An Applied Planning Support Toolkit Including Quantitative Methods, Software and Models in China

Ying Long, Xiaochun Huang, Lianna He, Hui Cheng, Wencheng Yu, Xin Zhang and Qiang Wang

Beijing Institute of City Planning, Beijing, China
email corresponding author: Longying1980@gmail.com

Abstract

Planning support systems (PSSs) have attracted extensive attention from scholars and decision makers for decades. Most of the existing research on PSSs is related to system design, implementation, application as well as evaluation of a standalone system in one area, e.g. *What if?*, CommunityViz and INDEX. There is no existing research on an entire framework of PSSs for various types of plans. In this paper, we propose a PSS framework for various types of plans in China, e.g. master plan, detailed plan, municipal infrastructure plan and transport plan. Based on an extensive literature review and multiple rounds of planner and decision maker surveys, the framework focuses on two aspects. On one hand, we itemize plan contents (termed as "plan elements") into various steps for each type of plan, e.g. population forecasting and establishing urban growth boundaries in a master plan. On the other hand, we list related PSSs for each plan element. In our research, PSSs embody three forms, which are existing PSS software (e.g. *What if*? and INDEX), planning support models to be developed or already developed as well as quantitative methods (e.g. scenario analysis, systems analysis, and logistic regression). The two dimensional framework provides a full picture of PSS applications in various types of plans. The framework has been applied in the Beijing Institute of City Planning (BICP) for several months, and has attracted

hundreds of application requests from planners.

1. Introduction

For decades China has witnessed rapid urban growth, especially of its large cities. Urban planning plays an important role in leading a sustainable development pattern. Planning support systems (PSSs) to support urban plan compilation and evaluation have attracted extensive attention from scholars and decision makers. Most of the existing research on PSSs is related to system design, implementation and application as well as evaluation of a standalone system in one area, e.g. *What if*?, CommunityViz and INDEX. The uptake of the developed PSSs is not advanced (Vonk, 2005; Vonk, 2007). In addition, most of the planners in China have backgrounds in architecture and lack quantitative analysis skills, let alone using a PSS. For this, the paper describes the construction, set-up and first evaluation-by-users of a large framework with an overview of plan 'elements' (stages in preparing plan documents such as Town Master Plans) and possible supporting methods, software and models (Planning Support components). The framework serves as a PSS Toolkit for the Beijing Institute of City Planning (BICP). A first user evaluation confirms that an online version of the "overview framework" serves its purpose as knowledge base within the institute BICP. We hope this work as an expert system for PSS selection for various types of plans in China, based on a conceptual framework of the planning process, can promote the application of PSSs in practical urban planning.

The concept of a "planning support system" (PSS), initially proposed by Harris (1960), was considered to be the latest form of computer-aided planning system (Geertman and Stillwell 2004; Klosterman 1997). Several books on PSSs have been published in recent years (Brail and Klosterman 2001; Geertman and Stillwell 2003; Brail 2008; Geertman and Stillwell 2009). PSSs have been applied mainly in spatial plans (Geneletti 2008; Kammeier 1999), urban environment improvement plans (Edamura and Tsuchida 1999), industrial location choices (Kammeier 1999), and land use plans (Klosterman 1999). Single PSS implementations and applications are reviewed widely in the literature. Typical PSSs related to land use plan are listed in Table 1. Various approaches have been used in these PSSs, and numerous factors are input into PSSs to predict land use patterns based on different scenarios. However, most of these PSSs focus on a sin-

gle aspect of urban planning, and, to the best of our knowledge, there is no existing reported research proposing a framework for various kinds of plans. The most relevant research is Geertman and Stillwell (2004), which reviewed a basket of PSSs.

