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Abstract

Urban renewal is a significant issue in developed urban areas, with a particular problem for urban planners being redevelopment of land to meet demand whilst ensuring compatibility with existing land use. This paper presents a geographic information systems (GIS)-based decision support tool (called LUDS) to quantitatively assess land-use suitability for site redevelopment in urban renewal areas. This consists of a model for the suitability analysis and an affiliated land information database for residential, commercial, industrial, G/I/C (government/institution/community) and open space land uses. Development has occurred with support from interviews with industry experts, focus group meetings and an experimental trial, combined with several advanced techniques and tools, including GIS data processing and spatial analysis, multi-criterion analysis, as well as the AHP method for constructing the model and database. As demonstrated in the trial, LUDS assists planners in making land-use decisions and supports the planning process in assessing urban land-use suitability for site redevelopment. Moreover, it facilitates public consultation (participatory planning) by providing stakeholders with an explicit understanding of planners' views.

Keywords: Urban renewal, multi-criterion decision analysis (MCDA), decision support, GIS, land-use suitability analysis (LUSA)

1 Introduction

There exists an eternal conflict between humankind and land. Demands for any form of land use are invariably greater than available land resources (Ozcan et al., 2003) – a situation exacerbated in many countries by rapid urbanization and population growth. While increased areas of land are required to sustain future development, land is a non-renewable natural resource and seemingly unlimited demand for the limited area available is causing increasingly serious problems. For instance, land reclamation in Hong Kong is being carried on for many years in order to create more land for the increasing land demands, however, it has always been a controversial means of land supply because some reclamation projects completed years ago deteriorated the ecological environment and even landscape of the Victoria Harbour.

One of the most effective solutions is to reuse land to accommodate changing demands, especially in developed urban areas where land can often be inappropriately utilized or underdeveloped. Urban renewal is a particularly urgent concern for local governments in older districts of developed cities, driven by aging buildings and deterioration of living environments.

Some tracts of land in older developed zones require redevelopment in order to accommodate new land use demands and needs of urban renewal projects. The challenge, however, is to ensure that redevelopment does not come at the expensive of existing community living conditions. There is thus currently a need for planners to know how to make land use decisions that ensure sustainable urban land redevelopment is compatible with existing neighbouring land use.

Hong Kong is a prominent case currently experiencing this challenge (Shen et al., 2009). Under conditions of severe land shortage, the government is continually searching for a means of providing enough land to meet the market demands and facilitate Hong Kong's current and future infrastructure needs. Currently, supply options comprise Rezoning Land, Land Resumption, Rock Cavern Development, Redevelopment, Reclamation and Reuse of Ex-quarry Sites (CEDD, 2011). Several of these (e.g., land redevelopment, land rezoning, and reuse of ex-quarry sites) involve the reutilization of land resources, while land redevelopment, rezoning and resumption usually take place in urban renewal projects.

Urban renewal is a significant contemporary issue in Hong Kong, with 46 redevelopment projects having been announced by the Urban Renewal Authority (URA) of the Hong Kong Government. However, successful redevelopment/renewal projects are difficult to accomplish. Many stakeholders are involved, including governments, developers and local residents, each having their own aspirations for the projects and often interacting with each other in frequent negotiations. The impact on surrounding residents is also an unavoidable issue. Under these circumstances, urban renewal projects often take a long time to complete, and the timing of the redevelopment is invariably unpredictable. In order to reduce impact on local residents, the Government needs to find a way to shorten the time involved and improve communications among the different stakeholders.

In this paper, an innovative GIS-based approach (LUDS) is introduced for supporting land-use decisions in site redevelopment/urban renewal and is illustrated by considering five different land uses in a high-density district in Hong Kong. From a literature review and interviews with experts, the key factors affecting land-use decisions in sustainable site planning are identified in terms of the physical, utilities/locational, cultural/historic, social, economic and environmental perspectives of land in general. In the experimental trial, twenty of the factors/criteria are selected to assess land-use suitability due to their applicability and data availability, and their weightings are determined based on the opinions of urban planners. Two sites located in the study area are examined to determine the most suitable form of land use, and an experimental study is conducted to validate and compare the process of land-use decision-making supported by LUDS and current planning practices. Finally, the benefits and limitations of the LUDS for supporting land-use decision-making in urban renewal projects are discussed.

2 Related work

Sustainable land use is an important topic in contemporary urban development. Land should be utilized in terms of its capacity to meet human needs and to ensure the sustainability of ecosystems (Cengiz and Akbulak, 2009). Land redevelopment in urban renewal is one form of resource re-use that intrinsically reflects sustainable development thinking. In following urban development trends and the increasing demands for living environments, the objective of urban renewal has moved from the simple clearance of large-scale slums to the improvement and rehabilitation of older areas. The fundamental premise of land sustainability is to ensure suitable land utilization by taking into account the attributes of the land and actual needs of users (Cengiz and Akbulak, 2009). Inappropriate land utilization, however, due to the alteration of land use types and land use intensity, leads to the damage of land resources and an increase in poverty, inequity and other social problems (FAO, 1976). These problems can be solved under the guidance of a sustainable land use plan.

Land suitability for specific purposes is assessed by land-use suitability analysis (LUSA) (FAO, 1985). This decision-making process considers not only the natural attributes of the land but also its socioeconomic and environmental features. In other words, land use decisions are based on complex, interrelated factors such as: the characteristics of the land itself; economic conditions; social, environmental and political constraints; and the objectives and needs of the land users (FAO, 1980). Land use planning should reflect both the economic realities of the planning area and the conflicting social and environmental requirements involved (Jankowski and Richard, 1994). Urban planners often face the challenge of needing to make complex decisions within a short period of time, while also considering the requirements of sustainable urban development and local economic competitiveness (Joerin et al., 2001). As a result, planners are becoming increasingly aware of technological advancements in suitability assessment and land use allocation (Collins et al., 2001).

