A Review of Research and Development on Intelligent Transport Systems in Hong Kong – A Geographic Information Systems Perspective

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Abstract

This paper presents an overview and analysis of research and development on Intelligent Transport Systems (ITS) in Hong Kong from a Geographic Information Systems (GIS) perspective. First, an outline of ITS development in Hong Kong is given, together with a summary of the application areas, development framework and development issues of ITS for Hong Kong. It then briefly describes the technology of GIS and summarizes the functions of GIS that can be applied to ITS. A review of the applications and development of GIS in Hong Kong then follows. In the later half of the paper, GIS-related research and development in Hong Kong are indicated by several examples in the selected areas, including a GIS data model, a mobile GIS, an Internet GIS, map matching-based navigation and integration with transport census data. These examples illustrate the role of GIS in the development and application of ITS in Hong Kong. Finally, the paper concludes with a depiction of the future outlook of GIS development for ITS, where the GIS spatial data standards for ITS are indicated as being one of the major issues.

1. Introduction

Addressed in ITS America (2000), Intelligent Transport System (ITS) refers to the collective applications of diverse technologies, including information processing, communications, control and electronics, in the transport telematics. This understanding is shared among transport planners in Hong Kong, where ITS in Hong Kong is primarily meant to be the deployment of advanced Information Technology to enhance the safety, efficiency, reliability and user-friendliness of the transport system (Secretary for Transport, 2001). In Hong Kong, ITS is being investigated and implemented to alleviate some transport-related problems or issues, such as traffic management, environmental pollution, energy problems, traffic accident and incident management, public transport fleet management, freight logistics, supply chain management, etc. The ITS can provide area-wide traffic data, travel time information, route guidance, traffic management and urban traffic control, etc.

In fact, Hong Kong has implemented ITS for more than two decades, since the installation of the first computerized Area Traffic Control system in 1977. Nowadays, in Hong Kong, ITS applications are commonly found in three major areas of transportation (Zen, 2001; Transport Department, 2001):
Traffic information, such as the Traffic Management and Information Centre and the Transport Information System (TIS); Traffic management, such as the Traffic Control and Surveillance System (TCSS) on various highways and the Area Traffic Control system; and Demand management, such as electronic parking meters, auto toll, Smart Card and Octopus Card, red lights and speed enforcement.

Most of these applications are already in operation in Hong Kong, except for the Advanced Traveler Information System (ATIS) or Transport Information System (TIS). However, the Transport Information System is still under investigation in Hong Kong. TIS for Hong Kong is a project initialized by the Transport Department of the Hong Kong Special Administrative Region (HKSAR) to centrally collect, process and disseminate static and real-time travel information to motorists and travelers for better trip-planning and traffic management. Travel information found in TIS could possibly include traffic flow information, travel time between origin-destination, incident and weather reports, traffic management alerts or even public transport information. An ITS feasibility study was completed in August 1999 (Transport Department, 1999). A central transport and traffic data warehouse was discussed in the study while methods of collecting, processing and disseminating static and dynamic traffic and transport information in Hong Kong were also comprehensively reviewed. A significant outcome of that feasibility study is that Geographic Information Systems (GIS) has been recognized as a core technology to be deployed for the future development of ITS in Hong Kong. The study is significant for also bringing out several important issues into discussion for the future TIS system. These issues include the requirements for high technical standards, legislative amendments, re-engineering processes to implement ITS, funding sources and institutional issues relating to collaboration between the government and the private sector.

At the meantime, ITS applications proliferate in other local industries. One of the distinguishing examples is the substantial investment by local bus companies in studies of the Global Positioning System (GPS) and the Geographic Information Systems (GIS) for application in better fleet management.

Different ITS applications have been implemented in Hong Kong. Most of these applications have led to substantial improvements in the transportation system, such as in terms of travel time and congestion levels. However, ITS in Hong Kong is, on the whole, rather disorganized in that there are numerous stand alone and non-interoperable ITS applications, each with incomprensive coverage. Most of the ITS applications are localized projects, the implementation areas and service targets of which are limited. An integrated approach to development is needed to deal with the limited scale and single-purpose nature of ITS development, in order to nourish the future of ITS implementation in Hong Kong. In light of this aim, the Transport Department of the HKSAR government took the lead in 1999 to conduct a strategic review of ITS development in Hong Kong. This review was completed at the end of 2001 (Transport Department, 2001). In the final report of this strategic review, a new Strategic and Action Plan for the long-term development of ITS was recommended to better integrate diversified information and telecommunication technologies, particularly in the areas of traffic management, the provision of transport services and the optimization of road space usage. This action plan was accompanied by a picture of a comprehensive ITS framework (Figure 1), together with eleven application areas of ITS technologies that were identified to be the focus areas of ITS applications in a future transport system.

