upon the introduction of ubiquitous computing, will positively propel and receive stimulus for growth (loop B5). Meanwhile, a ubiquitous computing environment will see increased concerns for IS, safety, and disclosure vulnerability (loop B4). This in turn gives rise to the need for new security technologies and demand for additional manpower (loop B2). The IS industry, therefore, has an intimate linkage to ICT, its upper-level industry, and evolves through dynamic interactions with it. With the emergence of a new technological paradigm like ubiquitous computing, its ecology is undergoing further changes and developing a complex nexus of dynamic interactions whose correct understanding requires a detailed analysis.

3.3 Designing a simulation model

Based on the causal-loop diagrams shown in Figure 2, we designed stock-flow diagrams for computer simulation runs with SD. We used STELLA, chosen for its graphic performance and the ease of comparing results. The data previously collected through a research grant on behalf of a Korean Government agency were used for the model (Kim, 2003).

Korea is the world leader in the high-speed broadband, 3G mobile communication, wireless broadband service, and ubiquitous life campaigns (Lee, 2003). Constants of the model were calculated by utilizing the data and external variables. Variables that are hard to be quantified were assigned to default values or ratios. Decision making related factors were treated as external variables to examine diverse scenarios. It is widely known that the size of IS industry corresponds to about 10 percent of the size of ICT industries. Figure 3 shows a shape of the dynamic behavior of flexible saturation points, an S-shaped curve changing with the manpower of the ICT industry after simulation runs.

Domestic IS manpower in Korea would be supplied from various sources, such as educational institutions (undergraduate colleges and graduate schools) and vocational training institutions (non-university or university vocational programs), as well as other related industry sectors which operate manpower conversion programs. The yearly new supply corresponds to the sum of graduates from the educational institutions, certification holders from training institutions, and workforce from manpower conversion programs. The cumulative net flow is calculated by subtracting outflow, including resignation and retirement from the total supply. Demand for IS manpower can be distinguished based on where it originates, from IS companies, related industries, and research institutions. The total demand is the sum of new demand, corresponding to the total projected number of new recruits for a given year in each of the demand sources, and additional demand created from the introduction of ubiquitous computing.

The projected number of new recruits was assumed to be determined based on the estimated sales and R&D budgets. As for the size of market, the model was designed to allow a lag of one year before it is reflected in the size of actual manpower demand. Next, models of the total supply of manpower from different supply sources and the total demand from different demand sources were created, respectively, to mark them as separate areas. Finally, a model of demand-supply gap was designed to reflect the difference between the demand and supply, which was also expressed as a separate area. The positive value of the demand-supply gap refers that demand is greater than supply, and therefore IS manpower should be supplied.

