Expert Evaluation as Means of Promoting GIS Software Development

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Abstract

The Chinese government invested considerable resources in developing the GIS software industry. Expert evaluation has been used as an important mechanism for assisting the distribution of R&D funds and to assess the performances of the funded projects. The expert evaluation serves as a resolution of the information asymmetry between the funding agencies and the GIS software developers. The formation of the expert committee, the formulation of the evaluation guidelines and the test questions, as well as the conduct of the evaluation contribute to the characteristics of the information obtained from the evaluation. Improvements can be made in these areas so as to enhance the quality of the evaluation and to generate positive influences on the behavior of the software developers. Meanwhile, decision makers should be aware of the advantages and limitations of the expert evaluation.

I. INTRODUCTION

In recent years, China has devoted major efforts to developing the GIS software industry. In 1995, China identified GIS software development as one of the *Gong Guan* ("tackling key problems") projects—R&D areas that are considered to be vital to the national economic development, to receive special funding from the *Commission of Science and Technology*. Between 1996 and 2000, i.e., the period of the *Ninth Five-Year Plan for National Economic and Social Development*, the *Gong Guan* program allocated approximately 20 million *yuan* (about $2.5 million) for GIS software development and pilot application projects (Fang and Jing, 2003). An additional 30 million *yuan* (about $3.5 million) were distributed to some forty GIS companies through the *Medium and Small Enterprise Fund*. These efforts in concentrating resources to tackle key problems have achieved notable success. By 2000, domestic GIS software started to command major market shares in data capture and processing. Software systems with functionalities and performances matching international market leaders have emerged and began carrying out large-scale applications in such areas as utility, planning, and land management (Zhou and Li, 2002; Chen, et al., 2002). Domestic GIS software systems began to gain acceptance and confidence from important user groups in China, as indicated by the successful incorporation of *MapGIS*, a leading GIS software system, into the operation of the manned space program. The encouraging results have led to an expanded funding through the government's *High Technology R&D Program*, or the 863 Program. In the first two years of the *Tenth Five-Year Plan for National Economic and Social Development* (2001-2005), the 863 and the *Gong Guan* programs together distributed more than 40 million *yuan* for GIS research and development (Fang and Jing, 2003).

The distribution of funds is increasingly based on open bidding. The annual expert evaluation, however, has served as one of the most important criteria in awarding government grants since 1996. Organized by the Ministry of Science and Technology (MOST) and conducted jointly by the *China Association of GIS* (CAGIS), the *International Association of Chinese Professionals in Geographic Information Science* (CPGIS), and the *National Remote Sensing Center of China* (NRSCC), the nation-wide GIS software evaluation was initiated in 1996 as a means for surveying the state-of-the-art of the GIS software industry and for selecting companies to participate in the *Gong Guan* program. Unlike the previous grants that covered the entire period of the five-year plan, the GIS R&D grants were renewed on a yearly basis, subject to the performance evaluated by the expert committee. Other government programs also used the evaluation as a criterion for selecting awardees of GIS projects. As the annual evaluation became widely recognized as an authoritative and a prestigious program, more and more companies participated, not only to achieve qualifications for government contracts but also to generate marketing effects. Due to the apparent achievement in the GIS software industry, the Chinese government and the GIS community have strong reasons to believe that the evaluation program has been a useful mechanism for the government to play effective roles in the development of science and technology, particularly in an economy gradually transferred from central planning to market orientation. Such recognition is further endorsed by the initiation of Remote Sensing Software Evaluation, started this year to pro-

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mote another area identified for key R&D efforts.

Due to its current success and the potential for further adoption by other national R&D programs, the expert evaluation model needs a careful review so as to make necessary improvements and to ensure proper usage in policy formulation and decision-making. This paper attempts to make a contribution in understanding the historical conditions for the success of the expert evaluation model, identifying the potential pitfalls, and making suggestions for improvement. In order to provide the context for the discussion, we will first present the general background on China's main programs for science and technology development, then a description of the expert evaluation model and its conduct. In the discussion session, we focus on the possible improvements on the specific aspects of the evaluation model.

