The Development of a Performance Assessment Model for Cadastral Survey Systems

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Key words:

Cadastral survey system, performance assessment, fit-for-purpose, multi-stakeholder analysis

SUMMARY

A cadastral survey system is an indispensable land administrative function. It provides spatial related cadastral datasets to the society. A sound cadastral survey system should fit for the purpose of the land administration system in fulfilling its societal requirements. Assessment model to check how well each cadastral survey system meets the demands of its society is rather rare. This paper introduces the development of a structured multi-criteria performance assessment model for cadastral survey systems. A set of criteria and performance indicators are defined. These model parameters aim to test the trustability and extensiveness of cadastral survey services in both developed and developing land markets. The established framework evaluates each system performance based on the judgements from land stakeholders and system achieved performance datasets. With sufficient feedbacks, a robust framework can be established to share ideas on the performance of cadastral survey systems. This paper emphasizes the development of the structured multi-criteria assessment model. Some preliminary results of implementing this assessment model in Hong Kong cadastral survey industry are also discussed.

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1. INTRODUCTION

A cadastral survey system operates to implement and process cadastral survey and mapping activities and then supplies spatial related cadastral information to system users. It provides spatial descriptions on land parcels. Land parcel is the basic spatial unit in the operation of a land administration system. Cadastral surveying is one of the core components of land administration activities. Further, together with land registration, these cadastral components consists an important infrastructure to facilitate the implementation of land use policies (UN-FIG, 1999).

The cadastral survey and mapping activities are regulated by the legal and institutional settings in each jurisdiction (Dale, 1976 and Dale, 1979). Thus, it is said in the field of cadastral surveying that every cadastre is different from another (FIG, 1995). However, assessing the system operation from a service aspect, Williamson (2000) indicated two common key performance indicators to evaluate the successfulness and general fitness of a land administration system and its sub-systems: 1) whether the system is trusted by general populace; 2) whether the system is widely used by land stakeholders. These evaluation criteria are closely connected to the recently introduced concept of Fit-for-Purpose Land Administration (FIG, 2014). Under this framework, Enemark (2013) also highlighted the influence of cadastral survey system in building a fit-for-purpose spatial framework for the sustainable development of the society.

A cadastral survey system aims to produces datasets in building and maintaining the spatial framework of a cadastre or cadastral system. The appropriateness of the cadastral survey system design may directly influences the performance of the process of land registration. Further, it affects the performance of the land administration activities in the land market. Benchmarking projects on the outcomes of how well a cadastral survey system fits for its societal requirements have rarely been systematically evaluated. Most benchmarking and evaluation projects in the field of cadastre and land management are focusing on a broad aspect of cadastral related land matters (see Setudler et al., 1997; Williamson, 2001 and Mitchell et al., 2008). Thus, currently, there is lack of assessment framework which targets the performance of cadastral survey systems directly. To comprehensively reflect the performance a cadastral survey system, opinions and judgements of involved stakeholders other than cadastral surveyors should also be collected and evaluated. However, normalized assessment framework which can represent and compare understanding from involved stakeholders is rather rare.

This paper introduces an on-going research project in building a self-assessment framework for cadastral survey systems in both developed and developing land markets. The general successfulness or fitness of a cadastral survey system is evaluated by a structured multi-criteria assessment model. Considering the technical, economic, legal and institutional aspects of a cadastral survey system, we proposed four assessment criteria termed as: Capability, Cost, Security and Service. Under each criterion, three representative performance indicators are selected to evaluate the performance of the system specifically. Land stakeholders are invited to give their judgements on: 1) the relative importance of those performance aspects in contributing a sound cadastral survey system performance; and 2) the performance gap between the should-be performance (optimal society required performance) and the currently achieved performance of the system. With sufficient feedbacks, the model intends to answer the questions on: what the "purpose" of the cadastral survey system is and how well the current system fits for its societal requirements.

The paper is structured as follows. First, an explanation on the contents of the established model is introduced. Then, the applied evaluation methodology - Analytic Hierarchy Process (AHP), is illustrated. The data collection strategy is also explained in this part. The third part of this paper introduces the preliminary results on implementing the established framework in the Hong Kong cadastral survey industry. At last, the paper concludes the preliminary findings of this research project and indicates the expected outcomes of implementing this self-assessment framework in the cadastral survey industries.

