State-of-the-Art and Future of Geographic Information Systems in Hong Kong

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Abstract

This paper presents an overview and analysis of Geographical Information Systems (GIS) in Hong Kong, through last 15 years of development in the territory. GIS in Hong Kong will be summarized in the following aspects: fundamental GIS data for Hong Kong, GIS applications in Hong Kong governmental departments, GIS applications in private sectors, GIS research and education in Hong Kong, Hong Kong GIS Association, issues for the future GIS development in Hong Kong.

GIS was first adopted by Hong Kong governmental departments such as, the Lands Department and others. Today, some 15 different local governmental departments have applied GIS to support their daily works. The fundamental GIS data have been captured and managed by Lands Department. In private sectors, GIS was firstly introduced in the area of automated mapping and facility management (AM/FM) by local utility companies, and this has been further extended to telecommunication, real estate, intelligent transport system and others. Since several universities in Hong Kong play the major role for GIS research development and education, this group of people are even very active in the international communities related to GIS. Hong Kong GIS Association plays a key role in promoting GIS in Hong Kong.

Although GIS development and applications in Hong Kong are getting mature, there are still a number of issues that affects its further development of GIS, e.g., developing an urban-levelled spatial data infrastructure for Hong Kong, towards a professional GIS institute for GIS industry in Hong Kong, the recognition of GIS profession in the local community and others.

I. INTRODUCTION

The first geographical information system developed in Hong Kong was the Land Information System of the Building and Lands Department, now the Lands and Planning departments. It indicated the beginning of GIS application in this city.

It was in the early seventies that a computerised land information system was first discussed in the Hong Kong Government. However, it was not until 1981 that a Special Committee on Land Supply stressed the need to introduce a computerised land inventory system, thereby allowing both public and private sectors to access land-related information. In response to the advice, an international working group was established in mid-1982 to investigate the proposed Computerised Land Information System. According to the findings of the working group, it was proposed that a pilot study was used to assess the feasibility of establishing a computerised territory-wide land information system. Hong Kong Island was selected as the site for the pilot study. The pilot study, however, was not carried out due to the high cost.

In July 1995, a Requirement Justification Study (RJS), aiming to analyse user requirements and justify the introduction of a computerised Land Information System, was commenced. Unlike the proposal of 1982, the scope of the RJS was town planning and map production within the former Building and Lands Department. A Project Definition Study of cost and benefit followed and was completed in late 1986. The final approval for the LIS was granted in 1987 after the benefits of computerised land information systems were realised. The first phase of the Land Information System, aiming to assist town planning and map production, was installed in late 1989.

Today, about 15 different departments in Hong Kong Government have applied GIS for supporting their daily works and many other governmental departments are working on introducing GIS for their departments. The fundamental GIS data for whole Hong Kong have been captured and managed by Lands Department. In private sectors, GIS was firstly introduced in the area of Am/FM by local utility companies, and this has been further extended to telecommunication, real estate, intelligent transport and others. Several universities in Hong Kong play the major role in GIS research development and education. Hong Kong GIS Association, which was established in 1995, takes a very active role in promoting GIS in Hong Kong. Although GIS development and applications in Hong Kong are getting mature, there are a number of issues that affects further development of GIS in this city.

This paper aims to give a review and analysis of GIS development and applications in Hong Kong, and this will be detailed as in the following aspects: fundamental GIS data for Hong Kong, GIS in Hong Kong governmental departments, GIS in private industry, GIS research and education, Hong Kong GIS Association, issues for the future GIS development in Hong

Kong.

II. FUNDAMENTAL GIS DATA FOR HONG KONG

Land Information Centre in Lands Department of the Hong Kong Government provides the fundamental GIS data for the Territories. The Land Information System is composed of three subsystems: the Basic Mapping System (BMS), the Cadastral Information System (CIS) and the Geographical Information Retrieval System (GIRS), which are used for ArcInfo. The BMS provides the facilities for data conversion, map library updating and production of standard format survey sheets. 19 layers of geographical features are maintained in the map library of the BMS.

The CIS maintains the land boundary record. It facilitates the preparation of cadastral plans and answers enquiries about land status. A total of thirty-three data layers have been created in the CIS for recording various types of land boundaries to meet the requirements of land administration. The GIRS was developed to retrieve data in the BMS, CIS, and special layers derived from the BMS. The GIRS can access both spatial and attribute information in any layers by giving a certain identifier such as building name, lot number, planning zone unit or geographical co-ordinates etc.

The fundamental GIS data are distributed in five databases, and these are Digital Topographic Map (DTM) data, Digital Land Boundary (DLB) data, Geo-Reference Data, Digital Orthophoto and GeoCommunity Data.

The Digital Topographic Map (DTM) database has been created and developed by Surveying and Mapping Office (SMO). The coordinate system used for this database is Hong Kong 1980 Grid with heights in meters above the Hong Kong Principal Datum. This database describes the topography of Hong Kong. The productions of DTM database include B1000 with scale 1:1000, B5000 with scale 1:5000, B10000 with scale 1:10,000, and B20000 with scale 1:20,000.

For B1000, there are totally nineteen layers in this database, and specifically they are Boundary Features, Building Related Features, Building Polygons, Contour Lines, Hidden Contour Lines, General Annotation, Miscellaneous Lines, Miscellaneous Points, Railways, Relief & Hydrology, Roads, Artificial Slope, Spot Height, Hidden Spot Height, Utility Point, Proposed Building Polygons, Proposed Road, Proposed Infra, and Proposed Site Polygons. The data formats availably in this product include E00, ASCII, DGN and AutoCAD (DXF and DWG), whereas more than 3,000 sheets are used to cover the whole topography of Hong Kong.

B5000 database contains the total of eighteen layers, which are Area feature, Boundary feature, Building feature, Bridge – filled polygon, ContourLine, Facility, General annotation, Hydrographic line feature, Hydrographic feature – filled poly-

gon, Land – filled polygon, Park – filled polygons, Railway, Road – filled polygon, ROAD, Spot height, Utility, Relief and Construction. E00, ASCII, DGN, and AutoCAD (DXF and DWG) are the available data format for this date set. More than 190 sheets cover the whole topography of Hong Kong. The following is an example of B5000 (Figure 1).