II. CHINA'S SCIENCE AND TECHNOLOGY PROGRAMS

Despites its success in transferring the economy towards market orientation, the Chinese government maintains prominent roles in the development of the science and technology. The Ministry of Science and Technology (MOST) and its subordinates in all levels of regional and local governments are the primary agencies that formulate policies in and distribute funding for developing scientific and technological programs throughout the country. Other agencies, such as the National Natural Science Foundation (NNSF), the Ministry of Education, and the National Defense Science, Technology and Industry Commission (NDTIC) also fund science and technology programs with specific focuses. Since the development of the GIS software industry falls in the domain of MOST, we will mainly present programs under this agency.

The key technologies R&D program[1]

Also known as the *Gong Guan* program, the Key Technologies R&D Program was initiated in the *Sixth FYPNESD (1981-1985)*. The primary objective is to concentrate national resource to tackle key technological issues that are directly related to national economic development. Over a period of twenty years, the *Gong Guan* program funded more than five hundred projects with near 15 billion *yuan* directly from the Central Government and 27 billion *yuan* from matching funds. This program funded the GIS technology initiative initially during the *Ninth FYPNESD*. According to the "China Spatial Information Network", a total of seventy-two GIS projects were funded during the period, most of which were through the *Gong Guan* program.[2] Other key information technological projects funded during that period include computer network technology, parallel computer, digital switch, optical network, CAD software, high definition television, high capacity and high density magnetic disk, integrated circuits, and LAN-based ATM switch, etc. For the new period of the *Tenth FYPNESD*, the *Gong Guan* program is funding R&D projects in small satellites for earth observation, information sharing for sustainable development, and digital government. The scope, the amount, and the prestige make *Gong Guan* a prominent technology R&D program in China.

The high technology R&D program[3]

This program was initiated by four top scientists in China who wrote a letter to the Central Government, suggesting the country should monitor closely the high tech development around the world and devote resources to developing China's own high technology program, particularly in biotechnology, information technology, and new materials. The letter resulted in the landmark document "The Compendium of High Technology Research and Development Program (The 863 Program)." It is code-named "863" because the letter was written on March 3, 1986. With the Central Government as the primary funding source, this program was established to support what are considered to be high technology areas. And it is directly aimed at reducing the gap between China and western countries in selected high technologies. The program also emphasizes in transferring R&D results to the market places.

The 863 program is coordinated by a designated Advisory Committee who directly reports to the State Council. The *MOST*, the Department of General Armaments, and the *NDTIC* are responsible for the organization and management of the program, which is structured hierarchically as domains, themes, projects, and sub-tasks. In each domain, an expert advisory committee is in place to provide strategic directions and evaluation. At the theme level, there are also expert committees who organize, implement, manage, and coordinate all projects under the subject area (MOST, 2001). Individual R&D groups carry out the projects and sub-tasks. Most of the GIS related projects funded under the 863 program belong to the theme "Information Capture and Processing Technology." During the first two years of the *Tenth FYPNESD* (2001-2005), the *863* program, together with the *Gong Guan* program, funded more than 40 million *yuan* on GIS related technology and product development (Fang and Jing, 2003). The main focuses currently are in two areas: remote sensing operational systems and large-scale GIS applications.[4]

The national key basic research program[5]

This program was initiated in 1997 during the third conference of the National Science Management Committee and later implemented by the MOST (MOST, 2003a). The National Key Basic Research Program is therefore also code-named the *973* program. The establishment of *973* reflects a strategic concern by the science community and the leadership on sustainable development, who realized that it was not enough to just follow the leading developed countries and China must originate its own technology to be competitive in the global

[1]The Web Site for the program is www.gongguan.most.gov.cn
[2]Please refer to www.csi.gov.cn
[3]The Web Site for the 863 program is www.863.org.cn
[4]The Web Site for this 863 subject is www.spatialdata.org
[5]The Web Site for the NBRP is www.973.gov.cn

economy. The primary objective for the *973* program, therefore, is to provide the basic scientific foundations that can support the long-term development of the national economy.