LUSA is a tool used to identify the most suitable locations for future land use for specific purposes (Collins et al., 2001) and involves the general model (McDonald and Brown, 1984; Mendoza, 1997)

$$S = F(x_1, x_2, \ldots, x_n)$$

where S is suitability grade, F is rating function, and x_1, x_2, …, x_n are factors affecting the suitability of the land/site. As this equation suggests, LUSA takes into account the different factors involved simultaneously by combining them into a standardized form.

LUSA aims to comprehensively determine the most suitable pattern for future land use to meet the needs of land users (Malczewski, 2004). In urban renewal processes, identifying the most suitable land use for a specific redevelopment site is a multi-objective decision task. It is difficult for planners to simultaneously consider multiple factors affecting land-use selection and the complicated relationships between land and other social or environmental factors. Studies of LUSA have taken place since the second half of the 20th century (McDonald and Brown, 1984; Jankowski and Richard, 1994; Mendoza, 1997). These are based on the premise that LUSA is an appropriate means of quantifying land development constraints and opportunities, and is able to assist in land use planning. For many, LUSA is essentially a process involving multi-criteria decision analysis (MCDA), that is, LUSA is an evaluation/decision problem with multiple affecting factors.

With the widespread application of GIS technology and the development of multi-criterion analysis approaches, a great deal of research into LUSA has been conducted and much progress has been made over the last decade. These studies started from agricultural land or meadowland in rural areas (Bojorquez-tapia et al., 2001; Cengiz and Akbulak, 2009) and gradually extended to urban areas (Joerin et al., 2001; Gomes and Lins, 2002; Dai et al., 2008). However, LUSA for metropolitan land, and especially land redevelopment/urban renewal in developed areas, is still rare. Regarding the specific methods of MCDA, according to Malczewski's survey of the literature (2006a), the AHP method, as one of approaches of MCDA, is capable of achieving LUSA. AHP is a powerful and commonly used tool for decision-making in land use suitability issues, involving social, environmental and economic factors (Jafari and Zaredar, 2010). The method was created by Thomas Saaty in the mid 1970s and gradually developed after its initial emergence. In combination with GIS technology, the Spatial AHP (SAHP) method was introduced for spatial multi-criterion analysis and has become a new feature in LUSA. AHP has several advantages over conventional LUSA techniques (Mendoza, 1997). Firstly, it relies less on the completeness of the data, and more on expert opinions or preferences concerning the factors of land suitability. Secondly, it allows the participation of both planners and stakeholders in providing their views in making land use suitability measurements. Without the AHP method, the land suitability mapping technique cannot incorporate decision-makers' preferences and stakeholders' opinions. Thirdly, it is more transparent and more likely to be accepted, especially when the results of LUSA serve as a basis for land use decisions in practice. Also, considering the nature of urban/land use planning, land use plans are ultimately made by the judgments of planners according to qualitative and quantitative analysis. AHP therefore has the advantage of effectively collecting expert/practitioners' views and being relatively simple to understand for non-professionals including land developers and local residents, enabling greater participation in public consultation activities.

The study described in this paper aims to solve land use problems encountered in urban renewal and to facilitate land-use decision-making in developed urban areas by providing an integrated solution to assist planners with this specific issue.

3 Development of LUDS

3.1 Process and Methods

Several research methods were used to develop and validate LUDS, comprising a comprehensive literature review, document analysis, interviews with experts, focus group meetings, experimental study and questionnaire survey. These were conducted in three phases as illustrated in Fig 1. The literature review of LUSA and sustainable site planning was necessary to determine current research progress in site analysis and to identify indicators for sustainable site planning, i.e. key factors affecting land-use decisions in site redevelopment. Document analysis was employed to supplement this by taking into account local planning practice. This involved reference to official documentation issued in Hong Kong, including relevant policies on land use and urban development, land use administrative regulations, and planning standards and guidelines.

Expert interviews were used to adjust and finalize the key factors/criteria identified by the literature review and document analysis, and address practical problems in current planning processes. This involved seven face-to-face interviews with experienced urban planning practitioners and academics.

A focus group meeting was held with six experienced urban planners and planning practitioners in Hong Kong. With the help of the AHP method, this determined the weightings of each criterion and verified its rating standards.

An experimental study was designed to test a research hypothesis that “the decision-supported process of LUDS performs better than the conventional decision-making process” associated with a causal-effect relationship: “LUDS provides easier handling and better performance of decision-makers in land redevelopment/rezoning”. This was a comparative experiment in which 30 participants were invited to complete two similar tasks with the two different decision-making processes. This was followed by a questionnaire survey to collect feedback from the experimental participants for statistical analysis.

3.2 Decision Support Model

The development process of the decision support model involved the determination of three elements: assessment criteria, criteria weightings and rating standards.

3.2.1 Criteria and Land Use Definitions

Table 1 provides the 37 criteria identified as a result of the literature review on land use planning (site planning and analysis) and expert interviews with planning practitioners. Based on seven in-depth interviews with experienced planning practitioners, some criteria extracted from the literature were adjusted to fit for this study. For example, ‘Neighbouring land uses’, ‘Access to

