A Multi-Criteria Performance Assessment Model for Cadastral Survey Systems

Haodong ZHANG, Lesly LAM and Conrad TANG, Hong Kong SAR, China

Key words: cadastral survey system, performance assessment, multi-criteria analysis

SUMMARY

Cadastral survey system is an indispensable land administrative function in a modern cadastral system.Few studies have been conducted for benchmarking cadastral survey systems across different jurisdictions. This paper describes an on-going research project on building a performance assessment framework for cadastral survey systems. By adopting multi-criteria analysis tools, a model is established via settling issues of what to measure and how to measure.An initial set of criteria and performance indicators are provided. These model parameters are used to compare cadastral survey systems under a common framework and measuring performances of each system by normalized yardsticks. This assessment framework needs the involvement of survey experts world-wide. With sufficient feedbacks, a robustassessment model can be established. It will provide a scientific means to express the general successfulness or fitness of a cadastral survey system, and indicates the particular area for its improvements.

A Multi-Criteria Performance Assessment Model for Cadastral Survey Systems

HaodongZHANG, Lesly LAM and Conrad TANG, Hong Kong SAR, China

1. INTRODUCTION

Cadastre and land boundaries are an integral part of human societies which have started from the dawn of civilization thousands years ago. Many countries refer cadastre as the legal evidence of land boundaries. Other societies may have equivalent legal and administrative systems to handle cadastral functions. The understanding of the cadastre and its potential has been continually altered due to dynamic humankind to land relationship (Ting and Williamson, 1999), and the consequent development of the cadastral science(Bennett et al., 2010). Notwithstanding the essential function of a cadastral survey system is to provide the descriptions of land boundaries,it is an indispensable land administrative function in a modern cadastral system.

Few studies have been conducted for benchmarking cadastral survey systems across different jurisdictions. Many research projects have been focused on a wider aspect of assessment of cadastral systems and land administration systems. Due to the lack of certain and specific indicators, digging cadastral survey related information from those models can only lead to a fractional and uneven assessment framework (Haldrup and Ktubkjær, 2013).

This research proposes a multi-criteria structural cadastral survey system assessment model using a set of performance indicators. Those indictors are categorized into four main assessment criteria: 1) land boundary determination accuracy, 2) cost of the cadastral survey, 3) land boundary security and 4) quality of the cadastral survey service.In order to measure those intangible criteria, the Analytic Hierarchy Process (AHP) method is adopted. Survey experts of each jurisdiction will be invited to determine the relative weights of these criteria to analyze the importance of different system aspects in achieving a desirable cadastral survey system. Given that there is a lack of a normalizedyardstick to measure the performance of cadastral survey systems, another multi-criteria analysis (MCA) method, which is the Preference Ranking Organization METHod for Enrichment Evaluation (PROMETHEE), is applied to establish the preference scale of the system performance under each criterion.Cadastral surveyexperts would provide both qualitative and quantitative information of their own systems. The difference of each system will be translated into a preference degree under each criterion and then scores will be marked. Afterwards, an assessment model can be established by settling the issue of what to measure and how to measure.

2. AIM, OBJECTIVES AND SIGNIFICANCE

This research aims at providing a world-wide assessment framework for cadastral survey system of different jurisdictions. By adopting the two multi-criteria analysis tools, this assessment model can flexibly offer rooms for comparison for regional performance of cadastral survey systems under similar legal and institutional settings.

The objectives of this research are:

1) Determining a set of significantassessment criteriathat can be used to evaluate how well a cadastral survey system has fulfilled the needs of the survey industry;
2) Prioritizing different aspects of a cadastral survey system by determining their relative importance in a desirable system performance; and
3) Benchmarking the performance of different cadastral survey systems under each criterion.

This research project provides a scientific means to express the general successfulness or fitness of a cadastral survey system, and in what particular area that it needs improvement. The determination of the set of assessment criteria and their relative importance impose significance in studying the key factor influencing the performance of a cadastral survey system. The model can be used by experts who have knowledge on local cadastral survey system to give an assessment of their own system and to compare with other systems.

3. MCAMETHODOLOGIES

To comprehensively benchmark cadastral survey systems, one needs to decompose the various cadastral survey performances into a set of criteria.State-of-the-art multi-criteria analysis methodologies can assist decision makers handily do the assessments and understand the derived results. In this research, we apply two MCA methods, namely the AHP and PROMETHEE, to build the assessment model.