2. ASSESSMENT FRAMEWORK

2.1 Overall Structure

In general, each cadastral survey system has its unique characteristics. Direct assess the opinions of the end user of the system is always important to evaluate the successfulness or fitness of a cadastral survey system. However, in most cases, to assess a cadastral survey system, the assessor needs to investigate all relevant system settings which is too resource demanding and time consuming. In addition, depend on the professional backgrounds of the assessor, the assessment results may varied from the understandings of system end-users.

According to Neely et al. (2005), the performance of a system is more practicable to be assessed when compared with the system design. The achieved performance indicates the outcomes of its system design. Further, the satisfaction level of system users on the system performance is also required to be checked. Thus, we measure the performance of each cadastral survey system and collect judgements on the system performance from involved stakeholders. Correlations between the satisfaction level of stakeholders and system achieved performance datasets will give clues on the efficiency and effectiveness of the system.

To develop an appropriate assessment framework, we first divide the overall performance into fours general criteria: *Capability*, *Cost*, *Security* and *Service*. The criteria set measures from the technical, economic, legal and institutional aspect respectively. Performance on the aspect of *Capability* and *Security* are applied to test the trustability of a cadastral survey system; and the performance on the aspect of *Cost* and *Service* are adopted to assess the extensiveness of the cadastral survey services.

Under each general performance aspect of the system, three selected performance indicators are adopted and intend to test the system performance more specifically. It should be noted that the selected performance indicators are the abstract of fundamental attributes of cadastral survey systems. Thus, a set of customized background questions on individual cadastral survey systems is required if one needs a more thoroughly understanding on a specific system. Figure 1 shows an overview of the structured performance assessment model.