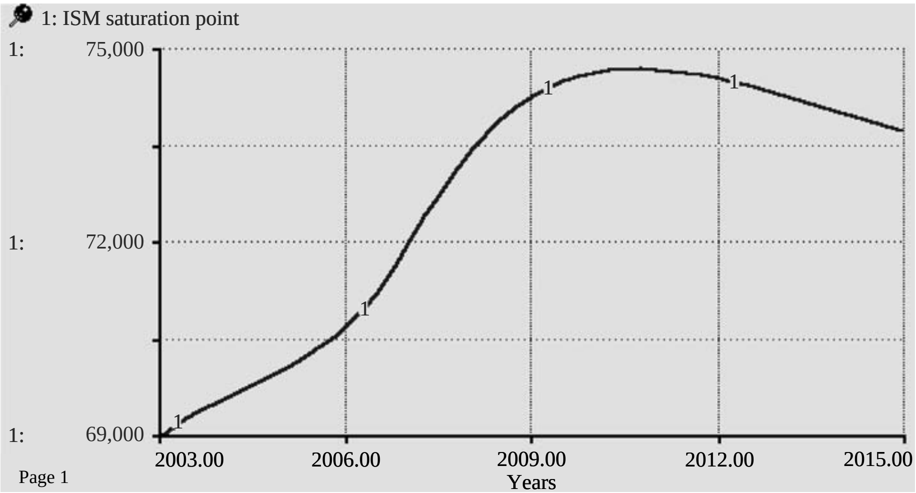


Figure 3.
Behavior of IS industry saturation point

In Korea, a classification standard for all the skill levels and each level's qualification for IS manpower has been prepared and published by the Ministry of Science and Technology. For manpower from educational institutions, those who completed the first two years of the four-year course (pre-major programs) were grouped together with two-year college graduates to separate from those who had bachelor degrees. The lengths of MA and PhD programs were set to two and five years, respectively. Furthermore, as shown in Table I, manpower was classified, depending on the level of education and experience into five grades, ranging from reserve, primary, middle, high and specialist grades. Workers of each grade were designed to move up to the next high grade after a given period of service and/or education. The demand of each manpower grade was allocated as a percentage of the overall demand.

4. Model implementation and policy implications

The time period for the simulation model was set at 2003 as the starting year, and 2015 as the ending year. The reason for setting 2003 as the staring year was that the data

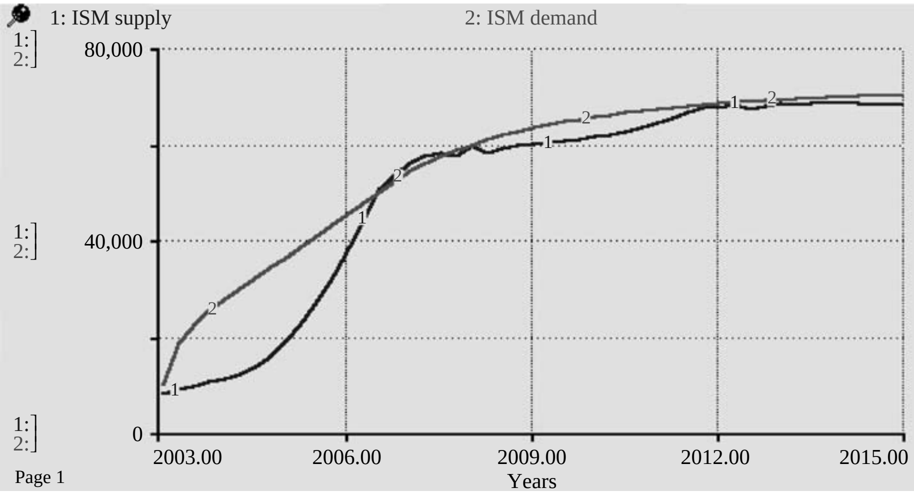
Level	Definition	Demand share (percent)
Reserve	Two year college graduates having majored in related fields Those that completed a short-term program at a private non-university institution	20
Primary	Two year college graduates having majored in relevant fields with two or more years of experience working in IS-related fields Holders of a BA or a MA in relevant fields	20
Middle	Two year college graduates having majored in relevant fields with nine or more years of work experience in related fields BA holders and MA holders in the relevant fields with six or more years or three or more years of work experience, respectively, in related fields For the sake of simplicity, 20 percent of primary-grade workers were assumed to annually move up to the middle-grade level	35
High	Two year college graduates having majored in relevant fields with 12 or more years of work experience in related fields BA holders having majored in relevant fields with nine or more years of work experience in related fields Holders of a MA in relevant fields with six or more years of work experience in related fields PhDs in relevant fields For the sake of simplicity, 20 percent of middle-grade workers were assumed to annually move up to the high-grade level	15
Specialist	Two year college graduates having majored in relevant fields with 15 or more years of work experience in related fields BA holders having majored in relevant fields with 12 or more years of work experience in related fields Holders of a MA in relevant fields with nine or more years of work experience in related fields PhDs in relevant fields with three or more years of work experience in related fields For the sake of simplicity, 20 percent of high-grade workers were assumed to annually move up to the specialist-grade level	10

