A Performance Assessment Model for Cadastral Survey System Evaluation

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Key words: cadastral surveying, performance assessment, fit-for-purpose, multiple criteria decision analysis

SUMMARY

As an indispensable land administrative function, a cadastral survey system operates to provide spatial related cadastral dataset to the society. A sound cadastral survey system should fit for the purpose of the land administration system in fulfilling its societal requirements. Few studies have assessed the efficiency and effectiveness of a cadastral survey system. This paper describes an on-going research project on building a multi-criteria performance assessment model for cadastral survey systems evaluation. A set of criteria and performance indicators are defined. These model parameters are applied to compare different stakeholders' opinions under a common framework and measuring the performance of individual system by normalized yardsticks. The model builds a platform to show different understandings of the cadastral survey systems. It evaluates each system performance based on land stakeholders' judgements and the achieved performance datasets. With sufficient feedbacks, a robust framework can be established to share ideas on how well the current cadastral survey system fits for the "purpose" from the society. This paper emphasizes the introduction of the established model and its assessment strategy. Some preliminary results of implementing this assessment model in Hong Kong cadastral survey industry are also discussed.

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1. INTRODUCTION

The most essential function of a cadastral survey system is to provide reliable information and descriptions of land parcels. Land parcels are the basic spatial unit in the operation of a land administration system. A cadastral survey system targets societal requirements by implementing cadastral survey and mapping activities and then supplies spatial related information to users. Together with land registration, these core cadastral components (FIG, 1995) become an important infrastructure to facilitate the implementation of land use policies (UN-FIG, 1999).

As indicated by Dale (1979), the cadastral survey and mapping activities are regulated by its own legal and institutional arrangements. Nowadays, as land becomes scarce community resource (Ting and Williamson, 1999), social and environmental interests are more seriously considered by land stakeholders for sustainable development (Bennett et al., 2008). Ruled by each jurisdiction's own background, no unique model can effectively fulfill its societal requirements world-wide. This notion cannot be regarded as a brand-new concept in the field of cadastre (see Dale, 1976 and Williamson, 1985). Still, unsatisfied land administration projects are continuously being reported during international conferences or in the publications. Merely complying with top-end technological solutions and rigid regulations for accuracy are summarized as the reason for most unsuccessful land administration projects (FIG, 2014). In addition, Enemark (2013) and Enemark et al. (2014) highlight the influence of unfit-for-purpose solution in building spatial framework for a land administration system.

A cadastral survey system produces spatial related datasets in building and maintaining the spatial framework of a cadastral system or land administration system. The appropriateness of a cadastral surveying system-design directly influences the performance of land registration in each jurisdiction. However, as an indispensable land administrative function, the end results of a cadastral survey system have rarely been evaluated. Most assessment projects in the field of cadastre and land administration are either focusing on a broad aspect of land matters (see Steudler et al., 1997; Williamson, 2001 and Mitchell et al., 2008) or using a specific cadastral activity to evaluate the cadastral survey system (see Chimhamiwa, 2011). Furthermore, there are very few projects with special focus on cadastral survey system performance in developed land markets nowadays.

This on-going research project aims to build a self-assessment framework for any cadastral survey systems in both developed and developing land markets. The general successfulness or fitness of a cadastral survey system will be examined through a structured multi-criteria assessment model. With a specific focus on the technical, economic, legal and institutional arrangements, we propose four criteria termed: *Capability*, *Cost*, *Security* and *Service*. Under each criterion, performance indicators are selected and evaluated by assessors for gap analysis. Land stakeholders, especially cadastral surveyors who are the key operators of the system are expected to give their judgements on what the "purpose" (optimum societal requirements) is and how well the system "fits for" it.