The MOST manages the *973* program through an expert advisory group and domain expert consultation groups who select and evaluate each project led by a principal scientist. The duration of each funded project is typically five years. A midterm review is conducted at the end of the second year, which evaluates the current achievement and finalizes the research plan for the remaining three years. Below are examples of funded projects that are of interest to the GIS community:

- Theories and Applications of Quantitative Information Collection and Fusion in Complex Natural Environments.
- Basic Theories, Algorithms, and Implementation of Virtual Reality.
- Theories and Applications of Quantitative Remote Sensing with Multiple Spatial-Temporal Variables on Earth Surface.
- The Formation and Evolvement of the Tibet Plateau and Its Environmental and Resources Effects.
- The Evolvement and Control of the Arid Ecosystem in Western China.
- The Driving Mechanisms of Carbon Circulations in China's Land Ecosystems.
- Knowledge Mining and Image, Audio, Natural Language Understanding.
- Theories and Methods for Organizing and Processing Large Amount of Information in Network Environments.
- Application Theory and High Performance Software in Information Technology.
- Theories and Methods on Agent-based Middleware for the Internet.
- Large Scale Scientific Computation.

During the Ninth *FYPNESD* (1996-2000), the government invested 2.7 billion *yuan* in the *973* program with projects ranging from agriculture, energy, information science, resources and environment, population and health, material science, and selective scientific frontiers. Because of the nature of the program, its impact on GIS software development has been indirect. Most of the resources and environmental projects, for example, utilize GIS as a tool, which often results in useful feedbacks to software developers regarding additional functionalities and performances. Basic research in information science, on the other hand, serves as the foundation for new algorithms and products.

In addition to *Gong Guan*, *863*, and *973*, the MOST has other programs to promote science and technology development. The *Sparkle Program* was set up in 1985 to assist the economic development in rural areas. The *Torch Program* was initiated in 1988 to promote technology transfer.[6] And in recent year, as another effort in transferring technology to the economy, the MOST established the *Innovation Fund for Small and Medium Technology Firms*, directly channeling state capital to high tech startups, and serving as an intermediate between the *863*, *Gong Guan*, and the *Torch Program*. The GIS software industry has obtained substantial funding from this program.

In addition to the Ministry of Science and Technology, there are many other entities responsible for funding the development of science and technology in China. The *National Natural Science Foundation* (NNSF), an agency directly under the State Council, has a similar funding emphasis in basic research but with a broader scope and often smaller in grant size. Individual ministries in the State Council often have their own science and technological program or share the management of such programs with the MOST. For example, the national key laboratories are managed by the Ministries of Education, Agriculture, Health, Birth Control, and the *NDTIC*, as well as by the Academy of Sciences. In addition, the Ministry of Information Technology has its own program to fund R&D projects in computer software. Nevertheless, the MOST is the major government agency that formulates and implements national policies in scientific and technological research and development. And it has the most impact on the GIS software industry in China.

Selection and evaluation of projects are typically conducted by various expert committees and through peer-reviews. Historically, the selection process was organized fairly well but the assessment of the results was somewhat unregulated. Inadequate assessment mechanisms led to the dominance of personal bias and potential corruptions. The leadership at MOST has long been trying to establish a fair, transparent, and scientific process for assessing R&D projects (MOST, 2003b). The annual GIS software evaluation reflects part of such efforts.

III. GIS SOFTWARE EVALUATION

GIS software development was identified as one of the *Gong Guan* projects for the Ninth *FYPNESD*. Earlier on, the MOST decided to adopt a contingency funding model. Instead of providing support for the entire five-year period, funding was renewed based on an annual assessment. An annual evaluation was therefore initiated in 1996 to assist the selection of awards and assessment of funded projects. In the past eight years, the annual evaluation was used as a reference for awarding GIS grants from most of the technology development programs in China.