B10000 database contains eighteen layers, and they are Boundary, Building, Elevation, Height, Facility, Facility Polygon, Hydrography, Hydrography Polygon, Reserve Park, Place, Railway, Railway Polygon, Relief, Relief Polygon, Road, Road Polygon, Utility and Vegetation. The available data formats include E00, DGN, AutoCAD (DXF and DWG) and TIFF.

B20000 contains sixteen layers, and they are Boundary, Building, Elevation, Height, Facility, Facility – filled polygon, Hydrography, Hydrography – filled polygon, Reserve Park, Place, Railway, Relief, Relief – filled polygon, Road, Utility and Vegetation. The data formats being available for this product are E00, DGN, AutoCAD (DXF and DWG) and TIFF.

The Digital Land Boundary (DLB) data also known as Digital Data is very similar to the DTM data. It has been created with the coordinate system of Hong Kong 1980 Grid, and with heights in meters above the Hong Kong Principal Datum. This database describes the land boundary in Hong Kong. The production provided online for the type of DLB database is C1000 with scale 1:1000.

For C1000, the total layers is twenty-two, and they are Easement, Engineering Reserves, Licence Areas, Lot, Modification of Lot, Overlapping Licence Area, Overlapping Lot, Overlapping Vesting Order/ Deposit Area, Utility Permits – Lines, Utility Permits – polygon, Vesting Order/Deposit Area, Walkway, Advance Possession Licence, Permitted Burial Grounds, Demarcation District Boundaries, Fish/ Mariculture Area, Forest and Mining License, Fung Shui Lanes, Overlapping Advance Possession Licence, Country Park and Nature Reserves, Resumption Limits, and Railwai Reserves.

Figure 1. An example of B5000 Digital Topographic Map of Hong Kong Convention & Exhibition Centre Scaled 1:5000 (Source: http://www.info.gov.hk/landsd/mapping/eng/digital_map/common/sample/b5_sample.jpg)

Geo-Reference Database stored geographic references information is for users to bring out enquiries about location and then practise spatial analysis. There are three types offered with this database such as Building Name and Address (BG1000), Site Polygon (SG1000) and Road Centre Line (RG1000).

Building Name and Address (BG1000) contains textual information only, and is stored in Bldgpoly.sdf file. This data is used to relate information with the B1000 DTM. The Bldgpoly.txt file stores the coordinates of the Building Block's Building ID and is in the label point, whereas add_bldgpoly.csv file stores any additional information with the same geo-referenced attribute. The information that users can find includes Building ID, Geographic Reference Number of the Building Block's label point that is the X and Y coordinates, Building Name, Starting and Ending House Number, Type of Address, Street Name and Street Code, and Site Code. However, this data is only available in ASCII data format.

Site Polygon (SG1000) provides information of an area such as hospital, estate, village, park, university and others. It provides information of an area with more main building that serves the same property, for instance, private residential site and police station. The following information is included in this data type: Site ID, Site Polygon's Geographic Reference Number (the X and Y coordinates), Starting and Ending House Number, Type of Address, Street Name and Code, Site Code, and X and Y coordinates of vertices of the polygon. There are several data formats, ASCII, E00, DGN, and AutoCAD (DXF and DWG), served with this data. In ASCII data format, the coordinate data is stored in the <site>.txt file, the textual information of the database is stored in the <site>.sdf file, and any additional information with the same geo-referenced attribute is stored in the add_<site>.csv file. The E00 data format stores <site>.E00 drawing file, the DGN format stored <site>.dgn, and the AutoCAD (DXF and DWG) format stores <site>.dxf and <site>.dwg drawing files. Finally, the <site>.csv file is used to store the textual information and is linked with the use of a common ID to the records.

In Road Centre Line (RG1000) database, attributes related roads such as roads, lanes, road tunnel, road bridge, expressway and others. are contained. Information in the database is Street ID, Street Code, Street Name, and the line's X and Y coordinates. ASCII, E00, DGN, and AutoCAD (DXF and DWG) data formats are available for this database. The <street>.txt file is used to store coordinate data, and the related textual information is stored in the <street>.sdf. Drawing files such as <street>.E00, <street>.dgn, <street>.dxf, and <street>.dwg are provided in E00, DGN, and AutoCAD (DXF and DWG) data formats respectively.

Digital Orthophotos Database is a database about digital images, with uniform information of scale and position, of ground surface. Two types of this database are Digital Orthophotos DOP5000 with 0.5m Ground Pixel and Digital Orthophotos DOP10000 with 1m Ground Pixel.

The DOP5000 (Scale 1:5000) are generated based on aerial photographs with 8000 feet's flying height. Rectification is done on tilting aerial camera and terrain relief of the photograph images' distortions, but building structures on the photograph images are not inclusive in the rectification. These digital images contain 189 tiles covered all areas in Hong Kong with the ground pixel size 0.5m * 0.5m. Their content is updated regularly, and TIFF data format is the only data format available for these digital images.

DOP10000 (Scale 1:10000) are generated from aerial photographs with 20,000 feet's flying height in 2000. The content of rectification is the same as that of DOP5000, and there are fifty-five tiles contained in one digital image with 1m * 1m ground pixel size. Also, TIFF data format is the only data format available for this type of digital images.

GeoCommunity Database (GeoCom) is the information of geocoded community with spatial reference in MS Excel database format. Much information such as address information, contact details, various public services and leisure facilities can be found in a great detail. It helps to search for different facilities' locations in a non-map environment. Furthermore, for supporting GIS analysis, the GeoCom is used with other digital map bases. The eighteen District Council Electoral Boundaries are used to delineate each district. In this database, there are seven categories used and their categories' names are Education, Leisure, Medical, Public Services/Facilities, Religion, Transportation and Tourism. The only data format available for this database is Ms Excel.

III. GIS IN GOVERNMENTAL DEPARTMENTS

Hong Kong governmental departments play a dominate role in using and applying GIS, and are the major users in the GIS. GIS has been used in local governmental departments for 15 years, and started using by Lands Department and Planning Department, and now there are more than 15 governmental departments having applied GIS for supporting their daily works. In this section, we start with a general review on each of those departments with available information followed by a detailed description on some of them.

A general review

Agricultural, Fisheries and Conservation Department developed systems such as Red Tide Management System, and Country Part Information System based on GIS. In these systems, both GIS and database were applied to manage spatial distribution of country parks, park boundaries. Both digital maps and aerial photos were used to generate the data sets for these applications.