This paper is structured as follows. First, an explanation on the structure of the established assessment model is introduced. Second, the assessment methodology and strategy are discussed with highlights of utilization of the adopted multi-criteria decision analysis methodology: Analytic Hierarchy Process (AHP). The initial results of a pilot study on the performance assessment of Hong Kong cadastral survey system will be followed. Finally, the paper discusses the initial findings of the case study of Hong Kong and suggests the directions for further development of the proposed assessment model.

2. ASSESSMENT FRAMEWORK

2.1 A Performance Assessment Model

In general, each cadastral survey system has its unique characteristics. To thoroughly assess a cadastral survey system, the assessor needs to have extensive resources of the system design and deep understandings of its jurisdictional background. In addition, system users' satisfaction level should be considered, which is also resource demanding. Neely et al. (2005) commented that the performance of a system is more practicable to be assessed and it is easier to quantify the efficiency and effectiveness of the system. Indeed, the strategy of conducting performance assessment is widely applied in land administration systems evaluation projects.

In this project, we built an assessment model to measure the efficiency of each individual cadastral survey system by its performance. Furthermore, the established assessment model will be applied to evaluate how well an individual cadastral survey system fulfills its society's requirements. Therefore, the performance gaps between the optimum societal requirements and the achieved performance can be identified and evaluated.

From an overall aspect, Williamson (2000) concludes a desired cadastral or land administration system performance should be decided by two key performance indicators: 1) whether the system was trusted by the general populace; and 2) whether it was extensively used by land stakeholders. Following these two key principles, for the assessment of cadastral survey system, we defined four key system performance aspects as the assessment criteria termed: *Capability*, *Cost*, *Security* and *Service*. The logic connections are represented in Figure 1.

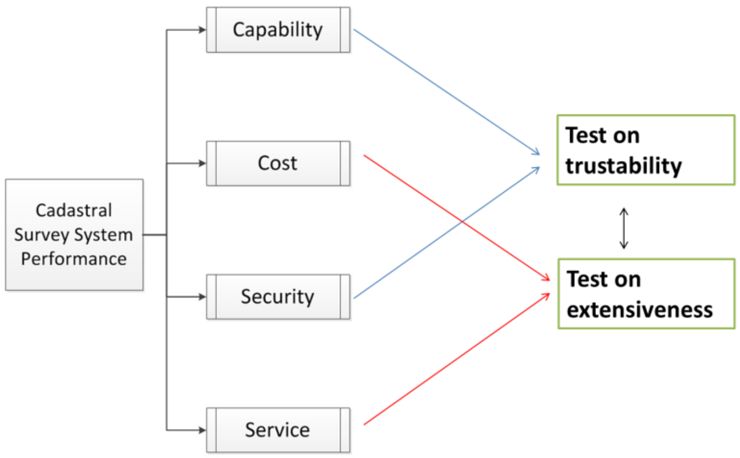

Fig. 1. Logic connections of the criteria set

2.2 A Multi-Criteria Assessment Model

To the best of our knowledge, very few assessment projects in the field of cadastre or land administration adopted single criterion to perform whole system evaluation process. In general, the term "multi-criteria" represents the utilization of Multiple Criteria Decision Analysis (MCDA) methodology. In this project, we selected Analytic Hierarchy Process (AHP) as the applied MCDA methodology for structured evaluation of the system performance. The detailed introduction of AHP will be addressed later. In this section, the selected assessment content is focused. The structure of the adopted criteria and their sub-criteria are illustrated in Figure 2.