Expert committee

The evaluation was coordinated by the *National Remote Sensing Center of China* (NRSCC), a unit under the MOST overseeing the areas of spatial information technology. The China Association of GIS (CAGIS) and the International Association of Chinese Professional in GIS (CPGIS) were the coopera-

[6]The Torch Program has a Web site at www.chinatorch.gov.cn

tors. The latter formed a working group for software evaluation and sent overseas specialists to the evaluation expert committee. The number of overseas members in the expert committee ranged from two to four in the past eight years. The other core committee members are from government agencies and academic units, mostly in the Beijing areas, reflecting the two largest user/research groups of GIS software in China. In the expert committee for the 2003 evaluation, near sixty percents of the members were from the academia, more than thirty percents from government agencies and less than eight percents from the industry. The experts were from a wide range of application domains: surveying and mapping, digital government, urban planning and construction, housing, military, land resource management, social and economic planning and development, forestry, transportation, hydrology, oceanography and coastal development, and utilities. Overall, the composition of the expert committee results in an application-oriented evaluation.

Evaluation guidelines and questions

The evaluation guidelines were formulated to provide a basis for developing the interview and test questions. The guidelines are revised every year to reflect changes in the technological horizon and feedbacks from the expert committee. Currently, three sets of guidelines are in place, one for platform systems, one for specialized systems, and another for application systems (CAGIS, 2002). Platform systems are designed to provide comprehensive GIS functionalities, while specialized system emphasize on particular architectures or functionalities. MapGIS and SuperMap, for example, would be considered as platform systems. GeoWay, a popular program for elevation data processing, and GROW, an AM/FM system, would be considered as specialized systems.

Platform systems are evaluated through three sections, i.e., basic functionality, problem solving, and usability. Each of the sections has individual categories. The 2002 guidelines divided basic functionality into five categories: data collection and manipulation, project management, analysis, visualization and map production, and spatial database management. Each category has a number of sub-groups. For example, the analysis group includes spatial analysis (overlay and map algebra), network analysis (routing, geocoding, location allocation), buffering (point, line, and polygon), statistical analysis (linear regression, trend surface analysis, and multivariate statistics), comprehensive analysis and model building.

Problem-solving tests the overall functionality, correctness, and performance. It does so by having the operator from software company solved application problems with data provided. Utilization of process automation is encouraged. A typical problem-solving question would require chaining a number of basic functions. Because problem-solving provides a comprehensive perspective of the software system, usability is typically evaluated simultaneously.

Specialized systems are assessed in nine categories. They are desktop systems, embedded systems, GPS and electronic maps, data collection and processing, data conversion, Web GIS, cartography, 3D modeling, and remote sensing image processing. Each has a list of functions to be evaluated. For example, a 3D system would be assessed based on the following functions: DEM formation, 3D display, viewshed analysis, profile, terrain measurements, and draping of thematic data on 3D surface (CAGIS, 2002).

At the beginning years of the annual evaluation, each function was not necessarily assessed using specific questions. Instead, the evaluators would go through the list of functions and ask specific questions or request specific operations to be performed. Due to the different backgrounds of the experts, the evaluation results among participating systems may be inconsistent. In recent years, specific operational questions or problem solving questions are carefully designed so as to facilitate objective and consistent evaluation of the particular functionality. For example, instead of asking "Can you perform line buffering?" or, "Would you create a 20 meter buffer around that river stream?" the evaluators would simply present a question "Approximately how many people need to be relocated within 50 meters from the river stream?" Then the evaluators would observe how the software is used to get the answer. The result would be compared with the key. This change was proven effective.

The test questions are grouped in themes. For example, four themes were used in a recent evaluation: large database management, comprehensive problems, WebGIS, and network analysis. The grouping changes from year to year to reflect technological changes and market demand, while covering the basic functionalities.