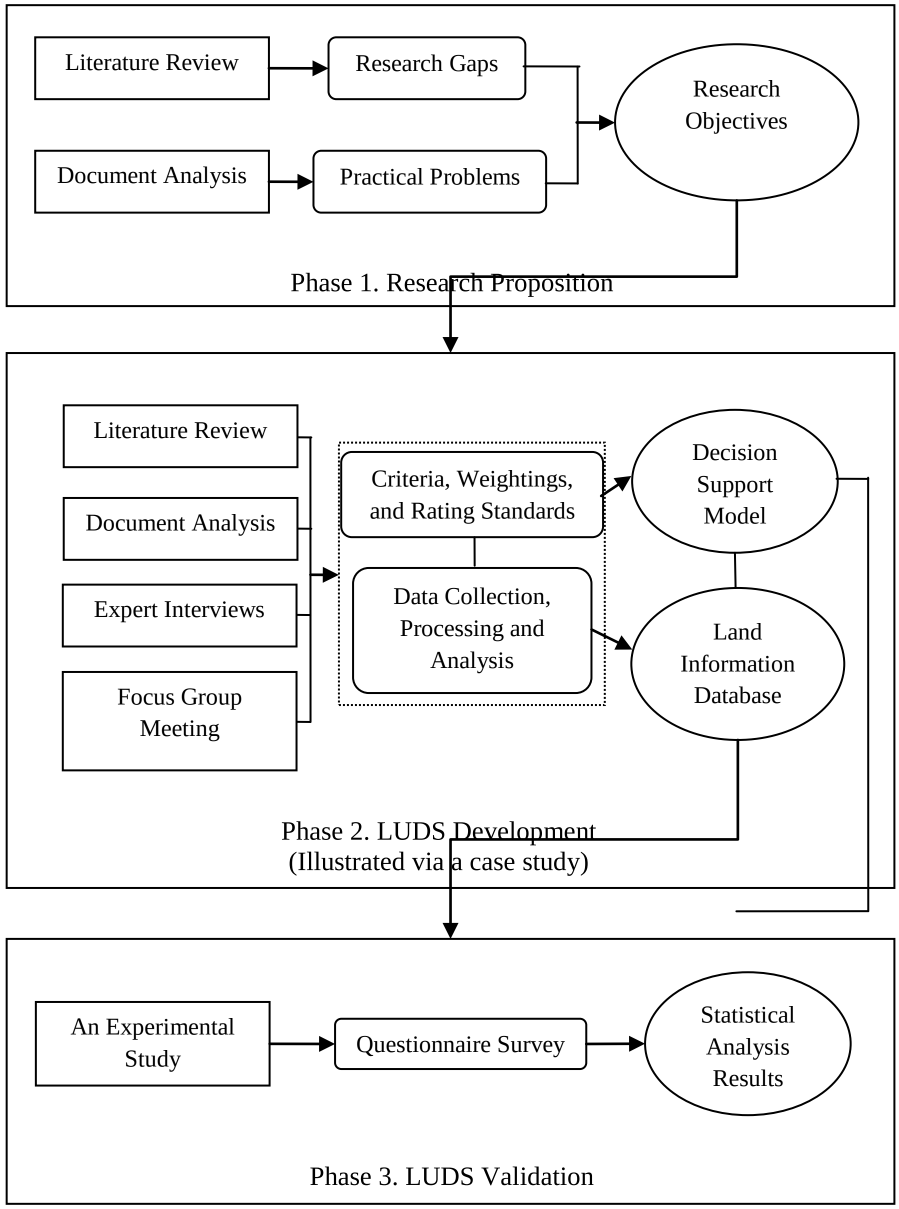

Fig. 1 Development process of LUDS

major living services' and 'Visual quality' were added or highlighted, and 'Attributes of soil', 'Hydrological conditions' and 'Characteristics of wildlife' were removed by the interviewees. These criteria are applicable to land suitability analysis for urban renewal projects because: first of all, these criteria are identified based mainly on the literature review on site planning and analysis (small-scale land use decisions); second, they are sorted by experienced planners from the perspective of land redevelopment in urban developed areas (service facilities installed and provided); third, urban renewal projects often take place on specific developed sites, and the accessibility and compatibility of the sites with their surrounding service facilities need to be

Table 1 Criteria for land-use decision-making in site redevelopment

Category	**Sub-category**	**Criterion**
Environmental/ Ecological	Vegetation	Vegetation rate
	Environmental indicators	Local air quality
		Local water quality
		Noise pollution
		Light pollution
Social	-	Local population
	-	Local employment
	-	Neighbourhood identity
Economic	-	Local GDP
	-	Property values
	-	Rents
Political/Legal	Legal properties	Political boundaries
		Land ownership
		Easements and deed restrictions
	Land use regulations	Statutory requirements for development
Utilities/ Accessibility (locational)	Land use	Former land uses
		Current land uses
		Neighbouring land uses
	Transportation	Road network
		Traffic volume
		Internal circulation
	Service utilities	Assess to major living services (e.g. transport hub, medical centre, open space)
		Utilities for basic housing (e.g. sewer, electric, gas)
Cultural/Historic	Sensory satisfaction	Aesthetics
		Visibility
		Visual quality
		Odours
	Historical features	Heritage landmarks

	Local built environment	Architectural/landscape uniqueness
Physical	Topography	Elevation
		Slope gradient
		Slope aspect
	Climate	Solar access
		Wind direction
	Geology	Terrain
		Seismic hazards
		Landslide hazards

Table 2 Definitions of the five land uses to be analyzed

No.	Category	Definition
1	Residential	Land sites for residential use, including private housing, public housing and staff/student hostels
2	Commercial	Land sites for commercial use, including offices, shopping malls, markets, hotels, car parks
3	Industrial	Land sites for industrial use, including industrial land, industrial estates, warehouses
4	G/I/C	Land sites for Government, Institutional and Community use and other public purposes, i.e. utilities
5	Open Space	Land use zones for the provision of open space and recreation facilities for the enjoyment of the general public, including parks, playgrounds, gardens

considered. According to the current land utilization map of Hong Kong, land sites in developed areas can be classified into six broad land use categories: residential, commercial, industrial, G/I/C, open space and vacant/under construction/others. Of these, the first five were adopted in this study, the definitions of which are provided in Table 2.

Note that the 37 general criteria provided in Table 1 are identified for all urban land uses. For weighting purposes, it is necessary to consider the criteria that are relevant to each particular land under consideration.