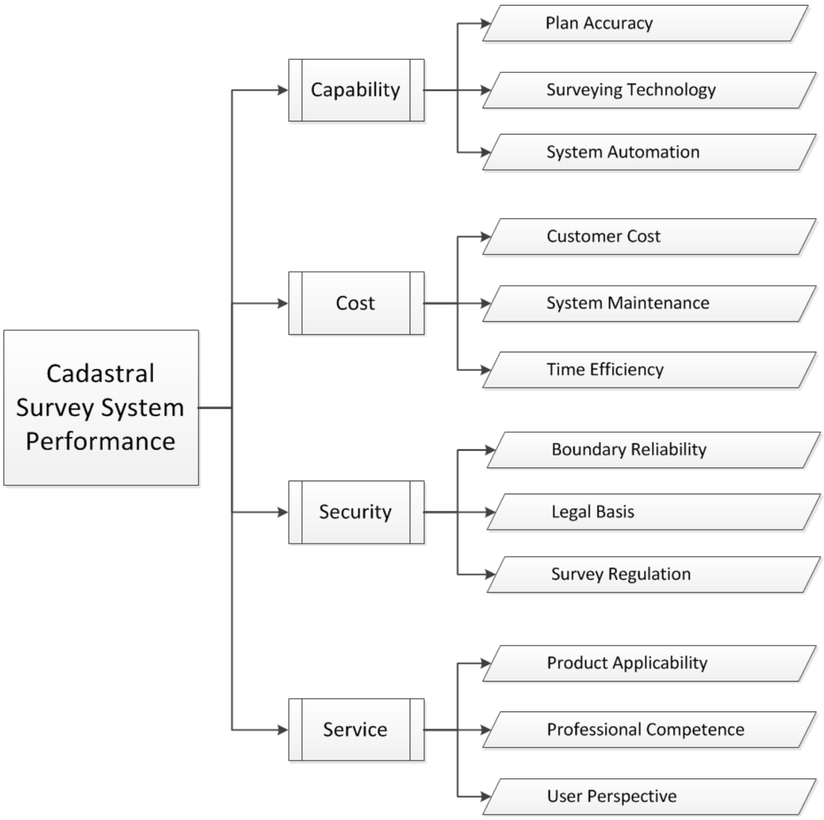

Fig. 2. The structure of adopted criteria set

The overall performance of a cadastral survey system is divided by four criteria: *Capability*, *Cost*, *Security* and *Service*. This criteria set covers the technical, economic, legal and institutional aspects of a system. Under each criterion, three sub-criteria are selected to measure the performance specifically.

2.2.1 Capability

Capability aims to evaluate the system performance with highlights on its technical dimension. In short, it asks the question "what can be done" by the current system. The sub-criteria set includes: 1) *Plan Accuracy*; 2) *Surveying Technology*; and 3) *System Automation*.

Plan Accuracy targets the horizontal accuracy of the currently produced land boundary plan. *Surveying Technology* exams the current adapted level of surveying technology to producing cadastral survey datasets. *System Automation* measures the level of system automation process with a focus on the database and data model approach.

2.2.2 Cost

Cost measures the performance of the system from the economic aspect. In short, it asks the question: "what is the cost" in providing cadastral survey and mapping activities to the society. Three sub-criteria are applied: 1) *Customer Cost*; 2) S*ystem Maintenance*; and 3) *Time Efficiency*.

Customer Cost indicates the individual cost of using cadastral survey service. *System Maintenance* focuses on the system cost of maintaining the cadastral survey services. *Time Efficiency* considers the cost in the time dimension by measuring the time spent on using cadastral survey services.

2.2.3 Security

Security evaluates system performance from the legal aspect. It asks the question: how reliable is the service? Three sub-criteria are selected: 1) *Boundary Reliability*; 2) *Legal Basis*; and 3) *Survey Regulation*.

Boundary Reliability measures the potential boundary disputes of surveyed parcels and the efficiency of the surveyed boundary (e.g. would it be overridden easily by newly discovered evidence or other rights, such as adverse possession?). *Legal Basis* intends to exam the performance of the updated legislation for the operation of cadastral survey system and the authorization of legal boundary for surveying. *Survey Regulation* assesses the technical and administrative guidance for the cadastral survey industry.

2.2.4 Service

Service measures the development of a cadastral survey system as a service provider. It contains three sub-criteria: 1) *Product Applicability*; 2) *Professional Competence*; and 3) *User Perspective*.