Table I.
The definition of manpower levels and their shares of demand

used in this model were available from the Korean Government agency since then. As shown by the simulation results in Figure 4, the overall manpower demand and supply behavior in the IS sector showed an excess of demand over supply, indicating a shortage of manpower. With the diffusion of ubiquitous computing, the imbalance between demand and supply is expected to worsen during the next five years and the gap would be narrowed after that duration. To alleviate the shortage of manpower, various initiatives are currently underway by the Korean Government, including creation of new IS-related academic departments and manpower conversion programs to retrain workers in the IT field, and to expand training outlets by private institutions. Through these measures, the imbalance is likely to be corrected within the next five years. Also, the IS specialist certification programs operated by the Korea Information Security Agency (KISA) and Information and Communications University since 2001, are expected to help relieve the imbalance to some degree.

Detailed analysis of the simulation results indicated that supply of manpower at the lower levels (reserve and primary) surpassed the demand after five years (Figure 5), whereas demand of manpower at higher levels (the middle and above) surpassed the supply (Figure 6). These results suggest that current policies to resolve the imbalance problem between supply and demand cannot achieve the required qualitative improvement (balance of manpower supply and demand at the middle level and above), even if they may resolve the problem within five years in quantitative terms. The bullwhip effect, drawn from beer distribution games, provides a good explanation for this phenomenon: a quantitative balance at lower levels and an imbalance at higher levels (Anderson and Johnson, 1997; Forrester, 1961).

An increase in demand triggers a rapid growth of supply in low-grade manpower, as private training institutions and non-university vocational programs respond quickly to demand fluctuations. However, as the supply of low-grade workers cannot meet the demand for more skilled workforce, the manpower shortage continues to be unabated. Meanwhile, supply continues and the labor market heads toward an oversupply.



Notes: Line 1: demand behavior; Line 2: supply behavior

Figure 4.
Behaviors of IS manpower demand and supply (overall)

