Proceedings of the Eastern Asia Society for Transportation Studies, Vol. 5, pp. 1025 - 1039, 2005

LATEST TECHNIQUES IN TRANSPORT FORECASTING AND MICRO-SIMULATION WITH EXAMPLES FROM AROUND ASIA

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Abstract: Current developments in transport forecasting models and computer graphics provide planners, engineers and decision-makers with powerful tools to analyse travel behaviour. This paper will review the application of the latest modelling techniques using the Cube software package, developed by Citilabs. Cube is one of the world's leading travel forecasting software packages, and the first to develop a fully integrated approach to travel demand forecasting, from "traditional" 4-stage models to Micro-Simulation, together with Freight, Land-Use and Environmental modules.

Using actual examples of models developed in several Asian cities, the paper will explore the application of Cube to multi-modal forecasting and micro-simulation modelling. We will highlight some of the key features of the modelling of travel behaviour in different cities around the Asian region, using case studies in Thailand, China, Hong Kong and Vietnam.

Key Words: Cube, Modelling, Micro Simulation, Forecasting,

1 THE CUBE TRANSPORT PLANNING SYSTEM

1.1 Introduction

Cube is a transportation planning software system designed for forecasting of passengers and freight movements. Cube offers advanced and flexible tools for the generation, distribution, mode split and assignment of personal and freight transport as well as detailed analysis of environmental issues. The latest module added to the planning system is Cube Dynasim, offering micro simulation of private and commercial vehicles, buses, trams, light rail, motorcycles, pedestrians and bicycles. The Cube system offers complete integration between the various functional libraries with efficient tools for handling all data in a user friendly and market standard software package.

The Cube functional libraries include:

- Cube Land for integrated transport and land use planning (forthcoming)
- Cube Voyager for multi modal person travel.
- Cube Dynasim for multi modal micro simulation.
- Cube Polar for environmental assessment.

The demand forecasting element has been developed based on legacy products Trips, TranPlan and TP+ that have been the world's top transport planning tools for decades. These systems can also be run under Cube.

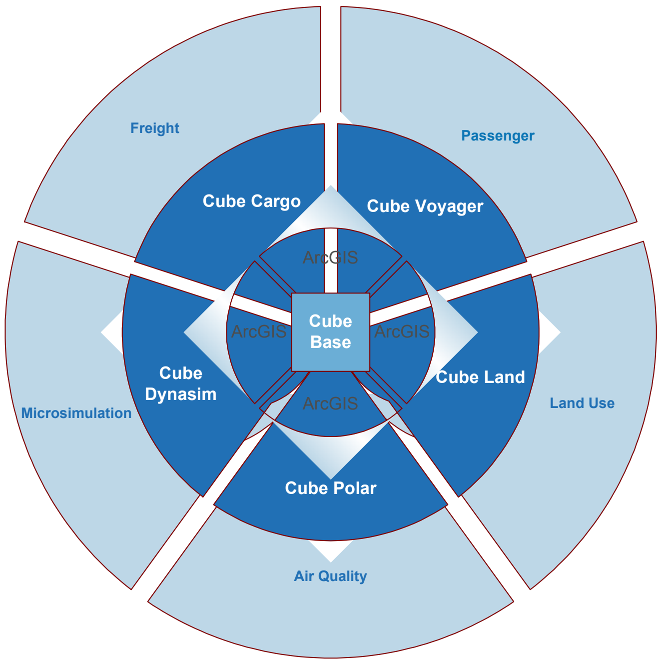

Figure 1 Cube Family Members

The Cube libraries are supported by state-of-the-art interfaces for handling the application, the data and the scenario testing. Cube allows for the easy incorporation of other software including industry standard ArcGIS from ESRI and various Microsoft Office programs. Third party software may also be readily incorporated into the system.

1.2 Examples of Cube Applications

The Cube transport planning system can be used for undertaking a wide range of planning tasks. It is used in transport planning departments, universities and other research institutions and by traffic and transport consultants in more than 70 countries worldwide.

To illustrate the application of Cube to different transport problems around Asia, we present some case studies to illustrate how the software has been applied for modelling of different situations in Bangkok; in Hong Kong and the Pearl River Delta; in Beijing; and in Hanoi, Vietnam. In each of the cities there are different challenges to the transport planner, and the application of Cube has been adapted to allow the characteristics of these places to be reflected in the modelling. The models have all been developed by MVA, the largest specialist transport planning consultancy operating in Asia.

2 BANGKOK MODELS AND APPLICATION OF CUBE

2.1 Overview of the Model

The application of Cube in Bangkok dates back to the mid-1990s when a comprehensive 4-Stage Multi-Modal model was built for the Bangkok Metropolitan Region on behalf of the Office of Traffic and Transport Policy and Planning (OTTPP), previously known as OCMLT.

A modified version of this model is still used by many Government Agencies and consultants in Thailand today using the Cube TRIPS software.

MVA, through its extensive work in Bangkok on both highways and public transport studies, have further developed these models using Cube into a comprehensive 3 tier forecasting model structured as shown in Figure 2 below.