Formulations of the guidelines and questions are currently coordinated through the Center for GIS Software Evaluation (CGSE), located at the Institute of Surveying and Mapping Sciences in Beijing. A selective group of members in the expert committee drafts the guidelines and questions. The guidelines are disseminated by the CAGIS to the GIS community through relevant media and its Web site. The evaluation questions are kept confidential and are disclosed to the participating teams at site.

Conduct of evaluation

This includes the process of assessing the software based on the test questions and preparing the evaluation reports. Individual teams of experts are responsible for conducting this process for their thematic areas. For example, the group on Large Database Management would provide the scores and the evaluation report on this theme for the software system evaluated. After all the thematic evaluations are completed, a selective group of experts would then work out a summary report based on group reports.

The evaluation process involves several stages. At the beginning, the participants are given the data used for the test. They have two days to install their own software on the testing hardware at the evaluation center, perform data conversion and import to their own databases. Certain test questions are also distributed at this point so that the participants can work on the questions simultaneously. Face-to-face evaluation is conducted in one day, when the evaluation experts go over each questions with the participants who would demonstrate the problem solving process and present the results. Members of the evaluation team may also ask additional questions or discuss certain issues with the participant. Each member records his/her own assessment. At the end of the day, each group would convene, discussing the performance on each question and assigning it a numerical score. The group prepares the thematic report that includes the numeric scores and a written assessment. Based on these thematic reports, a group of experts generates the comprehensive evaluation report for each participating software systems.

For platform systems, a one-hour presentation is arranged for each participating company, where such topics as company profile, management, financial status, customer base, and system architecture, are discussed with all of the members of the evaluation committee. This arrangement facilitates a better understanding on the overall system and fills in certain non-technical aspects for the evaluation experts.

IV. DISCUSSION

Governments play a vital role in science and technology development. There were instances that a national government formed entities to develop certain technologies, the Manhattan Project and the Space Program in the US are good examples. More often, however, governments, particularly those in countries dominated with market economy, act as regulators, investors, coordinators, and users in promoting the development of science and technology. In addressing the federal government's role in investing in science and technology, particularly in advanced technology, the US President's Committee of Advisors on Science and Technology noted that "The Federal government affects the levels of advanced technology investment in certain areas both by creating incentives for private firms to invest and by supporting advanced technology in key areas where private participation is inadequate. Protection of intellectual property and access to overseas are two examples where outcome affects U.S. firm's ability and willingness to invest in R&D" (PACST, 1996). Regarding the areas where the US government should invest in, the committee identified the following principle areas:

> "1. Technology that achieves well-defined public goals such as national security, protection of the environment, new energy sources, better health and education for all Americans, and training of the workforce.
>
> 2. Areas of national importance where the marketplace alone cannot justify a sufficient level of technology investment by private industry:
>
> (1) Where the benefits are widely spread for any one company to recover its investment at a profit;
>
> (2) Where the cost or risk is too great for any individual company to bear alone;
>
> (3) Where the potential benefits are too far in the future to pass the threshold of private investment criteria.
>
> 3. Efforts that ensure our nation benefits from our investments and leadership in basic research. The Federal government can facilitate the transfer to industry of the benefits from basic science investments by encouraging partnerships and by promoting the exchange of people and ideas between industry, academia, and government." (PCAST, 1996)

Though more specific and with a clear priority for economic development, the funding scopes and principles of the major R&D programs in China are not fundamentally different from those of the US, a country with a relatively well established political and economic framework. Many areas in spatial information technology, such as Satellite Remote Sensing and Global Positioning System, clearly fall into the domain of government investment. It is also not difficult to argue that GIS software industry, given the conditions in China, should be an area for the government to invest in.

It is much more difficult, however, to manage the details of the investment, or the funding process. What are the specific technological elements to emphasize? Who should receive the funding? How should the funded projects be assessed? These are universal questions. As we have discussed earlier, China relies on the domain experts' guidance to make these decisions. It is obvious that the composition of various expert committees and the rules that govern the operations of these committees will have significant influences on the quality of these decisions and eventually on the return of the investment.