Table 1. An inventory of typical PSSs

Publication	PSS name	Approach (es)
Landis 1994; Landis and Zhang 1998a, 1998b	CUF/CUF-2	Rule-based land suitability analysis
Clark et al. 1997	SLEUTH	Cellular automata
Wu 1998	SimLand	Cellular automata, AHP
Shi and Yeh 1999	N/A	Case-based reasoning
Klosterman 1999	What if?	Rule-based land suitability analysis
Allen 2001	INDEX	Rule-based land suitability analysis
Waddell 2002	UrbanSim	Microsimulation, discrete choice models
Lautso 2002	SPARTACUS (based on MEPLAN)	Input-output model, discrete choice models
Yeh and Qiao 2004	KBPSS	Knowledge-based reasoning
Carmichael et al. 2004	GB-QUEST	Rule-based land suitability analysis
Placeways, LLC	CommunityViz	Rule-based land suitability analysis
Li and Liu 2008	N/A	Cellular automata, multi-agent
Long et al. 2009	BUDEM	Cellular automata, logistic regression

Research relating to PSSs in China has been carried out frequently since the concept of PSS was first introduced into China in 2003 by Liu (2003). Du and Li (2005) applied *What if*? to a Chinese urban master plan. There have been two books published on PSSs, Yeh et al. (2006) and Long (2007), the second of which focused on geospatial techniques for establishing PSSs. Li (2010) analyzed the current condition of and future prospects for PSSs. Li and Zhan (2011) developed a PSS named UPlan. Long et al. (2011) developed an urban containment PSS in Beijing. The development and application of a standalone PSS is still the emphasis for Chinese researchers. Now, researchers in China are beginning to focus on proposing general techniques or multi-cases related to PSSs. For instance, Niu (2012) published a PSS book in which he proposed over 40 GIS tools

as PSSs, including six basic aspects: fundamental techniques, spatial overlay, 3D analysis, transportation network, spatial research and planning information management. A project conducted by the Chinese Academy of Urban Planning proposed a framework of digital techniques for urban planning and developed dozens of tools for urban master plans and detailed plans (Luo et al. 2009). In addition, decision support systems (DSS) or management information systems (MIS) are extensively applied in the Chinese urban management bureau or commission in the process of data management and issuing of land permits. In contrast to the information techniques used in the field of urban management, PSS is not much used by agencies and institutes compiling urban plans. In conclusion, there is a large body of literature in China in this field and some researchers have begun to combine various techniques to propose a framework of PSSs although most of them are still under development.

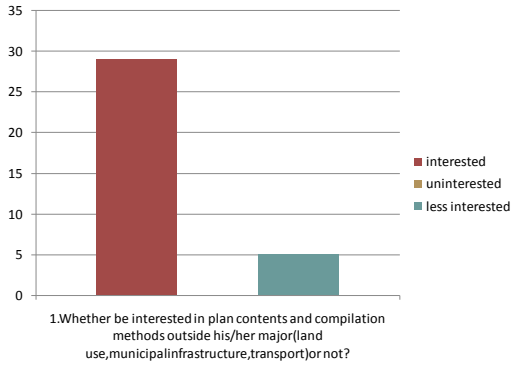
This paper is organized as follows. Section 2 introduces various methods we have applied in establishing the PSS framework. Section 3 illustrates the framework we have developed as well as an online query system for an improved application of this framework. We discuss the application of the framework in BICP and its potential contributions in Section 4. Last, we draw several conclusions and propose future research into the PSS framework.

2. Methods for establishing the framework

2.1. Requirement analysis

We used two methods to conduct the requirement analysis for the framework: two rounds of seminars and a survey. We held two seminars for planners to discuss the requirements of the framework. One seminar was held at the very beginning of the research, and the other was held when we were seeking feedback on a preliminary framework. In the first seminar, the 10 planners involved made 20 suggestions. Most of suggestions focused on the applicability of the framework as well as more types of plans to be included. Some also argued that the framework should be prepared for the next stage PSS development. In the second seminar, the 20 planners involved gave us 30 comments and suggestions. Most of them suggested that, based on their experience, several more detailed models, including those developed by BICP, should be included in the framework. Planning evaluation is also a very important aspect to include. The dataset required