Census and Statistics Department practised an every-ten-

year's population Census with using the Digital Mapping System in 2001. The data for this system was in a textual database that stored addresses and characteristics of every quarter in Hong Kong. The texture data were linked with a GIS (http://www.esri.com/news/arcnews/fall01articles/hongkongs.html).

Civil Engineering Department proposed and developed the system named Slope Information System in order to store the information of slope maintenance, location, and characteristics. (http://hkss.ced.gov.hk/hkss/eng/whatsnew/index.htm).

Lands Department also developed a Slope Maintenance Responsibility Information System (http://www.slope.landsd.gov.hk/smris/index.html).

Drainage Services Department developed and used Digital Mapping System to create the GIS database for storing the information on drainage network in Hong Kong.

Environmental Protection Department developed a database system for handling environmental pollution complaints, Water Quality and Pollution Load Information System (WQPLS), which is responsible to store data of the above aspects and collect the records on knowledge of the environmental pollution and condition of specific areas.

Fire Services Department has been using the Fire Station Planning Assisting System to analyse and locate the shortest path for providing emergency services. In addition, the Third Generation Mobilizing System (TGMS) has been developed to replace the Second Generation Mobilizing System (SGMS) to help monitor the operation of radio transmission network (http://www.info.gov.hk/hkfsd/home/eng/news/e-tgms.html).

Highway Department has developed and currently used the Road Record Maintenance System, which stores the road-related information and features, and can be used to analyse the condition of roads based on GIS technologies.

Hong Kong Police Force proposed and developed a system called Third Generation Command and Control Communication System to help track police vehicles (http://www.info.gov.hk/police/aa-home/offbeat/757/eng/n06.htm).

Lands Department, as one of the first governmental departments of Hong Kong to adopt GIS, developed and produced Digital Data and Maps to store various information of Hong Kong depended on particular requirements. BMS, CIS, GIRS, Electronic Guide Map System and Metadata Cleaning House as ones of Digital maps store metadata, slope and particular information of Hong Kong. (http://www.info.gov.hk/landsd/index.htm, http://www.info.gov.hk/landsd/mapping/text/digital_map/sampledata_t.htm).

Planning Department developed Online OZP served as a GIS database to store features such as landuse, and TPU. There

are also other GIS application projects developed by this department, and they include Planning Study on Landscape Value Mapping of Hong Kong in order to create a comprehensive landscape assessment for all land areas of Hong Kong (http://www.info.gov.hk/planning/index_e.htm).

Rating and Valuation Department has used GIS to store rating values related information, such as buildings and shops located on the ground floor of buildings.

Transport Department has been developing Intelligent Transport System (ITS) to store, manage and use transporting and road-related conditions.

Water Supplies Department also developed Digital Mapping System to store and analyse locations of water supplied pipelines.

After a brief summary on GIS application in Hong Kong governmental departments, we now go a step further and give some more detailed descriptions on several governmental GIS applications in Hong Kong.

Statistical data in the Census and Statistics Department

The Census and Statistics Department (C&SD) of the Hong Kong Government operates statistical systems and projects which produce information for analysis, policy formulation and operational planning by both the public and private sectors (Ho, 1995).

Among the wealth of statistical data, some can be geo-located, e.g., population census data and employment statistical data. Population census information is vital to the government in planning and policy formulation, particularly in such fields as housing, education, transport, and medical and social services. There are various types of statistical data in the Department. Population data is one of the most useful one for GIS applications. The statistics on characteristics of the population are classified as demographic characteristics, educational characteristics, economic characteristics, household characteristics, and housing characteristics (Ho, 1995).

Normally, the exercise of taking a population census is conducted every ten years, and a population by-census is conducted in between two censuses by the Census and Statistics Department in Hong Kong, in where there are approximate 6.8 million people who live while there are 2.2 million quarters, which represent the smallest unit of enumeration equated to a household. There are more than 35,000 operational maps for the 2001 Population Census; therefore GIS is used to make households easily be located for enumerators and to collect the census efficiently. A set of paper maps has been produced to show the location of each quarter and keeps with a textual database recording every quarter's characteristics and address. The 2001's population census was applied with the new ArcGIS object model, which runs on an Oracle with ArcView clients, in
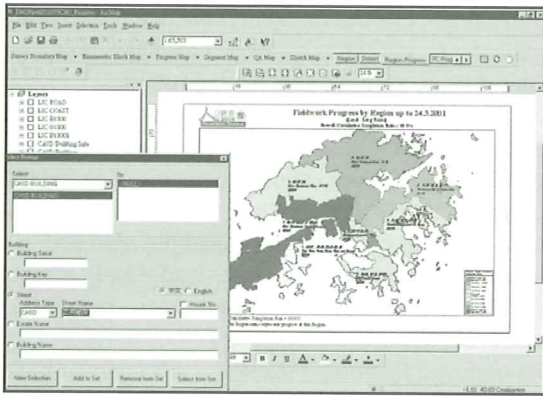
Figure 2. An interface of digital mapping system for Census (Source: http://www.esri.com/news/arcnews/fall01articles/ hongkongs.html)

ArcInfo and ArcSDE

Establishing a Digital Mapping System (DMS, Figure 2) has been achieved mainly to store and maintain the Census Base Map. With the additional function, which is to link to the textual address database, this system also provided tools to edit and maintain administration boundaries' and quarters' spatial locations, and to produce all required operational maps for the 2001 Population Census. The Functions of the system include
- *Display* — to display basic legends and view templates and to navigate textual and spatial data;
- *Edit* – to maintain the quarter maps by subtype editing, feature-linked annotation's creation, attribution, offset or alignment, and multiplayer snapping;
- *Query and Analysis* — to integrate elements into other modules from the display module, to calculate road distances and straight line between proposed walk route plans;
- *Validation* — to control data on entry, to control relationships between the towers and podium structures, and to maintain co-incident boundaries of administrative areas' relationships were made with feature and attribute domains, feature relationships, and the subtype data models; and
- *Output* — a range of scales of 35,000 operational print-maps was output for enumerators to take into the field.