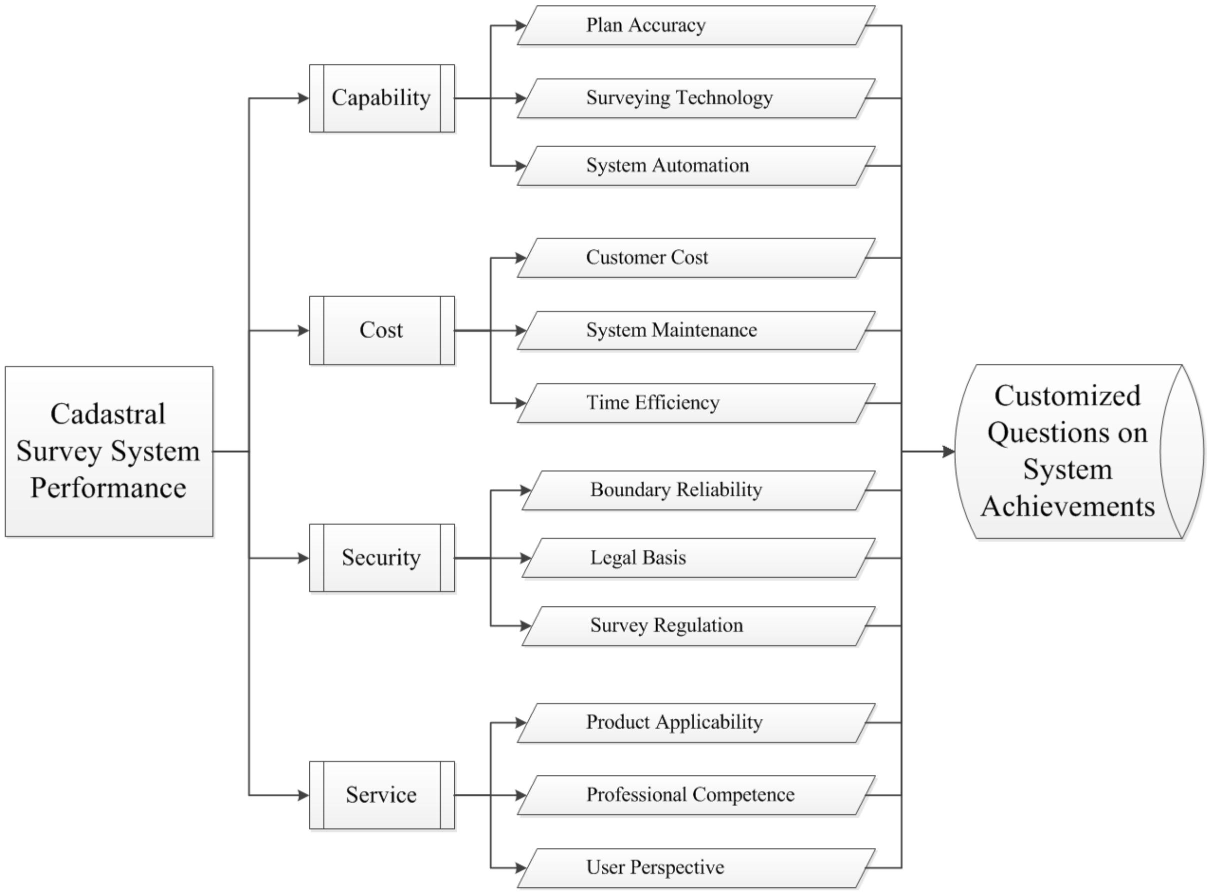

Fig. 1. The structure of established assessment framework

2.2 Performance Indicators

The overall performance of a cadastral survey system has been divided into four aspects: *Capability*, *Cost*, *Security* and *Service*. This set of criteria covers the technical, economic, legal and institutional aspects of a system.

2.2.1 Capability

Capability aims to evaluate the system performance with focus on its technical aspect. The selected performance indicators are: *Plan Accuracy*, *Surveying Technology* and *System Automation*. *Plan Accuracy* measures the quality of primary output of a cadastral survey system: the positional accuracy of the currently produced cadastral survey plan or land boundary plan. *Surveying Technology* measures the capability of the system in survey and mapping the required rights, restrictions and responsibilities. In other words, it exams the current adapted level of surveying technology on producing cadastral survey datasets. *System Automation* measures the level of system automation process with a focus on the database and data model approach. The level of the system automation is in the range of traditional paper level to the latest digital modeling level.

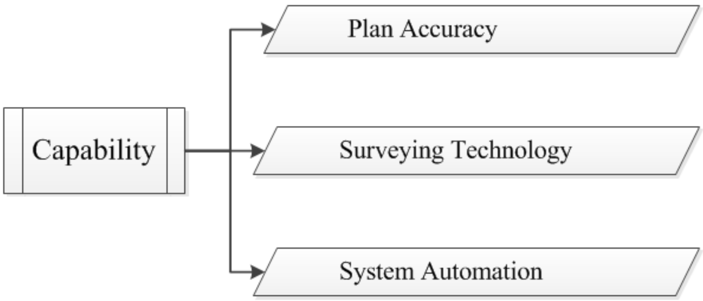

Fig. 2. Sub-criteria set of *Capability*

2.2.2 Cost

Cost measures the performance of system in two dimensions: currency and time. The sub-criteria set to assess the economic aspect of the system contains: *Customer Cost*, *System Maintenance* and *Time Efficiency*. *Customer Cost* indicates the individual burden of using the cadastral survey services. It measures economic aspect of the system from a user perspective. *System maintenance* measures the burden of the government or the cadastral survey services provider in maintaining the current cadastral survey system. *Time Efficiency* considers the cost in the time dimension by measuring the time efficiency on using or providing cadastral survey services.

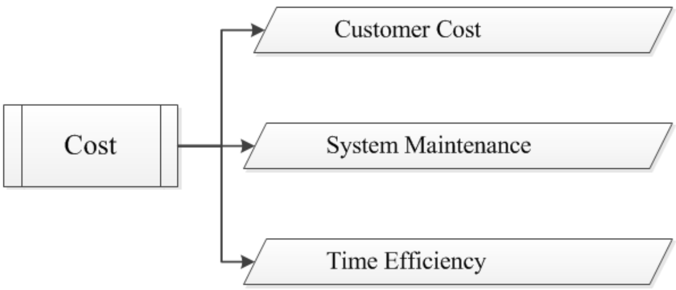

Fig. 3. Sub-criteria set of *Cost*

2.2.3 Security

Security evaluates the system performance from the legal aspect. It adopts *Boundary*