3.1 Analytical Hierarchy Process

The classical AHP is a decision method for organizing and analyzing complex decisions, which has been developed by Saaty since the 1970s.AHP is one of the most famous multi-criteria analysis methods in dealing with qualitative and quantitative issues by enter the judgments about the data. Vaidya and Kumar (2006) gives an overview of how widely this method has already been applied in different scenarios. The main principles that AHP concerns are hierarchy construction, priority setting and logical consistency (Macharis et al., 2004).

The fundamental hierarchy or structure of an AHP model contains three layers: goal, criteria and alternatives.The criteria can be further broken down into sub-criteria, sub-sub-criteria, and so on. Here, we use the cadastral survey system as an example. Figure 1 shows the structural model. The goal at the top layer is the preferredcadastral survey system. There are four criteria at the second layer which are accuracy, cost, security and service. The bottom layer lists the alternatives. The alternatives are ways to achieve the goal which need to be measured under each criterion.

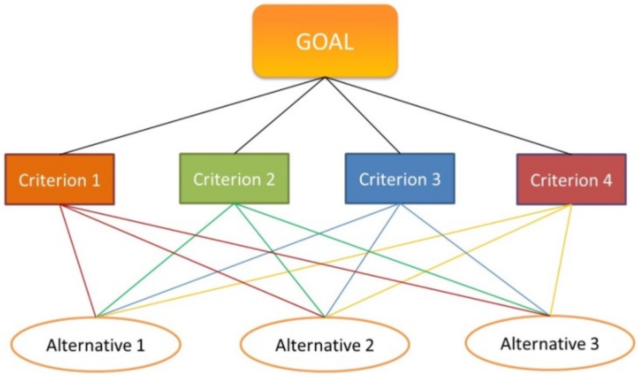

Figure 1 Structural model of an AHP method

It is expected that AHP is asuitable method for this study to determine the priorities of various performances of a cadastral survey system.AHP applies matrix to calculate the priority values of those criteria based on a set of comparison attributes. Pairwise comparisons are provided todecision makers to decide the relative importance in contributing the goal. The fundamental algorithm with the common 9-point pairwise comparison scale is applied. Table 1 lists the relative importance scale in AHP (Saaty, 1980).

Intensity of Importance	Definition	Explanation
1	Equal importance	Two elements (criteria/alternatives) contribute equally to the goal
3	Moderate importance	Judgment slightly favor one element over another
5	Strong importance	Judgment strongly favor one element over another
7	Very strong importance	One element is 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 the intermediate value is adopted by the expert surveyor

Table 1 Fundamental relative importance scale in AHP (Saaty, 1980)

Figure 2 illustrates a set of pairwise comparisons among the proposed four assessment criteria for a cadastral survey system.

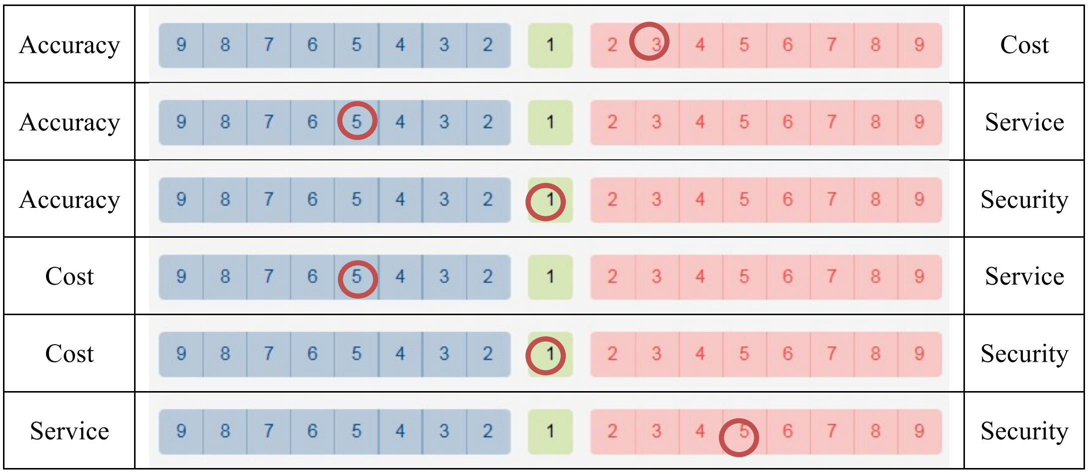

Figure 2 Pairwise comparisons

The matrix isconstructed based on the input judgment ofpairwise comparisons (Table 2).