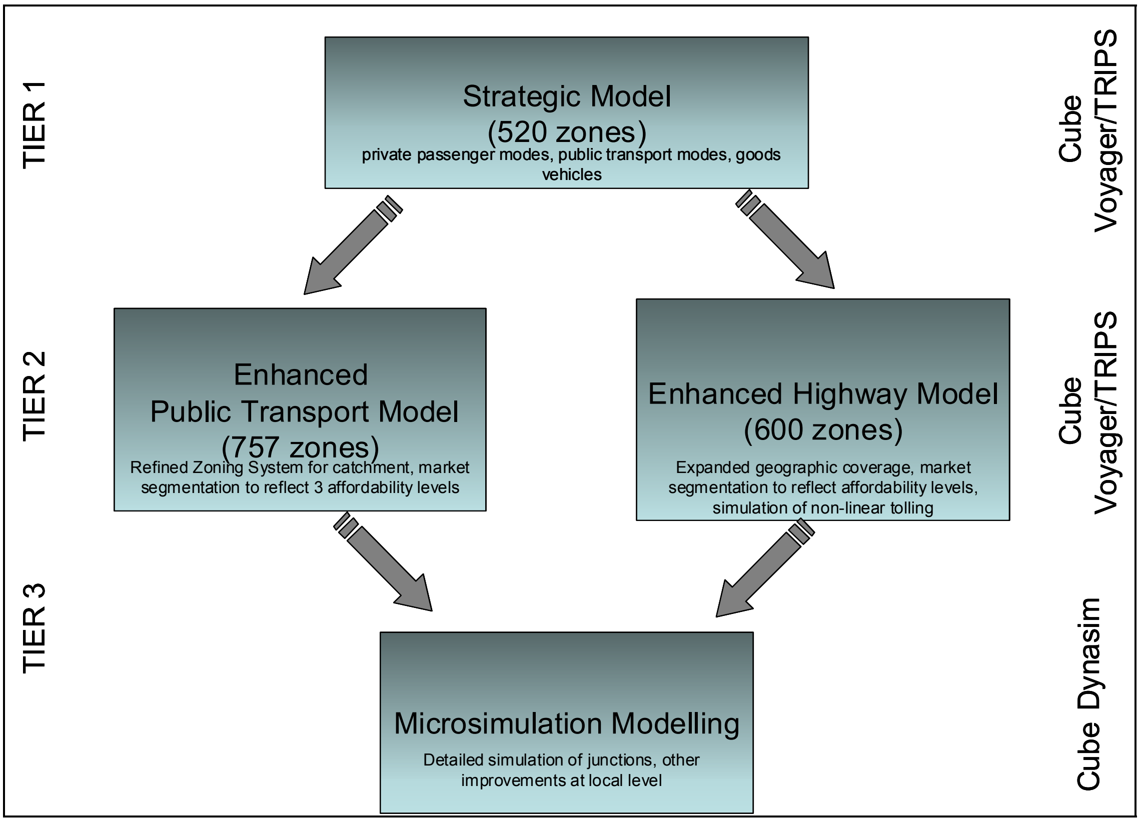

Figure 2 Cube Model Structure for Bangkok

2.2 Details of the Bangkok Strategic Model Structure

Tier 1 of the structure is a conventional strategic 4-stage model which cover the whole of the Bangkok Metropolitan Region (represented by 520 zones) and models cars, taxis, motorcycles, private Car, Taxi, Motorcycle, Private Buses, Commercial Trucks, Franchised Bus, Minibus and Van Services (air-con / regular), Mass Rapid Transit, Ferry, Local Commuter Rail.

The outputs from the 4-stage model are then passed to the Tier 2 'enhanced models' for Public Transport and Highways. The networks for these models are shown in Figure 3 below, which also shows how the thematic mapping in Cube can be used to represent zonal attributes.

The enhanced Public Transport Model includes a refined zone system with a 757 zones which separate out the walk-in from the ride-in catchment along the MRT lines. In addition, the Cube model includes market segmentation according to low, medium and high income affordability levels.

The enhanced Highway Model includes additional strategic toll roads, a refined zone system (600 zones) and market segmentation featuring differential affordability levels for cars and also modelling as separate categories motorcycles, trucks and buses as a preload. The model also features an ability to include ramp-to-ramp tolling by use of Cube Voyager's scripting language facility.

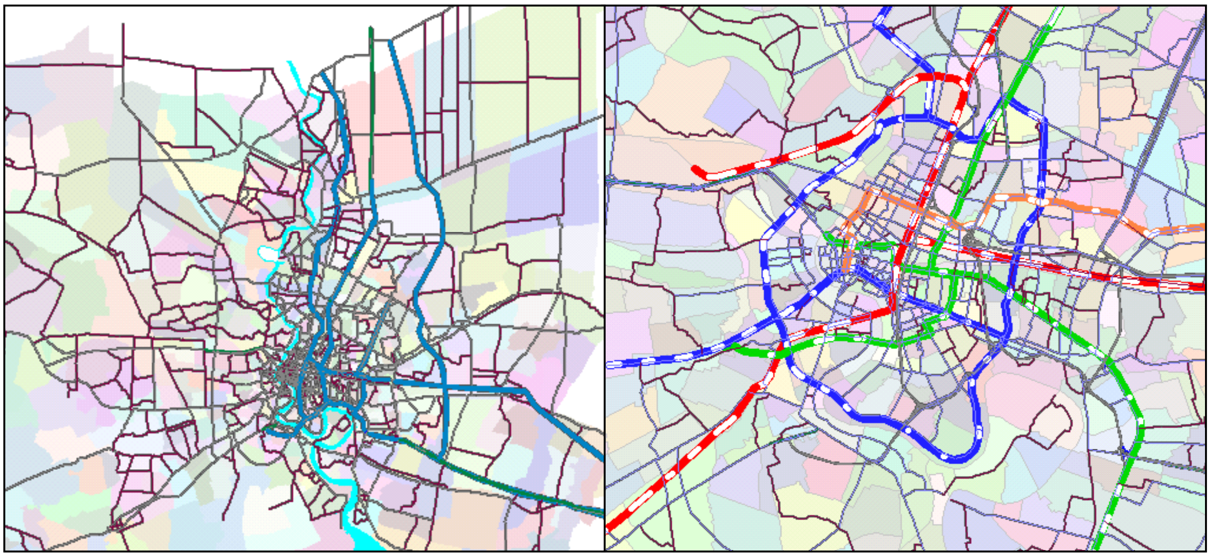

Figure 3 Bangkok Network (Highways and Public Transport) as Represented in Cube Graphics

The highway model is set up using multi-user class assignment. Motorcycles are modelled in Cube using a dedicated user class with separate value of time, vehicle operating costs and other characteristics. Motorcycles are banned from the expressway network using a simple facility in Cube which allows the user to include or exclude specific vehicle classes from a particular category of road.