Product Applicability measures the level of adopting cadastral survey products by land related professions and the involvement of current cadastral survey products for further system development (e.g. Spatial Data Infrastructures and Building Information Modeling). *Professional Competence* assesses the efficiency of professional service to fulfill client's requirements and the appropriateness of the licensing or practicing system. *User Perspective* checks the quality of the data and the overall satisfaction of general public.

3. ASSESSMENT METHODOLOGY

3.1 General Procedures

The established criteria set is closely connected to the fundamental functions of a cadastral survey system. It defines the assessment content in a flexible way. The assessor are required to give their judgements on what constitutes (which criterion contributes more to) a desired performance for his (including assessors of both genders) specific system. In this research project, the AHP pairwise comparisons are applied to determine the weight of each criterion. Figure 3 gives an example of AHP derived criteria weight distribution.

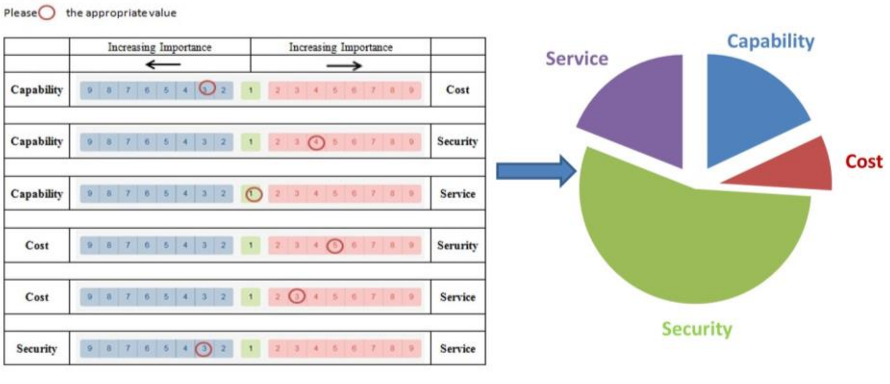

Fig. 3. A sample of AHP pairwise comparison methodology

Theoretically, the criteria weight distribution reflects the constitution of a desired system performance. Further, it aims to give hints on what the "purpose" is for the cadastral survey system based on a summarization of different AHP evaluation results from relevant stakeholders.

The next fundamental question in the assessment model is how well the current system fits for the "purpose". Benchmarking the current optimum societal required performance (should-be performance), stakeholders as the assessors are required to rate on the currently achieved performance. Gap analysis will then be conducted to evaluate the relative strengths and weaknesses of the current system (Figure 4). Furthermore, the overall weighted scores of current system rated by each individual assessor can be calculated based on his criteria weight distribution results. Thus, the normalized satisfaction level of the current system from different stakeholders can be assessed and compared.