	Accuracy	Cost	Service	Security
Accuracy	1	1/3	5	1
Cost	3	1	5	1
Service	1/5	1/5	1	1/5
Security	1	1	5	1

Table 2 Matrix of pairwise comparisons

The detailed mathematics and calculation techniques of the AHP are well described in Saaty (1980). Here, by skipping the calculation steps and using the standard method, the relative weights are derived(figure 3) from table 2 and the consistency ratio (CR)is calculated (0.055).

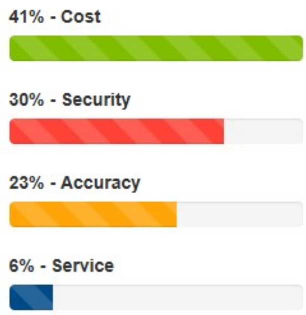

Figure 3 Criteria relative weight

One main criticism to this weight determination method in AHP is that it brings tedious judgment procedures to the experts. It is oftenwhen a large number of criteria or alternatives areinvolved, inconsistent judgments which are too close for randomness may be reached. Thus, in AHP, a consistency ratio needs to be calculated and that normally should be less than 0.1 in a standard way.The CR value in this exampleis 0.055 which means the logical consistency is acceptable.

The next step in AHP is to compare the performance of the alternatives under each criterion. The measurement methodology is same as the step to calculate the relative priorities of the criteria. Again, experienced judgments need to be decided by pairwise comparisons. In this example, alternatives are the cadastral survey systems of different jurisdiction. It is commonly known that the survey experts are very familiar with their own system and may only have some general impressions on other cadastral survey systems. In this research, the AHP methodologycannot be very efficientlyapplied to help those survey experts to do judgments. Hence, another MCA method, termed PROMETHEE, is selected to benchmark different cadastral survey systems.

3.2 Preference Ranking Organization METHod for Enrichment Evaluation

The PROMETHEE method was first developed by Brans (1982) and further extended into various versions (e.g. PROMETHEE II, PROMETHEE III and so on). The PROMETHEE II is the fundamentalmethodology to implement other versions of PROMETHEE and the majority users of PROMETHEE II are referred this version of PROMETHEE (Behzadian et al., 2010).Brans and Mareschal (2005) also indicated this outranking methodis often used to rank and select alternatives among a set of intangible or even conflicted criteria.

In this research, we adopt the PROMETHEE II. The general steps of PROMETHEE II are: 1) pairwise comparing alternatives under each criterion, 2) computing unicriterion preference degree, 3) calculating global preference index, and 4) calculating the net outranking flow. A more detailed description can be found in Behazadian et al., (2010). Here, considering the background of this research that there is no universal cadastral survey system model, ranking each cadastral survey system globally may not be very meaningful. Nevertheless, benchmarking cadastral survey system in a certain aspect or criteria (e.g. land boundary security) is more practicable. Thus, only the preference function of PROMETHEE has been focused in this study.Vincke and Brans (1985) firstly proposed the six basic types of the preference functions as illustrated in figure 4. Those functions translate the difference of the alternatives into a preference degree from 0 to 1. The reason to set preference functions is to normalize the value of the relative difference(Hayez et al., 2011). This function can help decision maker to decide how to express the difference in a selected scale.

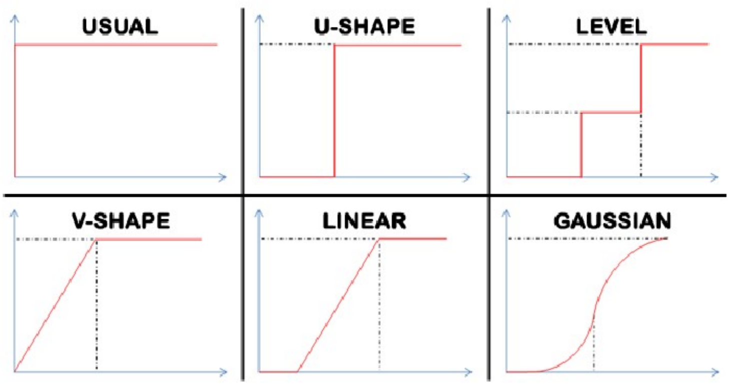

Figure 4 PROMETHEE preference functions (Hayez et al., 2011)

Both quantity and quality data are involved in the evaluation of cadastral survey systems. For quantity data assessment, the preference function can be handily processed once the function type has been defined; for quality data assessment, a qualitative scale should be established first and then the decision maker may select a preference function which is suitable to express the difference.