by each PSS is also necessary. In addition, at the very beginning of the research, we designed an online survey with six questions relating to the requirements for the proposed framework. We conducted this in BICP and got 34 responses (from a total of about 300 planners in BICP). Figure 1 shows the questions and the statistical results. From 34 responses, 29 planners were interested in plan contents and compilation methods from outside of their major area of interest. Nineteen planners had never or seldom applied quantitative methods in their planning practice, methods such as GIS, statistical approaches, models and visualization techniques. Thirty planners saw opportunities for PSSs to support their work, and 30, 7 and 27, respectively, saw opportunities for existing condition analysis, plan scheme compilation and plan evaluation in their work. Overall, planners in BICP showed great interest in using PSSs in their work, although this is not yet common. Their involvement in seminars and the survey significantly improved the applicability of the framework.



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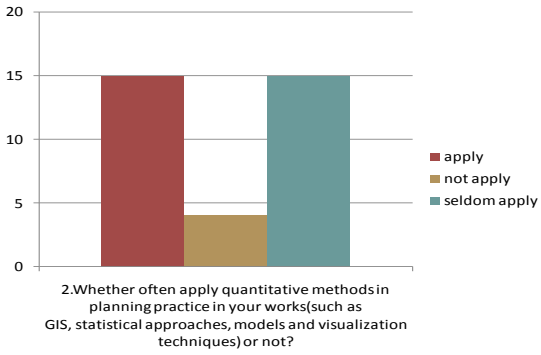

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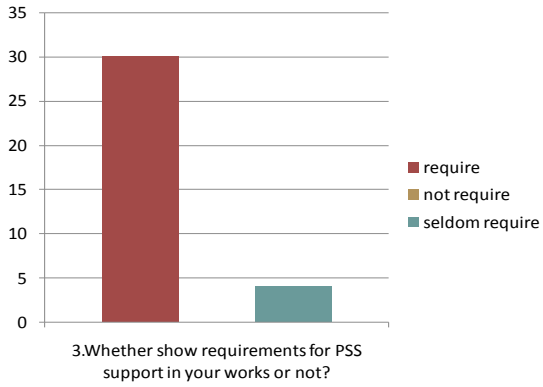

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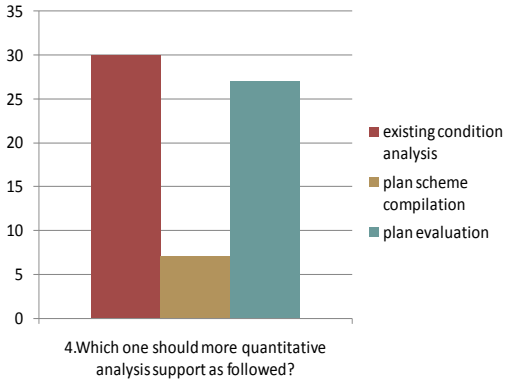

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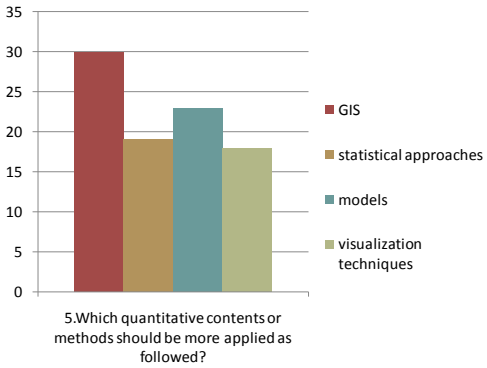

(e)

Fig. 1. The survey results regarding the requirements for the framework

2.2. Selecting the form of the framework

We designed the overall PSS framework based on the requirement analysis. First, we focused on both the urban plan compilation and evaluation. Second, we included both existing PSSs and PSSs under development by BICP in the framework. Third, quantitative methods/theories, although not PSSs, were included in the framework to broaden the horizons of BICP planners, who, we understand, mostly have backgrounds in architecture and lack quantitative analysis skills. Fourth, existing conditions as a key procedure of plan compilation and evaluation were highlighted in the framework. Fifth, the framework was as detailed as possible for planners' queries and applications. According to these principles, the structure of the PSS framework is in two dimensions (see Figure 2), the vertical dimension is for each plan element, which is a part of a type of plan. The horizontal dimension is each PSS technique including both theories and tools. Details of the framework format are as follows.