2.3 Micro Simulation Modelling in Bangkok

A third tier has been introduced for the micro simulation modelling using the Cube Dynasim module. Cube Dynasim performs microscopic, stochastic and event based simulation. The simulation produces vehicle movement on the network according to realistic driver behavior based on statistical observations. Cube Dynasim has tools for simulation, data analysis and visualization.

One of the key features of the Cube system is that the passenger forecasting for the strategic model and the micro simulation are fully integrated. To create a micro simulation model, the user simply draws a polygon around the area of network to be modeled in more detail, and then exports this to Cube Dynasim. This exporting process includes details of junction coding (such as lane definition and signal phase details), trip matrices (in the Bangkok application car/taxi and goods vehicle matrices were exported) as well as public transport line coding. Figure 4 below illustrates an area of the Bangkok model that was exported in this way, with the resulting simulation view seen in basic 3-dimensional output in Cube Dynasim.

The graphical interface displays the results as the actual movement of vehicles in animation and provides plots of a variety of commonly used evaluation statistics such as vehicle time, travel time, speed and queuing.

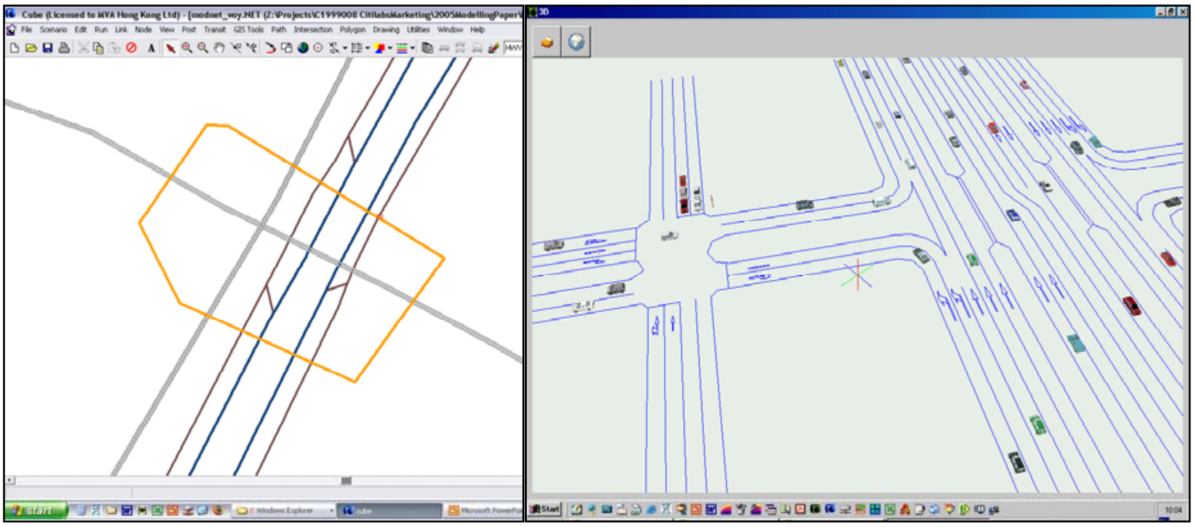

Figure 4 Exporting from Cube Voyager to Cube Dynasim

In Bangkok and any another city, observations of road traffic will show that flows vary from one day to the next and fluctuate around an average value. These fluctuations can have an important impact creating a very unstable situation. One of the key features of the Cube Dynasim application is that a number of randomized simulations have been produced showing not only the average situation, but also day-to-day changes in flow. This was done using a single button in the program.

Different scenarios can be easily set-up and tested using the Cube Dynasim software. In the Bangkok application, different junction configuration and flow (for different years) were analysed. Testing of different scenarios is made easy through the Cube Dynasim scenario management tool enabling the user to select the components they require for a particular scenario.

The simulation scenario is run with the click of button and the user can then animate and view the simulation in 2- or 3-dimensions. The 3-dimensional animation shown in Figure 5 below is directly from Cube Dynasim with additional 3D rendering included in the background file. The animation can be exported to a file that clients and others can view interactively at their own leisure by panning around, zooming in and out and even becoming ‘drivers’ within the vehicles themselves.

Figure 5 Cube Dynasim 3-Dimensional Animation

2.4 Summary of the Cube Application in Bangkok

The above section has provided an overview of the application of Cube in Bangkok. By providing a full integrated transport planning system, Cube is very suited to the multi-tiered approach to modelling where data are passed between different tiers in the process. It has also been shown that Cube can handle the modelling of all scales of study from the very strategic (Bangkok Metropolitan Region) through to the very fine details of some local intersections in Cube Dynasim. Indeed, it has been successfully applied in recent toll road studies where effects of different toll strategies have been tested in the strategic models, whilst impact of new parallel routes on toll road traffic has been animated in Cube Dynasim.

One possible refinement in the future would be to refine the forecasting of goods vehicle movements within Bangkok which could be done through Cube Cargo which provides a commodity-based approach to goods vehicle modelling. It represents transport logistics nodes where long-haul goods by different modes (road, sea, rail, air) are then consigned to trucks for distribution in the city. Through the common interface of Cube, it would be possible in future to refine the existing passenger-based model for Bangkok to take its goods vehicle matrices from Cube Cargo.