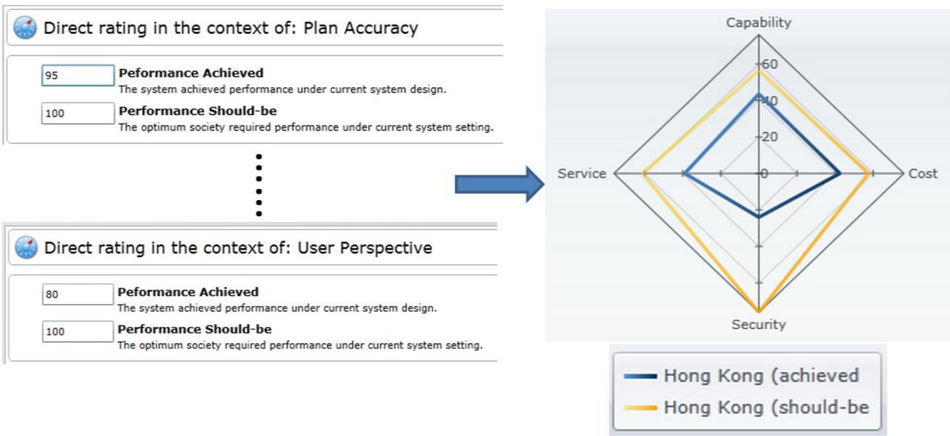

Fig. 4. Gap analysis of current system

It should be noted that the previously mentioned two types of judgements are both subjective individual opinions. It fits for the purpose of this assessment which is to provide a platform to show different understandings on the cadastral survey system performance. Sufficient feedbacks are needed to reflect the performance level of a cadastral survey system. There are two strategies adopted in the assessment to increase its reliability: one is to categorize different stakeholder types based on the assessors' professional backgrounds; the other is to invite informative answers from assessors on the specific performance datasets of the system. Correlation may be conducted between the given performance datasets and the previously defined performance satisfaction level. Therefore, with sufficient feedbacks, a robust multi-stakeholder assessment model contains actual performance of each cadastral survey system can be established.

3.2 Analytic Hierarchy Process

AHP served as the weight determination methodology in this assessment framework. The AHP method is a decision method for organizing and analyzing complex solutions. It was first introduced by Saaty in 1970s and widely used by researchers in different fields to transform qualitative and quantitative issues to the judgments about the data (Vaiday and Kumar, 2006). As indicated by Macharis et al. (2004), the fundamental principles that AHP concerned are: hierarchy construction, priority setting and logical consistency.

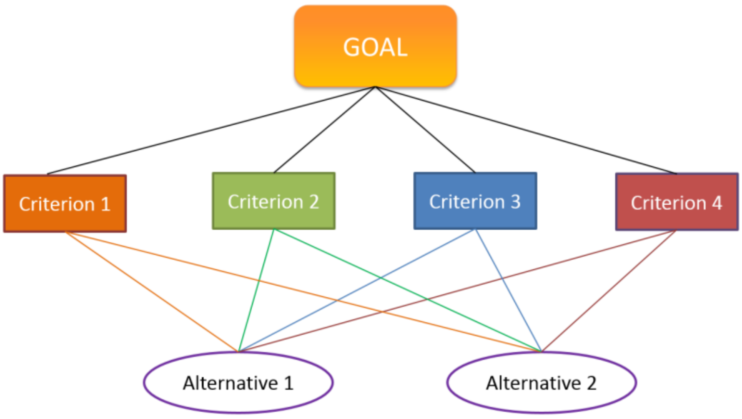

Fig. 5. Basic AHP structure

In general, an AHP solution contains three layers: goal, criteria and alternatives (Figure 5). In this project, the "goal" of the assessment project is an ideal/sound cadastral survey system performance that fits for the current optimum societal requirements. The detailed criteria set is introduced in section 2.2. *Capability*, *Cost*, *Security* and *Service* are the four selected criteria. Under each criterion, three representative and measurable sub-criteria are defined. In this project, we aimed to build a self-assessment model to evaluate how well a system fit for the optimum societal requirements. Thus, only two alternatives for each system, which termed as *Achieved Performance* and *Should-be Performance*, will be adopted.

In this model, priority settings of each criterion are derived from AHP pairwise comparisons. A matrix is used to calculate the priority values of those criteria with reference to the comparison attributes. Pairwise comparisons are provided to assessors to decide the relative importance of each pair of criteria in contributing to the goal. Here, the fundamental algorithm with the most common Saaty's 9-point pairwise comparison scale is applied. Table 1 lists the definition and explanations of each scale value.

