Application of Statistics on Cross-boundary Transport Planning in Hong Kong

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Abstract

Hong Kong is a Special Administrative Region (SAR) of China and maintains its own boundary with the mainland of China. The economic and social integration of the two places generates huge cross-boundary flows of people and goods. Providing efficient and convenient cross-boundary infrastructure facilities to facilitate cross-boundary travel is vital to the economic growth of Hong Kong and indispensable to the daily livings of the Hong Kong residents. This has also become an important policy objective of the Hong Kong SAR Government.

2. Construction of cross-boundary infrastructure facilities is huge public investment and has to be fully justified on a scientific basis. The Planning Department (PlanD) of the Hong Kong SAR Government is actively involved in the planning stage of these facilities and a lot of statistical data have been used in the planning process. In particular, the PlanD prepares projections of cross-boundary passengers and vehicles through transport models and the projection results underpin many planning studies on cross-boundary travel.

3. This paper introduces what statistical data have been used in the planning process and how they are applied. The data come from widely diversified sources. These include official statistics compiled by the Census and Statistics Department (C&SD) of the Hong Kong SAR Government and those by the statistical agencies of the Mainland, which provide comprehensive information on the socio-economic background of
the two places. Information from other government departments such as the passenger movement records of the Immigration Department and the vehicle movement records of the Customs and Excise Department would help understand the nature and patterns of cross-boundary travel.

4. The PlanD also supplements data for cross-boundary planning by conducting dedicated surveys and analysis on its own. The series of Cross-boundary Travel Surveys launched by the PlanD since 1999 has become a very important source of detailed data on the profiles of trip makers. A recent development is to conduct a survey on HK people living in Shenzhen in collaboration with the Shenzhen statistical agency.

5. Statistical data are crucial input to the cross-boundary travel planning process and the data available now have largely met the purpose. However, there is some concern about the availability of comparable data between Hong Kong and the Mainland, particularly the Pearl River Delta. This calls for more coordinated efforts among the relevant parties in the two places in collecting and producing statistics of common interest. The PlanD is now exploring on how to take this forward.

Introduction

6. The socio-economic ties between Hong Kong and the Mainland are growing stronger, leading to tremendous growth in cross-boundary travel over the years. In 1997, there were only an average of 205,000 cross-boundary passenger trips per day, but the number increased by 1.4 times to 491,000 per day as recorded in a survey in 2007. According to the survey result, vast majority (92%) of these trips were made by land, with only 4% each by sea and air. At present, there are eleven major immigration control points. Lo Wu and Lok Ma Chau are the dominant ones, with about 51% and 23% of passenger trips. Most of them (71%) were generated by people living in Hong Kong.

7. During the past decade, cross-boundary vehicle trips increased by 60% to 42,000 trips per day in 2007, representing an annual growth rate of 5%. About 26% of them were made by container trucks, 36% by goods vehicles and 30% by private cars. The latter have increased significantly with an annual growth rate of 21% during the decade.
8. People, both Hong Kong residents and visitors, are concerned about the time taken to cross the boundary. To ensure smooth traffic crossing the boundary, we need realistic forecasts of passenger and vehicle flow by crossing point, by transport mode and by design year. They are of paramount importance in the process of planning crossing facilities to meet the demand. However, the cross-boundary traffic is changing rapidly over time in volume, pattern and composition. How can we obtain sensible and practical estimations?

9. PlanD has adopted a classic 4-stage transport model to project the cross-boundary travel demand at each crossing point, taking into account all influencing factors such as transport network, land use development, cross-boundary public transport services available, passenger travel behavior and cross-boundary travel policy on both sides of the boundary. The four modeling stages are trip generation, trip distribution, modal split and assignment.