3 HONG KONG MODELS AND APPLICATION OF CUBE

3.1 Overview

MVA has been working in Hong Kong since 1977, and since that time has built a number of models covering the then Territory, and now Special Administrative Region (SAR) of Mainland China. The earlier models were focused on modelling intra-Hong Kong travel, but since opening up of the border and loosening of individual travel restrictions, the cross-boundary element of travel is now important.

As such, the Hong Kong models are now developed as part of a hierarchical structure with the top level being the Pearl River Delta area (the “Cross Boundary Model” - CBM), followed by a strategic 4-stage model of the Hong Kong SAR and below that more detailed models for public transport and within that for railway assignment. In addition, there is a model for refining the modelling of route choice for vehicles through three tunnels across the Hong Kong harbour. The models are connected together using the Cube interface which allows the user to set up the models in a flow chart type format. The models have been extensively applied for highways and public transport applications for both government and private sector clients.

3.2 Cross Boundary Model (CBM)

The model comprises three key components for demand forecasting, network building and modal split. Total cross boundary demand was forecast using regression models and the application of growth factors based on land use and socio-economic data. The demand was split into that from Hong Kong originating demand, and that originating from Mainland China.

The CBM networks were built using Cube and as a regional-level model only cover the main highway links. Public transport services included in the model include:

- The Kowloon Canton Railway (KCR) services from the Hung Hom terminus in Kowloon to Guangzhou and beyond ("through train")
- The KCR service from Hung Hom to the boundary at Lo Wu ("boundary train"); in the future there will be also a service to a second border crossing at Lok Ma Chau
- Direct bus services
- Direct ferry services
- Local public transport services feeding at both sides of the boundary to the cross-boundary services.

In addition, special links were needed for the immigration points which allow a delay to be placed on these to reflect the processing time. As the capacity of these points is limited in terms of processing capacity, the model is able to reflect this and a cap is applied if the demand exceeds the available capacity.

The CBM uses a multi-modal logit model set-up within Cube to allocate trips to the cross-boundary modes based on the lowest generalized cost for cross-boundary travel for each mode. The generalized costs for alternatives are generated using a bias path procedure. The modal split itself is hierarchical as it initially splits the total demand into the main modes of bus, ferry, through train and boundary train. The rail demand is then further split into the individual boundary crossing of Lo Wu, Lok Ma Chau or any other future point.

3.3 Domestic Models

The domestic models comprise a 4-stage model and more detailed models for public transport, and within public transport for rail. The figure 6 below shows how these have been set up in Cube using the flow-chart Application Manager.

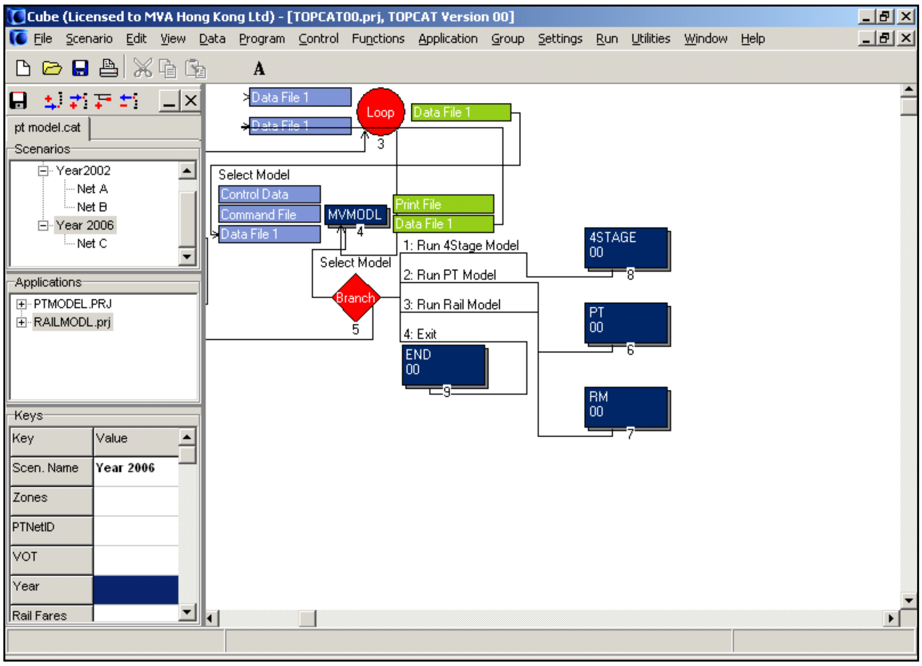

Figure 6 Structure of the Hong Kong Domestic Models in Cube

The figure shows how the main applications of the 4-stage model, public transport (PT) model and Rail Model (RM) are represented by the ‘process boxes’ shown to the right of the screen. Each of these are run in turn. The process is an iterative one that needs to be re-run until equilibrium is reached between the demand and supply sides. Cube allows the user to set up a conditional loop (the red circle in the figure above) in which a convergence criterion can be entered. The red diamond shown above is a ‘branch’ which is followed through to subsequent reporting of key statistics, but only if the model has satisfied the convergence criteria.

The model is run for different scenarios, which can be set up using the Scenario Manager tool in Cube which is shown on the left hand side of the screen in the uppermost of the three sub-windows in Figure 8 above. For the Hong Kong model as shown, different scenarios were set up for the years (2002 and 2006) and for different network scenarios (A and B). The bottom left-hand sub-window shows ‘keys’ which contain values for parameters associated with a particular scenario. In this particular model this includes value-of-time, public transport fares and other parameters. When the user selects a particular scenario, the value relating to this scenario is shown in the keys.