The ITS framework proposed in the Action Plan has three important features that will encourage ITS development over the long term.
First, future ITS applications will be functional and service-driven, instead of technologically driven. This means that future ITS services within the ITS will be provided based on the real needs of local travelers, in line with the socio-economic conditions and development of Hong Kong. In addition, a high degree of interoperability and efficiency among different ITS components within the integrated system is observed from this ITS framework. The second feature is the collaborative efforts of different local ITS-related bodies, such as local industries and tertiary institutions, to design and implement ITS services. Such public-private partnership provides strong local support to encourage the long-term development of ITS.

The eleven application areas identified in the future of ITS in Hong Kong are:

- Transport Information
- Urban Traffic Management
- Strategic Road Network (SRN) Management
- Public Transport
- Safety and Enforcement
- Payment, Toll and Parking
- Commercial/Emergency Vehicle Operation
- Pedestrian/Cyclist Facility
- Intelligent Vehicle
- Road Works
- Customer Services

These eleven areas visualize a comprehensive application of advanced IT technologies in Hong Kong’s transportation system in the future. Once this Action Plan is effectively implemented, it is believed that Hong Kong’s transport system will become safer, more efficient and environmentally friendly.
A Review of Research and Development on Intelligent Transport Systems in Hong Kong

Again, as addressed in the report on the feasibility of TIS (Transport Department, 1999), the role of GIS as a core technology for the future development of ITS in Hong Kong was recognized. The next section briefly describes the technology of GIS and will be followed by a section introducing research and development (R&D) of GIS for ITS in Hong Kong with several examples. The final section concludes the paper and also discusses the future outlook of GIS for ITS in Hong Kong.

2. Geographic Information System for ITS

2.1 Geographic Information Systems

Geographic Information System (GIS) is a spatial decision-support system. It can provide spatial information and quality indicators of the information to support the making of a decision, such as to recommend to a road user an optimized route from a given origin to a specified destination. A GIS is able to perform the following functions: acquire data, analyze spatial data, derive spatial information, represent results, indicate uncertainty in the derived information and analyze the effects on the final decision-making. Physically, a GIS is supported by spatial and non-spatial data, analysis models, computer hardware and software and people (Shi, 1994).

GIS developed from the need to combine information on the attributes of land with its geometric representation, in order to perform spatial analyses. The application of GIS technologies is divided into three phases: (1) inventory, (2) analysis, and (3) management and decision support. The initial reason to establish most information systems is to assemble, organize and undertake an inventory of features of interest – the first phase. In a GIS context, this can mean an inventory of forest types, soils, utility pipe networks, schools, etc.

In the second stage of GIS application, more complex analytical operations are undertaken based on the requirements of the user. In these operations, access to data spread across several data layers and the use of statistical and spatial analytical techniques are required. GIS applications such as determining the suitability of land for locating, for example, waste disposal sites or new retail stores, and monitoring changes in land cover are typical of this phase.

The third and most developed phase of GIS application sees the evolution of an information system from a transaction-processing system to a decision-support system. In this management phase, systems are used to support the activities of decision-makers.

2.2 Geographic Information System for ITS

As a spatial data management, storage, process, query, analysis and visualization system, a GIS can provide various functions for many spatially related applications, where ITS is one of the application areas. For example, a GIS can be applied:

- To manage digital maps, including base topographic maps and road network data;
- To handle transport-related attribute information, such as turning information at road junctions;
- To respond to queries on transport, such as on vehicle speed road networks;
- To conduct spatial analysis, such as to find the shortest path for given starting and end locations;
- To provide comprehensive analysis and modeling by integrating with other systems, such as transport predication systems; and
- Others.