In the expert committee for the annual GIS software evaluation, the majority of the members are users of GIS technology. They represent a wide spectrum of major GIS application domains in China, which gives the evaluation a strong application-orientation. A software system gains high scores for solving the problems will likely get a good evaluation. One that adopts advanced design with cutting edge technology, regardless how promising it would be, may not be recognized if it fails the test questions hence receives low scores.

Such user-oriented composition has some advantages. It reinforces the philosophy that the product must be able to perform the functions well, not only as individual operations but also for a variety of business processes. Because members of the expert committee are mostly leaders in their respective fields, they provide direct feedbacks to the software companies. The evaluation therefore becomes effectively a high level focus group survey, except that it is a third party, not the software company, who conducts it. In the current market

conditions in China, where government agencies and academic institutions remain the largest user groups, and where the GIS market is still relatively immature, the evaluation provides an excellent platform for the software vendors to meet their customers.

Some modifications on the membership of expert committee can be made to enhance its effectiveness. More senior software engineers with substantial experience in GIS software development and with up-to-date knowledge in information technology should be added to the committee and involved in the preparation of the evaluation guidelines and questions. Product Planners and Chief Engineers from GIS software companies are good candidates, as they should provide valuable technological perspectives. To avoid conflicts of interest, arrangements can be made. For example, certain members would not participate in the actual conduct of the evaluation. Forming an advisory committee can also help solve this problem.

Compared with other expert evaluation, the GIS software evaluation is unique in that it is co-sponsored by the International Association of Chinese Professionals in Geographic Information Science (CPGIS), a professional organization with the majority of the memberships in North America and Europe. CPGIS played a major role in initiating the evaluation project and has continuously provided support by having members participating in the annual evaluation. Due to its independence from domestic entities, CPGIS adds an important element to the fairness of the evaluation. In addition, the involvement of CPGIS enhances the information exchange between China and other parts of the world, particularly from other technology innovation centers. Over the years, as domestic organizers and experts gaining experience, CPGIS' roles in the preparation of guidelines and test questions as well as in the conduct of the evaluation have naturally become less prominent. The proper redefinition of CPGIS' parts should be an important element for the continuous success of the evaluation program.

Aside from the composition of the expert committee, another major issue is the formulation of the evaluation guidelines and test questions. The guidelines signal to the GIS software developer community what the government funding agencies would consider as important information about the software system and the respective company. A set of proper guidelines will have positive effects on the long-term development and the return of investment, while one with inappropriate bias may induce the risk of misleading the industry and failing to promote companies with good potentials. It is vitally important, therefore, to develop a set of evaluation guidelines that encourages innovation and reflects the industrial standards, development trends, and to some extents, market demands. The guidelines should eventually guarantee good companies with good software systems to receive good results of evaluations. That, of course, is easier said than done. While achieving a set of mature guidelines requires years of practices and perfection, we can compensate the subjectivity and insufficiency inherent in any evaluation guidelines by maintaining an open and democratic process for developing and revising the guidelines. The organizers should actively seek feedbacks from members of the expert committee as well as from the GIS community. There should be mechanisms, such as workshops and special sessions in annual professional conferences, to promote adequate discussions and debates. Eventually, however, we must realize that an expert evaluation can only provide some information about the participating software system and its company. In the case of the GIS software evaluation, the focus has been on functionality and to some extent, performance. Formal evaluation on management is left to something like CMM or ISO. The ultimate competitiveness as a market player is left to the financial metric to measure. Funding decisions, therefore, should be made on a combination of all sources of information about a particular software company.

Regarding the test questions, the recent adoption of problem-solving questions reflects certain degree of maturity of the evaluation. Not only does it provide a more comprehensive picture on the functionality, performance, and usability of the software system, but this style of questions also minimizes subjectivity and maintains consistency. The obvious drawback is the difficulty in giving partial credits when the answer is not correct due to errors in one or more operations involved. Decomposing the score for each question into major groups of operations may overcome this problem and enhance the objectivity of the scores. It also helps the participant diagnose the problems.