Slope information in Civil Engineering Department and Lands Department

Both Civil Engineering Department and Lands Department have been working on slope information in Hong Kong. Landslide is a major problem in Hong Kong. This is due to the natural environmental condition of the territory, i.e., extremely hilly terrain and deeply weathered rock profiles coupled with high seasonal rainfall and intense development. The Geotechnical Engineering Office (GEO) of the Civil Engineering Department, formerly called the Geotechnical Control Office, was established by the Hong Kong Government in 1977 to handle the

slope problem. A manual slope catalogue was prepared by them in 1977 and 1978. The catalogue was updated on an ad hoc basis until 1992. Then, in 1994, the GEO started and commenced the project of Systematic Identification and Registration of Slopes in the Territory. The result is the Slope Information System (SIS) with updated digital information about slopes in the territory. The objectives of the SIS are (Mak and Ip, 1995) to enable fast on-line analysis of the spatial relationships between slopes and their surrounding details of topography, structure and habitation; to provide reports on slopes to various levels of detail, for both individual slopes and groups of slopes; and to facilitate members of the public in making enquiries.

The SIS has three parts: a spatial data handling part for slope location on a base map, a textual information part, and an image part. The SIS was designed for professional users in the government, the general public and private geotechnical practitioners. The system is designed to have terminals in various GEO divisions linked to the headquarters of the Civil Engineering Department. It can be further accessed through the network communication backbone by public users.

There are about 54,000 registered slopes and related information (Figure 3). These include all slope information available to date. The data are organised into different layers. These layers include the registered slope boundaries, outdated slope boundaries, landslide records, boundaries of fill bodies, digital maps from LIS of Lands Department, and other slope information of a spatial nature. The data within the attribute database include results of previous geotechnical studies, slope information from site studies, instability records, development status and other data such as maintenance responsibility.

The SIS (Figure 4) is a geographic information system (GIS) to integrate several different information on slopes and then to link them into the geographic and textual databases. As the valuable information stored in SIS, it is very useful for management companies, property owners, geotechnical engineers, and the public. In order to provide and improve the efficiency, availability, and quality of engineering fieldwork, mobile GIS
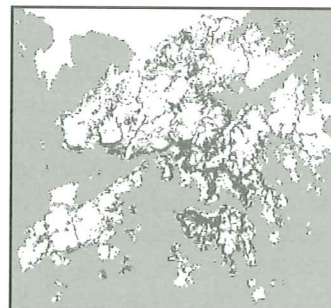

Figure 3. Slopes distribution in Hong Kong (Source: http://hkss.ced.gov.hk/hkss/eng/slopeinfo/ index.htm)

Figure 4. Slope Information System
(Source: http://hkss.ced.gov.hk/hkss/eng/slopeinfo/index.htm)

into a hand-held package and global positioning system are ones of the "mobile mapping application system". Finally, decision-making that relates to the public safety has been facilitated strongly by strengthening the office-field communication.

The town planning information system in the Planning Department

The Town Planning Information System (TPIS) was originally a sub-system of the Land Information System in the Building and Lands Department. It is now an independent system maintained by the Planning Department with data linked to the Land Information System. The TPIS, used with ArcInfo, was designed with the objective of supporting town planners in the Planning Department for spatial analyses and queries in their planning processes.

The existing system mainly serves for data storage and management. In order to efficiently carry out spatial analysis for planning tasks, several additional sub-systems are planned. These include a population distribution and land supply forecast system, a planning registers system, a strategic planning information system and a district decision support system.

There are thirty-three layers in the TPIS. These contain information about Outline Zoning Plans (OZP), Objections, Planning Applications, Planned Uses, Sub-regional Plans, Land Supply, Land Planning Units, Land Development Corporation Designated Areas, Development Proposals and Development Scheme Boundaries, etc. (Lam, 1995). The layers of major use to the staff of the Planning Department are the building layer, the land use layer and the land supply layer. These contain most of the relevant existing and proposed site-specific information. These spatial data are linked with attribute data that describe the land supply sites and building sites in a textual form. There are several new layers included highway network, proposed highway network, rail network, proposed rail network, open storage sites, port facilities and water control zone.

The TPIS can provide the following functions concerning the town planning process (Lam, 1995). These are carried out by providing various plotting and printing outputs.

- Statutory Planning Functions: OZP and notes schedules, OZP objection site, record plan and objection details, planning application site, record plan, report of similar precedent cases;
- Land Use / Supply Functions: land use plan and summary of land use categories, land supply report plan and summary on land availability record plans, urban renewal designated plan;
- Sub-regional Planning Functions: sub-regional plan and report of status and history of sub-regional plan, inventory record and site plans maintained by the Sub-regional Planning Section; and
- Site Enquiry and Miscellaneous Functions: enquiry to specific site and plotting extracted plan, plotting density zoning plan and area of special control plan, site search based on land supply data record, three-dimensional display of buildings in selected areas.

Planning Study on Landscape Value Mapping of Hong Kong

To become a world-class City, Hong Kong is required a comprehensive landscape assessment for the whole territory. As landscape is essentially valuable for developing strong society, economy and community, it is central to attracting business and tourism, and foreigners' economic activity. The study area has been covered the whole territory including urban and rural landscape. A project of planning study on landscape value mapping in Hong Kong has been carried out to establish the essential landscape baseline information and to provide a reference framework systematically in order to facilitate environmental and landscape assessments for Hong Kong.

GIS is used to establish the final Landscape Character Map and all information in the study with linking the textual database. Moreover, the Computer-Aided Sustainability Evaluation Tool system (CASET) is provided. With the use of the CASET system, GIS provides a recommendation to an indicator to measure varied policies' and proposals' impacts on landscape. GIS also helps to generate the Landscape Character Map's hardcopy and CD-ROM versions.

In order to ensure that different fields can be offered to sufficient range of expertise, all the elements affected landscape development are covered. The followings are some of the major GIS data sets in digital format: a) 1:10,000 orthophoto; b) digital geological maps; c) satellite imagery; d)Digital Terrain Model; e) cultural and heritage data; building topography; hydrological data; land cover data (Figure 5).

Utility management system in the Highways Department

It is a common problem for large cities to accommodate road excavation work while maintaining traffic flow. This is particularly crucial for Hong Kong because of the high traffic den-
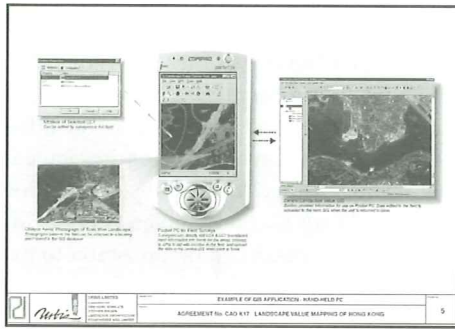
Figure 5. Hand-held PC was used to capture data in field (Source: http://www.info.gov.hk/planning/index_e.htm (Planning Studies - Appendix II Figures))

sity, narrow roads, and rapid development of the city. The Highways Department has been developing the Utility Management System (UMS) for the co-ordination and control of utility road excavation work with the aim of reducing disruption to the road users.