3.2.2 Rating Standards

To carry out the LUSA in this study, criterion standardization, weighting and composite scoring were accomplished by multi-criterion evaluation (MCE). This model provides a quantitative approach to LUSA, including the classification of land use suitability, rating of criterion values, and scoring for multi-criterion analysis. Firstly, land use suitability was classified into four levels - *very unsuitable*, *unsuitable*, *suitable* and *highly suitable* classes - and integers ranging from 0 to 3 were assigned accordingly. Secondly, the value of each criterion was obtained from the land-info database, and each correspondingly assigned a suitability level according to the rating standards. These ratings standards are a crucial part of the model and were determined by reference to the literature, Hong Kong planning standards and guidelines, and the views of the planning practitioners collected in focus group meetings. Thirdly, a linear scoring formula was used, in the form of:

$$S_i = \sum_{j=1}^{n} R_i(j) \times W(j)$$

where S_i denotes the land use suitability of land site i, i is the number of land sites; j=1, 2, …, n is the number of criteria; $R_i(j)$ refers to the rating of criterion j of the land site i; and $W(j)$ is the weighting of criterion j. By overlaying the selected criterion layers with their respective weightings, the final scores of each land site can be calculated. The suitability grade of each land site is also divided into four levels according to the final scores: *very unsuitable* (0-0.75), *unsuitable* (0.75-1.5), *suitable* (1.5-2.25) and *highly suitable* (2.25-3).

3.3 Land Information Database

3.3.1 Data/Information Involved

Specifying the required information for land-use decision-making is the first stage of database establishment. At this stage, crucial information required in land use planning is identified and defined. Five types of information are usually involved: 1) statistics relating to the local population, 2) the financial condition of the government and the people, 3) the physical condition of the land/location, 4) the internal structure and functional relationships within the city, and 5) the relationship between the city and other urban communities (Campbell and LeBlanc 1967). Population-related information comprises current and projected demographic information including population, employment, number of households, etc. Financial condition information contains the income characteristics of the population, property values, GDP, etc. Physical condition information refers to the topographic and spatial details of the land, such as slope, terrain and soil. Internal structure and functional relationship information is the most complex required in urban planning (Wu, et al., 2012), involving a series of considerations and criteria in terms of the internal accessibility and functional distributions for identifying particular uses of each piece of land according to its size, value and location. The relationship between the city and other urban communities focuses on the impact of economic activities from other surrounding cities and coordinated development among cities (this type of information is not included in the study).

Table 3 Information/data involved in the database

Category	**Sub-category**	**Information/Data**	**Data Source**
Physical	Topography	Elevation	Topographic maps
		Slope gradient	Topographic maps
		Slope aspect	Topographic maps
	Geology	Terrain	Topographic maps
		Seismic hazards	Geological report
		Landslide hazards	Geological report
		Depth to bedrock	Geological report
	Climate	Solar access	Local climate study
		Wind direction (prevailing)	Local climate study
	Soil	-	-
	Hydrology	Depth to water table	Hydrological report
		Drainage patterns	Hydrological report
Ecological/ Environmental	Vegetation	Vegetation rate	Remote sensing images
	Wildlife	-	-
	Environmental impacts	Air quality	Environmental assessment report
		Water quality	Environmental assessment report
		Noise	Environmental assessment report
		Light pollution	Environmental assessment report
Political/Legal	Legal properties	Political boundaries	Land registry
		Land ownership	Land registry
		Easements and deed restrictions	Land registry
	Land use regulations	Statutory requirements for development	Statutory regulations
Social	Local population	Population trends	Census projection
		Household size	Census statistics
	Local employment	Employment structures	Census statistics
		Employment needs	Employment prediction
	Neighborhood/	Community characteristics	Archives/Survey

	Community changes	Neighborhood identity	Archives/Survey
Economic	Production	Local GDP	Socio-economic statistics
	Consumption	Property values	Transaction records
		Rents	Lease records
Cultural/Historic	Sensory satisfaction	Aesthetics	Survey
		Visibility	Survey
		Visual quality (e.g. corridor)	Survey
		Odors	Survey
	Local built environment	Architectural styles	Archives/expert interviews
		Unique landscape	Archives/expert interviews
	Historical features	Historical buildings/landmarks	Heritage study
		Archaeological sites	Heritage study
Utilities/ Accessibility (locational)	Land use	Former and current land uses	Land registry and survey
		Neighboring land uses	Land registry and survey
	Transportation	Road function	Traffic design
		Internal circulation	Traffic design
		Traffic volume	Traffic survey
	Service utilities	Utilities for basic housing (e.g. sewer, electric, gas)	Detailed location maps
		Assess to major living services (e.g. transport hub, medical center, open space)	Detailed location maps

* "Soil" and "Wildlife" are not considered in land redevelopment within developed urban areas

Land use planning at site level is called 'site planning', which is the smallest-scale land use planning involving the development of a single piece of land by determining specific land uses (i.e. locating buildings and facilities) on the site, arranging for roads, water, and other on-site infrastructure, and developing detailed plans for grading, landscaping, and other site improvements (Wheeler, 2004). Site analysis is often the first and the most important step in site planning as site analysis aims to collect information relating to the site, assess the land-use suitability of the site and compatibility with the surrounding environment, and help understand the administrative requirements (e.g., building permits and other approvals) of the on-site project(s).

Based on existing literature and site planning theories, Table 3 summarises the information/data needs of a land information database associated with the decision support model.

3.3.2 Steps in Building the Database

The land information database was established as a geospatial information hub in which the digital map layers containing both spatial data and non-spatial data are stored. The database was created in GIS software - 'ArcGIS'. A powerful geo-data processing tool, 'File Geodatabase' in 'ArcGIS' was found to be most appropriate for creating the database, being able to process and store all required map layers in both vector and raster format. Because of its powerful data processing and spatial analysis capabilities, GIS was used as the platform for storing, processing, managing and displaying the geo-information data corresponding to each criterion. The geo-referenced criterion data are described as map layers within the GIS, with each map layer representing one criterion of land use suitability. The purpose of establishing this database was to provide the processed data for spatial analysis and geospatial visualization, and can therefore be regarded as the physical basis of LUSA. Two stages are involved – data collection and data processing.