Table 1. Satty's 9-point pairwise comparison scale (Satty, 1980)

Intensity of Importance	Definition	Explanation
1	Equal importance	Two elements (criteria/alternatives) contribute equally to the goal
3	Moderate importance	Judgment is slightly in favor of one element over another
5	Strong importance	Judgment is strongly in favor of one element over another
7	Very strong importance	One element is to favored very strongly over another
9	Extreme importance	There is evidence affirming that one element is extremely over another
2,4,6,8	Intermediate values between above scale values	Should be the intermediate value adopted by the assessor

The common steps to derive criteria weight can be generally illustrated by Figure 6. In step 1, assessor is needed to pairwise compare the criteria set in the same layer. Step 2 shows the established comparison matrix based on assessor's judgements. In step 3, the weight of each criterion that is calculated by the AHP algorithm is listed. Also, inconsistency ratio of the assessor's judgment is presented. A thorough explanation of AHP algorithms will not be discussed in this paper, but can be found at Satty (1980).

Fig.6 . Steps in AHP weight determination

The inconsistency ratio reflects the logical stability of assessors' judgements, and further this value can be applied to weight the influence of each assessor's judgements in summarizing stakeholders overall opinions.

4. ASSESSMENT STRATEGY

The established model intends to establish a platform to represent the development of cadastral survey systems world-wide. It does not aim to evaluate which system is better than the other. Under each jurisdiction, land stakeholders can express their ideas on the relative importance of different performance aspects of current system and their satisfaction level on each performance aspect. Correlating with achieved performance datasets, different stakeholders' opinions will show us a comprehensive performance level of the cadastral survey system in fulfilling its societal requirements.

The core task of implementing this model is to collect judgments and performance datasets from stakeholders. On one hand, international cooperation is sought. On the other hand, a pilot study of local cadastral survey system performance is currently conducted in Hong Kong under the coordination of the Land Surveying Division (LSD) of The Hong Kong Institute of Surveyors (HKIS). The strategy of implementing the established model in Hong Kong cadastral survey system assessment can be divided into three stages.

At stage 1, a consultancy panel is established. We supposed land surveyors are the type of stakeholders who know the system most. At this stage, as the key players of the system, thirteen land surveyors or surveying backgrounds members (4 from public sector, 3 from private sector, 3 young surveyors and other 3 from academia) are formed this consultancy panel under the coordination of HKIS. Through interview and questionnaire, opinions and comments are collected to calibrate the established assessment criteria and structured model.

At stage 2, an online questionnaire will be sent to all HKIS LSD members to collect their judgements on the performance level of our local cadastral survey system. In general, their professional backgrounds will be categorized into four types: public sector, private sector, academic and young surveyor.

At stage 3, this assessment model will be introduced to other relevant stakeholders through interviews or online questionnaire. Thus, comprehensive opinions can be collected to evaluate the actual performance of local cadastral survey system in fulfilling the requirements of the society.

With sufficient feedbacks, a robust platform can be established. To facilitate the process of opinions collection, a concise questionnaire was designed and utilized to collect assessors' judgements. Figure 7 shows the flowchart of the questionnaire. In general, an assessor can finish the questionnaire within 10 minutes by filling in all required questions. Information questions on the achieved performance datasets are optional.