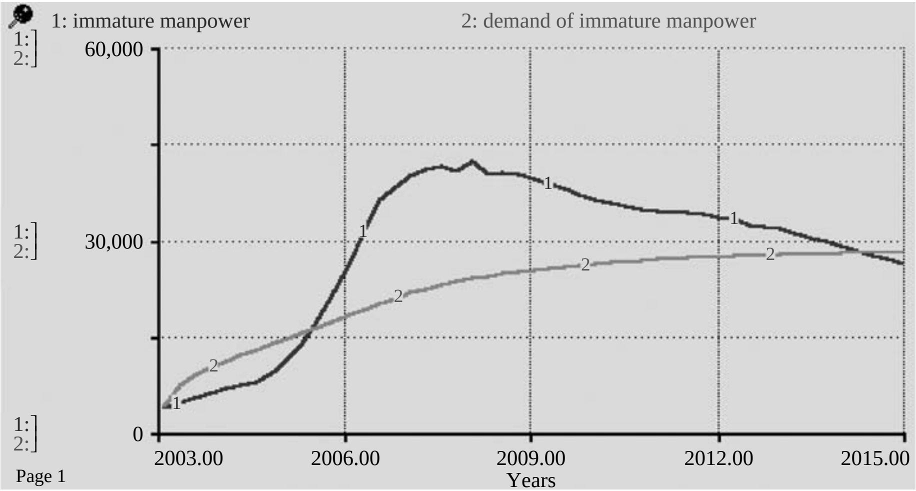


Figure 5.
Behaviors of IS manpower demand and supply at low levels

Notes: Line 1: demand behavior; Line 2: supply behavior

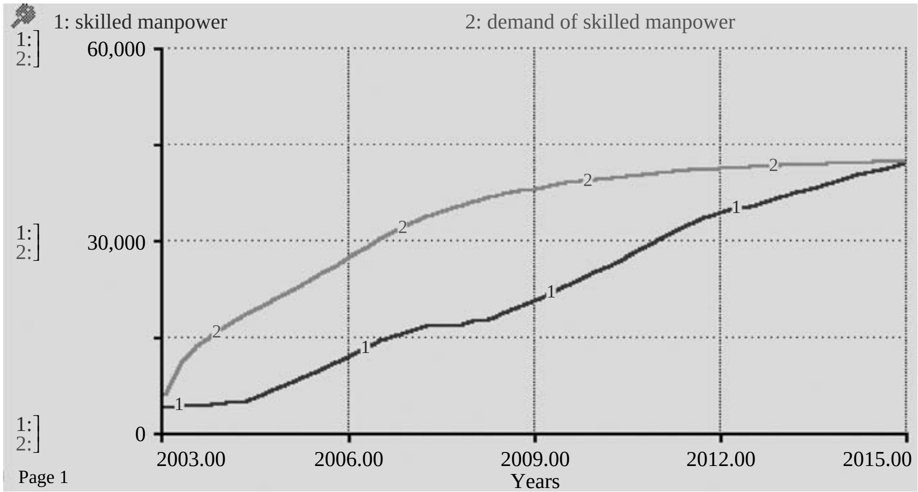


Figure 6.
Behaviors of IS manpower demand and supply at high levels

Notes: Line 1: demand behavior; Line 2: supply behavior

There is a time lag between the occurrence of demand for IS manpower and the supply of higher-grade manpower, as it takes a considerable amount of time before workers of the latter category become available for the market (time to complete required training and experience). This lag also explains the concurrence of an unemployment crisis and manpower shortage on the employer side.

SD models facilitate the judgment of reasonable scenarios as inputs to decisions and policies (Lyneis, 2000). Based on the simulation results, reasonable policy alternatives to narrow the variation of imbalance between IS manpower demand and supply, especially, at higher levels are provided. These policy alternatives are based on the assumption that the government would invest for long-term training and education of manpower in the IS industry.

First, as shown in Figure 6, the shortage of manpower at the middle level persists from the beginning (2003) of simulation to the end (2015). In Korea, the supply of manpower in the IS industry would come primarily from postgraduate programs and/or promotion from the primary level. Therefore, to reduce the gap, a policy needs to be executed to encourage college graduates to enroll into graduate programs in IS-related disciplines, by providing them with incentives (e.g. guarantee of employment). The success of such policy might depend on the Korean Government's intention to invest in such programs as research grants and support of university-industry cooperation.

The second policy alternative is to increase manpower shortage at the middle level so as to vitalize existing manpower conversion programs, and/or to develop new manpower conversion programs, which would allow the skilled workers in associated industries to engage in the IS industry after completion of the programs. The advantage of this alternative is to supply the needed skilled workers rather quickly. In Korea, many major corporations and government agencies have adopted such programs.

Finally, as shown in Figure 5, the supply of manpower at the beginning met the demand in a short time period (in three to four years). Private vocational training institutions have provided one-year programs and played a significant role in training and developing the manpower needed in the IS industry. Therefore, we propose dividing the current one-year training program of the institutions into a one-year and a two-year program. This alternative could make it possible to deploy manpower from the private institutions into different levels over the time.

To show the effectiveness of the proposed policy alternatives, the simulation model was re-run, applying changes in:

- doubling the amount of the government investment for the first policy alternative;
- tripling the amount of the government investment for the second policy alternative, reducing training duration from two years to one year; and
- doubling the amount of the government investment for the final policy alternative, dividing the current one-year program into one-year and two-year programs.

The results are shown in Figures 7-9. Overall, the gaps between demand and supply at all the levels appear to be narrowed considerably in shorter time periods (Figures 8 and 9), compared to the gaps (Figures 5 and 6).