2.3 The Development of Geographic Information Systems in Hong Kong

GIS has been applied in Hong Kong for over ten years. Departments of the Hong Kong government, such as the Lands Department, Planning Department, Civil Engineering Department and others, first used this technology. Today, more than 15 different departments in the Hong Kong
Government have applied GIS in their daily work. Another 15 governmental departments are introducing GIS for their operations. Of these, the Lands Department has already captured the basic GIS data for the entire area of Hong Kong for GIS applications in land development. Another major area of GIS application in Hong Kong is automated mapping and facility management (AM/FM) in utility companies such as Hong Kong Electric, Hong Kong and China Gas, and Hong Kong Telecom. The AM/FM applications of GIS in Hong Kong are rather mature compared with other application fields. GIS has also recently been introduced in many new industries, such as real estate, telecommunications, tourism and others. The application of GIS in transportation is an area now under development in Hong Kong. For example, the Government and several companies in Hong Kong have captured the road network and related transport information to eventually help cars and people navigate Hong Kong’s roads and streets.

The Lands Department has developed three GIS databases: the Basic Mapping System (BMS), the Cadastral Information System (CIS) and the Geographical Information Retrieval System (GIRS). These three databases are the most essential GIS data for Hong Kong. The BMS provides the facilities to convert data, update the map library and produce standard format survey sheets. More than fourteen layers of geographical features are maintained in the map library of the BMS. The basic spatial data infrastructure is made up of the following spatial databases: Digital Topographic Map Database (with digital topographic data of 1:1,000, 1:5,000, 1:10,000, 1:20,000), Digital Land Boundary Database (with cadastral maps 1:1,000), Geo-Reference Database (with building names and addresses, site polygons and road central lines with a scale of 1:1000), Digital Orthophoto (with a scale of 1:10,000).

These data form a part of the spatial data infrastructure for ITS development in Hong Kong. For example, the road central line data in the Geo-Reference Database is a very important base for building the geometric part of the road network for all of Hong Kong. This can serve many ITS applications that are related to spatial locations and road networks in Hong Kong, such as car navigation, route planning and others.

A review of the overall status of GIS applications in Hong Kong reveals that most are in the areas of mapping, GIS data management and spatial queries. There is a dearth of high-level GIS applications, such as spatial decision support or decision-making related applications.

Although GIS can provide a number of basic functions for ITS applications, further efforts in research and development are necessary to integrate the existing GIS with ITS. This is particularly true if we aim to develop a comprehensive system for ITS.

3. GIS-related Research and Development for ITS

In Hong Kong, many institutions are involved in GIS-related research and development for ITS. The local government plays a very important role in applying and implementing mature technologies and in developing spatial data infrastructure for Hong Kong to the benefit of the general public. Local companies actively bring GIS-related products to Hong Kong, such as GIS and transport-oriented GIS software. Several local companies are also working on GIS data (mainly road network data) for Hong Kong.

Several local universities are contributing to the fundamental research and development of the technologies. They are also disseminating and transferring the locally developed and overseas-developed technologies to Hong Kong. These universities include The University of Hong Kong, The Chinese University of Hong Kong, Hong Kong Baptist University and The Hong Kong Polytechnic University.

In The University of Hong Kong, GIS-related ITS development is mainly conducted at the...
A Review of Research and Development on Intelligent Transport Systems in Hong Kong

Centre of Urban Planning and Environmental Management, the Department of Geography and Geology, and the Department of Electrical and Electronic Engineering. A center on transport – the Institute of Transport Studies has been established. The Institute aims to define the transport research program as one comprised of mission-oriented activities (Institute of Transport Studies). A study on real-time traffic multimedia Internet GIS has been developed (Yeh et al., 2003). The system will transmit real-time videos and dynamic traffic maps obtained from the traffic that was modeled and analyzed from CCTV images. These images and maps have the ability to provide real-time multimedia traffic information on the World Wide Web. Real-time traffic information on road networks is estimated by advancing the video coding, image analysis and traffic modeling technologies. Such information will help users obtain real-time transport information quickly.

In the Chinese University of Hong Kong, ITS has been developed by various departments. Among them, GIS for transportation is mainly studied by the Department of Geography and Resource Management and the Joint Laboratory for GeoInformation Science (JLGIS). Advanced mathematical methods to resolve the problems of spatio-temporal accessibility in transportation, such as a genetic algorithm for multiple destination routing problems, were employed by Leung (1998). In JLGIS, GIS has been applied to transportation in several areas such as a data model for multi-modal mass transit systems (Yu and Lin, 2000), spatial data handling for ITS (Xiong and Lin, 2000) and agent-based pedestrian simulation (Shi and Lin, 2003).