Data Collection. The assembly of raw data/information is the foundation of decision support. Here, it provides information for LUSA on a geospatial visualization platform. Two types of data were used for different storage purposes, comprising the raw and processed data in the land information database. In order to establish a comprehensive geo-database for site planning and land use management, volumes of raw spatial data (such as digital topographic maps, aerial photographs and land utilization maps) and raw non-spatial data (such as statistical tables recording the information of population, employment, and housing price) were collected.

Data Processing. After collecting the raw data, the processed data (i.e. map layers in 'ArcGIS') were produced for the LUSA, including: derivation of the slope and elevation information from the topographic map; calculation of distances between land sites and main public facilities based on the location map of public facilities; and creation of the distribution map of housing prices by allocating housing price records to the relevant geospatial locations and using a spatial interpolation technique. This is a time-consuming process requiring GIS software operation skills. In addition, as the database is established in 'ArcGIS', all the raw data need to be digitized or converted into the storage format of 'File Geodatabase'. The detailed procedures and techniques for setting up the database including GIS spatial analysis will be presented in a separate paper.

4 The LUDS Experiment

A comparative experimental study was designed and conducted to test the effectiveness of LUDS. To prepare for the experimental tasks involved, a preliminary study was carried out in advance to provide specific data and planning scenarios. Upon completion of the experimental study, a questionnaire survey of the participants collected quantitative feedback data for statistical analysis.

4.1 Hypothesis of the Experimental Study

LUDS consists of a decision support model and associated land-info database and has the potential to enhance the understanding and engagement of participants in land use planning processes. In addition, the LUDS-supported process (LUDS-SP) can facilitate the process of site planning for land redevelopment by enabling planners to readily acquire the information they need to make decisions in a shorter time and in a more objective way than hitherto.

Therefore, the primary hypothesis to be tested in the experimental study was:

The LUDS-SP can support planners to make land-use decisions more objectively and efficiently, and enable planning participants (i.e. stakeholders in the planning process) to better understand the planning needs and concerns than is the case with the conventional planning process.

Here, the LUDS-SP refers to the planning process supported by LUDS, and the conventional planning process is defined as that used in current unsupported planning practice in Hong Kong.

4.2 Preparation of the Experimental Trial

4.2.1 Study Area

Land is a scarce and precious resource in Hong Kong and its Yau Tsim Mong district (Fig. 2) was selected for the experimental trial due to data availability and its level of land development. It is located on the Kowloon peninsula - one of Hong Kong's metropolitan areas – spanning 114° 09' – 114° 11' E and 22° 17' – 22° 19' N. The area covers 7 km^2 and has a current population of 304 900. The land in this district is highly developed and infrastructure such as roads, railways,

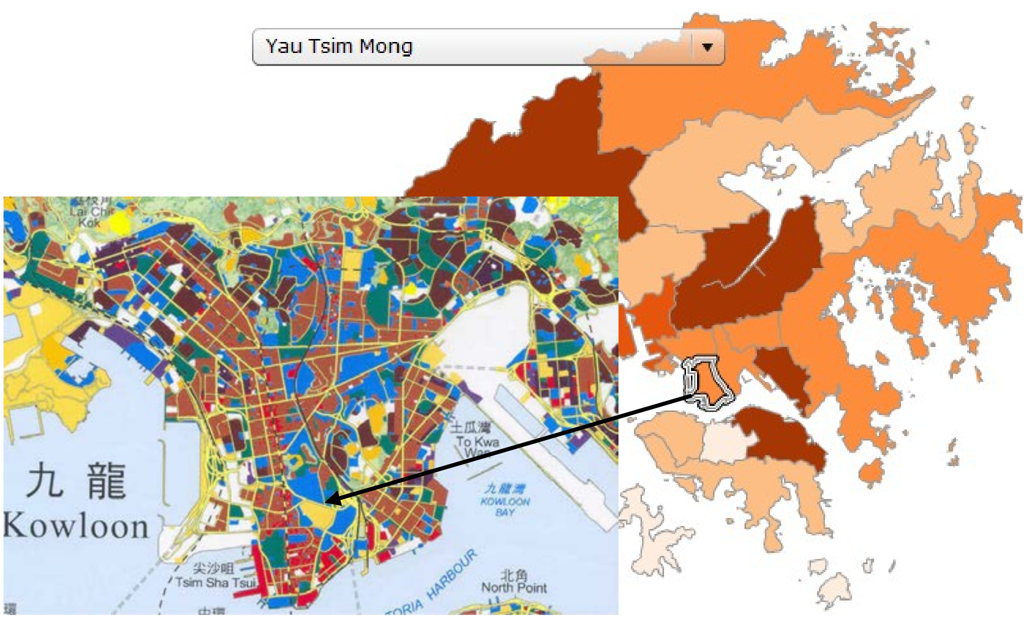

Fig. 2 Experimental trial study area

and main service facilities are already provided. Thus, this area is highly appropriate for an empirical study of LUSA and is able to reflect the characteristics and merits of LUDS.

4.2.2 The Model

Criteria

In view of data availability for the study area and the type of criteria (i.e. quantitative or qualitative) involved, 20 quantitative criteria of urban land suitability were chosen from the set of 37 general criteria provided in LUDS (Table 1). These were then classified into five categories of physical/inherent attributes, locational attributes (accessibility/compatibility), social attributes, economic attributes and environmental attributes as shown in Table 4. Inherent attributes refer to the existing or physical attributes of land tracts, such as current land use, slope and elevation.