**Launch of Cross-boundary Travel Surveys**

10. Cross-boundary movement records of passengers and vehicles are available from the customs and immigration authorities. These movement records allow us to perform behavioral analysis such as travelling frequency and any shift in travelling pattern upon extension of operating hours of control points or even opening of new control points. However, this source of information usually covers only some basic data such as age and sex of the passengers, the immigration control points they used and the time and day of crossing. Other important data items, such as purpose of trip, destination/origin, mode of transport, are all not available.

11. To fill this data gap, PlanD has launched a series of Cross-boundary Travel Surveys since 1999 more or less on a biennial basis. The main objectives of the Survey are:
   (a) to examine the patterns of cross-boundary trips, such as trip origins or destinations, trip purposes and mode of transport;
   (b) to examine the socio-economic characteristics of makers of such trips to establish the travelling behaviour of different categories
of cross-boundary trip makers; and
(c) to examine the movement patterns of different types of cross-boundary vehicles.

The Projection Model

12. To forecast the total cross-boundary passenger and vehicle trips, the PlanD employs basically two models, viz. the Total Passenger Demand Model (TPDM) and the 4-stage Cross-boundary Transport Model (CBTM). Historical data indicated that cross-boundary trips by air representing less than 3% of the total demand. The models are designed to focus on non-air passenger demand forecast and analysis of the interaction between the passenger demand and the land and sea-based public transport services provision. The model structure of CBTM is shown in Annex A and the traffic prediction process is simplified in Annex B for easy reference.

The Total Passenger Demand Model (TPDM)

13. Passengers of different types and different purposes have different travel characteristics and trends and should best be separately analysed and predicted. The output of TPDM is eight series of passenger trips as shown below by design year:
   (a) Commuting trips made by Hong Kong resident usually living outside the Mainland
   (b) Business trips made by Hong Kong resident usually living outside the Mainland
   (c) Leisure trips made by Hong Kong resident usually living outside the Mainland
   (d) Commuting trips made by Hong Kong resident usually living in the Mainland
   (e) Business trips made by Hong Kong resident usually living in the Mainland
   (f) Leisure trips made by Hong Kong resident usually living in the Mainland
   (g) Trips made by visitors from the Mainland
   (h) Trips made by visitors from other places
14. The series of Cross-boundary Travel Surveys is the only source of cross-boundary passengers by type and trip purpose. Trips of data series (a) to (c) are mostly made by people usually living in Hong Kong. Statistics and projections on Hong Kong population are available from the C&SD of the Hong Kong SAR Government. Trip rates are therefore computed and applied to the Hong Kong population to derive the projected passenger demand. Since trip rates are likely to be differ a lot across ages and genders, and the population in Hong Kong is projected to be aging, the trip rates are computed by age group by gender by purpose.

15. Annual figures on cross-boundary passengers and cross-boundary vehicles derived from administrative records of the Immigration Department and the Customs and Excise Department are important in establishing overall trends and predicting overall passenger and vehicle demand. Owing to the unavailability of destination information of passenger trips by sea and air in recent years, administrative figures from the Marine Department and Civil Aviation Department are collected as well.

The Cross-boundary Transport Model (CBTM)

16. Information required by the model can be broadly divided into four categories, viz. transport-related, Mainland-related, planning and development information and government policies.

17. Transport-related information includes utilization level of the existing highway and railway systems and public transport services, current major highway and railway network and their development plans in both Hong Kong and the Guangdong (GD) Province. The former comprise of cross-boundary coach, shuttle bus, franchised bus and ferry services as well as domestic public transport services on both sides of the boundary.

18. Mainland-related information includes statistics, news and published documents. Statistics cover population, GDP and socio-economic data of different cities in the Mainland, in particular within the GD Province. News and published documents cover official and unofficial reports, papers and news. To keep track of the latest
development in Mainland cities, PlanD and the C&SD have jointly developed since 2003 an inter-departmental information database, now called “Hong Kong-Macao-Guangdong Information Database” (GD database). The GD database consists of two parts. Part I contains major socio-economic statistics of Hong Kong, Macao, the GD Province and other major Mainland economic regions and Part II assembles up-to-date information such as government announcements, news and reference materials in respect of socio-economic, urban planning, transport, infrastructure, logistics, tourism and environmental protection aspects. This database is also equipped with a Geographical Information System to display more accurate and interactive geographical information of the Mainland.