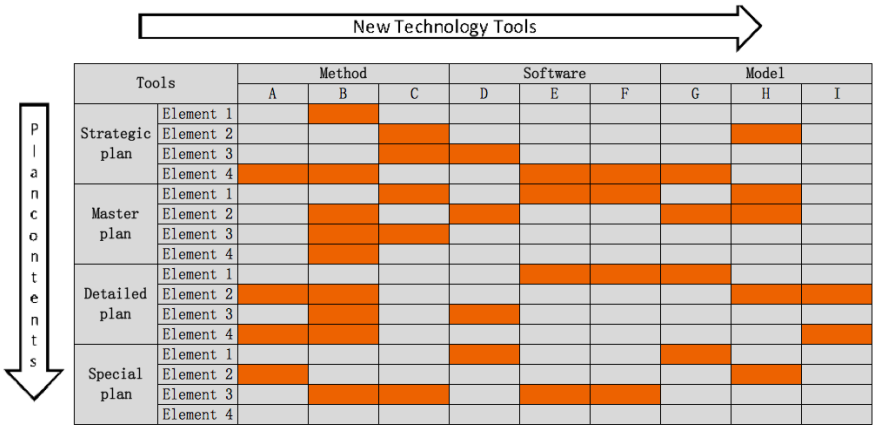

Fig. 2. The simplified PSS framework (Cells in dark means a PSS tool, a method, software of model, could be adopted to support the plan element)

2.3. The selection of plan elements

We based the selection of plan elements involved in the framework on existing urban planning laws, regulations and standards in China. The key reference was the City Planning Law of the People's Republic of China enacted in 2008, which defines the urban-rural planning system for plan compilation and plan evaluation. Plan compilation was further divided into downtown plans, new city plans, town plans and rural plans, and each type

was further divided into master plan and detailed plan levels. Therefore, plans involved in the framework included both plan compilation and evaluation, as shown in Table 2. In this stage, we focused more on plan compilation than evaluation in the framework in line with dominating historical and existing planning role of BICP, although Figure 1 shows that more planners are interested in applying PSSs in plan evaluation. We will extend the framework for plan evaluation in a near future.

Table 2. Plan types involved in the framework

Level 1	Level 2	Level 3-1	Level 3-2	Level 3-3
Part1: Plan Compilation				
	1 Strategic Plan	1.1 Spatial Development Research		
	2 Master Plan	2.1 Downtown Master Plan	2.2 New City Master Plan	2.3 Town Master Plan
	3 Detailed Plan	3.1 Street Level	3.2 Lot Level	3.3 City Design
	4 Municipal Topic	4.1 Water Supply Plan	4.2 Storm Water Drainage Plan	……
	5 Transport Topic	5.1 Transport Demand Plan	5.2 Road Network Plan	……
	6 Special Plan	6.1 Elementary Education Facilities Special Plan	6.2 City Fire Equipment Special Plan	……
Part 2: Plan Evaluation				
	1 Master Plan Evaluation	1.1 Urban Master Plan Evaluation		

Each plan in Level 3 was further itemized into various plan elements, for which we proposed a PSS in the framework. The plan elements were confirmed based on existing planning laws and guidelines, as well as recommendations from BICP. For example, 1.1 Spatial development was divided into several plan elements, including landscape analysis, existing condition analysis, land use suitability analysis as well as population distribution analysis. All these elements should be addressed under spatial development within a strategic plan (See Appendix 1 and the online attachment of the paper for all the plan elements).

2.4. The selection of PSS types

We classified PSSs into three forms, quantitative methods, software and models, based on an extensive literature review into PSS definitions as well as information from face-to-face expert surveys.