In the Hong Kong Baptist University, the study of GIS-related transport is mainly conducted at the Department of Geography. The emphasis of their research is on transport models. A spatio-temporal data model to support activity-based transport demand modeling in a GIS was developed (Wang and Chen, 2001). The proposed mobility-oriented spatio-temporal data model can conceptualize the spatial and temporal interactions of travel and activity behavior based on the concept of mobility.

In the Hong Kong Polytechnic University, GIS-related ITS studies are mainly conducted in the Department of Land Surveying and Geo-Informatics (LSGI) and in the Department of Civil and Structural Engineering (CSE). The university provided HK$8 million to set up a Research and Development (R&D) Program in Transport Information Systems (TIS). The R&D program aims to develop basic prototype tools to solve selected ITS issues. The long-term target is to make a significant contribution to transportation policy-making and infrastructure development in Hong Kong. Currently, there are four sub-projects under this program: (i) the development of a multi-mode public transport query and guiding system, (ii) a high precision in-vehicle navigation unit for fleet management, (iii) a real-time parking inquiry system, and (iv) the integration of GIS with the annual traffic census for transport information system applications. The University is working on data model of road networks in GIS, a mobile GIS solution for transport users with a higher response time, vehicle speed on the Internet for road users, a GIS-based navigation solution and, finally, the integration of GIS with the Annual Traffic Census for TIS.

3.1 Data Model of Road Networks in Hong Kong

The application of a GIS-related ITS is very much dependent on its fundamental basis – spatial data infrastructure. The data set for ITS, particularly transport information-related ITS, can include the following three types:

- Dynamic transport information, such as the traffic flow at each specific road section within an entire road network, the turning information for each road junction, etc.
- Spatial location information on road network and topological relationships between the elements of the road segments.
- Static transport-related information, also
called point-of-interest (POI), such as the location of a traffic sign or a patrol station.

Within the framework of transport-related information, GIS is used as a tool to present the latter two types information – the spatial location of road networks and the relationship between the elements of the road network. The first type of information – dynamic transport information – can be handled in a separated database and linked with GIS. Of these data, a road network data model in GIS is the core for the second and third types information to be handled in a GIS-related ITS.

A GIS data model of road networks for transport applications in Hong Kong was designed and developed. This model design possesses the following characteristics, which applies to the design of linear GIS features.

Dynamic segmentation: a spatial intersection of linear features in GIS, which is a key technique for describing transport-related features.

PolyLine format was applied to the Geo-object model. Here, a third dimensional co-ordinate – a dimension that provides linear measurement (m) – was applied and in the same time that was synchronization with geodetic coordinates and come with the coordinates (x, y, m).

Additional data items for future spatial queries, such as a "geo-reference number", were applied.

The basic elements of the designed model cover the following three categories: (i) spatial districts of transportation; (ii) road network elements and relationships between the elements, and (iii) POI related to the network and particularly to the transport application.

The spatial districting information in the model was used to demarcate the traffic generated and/or to divide Hong Kong’s land area into sub-spatial areas for which transport statistics were gathered. The sub-spatial areas include Districts, Comprehensive Transport Study (CTS) Zones, Base District Traffic Model (BDTM) Zones, Streets, Street Sections and Street Segments.

The basis elements for describing the road network are road segments and nodes. These elements were extracted from the basic topographic maps, such as a basic topographic map at scale 1:1000 for Hong Kong.

The topological relationships between the elements were defined. For example, the relationship between a road segment and component nodes were specified as a road segment that is defined by a “From_Node” and a “To_Node”, and this also defines the direction of a road segment. Furthermore, a directed road segment separates a district into a left and a right side.

A road network model serves as a base, and other related information, such as POI, can be added to this base. For example, car-parking information can be added to the road network and come with a
result of car parking information system. Figure 2 shows the application of the designed road network model, where the road network and car parking places are illustrated.

3.2 Mobile GIS Model for ITS

Mobile technologies, such as a mobile computer, mobile phone, PDA and other mobile devices, provide an efficient solution for the transport user, for either transport information inquiries or navigation. This can serve both individuals and users of vehicles. One of the major problems for a mobile user, at the current bandwidth of mobile telecommunications, is that the waiting time is too long, especially when a mobile user wants to access spatial information with large data volume, such as a road map.