19. Besides historical data, we need to know all relevant planning and development information such as forecasts of Mainland and foreign visitor arrivals, population and economic growth projections, land use and transport infrastructure plans and construction programme of both sides, Hong Kong Port Cargo forecasts, Hong Kong Port Master Plan as well as measures to improve the hardware and software provision at each control point. All these information are important inputs to the forecasting models.

20. Cross-boundary traffic demand is greatly affected by cross-boundary policies imposed by either the Mainland authorities or the Hong Kong Government. For example, since the implementation of the Individual Visitor Scheme (IVS) by the Mainland authorities in mid 2003, the Mainland visitor arrivals by IVS grew by 20%-30% annually whereas those not by IVS shrank by several percent annually. By the end of 2007, IVS covered 49 cities. Another example is the removal of regulatory constraints for road cargo by the Mainland authorities, including the “4-Up-4-down” rule and “1-truck-1-driver” rule in Jan 2005 and September 2005 respectively. Cross-boundary goods vehicle and container truck trips are being monitored to see if there is any increase in multiple truck trips and reduction of empty goods vehicles. As such, before any forecasting exercise, we need to be clear about the existing policies and the likely changes in order to minimize criticism to any of the predicted flow.
21. The CBTM itself comprises a Highway Model (HM) and a Public Transport Model (PTM). The HM predicts the cross-boundary flow of goods vehicles, container trucks as well as private cars and coaches by crossing point. The PTM estimates the cross-boundary flow of people by transport mode and by crossing point. The CBTM was originally developed in 1997. It was calibrated using survey data collected in 1996/97. With more information collected in the Cross-boundary Travel Surveys and up-to-date statistics, PlanD has regularly enhanced and recalibrated the model structure. Improvements have also been made to the passenger zonal trip end function and trip distribution function.

22. Both PTM and HM adopt a unified zoning system of 105 zones, of which, Hong Kong is represented by 40 zones, Macao as a single zone, Pearl River Delta region by 21 zones and the remaining areas in the GD Province by 29 zones. To cater for movements outside the GD Province, 5 zones are allocated and 9 other zones are reserved for future model applications to cover possible developments of new crossing point and network expansion.

23. The CBTM is a multi-modal model that can reflect choices of route and transport mode. The highway network includes both the highway network in the Mainland and Hong Kong. For the Mainland network, it covers expressway and major trunk roads and the information are updated regularly with the latest construction programme. Hong Kong network are prepared based on the latest transport infrastructure development program prepared by the Hong Kong SAR Government. Railway links and ferry routes are then added to the highway network to form a complete public transport base network. Once completed, all major cross-boundary and domestic public transport services information are incorporated. On the Mainland side, domestic public transport services cover the Guangzhou and Shenzhen Metro services and those bus and coach services provided near the boundary crossing points. Service details such as service frequency, fare, routing, journey speed and distance between stops are coded collectively for similar type of services.

24. The following paragraphs describe how passenger and vehicle trips are estimated by using the PTM and HM.
(A) Passenger Trips

25. The PTM comprises of a Zonal Trip Ends Model, Trip Distribution Model, Modal Split Model and Assignment Model. The Zonal Trip Ends Model employs twelve regression equations to derive a relative zonal trip end pattern for each category of passenger trip except for the category of visitor trips. The zonal trip end pattern of visitor trips is obtained by growth factor technique, making reference to relevant information collected from the Hong Kong Tourism Board and surveys. Since the sum of each zonal trip end is controlled by the respective trip total by residency by trip purpose, the actual amount of trip assigned to each zone is distributed on a pro-rata basis in accordance with the relative zonal trip end pattern derived from the respective regression equation. Applying the future planning and economic data in the model, we can obtain the estimated number of passenger trips generated from and attracted to each zone in a particular design year.