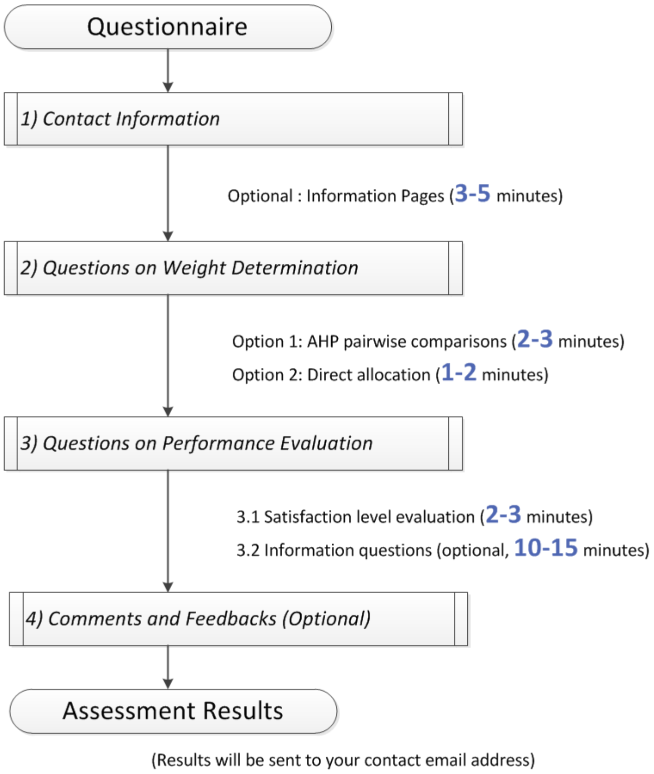

Fig.7 . Flowchart of the questionnaire

5. PILOT STUDY IN HONG KONG

The implementation of this assessment model is currently being conducted in Hong Kong cadastral survey industry. The formed consultancy panel has already been interviewed by our research team. Their opinions and judgements on the system performance are collected. Using the weight distribution of different assessment criteria as an example, summarized charts are listed in Figure 8.

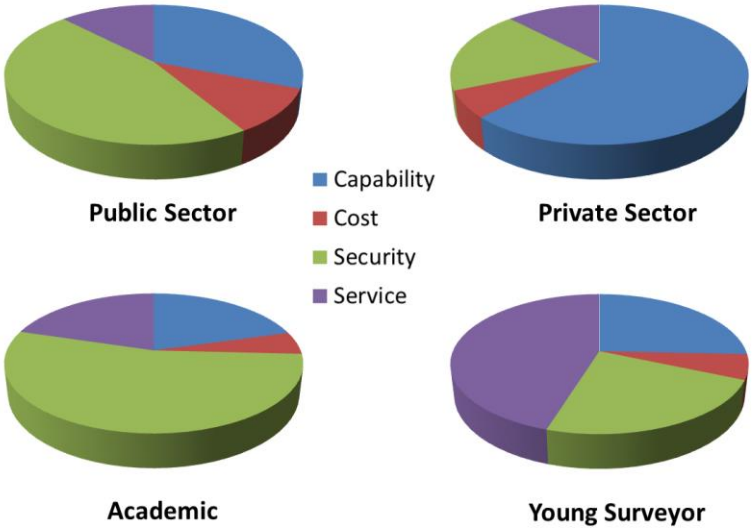

Fig.8 . Initial weight determination results in Hong Kong

Characteristic weight distribution scheme can be found from these four summarized weight distribution results. Both of the group “Public Sector” and “Academic” have more concerns on the criterion “Security”, and a reliable system is mostly expected by them. Comparatively, “Private Sector” prefers “Capability” and “Young Surveyor” considers the “Service” most. At this stage, we cannot conclude that the presented four charts can reflect the local cadastral survey industry opinions. But this initial results do provide us some clues on the requirements from different professions or stakeholders for the system.

Currently, an online platform has been established for relevant stakeholders. A concise online questionnaire will be sent to all HKIS LSD members soon. A set of more representative and comprehensive judgements on the system performance is expected.

6. CONCLUSIONS

This paper describes an on-going research project that aims to use an established model to answer questions on the cadastral survey system performance in fulfilling sociatal requirements. The established structural model settles the question of what to measure and how to measure through a set of criteria and performance indicators. Those model parameters intend to bring different understandings of a cadastral survey system performance into a common framework and measuring its performance by normalized yardsticks. Certainly this assessment framework cannot be well established without the involvement of relevant stakeholders. With sufficient feedbacks, a robust assessment results can be achieved and handily applied to measure the effectiveness and efficiency of a cadastral survey system. This research provides a scientific means to express the general successfulness or fitness of any cadastral survey systems in fulfilling the requirements of its society, and shed lights on areas for improvment.

ACKNOWLEDGMENT

This paper is supported by PolyU B-Q32N funding (RGC Ref No. 525712) and HKIS 2015 research funding.

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BIOGRAPHICAL NOTES

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