This project aims to develop a mobile GIS technology to reduce response times and improve the accuracy of information searches, particularly for transport-related applications.

Mobile GIS is an integrated technology combining mobile computing, Internet, GIS and location-based services. One of the major obstacles to its development is the lower response speed that is due to the immaturity of current database designs and to limited bandwidths in mobile telecommunications. In view of this, a new mobile GIS data model is proposed, which is based on a mobile view of spatio-temporal and attribute modeling. Correspondingly, a dynamic database is designed for the implementation of the mobile GIS model. It is a proactive approach, continuously updating the related spatio-temporal and attribute data according to the real location of the subscriber as well as the current time. The performance of the mobile GIS and corresponding dynamic database is evaluated for a wireless GIS web environment and on-line queries (as shown in Figure 3). In a commonly used GIS, the response time increases from 4 seconds to 12 seconds, when the number of the objects in the database increases from 10,000 to 70,000. While for a same case, by using the designed Mobile GIS model and corresponding dynamic database, the response time remains at 4 seconds. The result demonstrates that, using the proactive approach, the response speed increased by between 25% and 75%.

Here is an example of an application using the proposed Mobile GIS model for transport-related activities. A salesman needs to go to several stations. To save time, he needs to find the best path to travel to all of them. Such an operation is based on a mobile computer and requires a quick response time. The operational processing procedure is shown in Figure 4.

This research provides a transport user with a more efficient solution – one with a faster response time – by a newly mobile GIS model and corresponding dynamic database solutions. The con-

![Figure 3: A comparison of the performance of a normal database in GIS and the proposed Mobile GIS model with a corresponding dynamic database.](image)
Contents in the dynamic database were automatically updated to reflect real situations that a transport user might encounter. In addition, the automation of data updating ensures that transport users are provided with the latest information. The accuracy of the data can thus be guaranteed.

3.3 Real-time Vehicle Speed on the Internet

Traffic congestion is a major problem in Hong Kong. Although the Transport Department has created a web site connected to a series of video cameras, this can only show real-time traffic conditions by providing images of road junctions or of several selected locations on the highways. The ability to dynamically access information about real-time vehicle speeds on the overall road network of a city is a service that is very much needed by local road users.

A study to develop a system for providing real-time vehicle speeds on the Internet has been conducted. An user interface of the system is developed with which a user can access information about vehicle speeds on different road networks. A driver can thus choose to use the road

Figure 4: (a) shows the web site Home Page of Path Finding, (b) Select Current and Destination District; (c) shows the current location (in green) and the tie points (i.e., the stations to be passed) (in yellow); (d) shows the optimized path (in red) and the final station (in blue).
A Review of Research and Development on Intelligent Transport Systems in Hong Kong

over which he or she will be able to drive more quickly, and avoid congested roads.

In this study, vehicle speeds were examined on the road network of a pilot study area – Tsim Sha Tsui, one of the major tourist areas in Kowloon. Different colors of the road network indicate different vehicle speeds – blue, grey and red represent high, medium and slow speeds, respectively. By clicking a cursor on a particular road section, the specific speed range (such as less than 30 km/h, or between 31 km/h to 60 km/h, or larger than 61 km/h) will be given by the system.

This system is an integration of GIS, Internet technology and image matching methods. GIS is used to manage the digital map of the road network of the study area, as well as other related attribute data, such as speed. The Internet is used as a tool to disseminate information about vehicle speeds to users, who can access the real-time information from their own device, either a PC or a mobile device, such as a mobile phone. Image-matching technology, specifically the block-matching algorithm, is applied to detect the same car at different time spots, based on what vehicle speed on each road section can be detected.

3.4 GIS-based Vehicle Navigation – A Map-matching Solution

A global positioning system (GPS) is the most popular positioning system for vehicle navigation in ITS. However, a signal blockage problem may occur when the vehicle is passing through tunnels, area with tall buildings, narrow streets, or with dense tree cover. A test in Hong Kong shows that in a large part of Hong Kong the reception for GPS signals was poor. Furthermore, a reflection effect may exist when the satellite signals are bounced off by reflective surfaces, such as glass, metal, concrete, etc. Therefore, several car navigation technologies have been proposed, such as a signpost system, a dead reckoning (DR) system, a GPS plus inertial systems and a map-matching solution.