Additional thoughts need to be put on the scoring system. How much should a question or a section be weighted? The decision may be more effective if more vigorous methods are employed to derive the scoring system. For example, the Delphi procedure, a popular method for gathering expert consensus on particular inquiries, can be applicable. In a Delphi workshop, detailed survey questions are distributed to domain experts at site who would give answers, typically a range of numerical scores with a brief justification, to each question. The workshop monitor then summarizes the answers and distributes them back to the committee members who would revise his/her score on each question based on the summary information. The process would be repeated until a convergence of answers is reached (Linstone and Turoff, 1975).

While a detail description of the Delphi method is beyond the scope of this paper, we would like to emphasize anonymity as an essential characteristic of this technique for obtaining consensus. By keeping the participants' answers anonymous, it minimizes individual influences, or the so-called *bandwagon effect*, and encourages independent thinking. Anonymity ensures equal status among the participants. A particular opinion gains acceptance for its matching the majorities thinking and for its convincing reasoning, not because it is from a well

established and respected senior member. This may be particularly effective in the Chinese culture where seniority and hierarchy are widely observed.

While it is reasonable to focus on functionality in the initial stages, reliability of the software systems should increasingly play more important roles in the evaluation, as GIS is being integrated into management and operational processes. The current problem-solving questions provide some information on the reliability of the software system. They are however by no means systematic assessments on the reliability of the software. The evaluation guidelines should incorporate reliability requirements and the corresponding test questions and procedures should be developed. Existing models and methodologies for reliability testing and engineering, as well as in-depth research on errors assessment by the GIS academic community, provide a solid foundation for developing a set of guidelines and test questions targeting the reliability of GIS software systems (Herrmann, 1999; Shi, et al., 2002; Zhang, et al., 2002; Heuvelink, et al., 1998).

A final thought is about automatic testing. It has long been desired that some testing software would automatically complete the workflow of functional evaluations. With almost all GIS software systems adopted the component architecture, it is technically possible to assess certain group of functions programmatically. It is even possible to develop testing software for systems that share the same standard interface specifications, such as those from the OpenGIS Consortium. This may be worth exploring, at least for a core group of GIS functions.

V. SUMMARY

Expert evaluation is a necessary means to assisting government investment in science and technology. This view is supported by the theory of asymmetric information, championed by prominent economists George Akerlof, Michael Spence and Joseph Stiglitz, who were awarded the Nobel Prize in Economic Sciences in 2001 (Hiller, 1997). An asymmetry of information exists between the government funding agencies and the software companies. When the GIS software was identified as a *Gong Guan* program in 1995, the MOST needed basic information on the state-of-the-art of the GIS software industry in China so as to identify who to fund and how the funds should be distributed. The market was unable to provide much information as it was immature and the majority of the players in the GIS community were in the government and academic institutions that had not even entered the market. Assessments of previous projects were considered little use due to the lack of systematic and formal procedures. Under this circumstance, a highly structured and well-organized expert evaluation would be the best mechanism to gather information hence to resolve the information asymmetry.

Once established, however, the evaluation became a signal or screening device that may influence the behavior of the GIS software companies and possibly the development direction of the industry. The formulations of the evaluation guidelines and test questions, the composition of the expert committee, and the conduct of the evaluation process may discourage or encourage certain software companies to participate in the evaluation and to adjust their product designs. Evaluation guidelines that are substantially different from the perceptions of key software companies on the technology may result in a decrease of high quality participants in the evaluation. A highly imbalanced expert committee would generate similar problem. Since expert evaluation will continue playing important role in resolving the information asymmetry, efforts must be made to improve all aspects of the evaluation. Moreover, the funding agencies should realize the limit of information obtained from expert evaluation and should seek supplemental information from other means so as to improve the quality of the funding decisions.

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