Table 4 Criteria selected for the experimental trial

Criterion type	**No.**	**Criterion name**
I. Physical/Inherent attributes	1	Current land use
	2	Slope
	3	Elevation (relative)
	4	Vegetation
II. Locational attributes (Accessibility)	5	Distance to CBD/sub-CBDs
	6	Distance to airport
	7	Distance to railway/MTR stations
	8	Distance to bus terminus
	9	Distance to ocean/streams
	10	Distance to historic sites (Preservation)
	11	Distance to nearest hospital
	12	Distance to nearest primary/high school
	13	Distance to open space
	14	Distance to trunk roads
III. Social attributes	15	Population density
	16	Employment density
IV. Economic attributes	17	Output potential per land unit
	18	Average price/rent of properties
V. Environmental attributes	19	Air quality
	20	Traffic noise

* CBD refers to Central Business District of a city and sub-CBDs can be regarded as Business and Commercial Clusters within a city

Table 5 Criteria weightings for five land uses

Criterion No.	Weighting				
	Residential	**Commercial**	**Industrial**	**G/I/C**	**Open space**
1	0.059	0.007	0.012	0.019	0.021
2	NA	0.022	0.037	NA	0.021
3	NA	0.022	0.037	0.037	NA
4	NA	NA	NA	0.037	0.021
5	NA	0.176	NA	NA	NA
6	NA	NA	0.07	NA	NA
7	0.049	0.064	0.022 (Freight)	0.012	NA
8	0.049	0.034	NA	0.012	NA
9	0.007	NA	0.034 (Port)	NA	0.033
10	0.073	0.011	0.074	0.039	0.057
11	0.049	NA	NA	0.032	NA
12	0.042	NA	NA	0.032	0.033
13	0.04	NA	NA	0.032	0.099 (Neighbour)
14	0.026	0.034	0.153	0.009	NA
15	0.147	0.011	0.025	0.238	0.305
16	0.073	0.032	0.025	0.096	0.162
17	NA	0.403	0.206	0.068	0.069
18	0.067	0.134	0.206	NA	NA
19	0.106	0.051	0.1	0.168	0.09
20	0.213	NA	NA	0.168	0.09
Total	1.0	1.0	1.0	1.0	1.0

Note: The criteria with weightings are selected for the specific land uses

These restrict the usage of land sites in terms of the physical condition of the land. Locational attributes represent spatial accessibility and compatibility, and such considerations are currently regarded as the most important factor in site selection in urban areas. Ten of the twenty suitability criteria chosen were locational criteria. The six criteria for social, economic and environmental attributes covered the main issues of land use sustainability and also suggested a more effective and convenient way to quantify land use sustainability. The 20 criteria included physical, locational (accessibility and compatibility), sustainability (i.e. environmental, social and economic) considerations of land suitability in the study area, but excluded political/legal and cultural considerations.

As anticipated, some of the criteria were not applicable to some of the land uses (refer to Table 5) and were therefore absented from the weighting process.

Weightings

The criteria were weighted using the *Expert Choice* AHP software through a focus group meeting comprising six experienced planning practitioners in Hong Kong. The results are shown in Table 5.

Table 6 Suitability classification and rating standards of each criterion (partial)

Criterion No.	**Rating standards**		**Land uses**				
			Residential	Commercial	Industrial	G/I/C	Open space
1	HS	*3*	R	C	I	G/I/C	O, V/O
	S	*2*	C, G/I/C, V/O	R, G/I/C, I, V/O	G/I/C, V/O	C, I, R, V/O	I, R, G/I/C
	U	*1*	I	O	R, C	O	C
	VU	*0*	O	-	O	-	-
2 (%)	HS	*3*	-	[0.2-10]	[0.2-5]	-	<= 15
	S	*2*	-	(10-20]	(5-10]	-	(15-30]
	U	*1*	-	< 0.2 or (20-25]	< 0.2 or (10-15]	-	> 30
	VU	*0*	-	> 25	> 15	-	-
3 (m)	HS	*3*	-	<= 15	<= 10	<= 15	-
	S	*2*	-	(15-30]	(10-20]	(15-30]	-
	U	*1*	-	(30-40]	(20-30]	(30-40]	-
	VU	*0*	-	> 40	> 30	> 40	-
4 (percent)	HS	*3*	-	-	-	>= 20	>= 30
	S	*2*	-	-	-	[15-20)	[25-30)
	U	*1*	-	-	-	[10-15)	[20-25)
	VU	*0*	-	-	-	< 10	< 20
5 (km)	HS	*3*	-	<= 3; <= 2 (sub)	-	-	-
	S	*2*	-	(3-4]; (2-3] (sub)	-	-	-
	U	*1*	-	(4-5]; (3-4] (sub)	-	-	-
	VU	*0*	-	> 5; > 4 (sub)	-	-	-

Note: R – Residential, C – Commercial, I – Industrial, O – Open space, V/O – Vacant/Others;
HS – Highly suitable, S – Suitable, U – Unsuitable, VU – Very unsuitable.

Rating standards

The rating standards of the 20 criteria were initially proposed by the researchers according to planning standards and guidelines and other planning requirements in Hong Kong. These were then verified and finalized by the focus group of experts (Table 6 lists five examples). Taking the second criterion – 'Slope' for example, this criterion is not sensitive to residential and G/I/C use. For commercial use, the value of slope ranging from 0.2 to 10 percent falls in 'highly suitable' (score 3), 10 to 20 for 'suitable' (score 2), less than 0.2 or 20 to 25 for 'unsuitable' (score 1), and larger than 25 for 'very unsuitable' (score 0).

4.2.3 The Database

The raw data, including topographic, current land use, roads and railways and facilities location maps were collected in the forms outlined in Table 7, processed and stored in the database corresponding to the weighted criteria in Table 5. Data such as traffic noise distribution, population distribution, and the air pollution index (API), were obtained from governmental websites (e.g. Planning Department, Town Planning Board, etc.), while topographic maps, aerial photos, and transaction records of housing prices were purchased from government offices or relevant institutions.