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

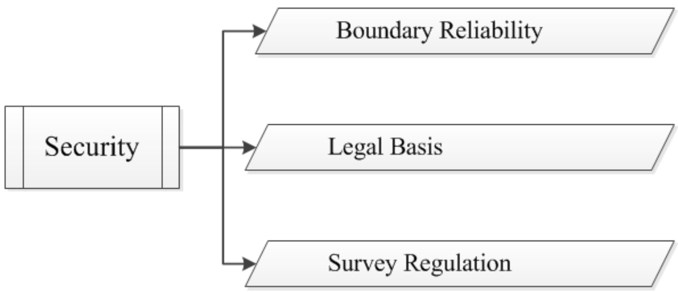

Fig. 4. Sub-criteria set of *Security*

2.2.4 Service

Service measures the development of a cadastral survey system from the aspect of service provider. Three sub-criteria are selected: *Product Applicability*, *Professional Competence* and *User Perspective*. *Product Applicability* measures the level of adopting cadastral survey outputs by land professions and the involvement of those products for further system development (e.g. Spatial Data Infrastructure and Building Information Modeling). *Professional Competence* considers the efficiency of professional services in fulfilling the requirements of system end-users; it also aims to test the appropriateness of current licensing and practicing system for the cadastral surveyors. *User Perspective* measures the quality of the cadastral survey services from the perspective of system end-users.

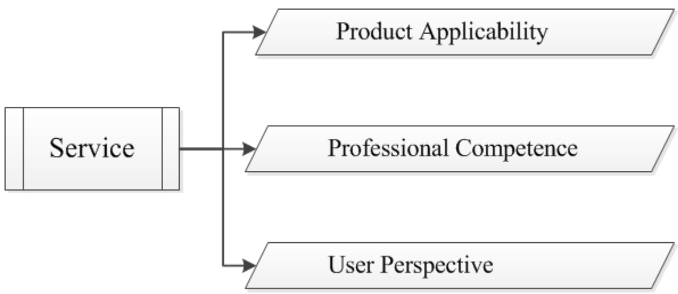

Fig. 5. Sub-criteria set of Service

3. ASSESSMENT STRATEGY

The established assessment criteria set covers the fundamental aspects of a cadastral survey system. Certainly, sufficient feedbacks are required to establish a robust model to share understandings on the system performance. Cadastral surveyors who know the system most is expected to give their comments and judgements on each selected performance indicators. To construct a comprehensive view on the system performance, general understandings on the system performance from land stakeholders other than surveyors are also required. It is expected those stakeholders may not have very deep understandings on the detailed performance indicators. But, as user of a cadastral survey system, their understandings on the general aspects of the system can be a very important criterion to evaluate the successfulness and fitness of current system. A flexible and normalized assessment scheme is developed to collect multi-stakeholders' judgements and bring them into a common evaluation framework. Below is a brief introduction of the application of AHP pairwise comparisons in building the evaluation model and the data collection strategy.

3.1 Evaluation Methodology

AHP supports group decision and is capable to measure and compare different understandings of stakeholders (Satty, 1980). AHP served as the weight determination methodology in this assessment framework. The weight of the criteria set reflects the relative importance of different performance aspects from the point of view of the assessor. The criteria weights distribution served as an indicator to reflect the recognition of an optimal cadastral survey system performance that meets the requirements of society.

The function of AHP pairwise comparison is the foundation of AHP multi-criteria decision analysis methodology. It is capable to structure complex decisions from a set of pairwise comparisons. This methodology is widely used by researchers in different fields to transform qualitative and quantitative issues to the judgements about the data (Vaiday and Kumar, 2006; Subramanian and Ramanathan, 2012). As indicated by Macharis et al. (2004), the general principles that a classical AHP methodology concerned are: hierarchy construction, priority setting and logical consistency.

In general, an AHP hierarchy structure contains three layers: *Goal*, *Criteria* and *Alternatives*. Figure 6 represents an example of general structure of AHP hierarchy structure. In Figure 6, there are 4 criteria and 2 alternatives.