In this research, the weight of criteria is determined by applying the method of AHP. The ranking and benchmarking issues are processed by adopting the preference functions of the PROMETHEE.

4. RESEARCH DESIGN

The operations of a cadastral survey system are closely related to legal, institutional, technical and geographical context of each jurisdiction. Studies and analyses of individual cadastral survey system are likely done before the implementation of new survey law or cadastral survey record reform. Unless there are serious problems surfaced from the land boundary system such that it could hardly support the land administration functions, a government seldom puts a lot of efforts to improve the efficiency of a cadastral survey system. Thus the suitability of one's cadastral survey system can be regarded as a representative indicator of the overall actual efficiency of its land administration system.

There is a saying that "cadastre is different from one place to another". Surveyors of different countries know too well about their own cadastral survey system. It is easy to be complacent on their system characteristics and tolerant to many shortcomings.At this moment, we have advanced positioning technology and well developed legal system to protect land boundary rights for development and transaction, yet all developed cadastral survey systems have discontents and complaints eventually surfaced in courts. An assessment scheme on the sufficiency of a cadastral survey system is significant to our societal development.

4.1 A Performance Assessment Model

Build up a workable assessment model is critical to measure the efficiency and effectiveness of the system. To assess the successfulness and fitness of a cadastral survey system, one needs to examine all the background conditions (e.g. political, economic, social, technological, and environmental conditions) and the corresponding system settings (e.g. legal, institutional and technical settings). Extensive resources are required by adopting this strategy. This is from the side of the service provider. One shouldalso investigate whether the cadastral survey system design can fulfill the needs of the society. This is from the side of service user and needs to check the overall customer satisfaction on the service which is again resource demanding. Therefore, in this research, we propose an assessment method of a cadastral surveysystem by its performance assessed by the survey experts of local communities. The performance of a system is more practicable to assess and it is easier to quantify the efficiency and effectiveness of the system (Neely et al., 2005).

To establish a performance assessment model, the determination ofmeasurement dimensions and performance indicators is critical(Chimhamhiwa, et al., 2009). The indicators should be closely related to the purpose of the measurement(Nenadal, 2008). Many performance indicators can be selected from recent researches, e.g. Steudler et al., (1997), World Bank (2003) and Rajabifard et al., (2007).This research will customizea set of most significant indicators to represent the various performance aspects of a cadastral survey system.

4.2 What to Measure – Criteria Set and Performance Indicators

Based on previous research experience, the initial proposed criteria set contains 4 assessment dimensions and 9 performance indicators (figure 5).

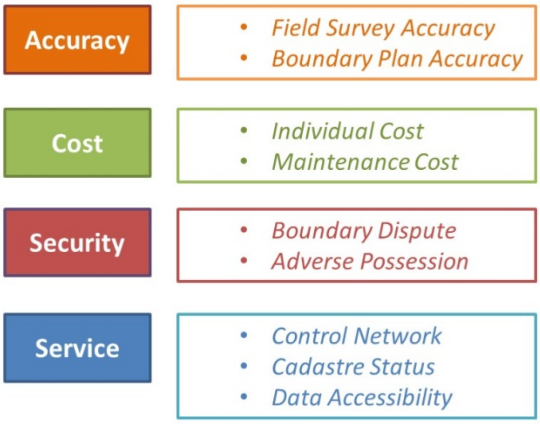

Figure 5 Assessment dimensions and performance indicators

4.2.1 Accuracy

It is not just the technically achievable horizontal positioning accuracy of a cadastral survey. More importantly, it is the achieved accuracy of the legal boundary line. In this assessment dimension, two performance indicators are adopted. One is the "field survey accuracy"; the other is the "boundary plan accuracy". Generally speaking, the field survey accuracy is decided by the accuracy of the control network, the technical level of the equipment and the related cadastral survey regulations; the boundary plan accuracy should reflect the actual achievable accuracy in a legal boundary database.