Input data can be easily checked using features available in Cube Graphics such as thematic mapping. Figure 7 below shows how population data can be seen both visually and in tabular format.

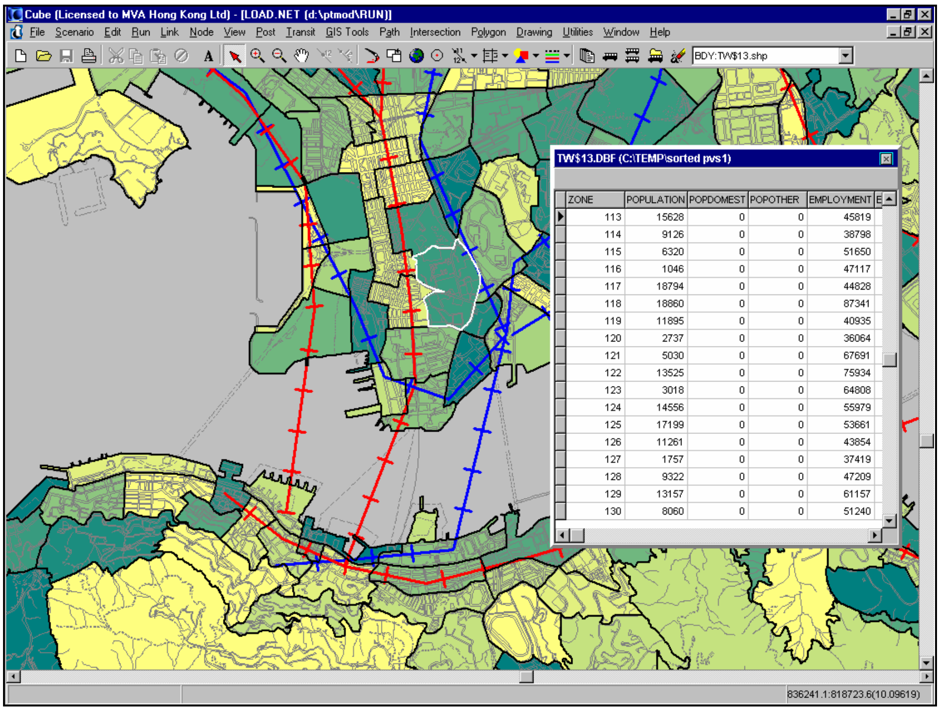

Figure 7 Thematic Mapping of Population by Zone in the Cube Hong Kong Model

The **4-Stage Model** follows the standard structure with components for trip generation, distribution, modal split and assignment. There are some refinements such as a trip generation model that comprises sub-models of income and vehicle availability, all of which are set up using the flow-chart interface earlier. The model produces and assigns trip matrices for road traffic and for public transport. However, for more detailed analysis sub-models have been developed to refine these.

As mentioned above, for public transport there separate sub-models for public transport and rail. The **Public Transport Model** sub-divides the zone system of the 4-stage model based on localized catchments of stations and bus stops, and then provides a detailed analysis of sub-mode choice within bus and between the two rail operators (KCRC and MTRC). Cube is set-up to build biased paths to calculate the generalised costs of various sub-mode alternatives namely taking bus only, bus with Rail, and within Rail (between the two operators). Cube builds multi-route paths and allows for mixing of fare structures such as station-to-station for rail, and boarding fares for buses. Total public transport demand is then apportioned to and subsequently assigned to the choices on a relative cost basis.

The **Rail Model** then further analyses the rail demand to represent the complexity of choices within the rail network. With a total of 5 suburban MRT lines and 2 KCR lines, there is considerable route choice available between station pairs and the model needs to fully evaluate the choices taking into account the usual components of waiting time, travel time, interchange time and fare paid. This is done by building bias paths for the different alternatives and splitting the demand between these.

Figure 8 shows the public transport network as set up in Cube, with a GIS background of the physical terrain.