1. Quantitative methods were documented in the textbooks of various urban planning-related disciplines, for example urban economics, urban geography, system science and geographical information science. These methods, like scenario analysis, systems dynamics and genetic algorithms, were extensively applied in urban studies and planning practice. Urban planners are generally required to master these methods.
2. Software in this paper was defined as existing PSSs developed by developers outside BICP, like ArcGIS, *What if*? and INDEX, commercial, shared, or free, which could support plan compilation and evaluation. It should be noted that some models like UrbanSim were also listed as software since they were not developed by BICP.
3. A model in our framework was defined as a tool specially developed to implement a function to support plan compilation or evaluation. Generally, models were all developed or will be developed by BICP, while existing models developed by third parties were excluded. Models in the framework were highlighted and will be regarded as the base for the next steps in various phases of PSS development.

2.5. Proposing PSSs for plan elements

Proposing appropriate PSSs for each plan element was the core procedure in establishing the PSS framework. Researchers with backgrounds ranging from urban planning, transport planning, municipal infrastructure planning to social planning were involved in this process. Literature review was the dominant approach used for proposing PSSs for each plan element. We also held several extra seminars for BICP planners to evaluate the proposed framework. More than ten urban planning experts were involved in developing this framework.

3. The new framework

3.1. The framework and detailed descriptions

We developed a comprehensive PSS framework for various kinds of urban plans in China. Using the methods for designing the framework, we proposed 128 methods, 59 software programs, and 58 models to be included in it. Table 3 shows a part of the framework. The complete framework, including inventories of methods, software and models, is in Appendix 1. For an example of the plan element "urban growth boundaries" in spatial layout of master plan compilation, the full description for the element is "delimit the urban expansion and settle the boundary of built-up area". Various datasets including boundary and area of built-up area over the years, previous land use plans, DEM, socioeconomic status, municipal infrastructure, transport infrastructure, land use status, as well as constraining elements are necessary for establishing urban growth boundaries. Methods like cellular automata and trend analysis, and software like SWARM, REPAST, NETLOGO and ArcGIS (Spatial Analysis module) could be used in the process. Furthermore, we propose several existing or to-be-developed models, e.g. Beijing Urban Spatial Development Model (BUDEM), Urban Growth Control Model (UGCM) and Land Use Layout Analysis Model (LULAM), to support establishing urban growth boundaries.

Table 3. Part of the PSS framework proposed

Level 4	Planning element	Descriptions	Data	Method	Software	Model
Problem analysis	Topography and geomorphology	Analyze the topography and geomorphology, construct the digital elevation model, and compute the slope and aspect	DEM, RS		ArcGIS (3D Analyst Tools)	Basic topography model
	Current conditions	Analyze the current situations of natural resources, historical evolution, spatial layout, infrastructure and social and economic issues	Natural resources(ecological environment, land resource, water resources, etc.), engineering geological conditions, historical and cultural resources, land cover status, municipal infrastructure, transport infrastructure, population, industry		PSS tools of Chenghui, ArcGIS (Analysis Tools), Excel	Status comprehens model
	Land use suitability	According to the requirements of land cover, analyze the land cover suitability (usually divided into suitable, comparatively suitable and unsuitable levels), determine the constraining factors of exploitation, find out the optimal way of land use and a sound plan scheme	Elevation, slope, existing land cover, existing land cover, municipal infrastructure, transport infrastructure, natural resources(water source, wet land, forest)	Grid algebra operation, multi-attribute evaluation, basic topography analysis model, grey system theory	ArcGIS (Spatial Analyst Tools)	Land use suitabil model
	Population spatial distribution	According to the population of each statistical unit, display and analyze the spatial distribution of population with a continuous surface of population density using spatial interpolation	Population and land use in towns and sub districts(total number of population and buildings)	Density core analysis, spatial interpolation, monte carlo	ArcGIS (Spatial Analyst Tools), GeoDA	Spatial distribut population predic
Forecast of development trend and scale	Population development trend	Analyze the scale of population in different historical stages and judge the development trend in the future	Demographic data over the years	Synthetic growth-rate method	SPSS, Excel	
	Urbanization development trend	Analyze the spatial distribution, expansion, direction and mechanism of urban construction land in different historical stages(e.g. location, accessibility and public policy)	Existing land cover, existing land use, DEM, municipal infrastructure, transport infrastructure over the years	Remote sensing interpretation, Logistic Regression model, principal component analysis, phase analysis, land use evolution analysis model	Erdas, Envi, ArcGIS (Spatial Analyst Tools), SPSS (Logistic regression, correlation analysis, principal component analysis), GWR3X	Land use evolutio model, beijing ci development analy