It is understood that the accuracy requirement of different jurisdictions is varied due to the different humankind to land relationships. Generally speaking, the more developed society, the higher demand on the accuracy. The optimal survey accuracy for urban and rural are different. Thus, we use a proportional scheme to express the relative importance. A survey expert will be ask to compare the system prescribed accuracy and the most suitable accuracy of the system.

4.2.2 Cost

There are two cost performance indicators. The "individual cost"is mainly focused on the user aspect; while the "maintenance cost" is applied to indicate the relative government cost on its land boundary system. The individual cost is defined as a ratio of the average cadastral survey cost paid by the client versus the land value of the subject parcel. The maintenance cost is defined asa ratio of the total number of government land surveyors versus the total number of land parcels to indicate the relative maintenance burden of the government.

4.2.3 Security

The adopted performance indicators under this criterion are: “boundary dispute” and “adverse possession”. The boundary dispute counts onthe number of boundary dispute lawsuits surfaced per year. Further, this number will be normalizedunder a common scale against the total parcel number. There is no doubt that the law clause on adverse possession may provide a shortcut to the boundary adjustments in some certain situations. However, on the issue of cadastral survey land boundary security, the existence of adverse possession law clauses may decrease the legal reliability of registered boundary records. Here, the adverse possession measures the influence degree of the existence law clause of adverse possession to the security of land boundary records.

4.2.4 Service

For the service criterion, three indicators are adopted. The indicator “control network”represents the technical level of the current cadastral survey control network. The status of the cadastre reflects the legal sanction of boundaries and will influence the quality of cadastral survey products. Thus, the “cadastre status”is applied to investigate whether the current cadastre is a legal based cadastre or only a fiscal based cadastre. In addition, this indicator measures how well the current cadastre facilitates other applications. A qualitative scale will be used to distinguish different cadastre statuses. The indicator of “data accessibility” measures how conveniently and comprehensively the customer can have access to the relevant data of a specific parcel. Again, a qualitative scale will be used to reflect the degree of the user satisfaction.

4.3 A Hierarchicalmulti-Criteriaassessment Model

Cadastral survey services are constantly reported in international conferences. Developing systems always reference to well-developed systemslike the Germanic cadastral systems or title survey systems. Even those well-developed systems are continuously reformed or enhanced to fit theirdynamic society requirements. This also means there is no perfect cadastral surveysystem exists and each systemhas its own strengths and weaknesses. To objectively reflect thesuitability of a system, a multi-criteria analysis model which evaluates the system from different aspects needs to be developed.

The selection of criteria are done by breaking down the context of a cadastral survey system into several dimensions which are termed as criteria.The criteria areintended to bring different understandings into a common framework. The actual performance of the system under each criterion needs to be measured by at least one performance indicator. Performance indicators, which are the sub-criteria,indicate what is happening in the system and how well the system design fulfills the society requirements. The hierarchical structure of this multi-criteria evaluation model is represented in figure 6.