Table 7 Data forms

Spatial data	**Non-spatial data**
• Topographic map	• Population distribution
• Aerial photos	• Employment distribution
• Current land utilization map	• Air pollution index (API)
• Land use plan (Outline Zoning Plan)	• Records of land sales
• Roads network	• Records of housing price
• Railways (MTR) network	• Records of office rent
• Location map of public facilities (e.g. hospitals, schools, parks, etc.)	• Records of industrial rent
• Location map of historic sites	
• Distribution map of traffic noise	
• Vegetation coverage map	
• Buildings information map	

After data processing, including the processes of spatial analysis in 'ArcGIS', 20 map layers were created corresponding to the 20 criteria, with each map layer providing the values for each criterion. This readied the database for the LUSA process.

4.3 Description of the Experimental Study

4.3.1 Participants of the Study

The experimental study involved 30 Urban Planning and Urban Design Masters students from the Hong Kong Polytechnic University. All had an educational background in relevant majors such as urban planning, land management, construction management, environmental science, and economics, and with some having work experience in planning-related fields. Most importantly, the experiment was conducted at the end of the semester, following a course detailing the complete theory and practice of urban planning and renewal in Hong Kong. This knowledge background was taken to provide sufficient qualification for involvement in the experimental study. In addition, none of the participants had any prior knowledge of the nature of the experiment involved.

4.3.2 Experimental Arrangements

The duration of the experiment (in a form of workshop) was approximately two hours. The 30 participants were randomly placed into 6 equal size groups. Each group was then given two tasks to perform involving deciding on the most suitable form of redevelopment of two pieces of land (Site A and Site B) in the experimental trial study area.

For Task 1, Groups 1, 2 and 3 used conventional planning practice to consider and assess the land-use suitability of Site A in response to some basic information concerning the planning area (hardcopy of 2D draft plan, current land utilization, existing planning-related studies, etc.) and relying mainly on qualitative judgment. Meanwhile, Groups 4, 5 and 6 applied the LUDS-SP to the same task for Site A. Firstly, they were provided with the key factors which are usually taken into consideration during the planning process. Secondly, a GIS-based visualization platform (i.e. the land information database) was provided which vividly demonstrates a variety of information displayed on spatial maps; including the geographic locations of each site and building, topographic maps including slope, elevation information, and the surrounding environment of each site and building. Thirdly, a quantitative model for LUSA was introduced to support the participants in making final land-use decisions through comprehensively examining the land-use suitability of each piece of land based on both non-quantifiable factors (such as political, cultural and public demands) and quantifiable factors to be considered objectively in the model.

For Task 2, Groups 1, 2 and 3 turned to the LUDS-SP for Site B, while Groups 4, 5 and 6 used the conventional process for Site B (Table 8). Hence, a cross-comparison method was adopted in the experiment to ensure two points: 1) every group experienced both planning processes with similar tasks and 2) every group undertook the same task just once.

Table 8 Cross-comparison experimental scheme

Venue	Room 1			Room 2		
	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Task 1 (Site A)	*Conventional Process*			*LUDS-SP*		
Task 2 (Site B)	*LUDS-SP*			*Conventional Process*		

The experimental study was organized into four sessions. The first session comprised a workshop briefing, in which (site-level) land use planning in urban renewal and the two kinds of planning processes were introduced to all participants and the six groups were randomly formed. The second session concerned Task 1, in which each group discussed and finished their task. Similarly, the third session involved the groups starting and completing Task 2. During the group discussion, in order to avoid any mutual exchanges on the impact of the different planning processes involved, Groups 4, 5 and 6 were separated from the other three groups by moving to another room. The final session was the questionnaire survey, in which all participants were required to complete individual questionnaires concerning their perceptions of the experiment.

4.4 Questionnaire Survey of the Experimental Participants

There are three sections in the questionnaire (15 questions in all): Background information of the participants (4 structured questions), comparison between LUDS-SP and the conventional process (9 structured questions), and satisfaction/dissatisfaction with LUDS-SP (two open-ended questions). Section 1 aimed to verify whether the participants have similar educational background and experience in urban/land use planning and public consultation activities. Sections 2 and 3 were designed to identify the advantages of LUDS-SP over the conventional process of site redevelopment planning and the participants' overall perceptions of LUDS-SP.

Thirty completed questionnaires were collected after the experimental trial. Section 1 indicated that all participants were familiar with urban/land use planning and urban renewal/land redevelopment, with many claiming to fully understand the nature of public consultation in the planning process (27/30) and previously experiencing group discussion/decision-making (29/30).

Table 9 summarises the results from Section 2 aimed at determining the extent to which the participants agreed or disagreed with a set of statements made on a scale of 1 (strongly disagree) to 4 (strongly agree).

As Table 9 shows, on average the participants agree that LUDS-SP offers an improvement on conventional planning practice. Specifically, they agreed that LUDS-SP enables users to better understand the planning area and the attributes of sites (Q5 – Q7), and that the key factors affecting land-use planning and quantitative analysis of LUSA enable users to make better decisions during the planning process (Q8 – Q9). Here, a better decision basically refers to such a decision made based on more comprehensive considerations of land use planning and more objective/quantitative analysis results of land-use suitability. Moreover, they also agreed that the information provided by LUDS-SP is more comprehensive, useful and easy to understand for both planners and non-professionals (Q10 – Q12). For the overall question Q13, all participants consented to the statement "LUDS-SP can support the planning process in urban renewal" with the lowest standard deviation (0.373). In detail, the statement "LUDS-SP enables me to get familiar with the planning area more quickly" received the highest score (3.40), with statements in Q8, Q10 and Q11 having relatively lower scores (3.10).