The following application modules are designed for the UMS to control the road excavation works for utilities: excavation permit processing, emergency work processing, reinstatement processing, inspection and enforcement processing, complains processing, management reporting.

The GIS data used in the UMS are grouped in the following categories: base map from LIS of Lands Department, location reference data with the elements of road name, road chain age, house number, lot number and lamp post number, zone boundaries with elements of public road boundary, construction and maintenance history special routes and special protection zones, and working data.

One of the major functions of the UMS is to carry out spatial analysis to identify the conflicting works proposals. It is the aim of the Highways Department to prevent two or more contractors working at about the same time in the same district unless it is done in a co-ordinated way. When the conflicting proposals are identified, the Highways Department will inform the utility managers either to change their working method or to change their program so as to reduce the overall disruption to the road users. The UMS is under development at this point.

The enhanced computer assisted command and control system in Hong Kong Police Force

Being developed by Information Technology Branch (ITB) in the late of 1980s, the Enhanced Computer Assisted Command and Control System (ECACCS) (http://www.info.gov.hk/police/aa-home/offbeat/757/eng/n06.htm) has acted importantly as the key computer system for the police force supporting the emergency services (999). This system is performed reliably to provide incident handling and dispatching functions

and reacting efficient and effective responses to emergency service requests from the public.

One of the three IT systems comprised in the Third Generation Command and Control Communication System (CCIII) starting in late 2004 is named the Automatic Vehicle Location System and Geographic Information System (AVLS&GIS), in which Geographic Information System (GIS) technologies and Global Positioning System (GPS) are embraced. This technological system is enabled dispatchers and call-takers to identify and recognize the instant incidents' and police mobile units' locations on digital maps.

GIS in Buildings Department

GIS is used to replace some of 2200 paper-based survey sheets by digital maps in the Building Information Center (http://www.info.gov.hk/bd/english/inform/development.html). This system enables users easily retrieving latest digital base maps stored in the Computerised Land Information System (CLIS) in the Lands Information Center. The Building Department (BD) will be uploaded to CLIS in order to facilitate data to share with other departments and the public. This project is still on-going and scheduled to be completed in 2004. With the Building Condition Information System (BCIS) project and Building Development Information System (BDIS) project, both of which have already been completed, this system will be integrated in BD.

Building Development Information System

This system was completed in 1998, which is run on middle range server to handle and manage new building development's information. The system helps to track the plan submissions and site progress with statistics and handling searching and enquiries being compiled.

Building Condition Information System

It has already been completed in the June of 2002. It is similar to the Building Development Information System, as an information system to run on middle range server to handle and manage building related information. Instead of new building development, but of existing buildings this system is for keeping records, compiling statistics, handling searching and enquiries, and monitoring operations daily.

Third generation mobilizing system in Hong Kong Fire Services Department

Third Generation Mobilizing System (TGMS) is an on-going project and will be launched in early 2004 (http://www.info.gov.hk/hkfsd/home/eng/news/e-tgms.html). The project aims to replace the existing Second Generation Mobilizing System (SGMS). This project involves many advanced technologies in order to improve the call-taking and resource-dispatching efficiency and effectiveness in SGMS. Specifi-

cally, this system will minimize the number of "blind spot", and to improve the operation of the mobilizing systems on fire appliances and ambulances.

Geographic Information System (GIS) is one of the twenty-one major subsystems in TGMS, and is responsible to indicate the nearest emergency resources from displaying maps and providing spatial analysis to facilitate front-line operation. GIS is integrated with other subsystems, such as Automatic Vehicle Location System (AVLS) and Computerized Mobilizing System (CMS). More than forty different types of spatial data collected from various governmental departments are incorporated into GIS, data conversion and program development required to be spent much efforts to achieve.

IV. GIS APPLICATIONS IN PRIVATE SECTORS

GIS applications starts from utility companies in Hong Kong for automated mapping/facilities management (AM/FM). This has been greatly extended to telecommunication, real estate, mapping, transport and others. Here is a summary to some of the GIS applications in private sectors, of which information are available.

GIS in the Hong Kong Electric Company

The Hong Kong Electric Company (HEC) was one of the first companies in Hong Kong to apply GIS in AM/FM and support their facility management. In 1979, the Company started implementing automated mapping for planning, designing, operating and maintaining the company's underground power line networks in the areas of Hong Kong and Lamma Islands.

The graphic data used in the system include facility maps and schematic maps. The facility map is used for acquiring power label locational information in planning and maintaining power cable operation. On the other hand, the schematic map is used to show relationships and layout of different electrical components in a circuit. For instance, the location of a power cable can be retrieved from a facility map. Details of the cables, such as the type of cable and the switch used to connect the cables can be retrieved from the schematic map data. A characteristic of the data management system is the shamelessness of map management. This facilitates the retrieval of spatial data. For example, a user can continuously view a whole cable by scrolling on the screen, though the cable may have originally covered several paper maps.

A developing trend of the system is to connect it with systems from other organisations for complex analysis. The company, for instance, tries to connect with the customers' address database. By this connection, the company can have better communication with those customers who are affected by a temporary power cut-off due to maintenance or an emergency.

The Hong Kong and China Gas Company Ltd.

The Hong Kong and China Gas Company Limited (Towngas) is the oldest public utility company in Hong Kong. The company has one million domestic, commercial and industrial customers and has over 2,000km of gas pipes distributed throughout the Hong Kong territory. Towngas was the second public utility company in Hong Kong to implement an AM/FM system. It was the first commercial organization to extensively employ the digitised maps of the Land Information Centre (Leung, 1995).

The development of the Towngas AM/FM system included two phases. In the first phase (1993-1994) of development, the data covered Hong Kong Island, which is one-third of the whole gas supply network. The nature of this phase was a pilot study to minimise the project risk. The second phase (1994-1996) was carried out based on the successful completion of the pilot study. The area covered by the system was extended into Kowloon and the New Territories in this phase.