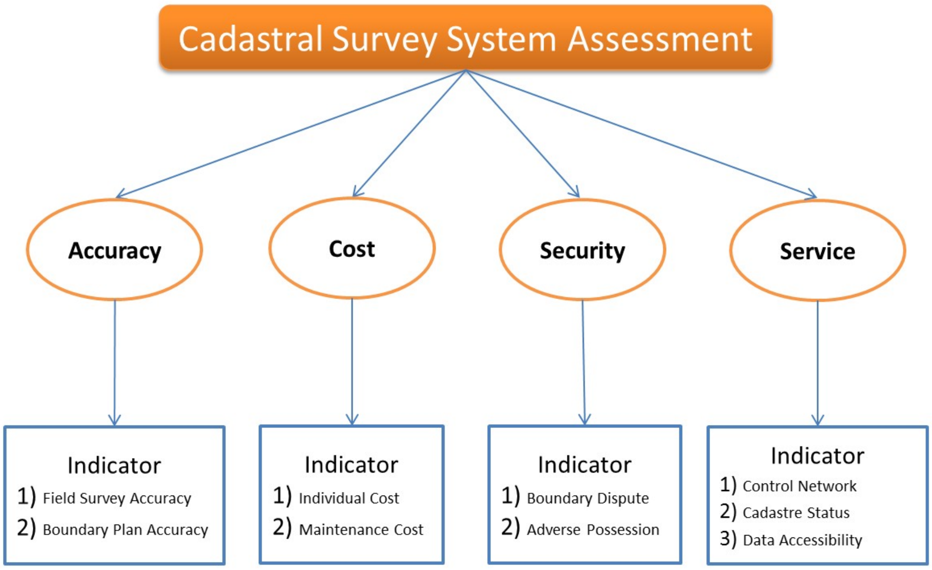

Figure 6 Hierarchical multi-criteria assessment model

Two MCA methods, AHP and PROMETHEE, are applied to enhance the assessment efficiency of this hierarchical multi-criteria model.The AHP provides a standard method to derive priorities for each criterion by pairwise comparisons, whether it is quantitative or qualitative. The derived weight of each criterion reflects the expert judgments on the degree of importance that criterion contributing to a desirable cadastral survey system. The preference functions of the PROMETHEE offer a set of flexible yardsticks to ascertain the performance differences of alternatives under each criterion.

5. CURRENT STAGE AND FUTURE VISION

Thegoal of this research project is to scientifically establish a cadastral survey system assessment framework. To achieve this goal, ourresearch project can be divided into three stages:

1) Determination of a set of most significant criteria and indicators for the performance assessment of cadastral survey systems;
2) Determination of the relative weights of each selected criterion and sub-criterion; and
3) Determination of the yardstickof the performance measurement for each criterion and its sub-criterion.

The research is now under the stage of selection of the criteria which is the primary task of the project. An initial set of criteria has been proposed (Fig.6). The steps of verification and calibration of that selected criteria set are currently followed. Presently, we are seeking professional assistances from survey experts world-wide, asking them to give comments on the proposed criteria set and line up in priority sequence a few essential factors that he/she considers the performance of a cadastral surveying system should be assessed with. Upon the collection of the feedbacks, a set of 4 to 6 criteria will be used.

Once a set of agreeable criteriais achieved, the cornerstone of the project is fixed and an assessment model can be established. The next step is to send thequestionnaireto invite survey experts from representative jurisdictions to determine the weight of each criterion and input the essential country data related to the measurable performance indicators. Expectedly,professional judgments on the relative importance of each criterion may be varied by individualexperts.The adopted strategy of this assessment model, under a fixed context, presumes to provide a flexible measurement yardstick.

Future vision of the workflow of this assessment model can be described as follows:

1) Country datasets of each performance indicator are stored on the assessment platform;
2) Cadastral survey experts can access to the platform;
3) Assessment alternatives will be selected by the expert;
4) A set of most agreeableassessment settings is provided as the default value, while the user can customize those settings by his/her own judgments; and
5) A report of the performance scores and the ranking results will be provided to user instantly to show the relative strengths and weaknesses of the system.

6. CONCLUSIONS

This paper describes an on-going research project that aims to establish a multi-criteria performance assessment model for cadastral survey system assessment. This model is designed to answer the question of what to measure and how to measure the performance of a cadastral survey system.An initial set of criteria and performance indicators are provided. Those model parameters are trying to bring the different understandings of a cadastral survey system into a common framework and measuring the system performance by normalized yardsticks.Certainly, this assessment framework cannot be well established without the involvementof survey experts world-wide.With sufficient feedbacks, a robust assessment model can be achieved and handily applied to measure the effectiveness and efficiency of a cadastral survey system. Hopefully, the model can be calibrated and accepted by the majority of survey experts world-wide. The research thus aims to provide a scientific means to express the general successfulness or fitness of a cadastral survey system, and in what particular area that it needs improvement. In addition, it offers rooms for comparison for performance of any cadastral survey systems under similar legal, institutional and any combination of groupings.

ACKNOWLEDGMENTS

This paper is supported by research project PolyU B-Q32N funding and HKIS LSD conference funding.

REFERENCES

Behazadian, M., Kazemzadeh, R. B., Albadvi, A.& Aghdasi, M. (2010). PROMETHEE: A comprehensive literature review on methodologies and applications. *European Journal Operational Research, 200* , 198-215.

Benneett, R., Rajabifard, A., Kalantari, M., Wallace, Jude. & Williamson, I. (2010). Cadastral futures: Building a new vision for nature and role cadastres. *Proceedings of the XXIV FIG International Congress*, Sydney Australia.

Brans, J. P. (1982). L'ingénierie de la décision; Elaboration d'instruments d'aide à la décision. La méthode PROMETHEE. In R. Nadeau, M. Landry *L'aide à la décision: Nature, Instruments et Perspectives d'Avenir* (pp. 183-213). Québec: Presses de l'Université Laval.