We have detailed descriptions for each PSS in the framework, which readers can use to learn more about the PSS. In addition, several models have been developed in BICP, like BUDEM, BLUTI, SWMM and SCD.

3.2. The online query system

In addition to a hard-copy version of the framework, we have created an online version of the framework, from which one could query related PSSs for a plan element, query the application fields of a specified PSS, and learn about a PSS with downloadable materials in PDF form. The main interface of the online query system is shown in Figure 3. This browser-based system was developed using Asp.Net and C# on a Windows 2003 platform. The contents of the framework were stored in a Microsoft SQL Server 2005. The functions of the system included: (1) querying required PSSs/data/guidelines for a specified plan element; (2) querying the plan elements where a specified PSS could be applied; (3) downloading existing PSSs; (4) querying the person in charge of a PSS; (5) searching a plan element of PSS. This system was installed on the BICP intranet and could be easily accessed by planners in the institute via a browser.

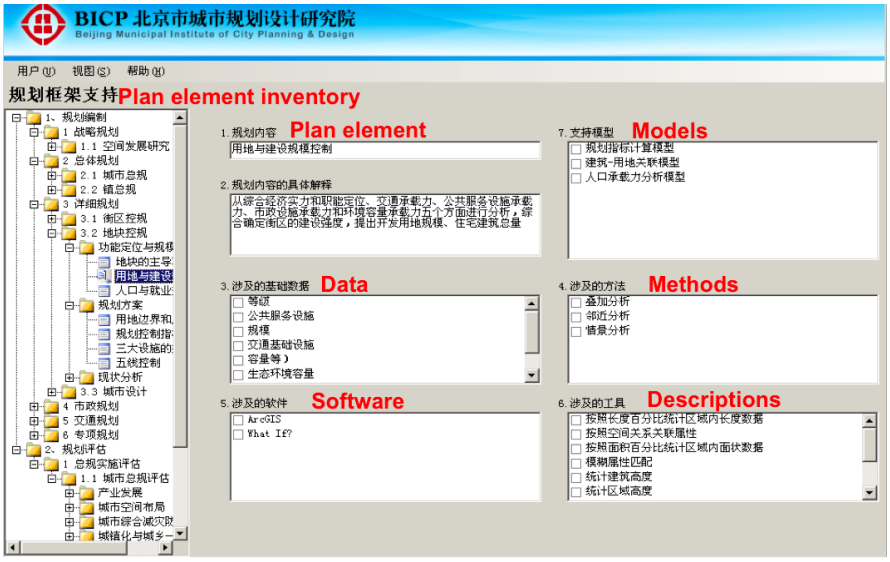

Fig. 3. The main graphical user interface of the online query system for the PSSs framework

4. Discussion

4.1. Application and user evaluation of the framework in BICP

The framework has been available at BICP, a top official planning agency in China with more than 300 planners, for several months. It has attracted hundreds of application requests from planners. The applications of the framework include the following aspects.

First, we developers organized a large-scale training workshop for all planners in BICP so as to widely apply the framework in BICP. The contents of the workshop range from the development background, overall structure, user manual of the online system, as well as our further plans. Most of planners agreed that they have gained basic knowledge on the framework and its user manual.