ITS in Brilliant Technology Development Limited

The Brilliant Technology Development Limited (BTS) develops technologies for vehicle positioning by utilizing the satellite technology. It built Intelligent Transportation Systems (ITS) integrated from Global Positioning System (GPS) and GIS technologies.

GIS is used to create maps of comprehensive traffic information, for instance, road network, turning lanes, and traffic direction. It is also used to create database to capture location of public facilities and shops including hotels, gas stations, and banks. The Intelligent Road Network Database (IRND) has been established, and is a digitally vector map to identify the road's condition in a great detail.

Within the database for these products, every street even the smallest local street is captured and almost all streets are attributed with traffic information and, of course, names. These maps are developed from relational database structure for navigation, so much detailed information such as turning lanes, center-line and tunnels is captured and shown.
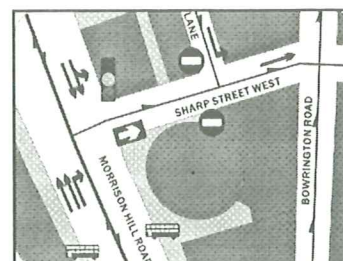
Figure 6. An example of IRND
(Source: http://www.brillianttec.com/products.html)

The information in the IRND (Figure 6) includes traffic direction, number of lane, road class, vehicles' maximum allowed height, maximum allowed length, and roads' restrictions are captured and stored.

GIS in PCCW's Cascade Limited

PCCW (http://www.cascade-ltd.com/) developed MAPvigator, an applicable platform responsibly to develop and deploy mapping application in the internet and with the functions and tools to store and visualize information of places. MAPvigator provides customers an integrated picture with information captured, combined, and created in maps of the Internet.

Automated Mapping Facilities Management & Geographic Information System (AM/FM/GIS) is widely used among Hong Kong governmental departments and utility management. There are 150 workstations and 14 SMP servers in Hong Kong, and more than 1.5 million features are managed by the system. Its users mainly are engineering staffs from the international and local networks and mobile lines of business

Digital maps from Universal Publications, Ltd

Universal Publications, Ltd (http://www.up.com.hk/index_e.htm) uses geographic information systems to produce Digital Mapping Products, including both raster maps and point data sets.

Digital Raster Maps:
- 1:50,000 scaled maps that cover the whole Hong Kong in raster format; and
- 1:5,000 scaled maps that cover only urban areas, such as Kowloon, Hong Kong Island, and all New Towns, in Hong Kong also in raster format.

Digital Point Data Sets:
- Places and street names of Hong Kong
- Places of interest in Hong Kong, for instance, hotels and hostels, cinemas and public performing places, museums, shopping malls, primary and secondary schools and universities, public libraries, etc;
- Buildings' directory, such as building names and detailed addresses. There are approximate 15,000 such information;
- Major chain shops, inclusively all banks, convenient shops, Seven-Eleven, Circle K, Manning, and The Spaghetti House in Hong Kong; and
- Information about Commercial buildings of Hong Kong.

GIS in The Centaline Property Limited

This company developed GIS-based digital map, CentaMap (http://www.centamap.com/cent/index.htm), on Internet for users to search the location where they are interested in. The CentaMap is basically derived from the digital map base of 1:10,000 from Lands Department. The maps can be printed in the scale of 1:300,000. There are seven levels used in this map.

For the level 1, layers about the ages, functionalities, the number of floors and height and the area of individual buildings are shown with 1:800 scale. For the level 2, the transportation, Western and Chinese restaurants, rental of buildings are shown with 1:2000 scale. For the level 3, shopping centers, entertainments, and other facilities are provided with 1:4000 scale. For the level 4, advanced education, financial profession, social organizations, and population census are provided with 1:6000. For the level 5, services for living and societies are shown with 1:10,000 scale. Environmental and natural ecosystem, construction of buildings, and history of particular areas are provided in the level 6 with 1:25,000 scale. For the level 7 with 1:80,000 scale, wild camp sites and Hong Kong Islands, and geographic information are shown. Finally, the level 8 provides the information about living, introduction of Hong Kong, and industries and companies.

Moreover, pictures are linked to the GIS database so that users can view the pictures after choosing the areas. In the CentaMap, tool box included choosing various languages, information window and location search engine, map face window, map navigation bar, and information query bar are offered to help users search their interests.

KMB Hotline by The Kowloon Motor Bus Company Ltd.

In the early 2002, the Kowloon Motor Bus Company Ltd. (KMB, Figure 7) introduced a system named Digital Map Passenger Enquiry System (http://www.kmb.com.hk/english.php?page=profile&file=care/index.html) to enable enquiry handling efficiency being increased by 100 per cent.

It is an Intranet GIS-based system providing functions on information presentation, retrieval, and storage to the staff of hot line. This map-based system assists operators to locate callers and identify the most suitable route for their asked destination quickly. True point-to-point routing from-to in Hong Kong is allowed to search the nearest bus stop and to identify required transfers along the routes customers require. Bus services' up-to-the-minute information of traffic conditions are included and given.
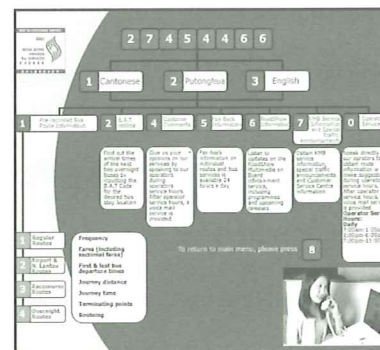

Figure 7. The KMB Customer Service Hotline
(Source: http://www.kmb.com.hk/english.php?page=kmbhot)

V. GIS RESEARCH AND EDUCATION

Among the seven local universities in Hong Kong, four institutes actively involve in GIS education and research. These are The Chinese University of Hong Kong, Hong Kong Baptist University, The Hong Kong Polytechnic University and The University of Hong Kong.

GIS education in Hong Kong

Currently, there is a wide range of GIS and related education available in the Territory of Hong Kong, from high diploma, BSc, MSc, MPhil towards PhD.

There are three levels course-based programs related to GIS: high diploma, BSc and MSc. A high diploma in GIS is provided by the Department of Land Surveying and Geo-Informatics, The Hong Kong Polytechnic University. In BSc level, GIS education is provided by several programs related to GIS, these include BSc in Geography by Department of Geography and Resource Management at The Chinese University of Hong Kong, BSc in Geography by Department of Geography, Hong Kong Baptist University, BSc in Surveying and Geo-informatics by Department of Land Surveying and Geo-informatics, The Hong Kong Polytechnic University, and BSc in Geography by Department of Geography of The University of Hong Kong.