A close examination of the results showed that the manpower demand and supply would become stable in a short time period (after about five to seven years) in both qualitative and quantitative terms. The manpower shortage at the reserve level (Figure 8) would be offset by the surplus in the primary level (Figure 9). Also, the manpower shortage at the middle level could be replenished with the oversupply from the specialist level. Execution of the proposed policy alternatives to increase the skilled workforce resulted in surplus of high and specialist manpower started earlier than in

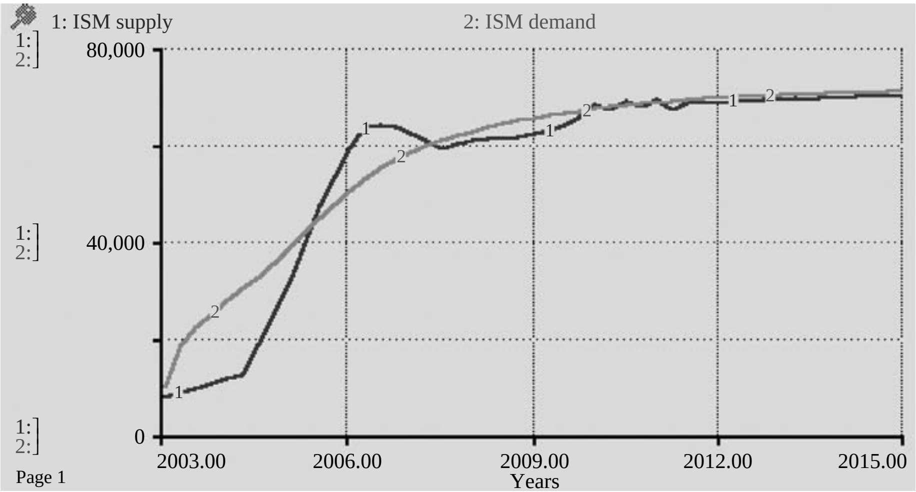


Figure 7.
Behaviors of IS manpower demand and supply (overall) (after rerunning)