Second, BICP planners regard the framework as a knowledge base of PSSs. In the framework, each PSS has been associated with a planner who is familiar with and experienced in its use. The users can contact the associated person to gain more knowledge in the usual way by Instant Messenger in BICP. Building on BICP's existing spatial databases, the framework can promote the application of new techniques in urban planning compilation and evaluation. Currently these techniques are not common in architecture-dominated official and private planning institutes in China, thus our framework has potential applications in those entities. The application of the framework could broaden the horizons of planners by introducing a large body of planning support techniques and then promoting their efficiency and increasingly scientific results.

Third, BICP planners regard this framework as a knowledge base of urban planning theories. New urban planners could complete practical tasks more effectively using information from the framework. Newcomers could get to know the detailed procedure of a specific job, like a detailed plan in a town, by checking the plan element rows of the framework. In addition, planners with various backgrounds like urban planning, transport planning and municipal infrastructure planning could learn more about unfamiliar plan fields. In current China, it is not easy for planners to familiarize themselves with different specialist areas. Assisted by the framework, this situation is expected to improve and new plan schemes are expected to be better than before because of more shared understanding among planners of various backgrounds. As a byproduct, planners in different fields could get familiar with plan contents of others by querying the framework, a process that was not easy prior to the launch of the framework.

Fourth, we drafted the development plan of PSSs in BICP using the new framework. We have decided to develop several fundamental urban models during 2011–2015, based on aggregating models in the framework. These models include the existing land analysis model, the urban spatial development model, the land use and transportation integrated model, the low carbon urban model, the urban planning implementation evaluation model, and the municipal facility evaluation model, as well as the storm water management model.

4.2. Potential contributions

The contributions of our research in the regime of PSS are as follows. First, to our knowledge, this research is the first attempt to establish a comprehensive PSS framework including quantitative methods, models and software for various types of plans, rather than a standalone PSS. The framework is an integration of existing PSSs and those yet to be developed. Second, this framework is a form of urban planning knowledge base, in which users with different education background can share their knowledge both on urban planning theory and PSSs. It will be a complementary digital infrastructure for the well-studied spatial database and is expected to promote the potential application of PSSs. It could also be used as training material for novices in this field. Third, the development plan for the PSSs can be compiled based on the new framework, which provides a platform for both long-term goals and short-term development. Seven comprehensive models, e.g. urban spatial development model and existing condition evaluation model, have been proposed to develop by BICP during 2011-2015. Fourth, this research has passed the rigid review process by PSS processors and practitioners in China. The review reports said the work as a fundamental research has its potential extended application and could promote PSS development in the whole country.

5. Conclusions and next steps

In this paper, we have proposed a PSS framework for various types of plans in China, e.g. master plan, detail plan, municipal infrastructure plan and transport plan. Based on an extensive literature review and several rounds of planner and decision maker surveys, the framework focuses on two aspects. On one hand, we itemized plan contents (termed as “plan elements”) into various steps for each type of plan, e.g. population forecasting and establishing urban growth boundaries (UGBs) in master plans. On

the other hand, we listed related PSSs for each plan element. In our research, PSSs embody three forms, existing PSS software (e.g. *What if*? and INDEX), planning support models to be developed in the future or already developed, as well as quantitative methods (e.g. scenario analysis, systems analysis, and logistic regression). The two dimensional framework provides a full picture of PSS application in various types of plans. This framework has two forms of application, the hard copy and the online system. We have revised the established framework several times following discussions with and feedback from planners using the framework. This framework is a first systematic attempt to integrate existing planning support techniques and provides users/planners with a knowledge base in both planning procedures and PSS. It is being heavily used in BICP.

Finally, there are several actions that can enhance this study. First, more plan types are expected to be included in the framework, e.g. more special plans and planning evaluation, as highlighted in the latest City Planning Law of the People's Republic of China. Second, PSS items like existing methods and software can be continuously enriched by literature reviews and planner surveys. Third, the online query system can be further developed by linking existing data and PSSs to run the PSS directly in the online system. Fourth, BICP will develop new planning support models and specify them in the proposed framework.

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