Brans, J. P. & Mareschal, B. (2005). PROMETHEE Methods. In J. Figueira, S. Greco, M. Ehrgott *Multiple Criteria Decision Analysis: State of the Art Surveys* (pp. 163-189). New York: Springer.

Brans, J. P. & Vincke, P. (1985). A preference ranking organisation method: The PROMETHEE method for MCDM. *Management Science, 31* (6), 647-656.

Chimhamhiwa, D., van der Molen, P., Mutanga, O.& Rugege, D. (2009). Towards a framework for measuring end to end peroformance of land administration business process - A case study. *Computers, Environment and Urban Systems, 33* 293-301.

Haldrup, K. & Stubkjær, E. (2013). Indicator scarcity on cadastre and land registration in cross-country information sources. *Land Use Policy, 30*, 652-664.

Hayez, Q., De Smet, Y.& Bonney, J. (2011). D-Sight: a new decision support system to address multi-criteria problems.*CoDE-SMG – Technical Report Series*, Ixelles Belgium.

Macharis, C., Springael, J., De Brucker, K.& Verbeke, A. (2004). PROMETHEE and AHP: The design of operational synergies in multicriteria analysis. Stengthening PROMETHEE with ideas of AHP. *European Journal Operational Research, 153* , 307-317.

Neely, A., Gregory, M., & Platts, K. (2005). Performance measurement systemdesign: A literature review and research agenda. *International Journal ofOperations and Production Management*, 25, 1228-1263.

Nenadal, J. (2008). Process performance measurement in manufacturingorganizations. *International Journal of Productivity and PerformanceManagement*, 57, 460-467.

Rajabifard, A., Williamson, I., Steudler, D., Binns, A.&King, M.(2007). Assessingthe worldwide comparison of cadastral systems. *Land Use Policy*, 24 (1),275-288.

Saaty, T. L. (1980). *The analytic hierarchy process: Planning, priority setting, resource allocation.* Texas: Mcgraw-Hill.

Steudler, D., Williamson, I.P., Kaufmann, J. & Grant, D.M. (1997). BenchmarkingCadastral Systems. *The Australian Surveyor*. 42(3), 87-106.

Ting, L. & Williamson, I.P. (1999). Cadastral Trends: A Synthesis. *The AustralianSurveyor*, 4(1), 46-54.

Vaidya, O. S. & Kumar, S. (2006). Analytic hierarchy process: An overview of applications.

European Journal Operational Research, 169 , 1-29.

World Bank. (2003). Comparative study of land administration systems – Criticalissues and future challenges. Preliminary report, August 2003.

BIOGRAPHICAL NOTES

Haodong Zhang: BSc, MSc
Haodong is currently a Ph.D. student at The Hong Kong Polytechnic University under the supervision of Dr. Conrad Tang. His research interest is mainly focused on the enhancement of Hong Kong land boundary survey system.

Lesly Lam: BSc(Hon) Geomatics, MSc, Ph.D.student
Lesly is the current Chairman of the Land Surveying Division, The Hong Kong Institute of Surveyors.

Conrad Tang: BScEng, MEng, LLM, PhD, FHKIS, RPS(LS)
Conrad is Associate Professor in the Department of Land Surveying and Geo-informatics, The Hong Kong Polytechnic University. He is a fellow member of Land Surveying Division, The Hong Kong Institute of Surveyors. He has served as the Hong Kong delegate to Commission 7 of FIG since 2000.

CONTACTS

Mr. Haodong ZHANG
Department of Land Surveying and Geo-informatics
The Hong Kong Polytechnic University
ZN602, Department of Land Surveying and Geo-informatics,
The Hong Kong Polytechnic University, Hung Hom
Kowloon
Hong Kong
Tel. + 852 3400 8151
Email: zhdong66@gmail.com

Dr. Conrad TANG
LSGI, HKPolyU
Tel. + 852 2766 5963
Fax + 852 2330 2994
Email:lstang@polyu.edu.hk
Web site: www.lsgi.polyu.edu.hk/staff/Conrad.Tang

Mr. Lesly Lam
Assistant Director
Operations Department
Vanke Property (Hong Kong) Co. Ltd.
55/f, Bank of China Tower,
1, Garden Road, Central,
HKSAR