Map matching is a GIS-based solution for ITS to enhance the level of accuracy of vehicle navigation. Digital maps in GIS are used to support improved positioning accuracy. Map information can be incorporated directly into the estimation process of a GPS system when there are an insufficient number of visible satellites (Brown, 1992).

Among the conventional map-matching algorithms, the probabilistic algorithm derived the map-matching model based on rigorous statistical methods. Hence, the driver is provided with accurate information on the vehicle’s location – it is the most feasible map-matching algorithm for ITS. It is also noticed that the accuracy of the digital map is significant. As a result, a theoretical model will be proposed in this study and this model will integrate the probabilistic algorithm and a positional error model in GIS to enhance the performance of the map matching.

Two approaches were used in the modified probabilistic method: the simulation and the analytical approaches. The simulation approach is simple. It repeats the existing probabilistic method several times with different uncertain road networks to compute the probability of the vehicle traveling along each road segment. The analytical approach integrates a positional error region for a line segment in GIS with the existing probabilistic method. However, there exist different positional error region models for a line segment in GIS, such as the E-band, the $\varepsilon$-band and the g-band. The details can be found in Shi (1994).

The error region for a road segment is determined based on the error regions of two nodes of the road segment. We defined the error region of the sensor-detected vehicle location in which the vehicle location is considered as a point. Hence, the two nodes of the road segment can be defined in the same manner. That is, an error region of each node is defined as a rectangle containing the error ellipse (confidence region with a predefined
probability) of the node (Figure 5). Then, an error region of the road segment is defined as a rectangle, which contains the error regions of the two nodes of the road segment. In Figure 5, the rectangle bounded by the thick line is the error region of the road segment.

In this study, we further developed the existing probabilistic map-matching method in which the sensor errors are considered. Our modified probabilistic method considered both the sensor errors and the positional errors of a road network. This can increase the accuracy of the map matching in vehicle navigation.

3.5 Integration of GIS with the Annual Traffic Census for TIS

In Hong Kong, in the middle of each year the Annual Traffic Census (ATC) report (Transport Department, TD, 1994-2001) is used to present the statistical results of traffic data collected at the automatic traffic-counting stations. Over 1,500 counting stations were operated in 2001. The ATC data are stored and manipulated in MS Access database for better protection and management. Object-oriented modeling is used to encapsulate the ATC data to make it easier to retrieve for short-term traffic forecasting as required in the Transport Information System (TIS). Integrating TIS with GIS would certainly help facilitate pre-trip planning and road traffic management on Hong Kong’s transport network. The integrated modeling approach for forecasting travel time could generate the short-term predicted travel time database that is required for fleet management and for the TIS being developed by the Hong Kong SAR.

On the basis of the existing and predicted Annual Traffic Census (ATC) data, a short-term traffic-forecasting model was developed for integration with GIS in order to manage queries on road networks and the spatial distribution of traffic flow. This is a further development based on a number of existing studies, particularly on the subject of annual traffic census, traffic forecasting and GIS modeling (Shi and Pang, 2000). The traffic flow simulator (TFS) developed by Lam and Xu (1999), a flexible route choice model, has recently been extended (Lam et al., 2002) to predict travel time and traffic flow by the time of day in the near future. The travel time prediction is based on static network data, historical data and real-time traffic data. The proposed system architecture of TIS is shown in Figure 6.

It is possible to provide travel information on a real-time as well as a predicted basis and distribute it to the local travelers via different popular media of communications, such as mobile phones, television, radio, in-vehicle displays and new Personal Digital Assistants (PDA). With more travel information in real time or in the near future (e.g., the next 15 minutes), local travelers will be able to better plan their trips, in terms of choosing routes or departure times.

Figure 7 shows a part of the road network on the Hong Kong Island that has been converted from an existing strategic transport model, called the CTS-3 (Third Comprehensive Transport Study) model. This CTS-3 network model is also
A Review of Research and Development on Intelligent Transport Systems in Hong Kong

concurrently the source model for developing the GIS network model in the TIS prototype. The GIS road network model serves as a basis for presenting the ATC counting locations, and provides information on travel time and routes at peak hours, as shown in Figure 8.