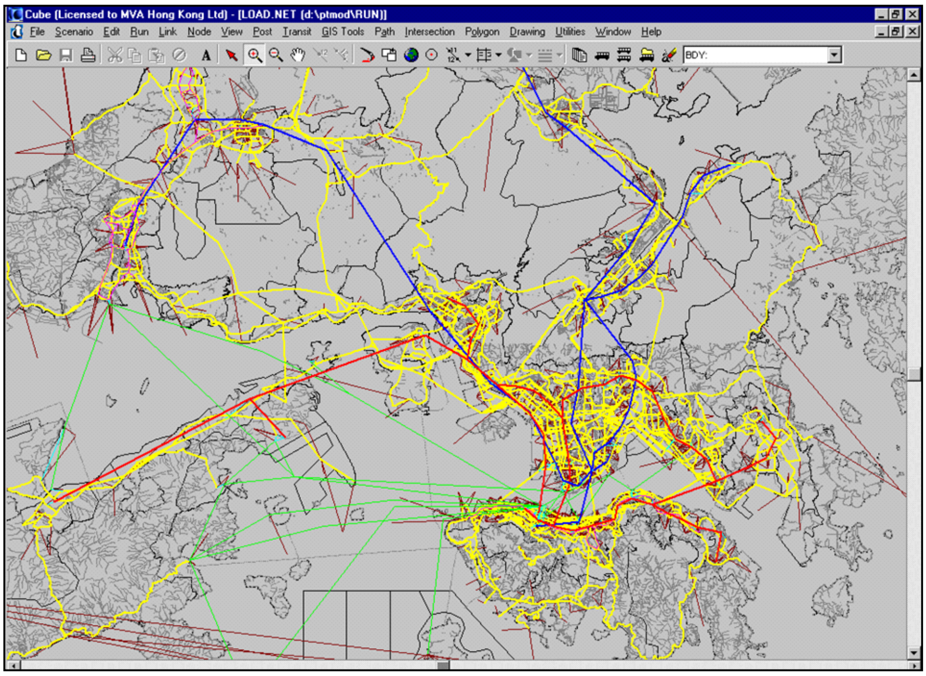

Figure 8 Hong Kong Public Transport Network in Cube

A further sub-model in the Hong Kong hierarchy of models is that of routing choice for cross-harbour vehicle traffic where the available options are the Cross Harbour Tunnel (CHT), the Eastern Harbour Crossing (EHC) and the newest tunnel, the Western Harbour Crossing (WHC), all having significantly different toll charges. The **Route Choice Model** takes the total highway demands from the 4-Stage model and determines the market shares of cross-harbour traffic between the competing facilities based on their respective toll levels, traffic conditions and generalized cost of each for all cross-harbour origin/destination movements. The splitting of demands is undertaken by a logit model which is defined in Cube and iterates until a converged solution is obtained. The model has been calibrated to the observed split in traffic between the three tunnel facilities.

3.4 Summary of the Cube Application in Hong Kong

In a similar way to the Bangkok models, a tiered structure of models has been developed for Hong Kong comprising a cross-boundary model, conventional 4-stage model and then more detailed models for public transport and rail, and for route choice of vehicle traffic between the cross-harbour tunnels. The Cube integrated system is used to pass data between the different layers in the hierarchy. The models have been applied extensively on highways and railway planning projects.

In addition, various local area models have been developed for specific development projects in various part of the Hong Kong SAR. These are cordoned from the main models, a process which is automated in Cube by simply drawing a polygon around the area in the larger model to be exported. In a similar way, micro simulation models using Cube Dynasim can be developed, as was illustrated for Bangkok in section 2 above.

4 BEIJING MODEL APPLICATION OF CUBE

4.1 Overview

MVA developed a traditional 4-stage model in the early 1990s for the Beijing Urban Transport Study using Cube Trips. This was built from scratch and using a compilation of data including household interview survey, driver's diaries and taxi data. These were used to build trip matrices and calibrate relationships that then fed into a 4-stage model.

The model was subsequently been updated in the mid-1990s and again in the year 2000, each time new count and interview data being used to update the information on travel demands and patterns. The model has also been updated to operate with the Cube Graphics interface providing GIS-quality graphics presentation. In addition, Cube features a Chinese language interface as shown below.

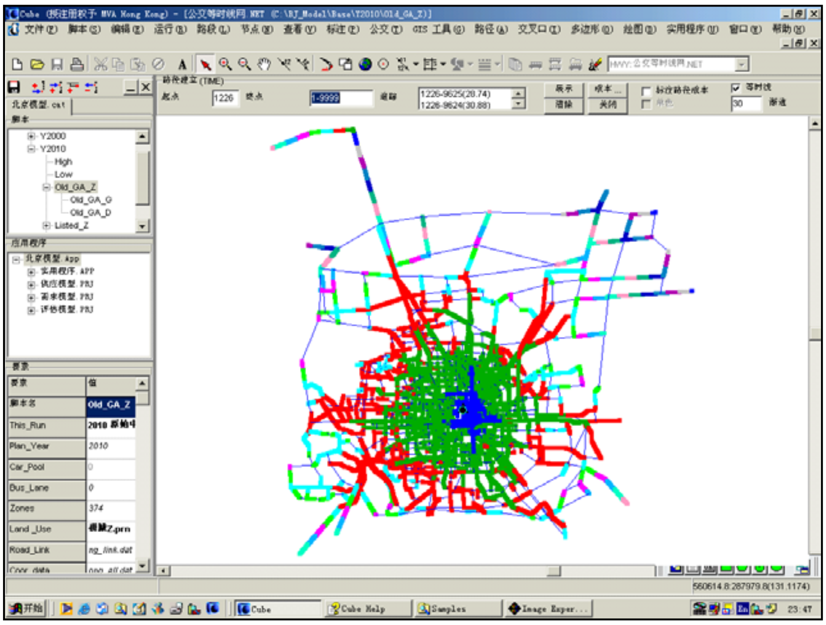

Figure 9 Cube Chinese Interface and Public Transport Isochrones

4.2 Modal Split and Treatment of Bicycles

At the topmost level of the current Beijing Cube model is a trip generation and distribution stage which is split into two categories – car and others. The 'others' trips are then further split using a logit function into which costs for the alternative modes are fed to allocate trips to public transport, taxi, worker's coach and to bicycle. The public transport trips are then further split into metro (rail) and bus.

Bicycles currently represent about one-third of the total daily tripmaking in Beijing and so it is important to accurately reflect them in the modelling process. Cube allows these to be defined as a separate mode, and they are allocated an observed passenger car unit (pcu) factor of 0.2 reflecting the amount of roadspace that they typically use. Bicycles may either use dedicated bicycle lanes (which can be physically segregated from other traffic or just be divided through road markings) or be part of the mainstream traffic flow. The dedicated bicycle lanes are handled in Cube by defining them as a separate link class which restricts the use of these links in the assignment to bicycles; in addition, separate bicycle-related speed characteristics based on local observations are attached to these links. The Cube model features a mechanism to check the volume to capacity ratio of the dedicated bicycle lanes and for those lanes that are separated only by road marking can reflect the effects of possible overspill onto the road carriageway on other vehicle types.

4.3 Summary and Future Developments

Whilst the Beijing model is built as a traditional 4-stage model, the need to represent bicycles traffic accurately (given that it forms a significant proportion of the travel demand in Beijing) means that the modelling platform must be sufficiently flexibility to accommodate this. The Cube model is ideally suited to this by allowing the use of different user classes each with specific attributes, and for the network to be defined so that links can be banned to certain categories of vehicle.