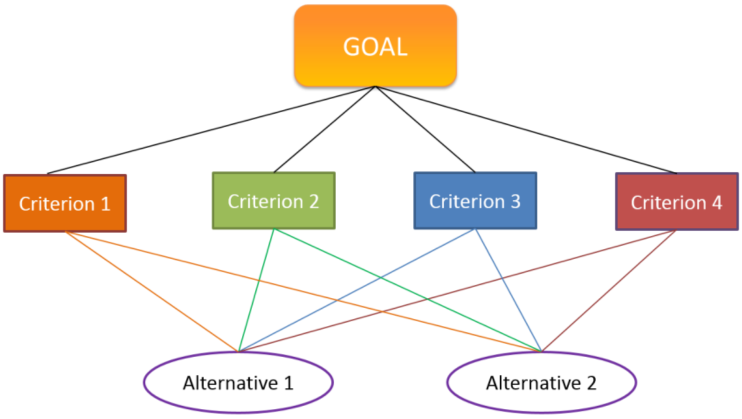

Fig. 6. Layer strucutre of an AHP methodology

For the established cadastral survey system evaluation model, its hierarchical framework has already been introduced by Figure 1. The *Goal* of this project is a fit-for-purpose cadastral survey system performance. The criteria set mainly concerns different aspects of the system termed: *Capability*, *Cost*, *Security* and *Service*. Each criterion need to be compared with another criterion on the same layer. Assessor needs to give his/her own judgments on the relative importance of the criterion in contributing the *Goal*. Figure 7 shows an example of using AHP pairwise comparison function to derive the weights of the proposed four performance aspects.

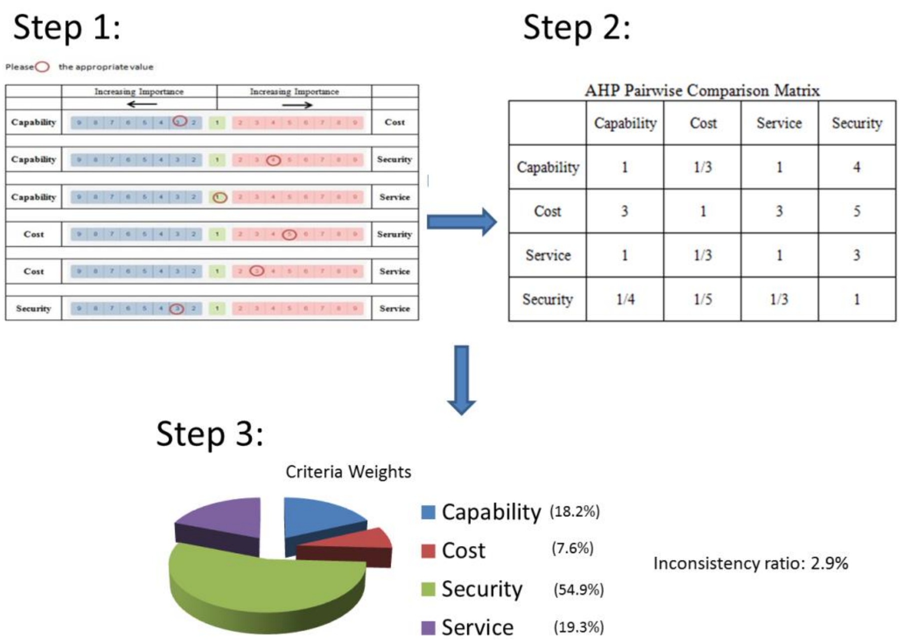

Fig. 7. An example of AHP pairwise comparisons

To derive appropriate priority settings of the criteria set, two things need to be considered: 1) the pairwise comparison algorithm; 2) the inconsistency ratio of the judgements. Here, we adopted the fundamental AHP algorithm with the most common Satty's 9-point pairwise comparison scale (Satty, 1980) to derive the weights of the criteria set and calculate the inconsistency of the given judgments. Table 1 lists the definition and explanations of each scale value. A thorough explanation of AHP algorithms will not be discussed in this paper, but can be found at Satty (1980).