Development of an integrated system with ATC and GIS in Hong Kong will facilitate data retrieval and access transport-related information, especially the spatio-temporal distribution of the data. This system can be extended to incorporate the enhanced Traffic Flow Simulator (TFS) for providing short-term traffic flow and travel time forecasting in the Transport Information System (TIS). On the basis of the proposed system architecture and linkage, a prototype TIS platform is being developed to assess the benefits/performance of TIS in a pilot study area – Hong Kong Island.

4. Summary and Future Outlook

4.1 Summary

In this paper, a review and analysis of the research and development of ITS in Hong Kong from a GIS perspective was provided. First, an outline of ITS development in Hong Kong was described. Here, three ITS application areas, an ITS development framework and eleven ITS development issues in Hong Kong were summarized. Based on a feasibility study for the development of ITS in Hong Kong, GIS was recognized as a core technology for the future development of ITS in Hong Kong.

Second, the technology of GIS and a summary of the GIS functions that can serve ITS were depicted. They were followed by a summary of the applications and of the development of GIS in Hong Kong. Here, the spatial data infrastructure constructed by the Hong Kong government was considered an essential basis for ITS and TIS, although it needs to be developed much further. The GIS application areas in Hong Kong have been widely extended to many new areas, such as real estate, telecommunications, tourism, transportation, etc.

Third, GIS-related research and development activities in Hong Kong were outlined by several examples of the selected areas, including a GIS data model, mobile GIS, Internet GIS, map matching-based navigation and integration with transport census data. Some of these were jointly developed with local industry, and have been applied in Hong Kong. The GIS data model for

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Figure 6: System Architecture of TIS in Hong Kong
road networks was developed as a basis for ITS, and further thematic applications, such as car parking information, can be built on top of this base to lead to many ITS applications that are related to road networks. The mobile GIS solution for transport users was developed with a higher response time. Users can thus access GIS-based transport information at rates of higher speed and accuracy. The study of vehicle speed on the Internet can provide transport users with a current speed distribution of the road network. This can be accessed either via a PC at home or via a mobile device at a vehicle, such as a mobile phone. A GIS-based navigation solution, a new map-matching method, was proposed with the aim of improving the accuracy of car navigation. Finally, an integration of GIS with the Annual Traffic Census for TIS is under development with the target of enhancing pre-trip planning and road traffic management on Hong Kong road networks. A prototype of the Transport Information System (TIS) is being developed with the use of a short-term traffic forecasting model based on the existing and predicted Annual Traffic Census data, and with the integration with GIS for managing queries on the road network and spatial distribution of traffic flow.

4.2 A Future Outlook

A number of issues needed to be further studied and developed within the framework of GIS for ITS. These include both macro and specific issues, and both technological and institutional issues. For the macro issues, we need to consider a spatial data infrastructure for ITS in Hong Kong that would include spatial data standards; policies on
A Review of Research and Development on Intelligent Transport Systems in Hong Kong

the sharing of data among different data owners and users of ITS; investments in spatial data, the cost and price for ITS data; the cost of using ITS products on the Internet – free or full cost recovery; and the management of spatial information for ITS.

A GIS spatial data standard for ITS is essential, since this will be related to future data sharing and the efficient use of the data among various ITS users – either government departments or the private sector, individual or group users. Data sharing among various institutions is another problem to be resolved in future ITS and GIS development. This is not only a technical issue but also, and more importantly, an institutional issue. This problem has been facilitated by data exchange standards. The following aspects, for example, should be considered in developing GIS spatial data standards for ITS: map projections and coordinate systems, feature and attribute classifications, relationship classifications, feature representations, quality specifications, logical data models and structures and others. Since many users of GIS spatial data will cover geographic locations in both Hong Kong and southern China, the consistency of the standards between Hong Kong and mainland China should also be considered.

Data quality is recognized as a fatal issue only when GIS data is used for applications, especially for high-level GIS applications such as spatial decision support. This definitely applies to ITS integration with GIS. The essential issue in data quality is to find a practical solution to access GIS data quality. Another problem to be resolved is how the quality indicators in a database for metadata are to be facilitated.

In general, it can be concluded that, as a spatial data and information management technology, GIS can support ITS in spatially related transport information manipulation, analysis and modeling. The integration of transport modeling with new technologies, such as GIS, GPS and mobile communication, is a new trend for future studies.

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