Three universities offer GIS related programmes in MSc or postgraduate diploma level: Postgraduate Diploma (PgD) in Applied Geoinfomatics by The Chinese University of Hong Kong, MSc/PgD in Geomatics (GIS) by The Hong Kong Polytechnic University and MSc/PgD in GIS by The University of Hong Kong, and all these three programmes are part-time-based.

For research degree, four universities, which are The Chinese University of Hong Kong, Hong Kong Baptist University, The Hong Kong Polytechnic University and The University of Hong Kong, can provide M.Phil and Ph.D educations.

GIS research in Hong Kong

Hong Kong Baptist University

GIS related projects are undertaken in Department of Geography at Hong Kong Baptist University. Some of the recent projects are:
- Human impact assessment on fragile ecosystem of arid environment of western China.
- 3-Dimensional Landscape Modelling
- Digital terrain analysis
- Quantitative vegetation assessment using digital remote sensing
- Digital image processing methodology and algorithms on auto-classification of close-range high-resolution digital images.
- Quantitative assessment on the accuracy of DTM interpretation algorithms
- GIS for water and soil conservation in the Upper Yangtze River Basin
- Digital image processing methodology and algorithms on auto-classification of close-range high-resolution digital images

The Chinese University of Hong Kong

The Department of Geography is active in scientific research as well as in local consultancy projects. The followings simply reflect projects that are in progress at the moment:
- Spatial-temporal decision support system for dynamic monitoring and analysis of air quality in the South-China-Hong Kong region
- Optimal mapping between problematic models and parallel genetic algorithms
- Knowledge acquisition for spatial inference using genetic algorithms
- Integration of remote sensing and census data for environmental quality assessment
- Hypespectral data analysis of typical surface covers in Hong Kong
- Land use and land cover change detection using Landsat TM images
- Impacts of global climate change and regional land-use alteration on water resources in the Dongjiang basin
- Airborne Remote Sensing for Developing Hong Kong Spatial Data Infrastructure
- Satellite Remote Sensing Forecasting System on Fisheries of South China Sea
- A Joint Experiment on the L-SAR All-weather Remote Sensing System for Landslide Monitoring in the Hong Kong Region
- A Neural Network Approach to the Solution of Multiple-source Multiple-destination Communication Problems in Space and Time
- GIS-T for supplier selection, material handling, routing and distribution planning, facility layout, production scheduling.
- Development of web-based GIS-T training package.
- An algorithm for locating facilities in a network system based on node accessibility and spatial clustering

The Hong Kong Polytechnic University

Department of Land Surveying and Geo-Informatics (LSGI) at The Hong Kong Polytechnic University has involved in the research of GIS since earlier 1990s. The research areas cover (a) theoretical researches and technological development, and (b) application consultancy projects. Other departments are getting more and more involved in GIS, including Computing Department, Civil and Structure Department, Building and Real Estate Department, Building Service Department and others.

Theoretical Researches and technology development

In theoretical research and technology development area include

- Research and development for Transport Information System
- Voronoi diagram for GIS
- Marin GIS
- multi-scale GIS models and generalization,
- spatial relationships in GIS
- map matching for navigation
- uncertainties and spatial data quality in GIS
- 3D and dynamic GIS data structure and models
- spatial data infrastructure for Cyber Hong Kong
- integrated 3D GIS and virtual reality
- mobile and internet GIS
- extraction features and image fusion based on high resolution satellite images
- image compression

Consultancy projects

The Department of LSGI has been involved GIS development in local governmental departments, particular in the high level consultancy projects, such as feasibility studies, GIS model design, metadata data model and transferring GIS and related technologies by training. The governmental departments for which the Department severed as a consultant or training for include, for example, Agricultural, Fisheries and Conservation Department, Civil Engineering Department, Highway Department, Hong Kong Police Force, Lands Department, Rating and Valuation Department, Transport Department, Registration and Electoral Office and Works Branch of Government Secretariat. The Department also collaborates with several local companies in GIS development.

The University of Hong Kong

GIS related research are conducted by many departments within the University, including architecture, civil engineering, computer science, ecology, electrical engineering, environmental management, geography, surveying, and urban planning. A multi-disciplinary GIS Research Centre (www.hku.hk/cupem/hkugis/) has been set up in 1994 to form a network and focus for promoting geographic information system related research and development activities in the University and inter-institutional, regional and international cooperation in geographic land information system research. Some of the recent research projects are :

- Expert systems in GIS for handling of large spatial databases, and 3-dimensional spatial data structures.
- Application of GIS in urban planning, environmental management, transport management, telecommunication, facility management, and marketing.
- Virtual HKU Campus:
- Real Time Traffic Multimedia Internet Geographic Information System (GIS):
- Real Time Dynamic Traffic Forecasting
- Agricultural Land Loss and Economic Development in the Pearl River Delta.

- Applications and uncertainties of cellular automata in urban planning.
- The Use of Satellite Synthetic Aperture Radar (SAR) Images in Land Use Change Detection,
- Integration of Case-Based Reasoning with GIS,
- An Object-Oriented Approach in the Design of Planning Support System,
- Spatial-temporal Modelling of Landslide Susceptibility,
- Building a Domain Model for Knowledge Acquisition in Facilities Siting.
- Representation of Real Property Information
- GIS for Road Accident Analysis in Hong Kong

VI. THE HONG KONG GEOGRAPHIC INFORMATION SYSTEM ASSOCIATION (HKGISA)

The Hong Kong Geographic Information System Association has been established since January 9th 1995 in Hong Kong. The Association's objectives are to develop and promote advancement and interest in geographic information system (GIS) in Hong Kong. There are three types of memberships provided and they are Full Membership, Corporate Membership and Student Membership. The members of the Association are from local governmental department, the universities in Hong Kong, and private sectors.