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 inconsistency ratio reflects the logical stability of assessors' judgements. The logic of a set of totally consistent judgments can be exampled as: if *Criterion A* is two times more important than *Criterion B* and *Criterion B* is two times more important than *Criterion C*, then *Criterion A* should be four times more important than *Criterion C*. Otherwise there are inconsistencies in the set of judgments. In most cases, the inconsistencies are unavoidable in AHP pairwise comparisons. Here, we applied the inconsistency value to weight the influence of each assessor's judgments in summarizing stakeholders' overall weights pattern.

The criteria weights pattern reflects assessor's recognition on the constitution of an optimal performance for current system that meets the requirements of society. After settle the first two layers of AHP hierarchy structure, the next step is evaluating the performance of the *Alternatives*. The established model adopts the scheme of self-assessment, so there are only two alternatives for a specific system. One is the *Should-be Performance*, which represents the performance that best-fits the societal requirements on its cadastral survey system. The second one is *Achieved Performance*, which indicates the actual achieved performance of the current cadastral survey system. Benchmarking with the *Should-be Performance*, assessors are required to give their own judgements on their satisfaction level of the *Achieved Performance*.

3.2 Data Collection

In the established model, an evaluation platform is devised to assess the performance of a cadastral survey system, irrespective of legal and technical background differences. It can be done only with relevant feedbacks from the users and stakeholders of the system. With sufficient feedbacks, the model has its flexibility to evaluate any cadastral survey systems. Thus, data collection is the crucial step in evaluating the performance of the subject cadastral survey system. In addition, the subject cadastral survey system aims to be assessed by its own stakeholders. Hence, to construct a comprehensive view of the system performance, this self-assessment framework needs to collect data from involved land stakeholders.

It is expected that surveyors who understand the system most will provide detailed judgements on the system performance. It is also understood that stakeholders other than surveyors may not have very deep understandings on those very specific assessment criteria. The hierarchy structure of the assessment framework provides a normalized platform for surveyors and other land stakeholders. Surveyors are required to give their judgments for the entire criteria set and evaluate the performance gap on all proposed performance indicators. Other stakeholders are only need to provide their judgements on the performances on four main assessment criteria without considering the sub-criteria set of those performance aspects.

To collect judgements from stakeholders, an online questionnaire is designed. The general procedures of the questionnaire are illustrated in Figure 8. There are two key strategies in design the questionnaire: one is to be concise and the other is kept the privacy of participant assessors. From our experience, surveyors can complete the questionnaire in 15 minutes or less; other stakeholders are able to complete the questionnaire in 5 minutes. The objective of the data collection is to recognize different groups of stakeholders' understandings on the "purpose" of a cadastral survey system and how it fits for its "purpose". Thus, individual results will not be discoursed. The privacy of participants can be kept and only combined group results will be presented.