With rapidly increasing car ownership in Beijing, the traffic model is currently being further updated. This will include refining the trip generation and distribution stages with an approach based more precisely on car owning and non-car owning households, taking into account changes in income and other elements such as policy in future years. The geographic coverage of the Beijing Cube model is also being extended to reflect the spread of Beijing in recent years with rapid development.

5 APPLICATION OF CUBE IN VIETNAM WITH AN EXAMPLE FROM HANOI

5.1 Overview

MVA has developed Cube models for both Hanoi and Ho Chih Minh City as part of transport forecasting studies. Whilst each city has its own characteristics, the issues in terms of modal split and vehicle mix are similar in the two cities. Therefore for the purpose of illustrating how Cube has been used to model the issues, the example of Hanoi is adopted.

5.2 Model Framework and Treatment of Modal Characteristics

The Hanoi model is built on a traditional 4-stage framework of trip generation, distribution, modal split and assignment, and the model is structured in this form using Cube, with a loop to iterate the model until convergence is reached, as shown in Figure 10 below.

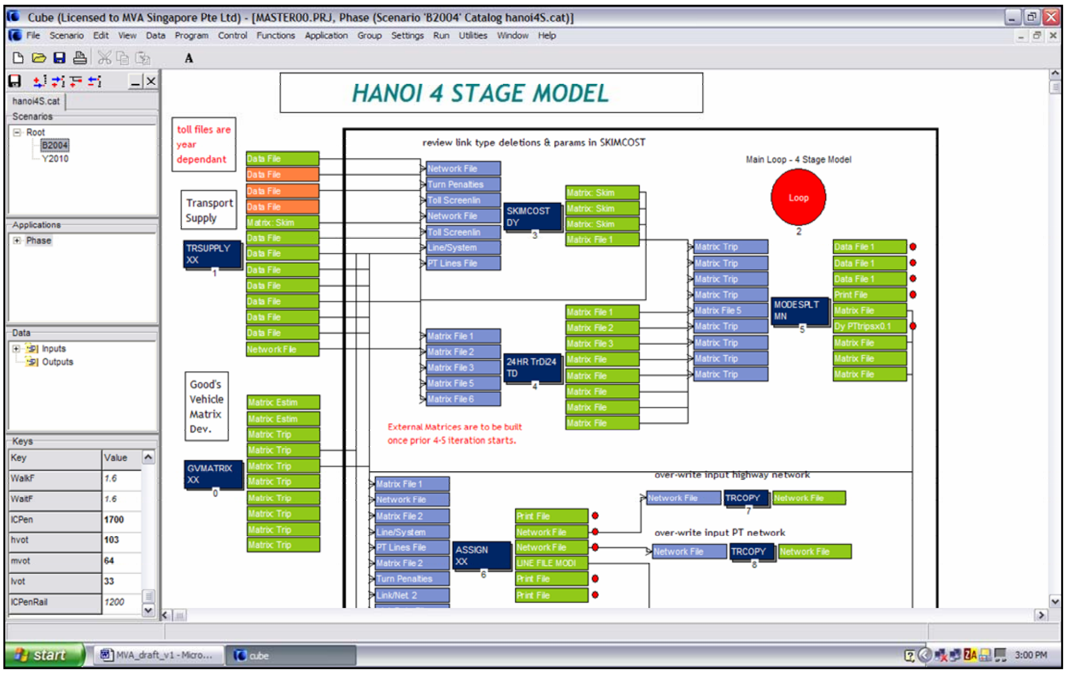

Figure 10 Hanoi 4-Stage Model in Cube

The model was originally developed from scratch as part of a railway feasibility study for Hanoi conduced in the late 1990s, and was built from extensive survey data, including household interview data. An extensive database of land use and income levels was compiled in parallel. It has subsequently been updated in recent times for other rail studies.

Trip generation is based on three categories reflecting income and thus vehicle availability:

- High income households – either owning or having access to car;
- Medium income households – comprising household owning or having access to motorcycle but not to cars; and
- Low income households – comprising the households not in the above categories

The mode split is a two-step process, the first splitting the total trip demand into private modes (which form the overwhelming majority of trip-making) and a second level estimating diversion to public transport. In the first stage of the process, the available modes are determined to their income band, as indicated above, and where there is choice then distance and purpose of travel is a key component. For example, irrespective of income level, bicycle is a very popular mode. This splitting of demand is done using Cube Voyager and specified according to locally-determined parameters.

Even in the past five years, there has been a significant shift in modal split, with a significant increase in motorcycle usage (now comprising around 70% of total tripmaking) with a decrease in bicycle trips. There have also been significant increases in car and bus trips, though both from a very small base. Further significant changes are expected in the future, with policy goals to significantly increase public transport share, whilst car ownership is expected to grow. These changes in demand and mode choice have been modelled in Cube by varying the parameters input to the process in terms of income grouping of households and parameters determining the shift from private to public transport modes.

The highway assignment is undertaken in Cube using a multi user-class equilibrium assignment. Separate user classes are defined for car, motorcycle, bicycle and goods vehicles, each with separate generalized cost calculation and speed-flow relationships. Motorcycles have a low pcu factor (0.3) to reflect the amount of roadspace that they occupy.

The Cube model is set up to pass the congested network speeds from the highway assignment to the public transport network, and a distance based penalty is then added to the implied journey times to represent the commercial speeds of buses including stop and dwell times. The Cube model uses the mult-route path building facility in the public transport model to calculate routes and allocates trips between them in proportion to their cost.