Table 9 Summary of the survey results for Section 2

Section 2	**Standard Deviation**	**Mean**	**Agree/Disagree** with the statements in the questions
Q5. LUDS-SP enables me to get familiar with the planning area more quickly	0.490	3.40	Agree
Q6. LUDS-SP enables me to have better understanding of the attributes of each site	0.458	3.30	Agree
Q7. LUDS-SP enables me to have better understanding of land-use suitability of each site	0.522	3.17	Agree
Q8. The quantitative analysis of land-use suitability facilitates me to make better decisions during the planning process	0.473	3.10	Agree
Q9. The key factors affecting land-use planning facilitate decision-makers/planners to better examine the planning needs	0.512	3.27	Agree
Q10. The information provided by LUDS-SP is more useful for decision-makers/planners to make decisions during the planning process	0.539	3.10	Agree
Q11. The information provided by LUDS-SP is more comprehensive and easy to understand for non-professionals during public consultation	0.473	3.10	Agree
Q12. The geospatial information visualized via GIS helps me understand the land conditions and the site surroundings	0.537	3.33	Agree
Q13. LUDS-SP can support the planning process in urban renewal	0.373	3.17	Agree

(4: Strongly agree, 3: Agree, 2: Disagree, 1: Strongly disagree)

In Section 3, two open-ended questions were asked: "what do you like MOST about LUDS-SP?" and "what do you like LEAST about LUDS-SP?". In summary, the characteristics of LUDS-SP liked most are: the key factors affecting land use planning, the quantitative analysis of land-use suitability, the comprehensive and detailed information provided with GIS, and that it is easy to understand for non-professionals. The aspects liked least are: the quality of some data, the complexity of operation due to the unfamiliar software involved, and that only quantitative/objective information was available in the database.

5 Discussion

Unlike other studies, which investigated land use suitability in large-scale rural and urban land areas (Bojorquez-tapia et al., 2001; Burnside et al., 2002; Ozcan et al., 2003; Aly et al., 2005; Malczewski, 2006b; Dai et al., 2008; Bobade et al., 2010; Pourebrahim et al, 2011), this research focuses on small-scale urban developed areas. The differences from the ordinary/general land suitability assessment are reflected in the coverage (categories) and emphasis of the assessment criteria. Firstly, these identified criteria cover not only the physical and locational attributes of land, but also legal and cultural considerations of land use, as well as sustainability concerns (i.e. environmental, social, economic perspectives). Secondly, some criteria, particularly the ones concerning land-use accessibility and compatibility put emphasis on small-scale land use planning (site level) for urban renewal projects. Thanks to progress in computing sciences, advanced systems such as GIS and MCDA can help planners handle the increasing complexity involved in making land use planning decisions. In the event, GIS and MCDA were found to complement each other very well. On one hand, GIS technologies and processes play an important role in analyzing decision problems. On the other hand, MCDA provides a rich collection of techniques and procedures for structuring decision problems, and designing, evaluating and prioritizing decision alternatives (Malczewski, 2006a).

The experimental trial indicates that LUDS is likely to be useful in support of planning decisions for site reuse in the process of urban renewal. In short, feedback from participants indicated quite clearly that LUDS-SP aided land-use decisions better than the conventional planning process, offering good support for the hypothesis formulated earlier. The suitability analyses provided a quantitative and objective reference to planners to help improve their decision-making processes, which currently rely heavily on subjective and qualitative judgments. In other words, the output of LUDS can assist planners in making final land-use decisions on the basis of more comprehensive considerations. Furthermore, LUDS serves as a prototype decision support system for site planning in urban renewal.

LUDS was systematically developed by using MCDA, AHP and GIS to enable planners and the public to easily understand the rationale underlying decisions and for enhancing public engagement in the planning process. The main benefits of LUDS are that it provides urban planners with a clearer and more comprehensive understanding of the suitability of land/sites in urban renewal areas and enables more sustainable land-use decisions to be made. In addition, LUDS also creates a channel for planners to convey their ideas visually to stakeholders and other members of the public, providing the opportunity for in-depth and effective communications with all interested parties to enhance participatory planning. It is expected, therefore, that the findings will be applicable to land-use decision-making (or site selection) concerning land redevelopment for urban renewal projects in general.

6 Conclusions

LUSA is very important for land redevelopment and site selection in urban renewal. As land sites in developed urban areas are usually divided by road networks and have many uses, land use planning for urban renewal in these areas is quite different from planning new towns or vacant areas. Consequently, special LUSA methods are needed for land use planning for urban renewal. This study develops a GIS-based integrated approach for quantitatively assessing land use suitability for five different land uses in urban renewal areas. This combines GIS technology with the MCE method to inform land use suitability based on the comprehensive consideration of the land's physical attributes, locational attributes (accessibility/compatibility) and the needs of sustainable land use (social, economic and environmental attributes). Five forms of land use suitability maps can be generated to illustrate the specific suitability of each land site. These can be used as a reference for urban planners in making decisions concerning urban redevelopment projects.

The nature of planning is changing in Hong Kong, from scientific approaches based on political process-oriented perspectives, to collective-design approaches focusing on communication and the involvement of non-experts (public, interest groups, communities, stakeholders, nongovernmental organizations, etc.). GIS has also evolved from a 'close'-expert-oriented to an 'open'-user-oriented technology (Malczewski, 2004). These two trends simultaneously stimulate a movement towards the use of these technologies to increase the democratization of planning processes via public participation/engagement. At present, it is desirable for a good land use plan (i.e. land-use decisions) to be produced which takes into account all the various interests involved. LUDS will enable town planners to communicate better with other stakeholders involved in the planning process by viewing the visual maps and statistics at group meetings/workshops.

Although LUDS is innovative and effective in LUSA, there still are some limitations. Firstly, the mapping techniques in LUDS are based on the assumption that geographical location is the most important factor affecting site selection in urban areas, and the land price, housing price or office rent are fundamentally determined, and spatial distributed, by this. Secondly, the availability of data restricts the accuracy of LUSA (only 20 quantitative criteria with available data were examined in the experimental trial and some qualitative criteria such as cultural, political considerations were not analyzed because they cannot be quantified without people's subjective judgments), and data collection and processing involve quite a number of time-consuming processes. Thirdly, the accessibility of land sites is calculated by simply using the average straight-line distance instead of average access time estimated from the road network. These issues indicate that some improvements are possible in order to obtain better LUSA results in the future.

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