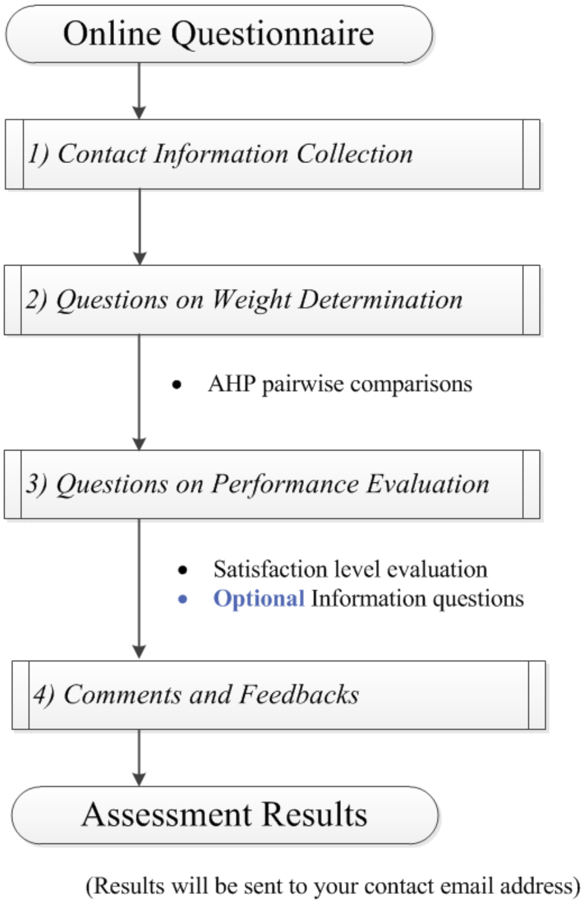

Fig. 8. Flowchart of the questionnaire

4. IMPLEMENTATION IN HONG KONG

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) and the Department of Land Surveying and Geo-Informatics (LSGI) of The Hong Kong Polytechnic University (PolyU). The strategy of implementing the established model in Hong Kong cadastral survey industry can be divided into three stages.

At stage 1, a consultancy panel was 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, land surveyors or surveying backgrounds members are formed this consultancy panel under the coordination of LSD and LSGI. Through interview and questionnaire, opinions and comments were collected to calibrate and refine the established assessment criteria and structured model.

At stage 2, an online questionnaire was sent to HKIS LSD members to collect their judgements on the performance level of the local cadastral survey system. Their land surveying backgrounds were categorized into four types: *Public Sector*, *Private Sector*, *Academic* and *Young Surveyor*. This step is currently undergoing processing.

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

Currently, we receive 30 feedbacks from the consultancy panel (land surveyors from public sector, private sector, academia and young surveyors). Their opinions and judgements on the system performance are collected and analyzed by the AHP methodology. Using the weight distribution of different assessment criteria as an example, summarized charts are listed in Figure 9.

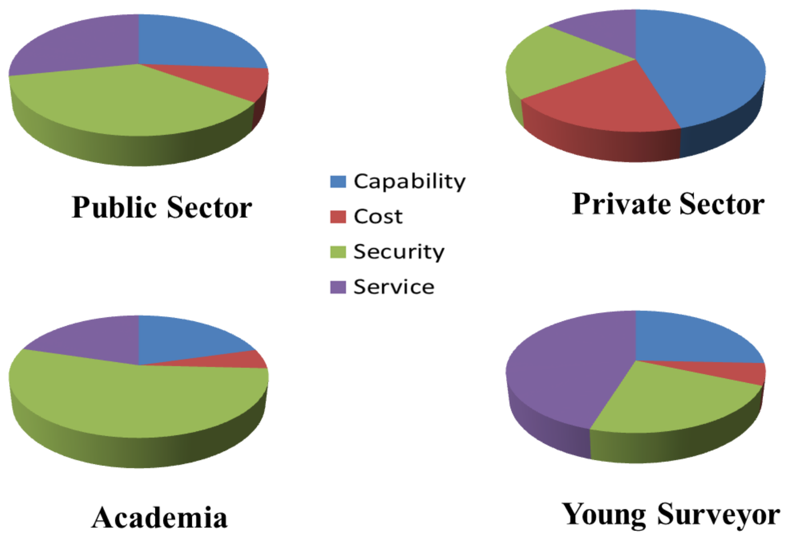

Fig. 9. Weights distribution pattern of Hong Kong land survyors

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 these preliminary results do provide us some clues on the expectations from different professions or stakeholders for the system.

Currently, an online questionnaire has been sent to HKIS LSD members. A more concise questionnaire will be sent to other land stakeholders soon. Hence, a set of more representative and comprehensive judgements on the current Hong Kong cadastral survey system performance is expected.

5. CONCLUSIONS

This paper describes the development of an AHP based performance assessment model for cadastral survey systems. The established evaluation model aims to assess the performance of cadastral survey systems, irrespective of those legal and technical background differences. The established structured model settles the question of what to measure and how to measure through a set of assessment 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 achievements by normalized yardsticks. Through the performance gap under different performance aspects of the system, the model attempts to investigate what are the purposes of the cadastral survey system and how well it fits for those purposes. Certainly, this assessment framework cannot be well established without the involvement of relevant stakeholders. With sufficient feedbacks, robust assessment results can be achieved and handily applied to measure the effectiveness and efficiency of a cadastral survey system. The research outputs hopes to provide 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 improvement.

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BIOGRAPHICAL NOTES

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