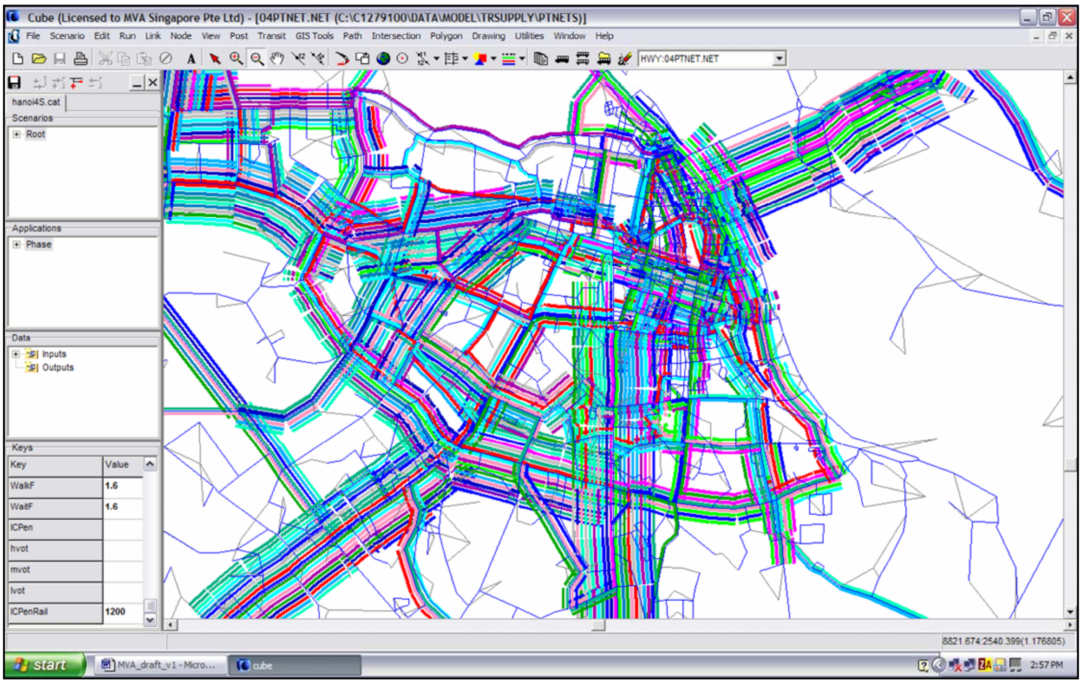

Figure 11 Public Transport Lines in Central Hanoi (from Cube)

5.3 Summary and Future Developments

The example of Hanoi has been discussed in reflecting the issues faced in modelling the largest cities in Vietnam. Modal split has already changed significantly in the past five years, but by varying the parameters and input assumptions, the Cube model has been easily adapted to the local situation. In the future, public transport demand is expected to increase in line with policy goals, and so some further refinements in terms of rail/bus share may be required in the modelling process. One possibility is for this to take the form of a public transport sub-model of the type that has been developed in Bangkok or Hong Kong to fully reflect the costs and choice between these competing modes.

6 OVERALL SUMMARY AND CONCLUSIONS – CUBE APPLICATIONS IN ASIA

The Cube transport planning software has been used to model most of the major cities around the Asia region. This paper has considered some selected examples from cities around the region which face slightly different transport issues and therefore need the modelling to reflect this.

The Bangkok Cube models have been developed from a strategic level down to more detailed models for public transport (with refined zone systems to represent rail catchments) and highways (including separate modelling of motorcycles and ability to include expressway ramp-to-ramp non-linear tolls). At the finest level of detail, micro simulation modelling in Cube Dynasim has been carried out by exporting part of the network from the strategic models, a time-saving mechanism that enables the user to be running a micro simulation model in just a matter of minutes. The Cube models have been extensively applied for studies in toll road forecasting, public transport and areas of the models have been cordoned and used for local area traffic analysis.

The Hong Kong models are also hierarchical and consider at the top level the wider demands in the Pearl River Delta as cross-boundary trip making has increased significantly in recent years. The majority of trips in Hong Kong continue to be made by public transport, and this is reflected in the finely detailed modelling of the choice between public transport modes (with Cube able to fully consider the multi-routing choices), and within the rail mode the choice between individual rail routes given the comprehensive coverage of the network allowing such choices for a significant number of movements. The Hong Kong models have been applied extensively on consultancy projects for both the private and public sectors, and for both highways and public transport projects. Again, sections of the strategic area models have been cordoned and exported out to form local area models as a basis for inclusion of further details and analysis.

The Beijing and Hanoi models are simpler in structure, being traditional 4-stage models. However, each model addresses the specific issues of traffic of patterns and modal split in the two areas. In Beijing, the bicycle remains a very important mode of travel and this is modelled in Cube as a separate category and account taken of possible overspill from dedicated bicycle lanes onto the main carriageway. In Hanoi, the important of bicycle has decreased in recent years but motorcycle is now the dominant mode and accurate representation of this as a separate mode is important. The ability to forecast changes in modal share in the future are also a very important aspect of these models.

By offering a completely integrated transport planning system, Cube is fully able to offer the flexibility for future developments of models. For example, the Cube Cargo model can refine the forecasting of goods vehicle trips in the urban passenger models; this is an element that can simply be ‘bolted in’ to the existing interface with model set-up in flow-chart format and viewing of network through the same GIS-quality interface, and data exchange between the other modules. Cube Land, a system for integrated land use and transport planning that is currently under development, will also be able to be ‘bolted in’ to existing models in a similar way. Through this, and the flexibility already existing in the passenger forecasting module to customize models to the local situation, Cube offers significant potential to enhance existing models in the future.