For the Executive Committee of the Association, the Officers, such as the President, the Vice President, the Hon. Secretary, the Hon. Publication Secretary, the Hon. Treasurer, and three elected members, and Immediate Past President are inclusive. The Association's President, elected at the Annual General Meeting, is Chairman of the Executive Committee and should have been an Officer of the Executive Committee for at least one term. The Vice President, also as Vice Chairman of the Executive Committee, is also elected at the Annual General Meeting for at least one year standing. There have been five terms of Executive Committee, with the following elected Presidents severed for the Association: Prof. Anthony Yeh of The University of Hong Kong, Mr. Chan Hak of Lands Department, Hong Kong Government, Prof. Fung Tung of The Chinese University of Hong Kong, Dr Wenzhong Shi of The Hong Kong Polytechnic University, and now Prof. Anthony Yeh again.

The Association has provided a forum and network for people who participates GIS research, applications, education, hardware and software in order to have interactions between them and exchange information of the rapidly developed GIS technology. The Association offers the activities of seminars, exhibition and talks. For example, the latest activity, which was successfully done and held in Wuhan, China, from 15th to 18th October 2003 , was AsiaGIS 2003. Other activities included the GIS and Public Health on 27 September 2003, GIS in Urban Planning on 5 December 2002, the Annual Dinner of the Association on 22 January 2002, Environmental GIS Workshop on 14 November 2001, and Best Student Research Award Compe-

tition from 1999 to 2002.

VII. ISSUES FOR GIS FUTURE DEVELOPMENT IN HONG KONG

Progress so far

After 15 years of development, GIS has been widely applied in Hong Kong. In Government, GIS starts by two department and now is widely adopted by more than fifteen departments. In private sectors, GIS has been used by telecommunication, real estate, transport, civil engineering, mapping and others, while used by utility companies only ten years ago. The level of GIS applications in Hong Kong started from the stage of GIS data collection, data storage, retrieval and management, towards to spatial analysis and decision support as they are today.

The fundamental GIS data in Hong Kong has been mainly captured by Lands Department, while specialised data such as transport and urban planning data are collected by other governmental departments and local industry. These data form very important basis for the GIS applications in Hong Kong. In fact, these data have already supported many GIS applications in Hong Kong, although a spatial data infrastructure is yet to be further developed.

Quite a large number of graduates with knowledge in GIS have educated by the local educational institutes, from high diploma, BSc, MSc Mphil and up to PhD levels. These graduates, after further professional training, are now the major forces for the GIS development and applications in Hong Kong.

Although there has been a great progress in Hong Kong, in terms of GIS development and applications in the past fifteen years, there are however a number of issues which affect a healthy and sustainable development of GIS in this city.

Issues for future GIS development in Hong Kong

Towards a sustainable GIS industry

Currently, the local government plays a major role in providing GIS projects for local GIS companies in Hong Kong, and local and also abroad companies are also getting more and more involved in this GIS industry. The GIS projects are mainly conducted by GIS consultancy companies or other related companies, either in small or middle scale. Large GIS company is very few and is going to be developed in Hong Kong. GIS in Hong Kong can be developed healthily for a longer term, only if we have a large and sustainable GIS industry to support this. With such a stable and large industry, there will be constantly and large scale GIS projects provided in the local and regional market. The local GIS firms can thus grow up step by step, and requirements on skilled and well educated GIS specialists will be increased. The people who are working in GIS

and related areas, such as local GIS companies, local governmental department using GIS, and local educational institutions, can thus be benefited from such a positive development of GIS in Hong Kong. A sustainable development of this industry is very much relied on the recognition of the importance of GIS to Hong Kong economic development by both local government and community, and a constant and specialised funding injection to GIS industry is very essential.

Urban level spatial data infrastructure

Spatial data infrastructure can be understood as an infrastructure with comprehensive spatial data sets serve to the GIS development and applications. Up to now, quite some GIS database/ data sets have been established and captured for Hong Kong, while the major GIS data sources are from Lands Department. On the other hand, other governmental departments and local private companies have also collected some of the specialized data source for GIS. These form a very strong basis for the development of spatial data infrastructure for Hong Kong, although we can't state that we have already had a spatial data infrastructure for Hong Kong at this movement. A number of major issues needed to be resolved before we can have such a spatial data infrastructure for Hong Kong, such as the scope of the spatial data for Hong Kong, a comprehensive framework of the spatial data infrastructure for Hong Kong, spatial data standards and metadata standards for Hong Kong, data exchange standards and data sharing strategies, both technological and policy aspect, and others. The long termed GIS development for Hong Kong is dependant on a well established spatial data infrastructure for this city, just like the well developed urban infrastructure for Hong Kong.

A GIS professional institute for Hong Kong

Hong Kong GIS Association has done a great job for the GIS development and promotion in Hong Kong. However, HKGISA is still not a professional management body at this stage. A further development of this Association will be towards a professional institute. Such a professional institute will be responsible for, for instance, issuing licences to GIS specialist, quality control and monitoring GIS industry in conducting GIS projects, continuous professional development, and other. A GIS professional institute in Hong Kong will definitely contribute to a healthy and long termed GIS development in this city and the region as well.

New technologies

There are a number of new technologies that can contribute to urban GIS applications in Hong Kong. From data capture point of view, two newly developed technologies contribute to the efficient GIS data capture and updating more precisely and in real time, which are laser scanning and high resolution satellite images. Laser scanning technologies can be classified as air-born and terrestrial laser scanning. Both technologies can

be applied to directly capture three-dimensional coordinates for ground features, such as buildings, roads and earth surface and up to centimetre level of accuracy. There are a number of high resolution remote sensing image being available. For instance, 1-meter resolution IKONOS images and 0.6-meter QuickBird images are ready for applications. These images have a short revisit period, i.e., 3 and 1 day respectively. This characteristic will be crucial for changing detection-based urban GIS applications.

There are a number of progresses in GIS modelling, such as spatio-temporal, dynamic and three-dimensional GIS models. These new technologies can either extend GIS applicable areas, such as to extend current two-dimensional GIS to three-dimensional GIS applications, which are very essential for complex urban like Hong Kong. Currently static GIS technology can be further improved by temporal or dynamic GIS models. These will provide a new solution for GIS applications for rapidly developing areas, such as new urban areas in Hong Kong and Southern China.

Integration of GIS with other related technologies is another important issue. By integration of 3D GIS and virtual reality, the presentation can be improved; integration of GIS, GPS and mobile telecommunication devices leads to very new GIS applications such as Intelligent Transport System, individual navigation and location-based service. The applicable areas and level of GIS applications can be further enhanced by applying these new technologies.

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