Notes: Line 1: demand behavior; Line 2: supply behavior

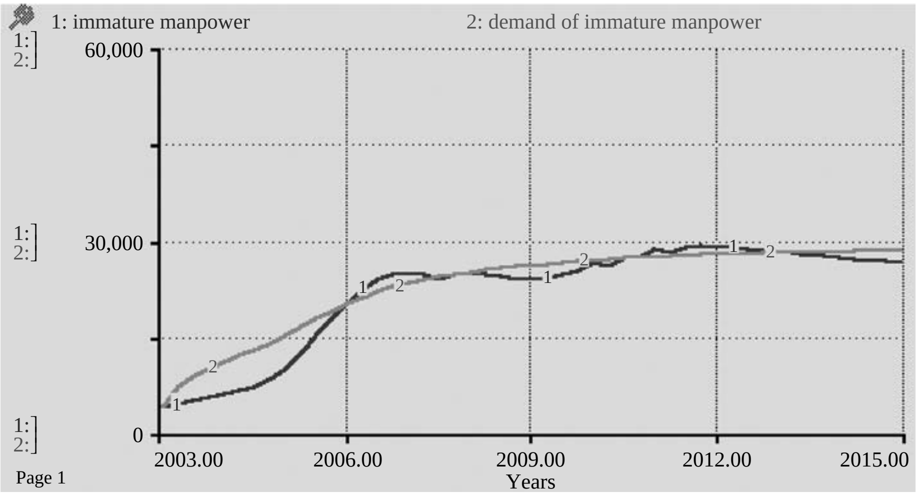


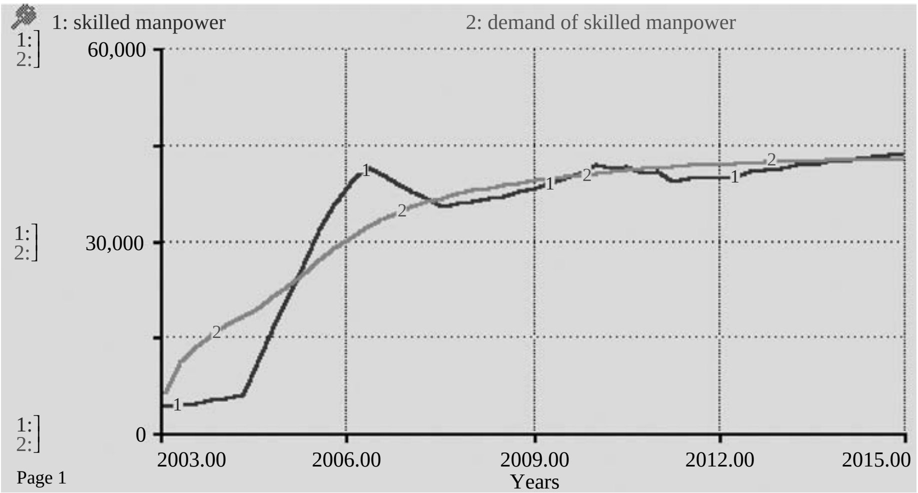
Figure 8.
Behaviors of IS manpower demand and supply at low levels (after rerunning)

Notes: Line 1: demand behavior; Line 2: supply behavior

the previous model. This implies that there is a problem awaiting a solution to deal with the surplus in high-skilled manpower in the future.

5. Conclusion

Forecasting and modeling have always been an important aspect of manpower planning process in a variety of businesses and government agencies (Bechet and



Notes: Line 1: demand behavior; Line 2: supply behavior

Figure 9. Behaviors of IS manpower demand and supply at high levels (after rerunning)

Maki, 1987; O'Brien-Pallas *et al.*, 2001). More reliable manpower demand and supply forecasts can provide a basis for making better decisions for avoiding redundant investments, achieving efficient and balanced growth of an industry, and developing an economy (Chan *et al.*, 2006; Kao and Lee, 1998; Kwak *et al.*, 1977). Various modeling and forecasting techniques have been applied for either demand or supply forecasting needs, or both. Many studies have focused solely on either demand or supply, and a limited number of studies have focused on a combination of the two (O'Brien-Pallas *et al.*, 2001). Much of the literature on demand analysis is devoted to manpower forecasting at the corporate level (micro level), yet manpower forecasting at the industry level is equally important, especially for economic development of a country (Kao and Lee, 1998).

In this study, a manpower demand and supply forecasting model with SD was proposed and applied to IS industry in Korea, whose market growth is dependent on that of ICT industries. Three factors were incorporated into the model: the feedback structure, time lags, and flexible saturation points. The data previously collected by a research grant were used as inputs to variables of the model. The results of the simulation runs showed that the demand for IS manpower in Korea would exceed the supply during the forecasting period (2003-2015). Overall, the supply increased at lower levels than the primary level. Manpower at the middle level, expected to be required at most in the market, continued to be insufficient during the modeling period. After applying policy alternatives to the model and re-running the simulation, the gaps between demand and supply at all the levels were reduced in shorter time periods than without applying the policy alternatives.

This study has several limitations. First, manpower demand and supply planning is an issue which requires consideration of both quantitative and qualitative aspects. In this study, general qualification levels prepared and announced by the Ministry of Science and Technology were considered as the qualitative aspects. For greater analytical accuracy, however, future research must consider more detailed manpower demand and supply behaviors for the various technology and skill levels. Second, some variables of the simulation model, especially policy-related ones, were assigned to ratio values which might influence the accuracy of the simulation results. Therefore, future researchers should improve the accuracy of the model by introducing actual measurement values into some variables with ratio values. Another limitation, and thus the goal of our future research, is that this study considered only a domestic manpower planning which should be expanded to consider the open global economy. In the networked global economy, manpower forecasting should consider global flow of manpower in the form of outsourcing and outward-oriented foreign direct investment, albeit government policies regarding immigration and international trade.

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Further reading

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