26. The Trip Distribution Model is used to estimate the number of trips made between pairs of zones. The model has adopted the Gravity modeling technique. As each trip category has unique characteristics, seven individual sets of cost deterrence functions were established to obtain the trip matrices of each trip category. By applying the future network assumptions, the future year Origin and Destination trip matrices are obtained. The summation of these trip matrices is the total demand matrix ready for the next step of estimation process – modal split.

27. Modal split is the process of determining which transport mode is used by the passenger trips between each pair of zones. The choice of transport mode is affected by many factors, including individual trip end factors such as income, car ownership and availability; zonal trip end factors such as distance from city centre and accessibility to public transport; characteristics of the journey such as trip purpose and the characteristics of the spatial separation of the trip ends such as cost of travel, in-vehicle time, walking and waiting time and parking cost and availability. Based on statistics, the proportion of cross-boundary trips by air is first compiled and deducted. Cross-boundary private cars are subject to quota control. A quota allows a private car to be driven across the boundary via a specified crossing point without any limit on the
number of crossings. Hong Kong citizens who have made investments or donations up to a certain amount or are holding certain political offices on the Mainland are eligible for applying for the quotas. In order to determine the passenger trips by private car in each prediction exercise, we need to make some assumptions on the Private Car Quota Policy in future. Based on the assumptions and the relationship obtained from statistics between number of quota and private car trips, the proportion of passenger trips using private car is calculated.

28. The next step is to use the *Multiple Logit Model* to compute the proportion of the rest of the trips between each origin and destination that use a particular transport mode. The transport modes include boundary train, through train, cross-boundary coach/bus and ferry. The final route assignment step is to allocate trips between an origin and destination by a particular mode to a route. Unlike private cars, public transport is confined to the services that the various ferry, bus and train companies run. On public transport, one can only go between the places served by public transport, at the time and places they serve. To do this, we need to code the public transport route as well as fare and movements between origins and destinations, all are disaggregated by mode. Once we have obtained the number of passenger trips by transport mode by control point, we need to convert the passenger trips by cross-boundary coach, bus and private car into numbers of vehicle trip by using different *occupancy rates* derived from surveys.

29. The resulting vehicle flow will be added to the estimated vehicle flow obtained from the HM to form the total cross-boundary vehicle flow at individual control point. Up to this point, the passenger trips are presented as annual figures. For planning purpose, the annual passenger trip is converted to average weekday daily passenger trip by dividing it with an annualization factor which is derived from statistics.

30. The CBTM implicitly assumes sufficient public transport services to serve the predicted passenger demand and very small changes to the overall accessibility, which means that the estimated demand is not service dependent. In order to study the effect of any major changes to cross-boundary public transport services to the demand, an *Elasticity Model* is developed which takes into account changes in generalized cost.
The cost comprises waiting time, access and egress time, interchange time, in-vehicle time, immigration time and fares. For each Origin-Destination (OD) pair, the generalized costs of the case with and without the major public transport service are compared in order to estimate the volume of additional demand.

(B) Vehicle Trips

31. The key determinant factor in assessing the cross-boundary vehicle flow is the prediction of the total cargo volume between Hong Kong and the Mainland, in particular the Pearl River Delta region. The cross-boundary freight volume is projected based on the estimation from the Port Master Plan 2020. All air cargo is excluded, as they do not contribute to freight volume across land crossings. Crude materials such as aggregates and liquid bulk are also removed from the total tonnages of cargo for analysis as their transport would unlikely be transferred from river to road.

32. After deducting the volume of air cargo, crude materials and liquid bulk from the total Hong Kong cargo, the rest of the tonnage is classified as road eligible cargo, which can be sub-divided into road-based cargo, river-based container cargo and river-based break bulk. The HM employs a freight modal split function to separate the road eligible cargo demand into modes of road and river based on the respective transport networks and travel costs. This model is developed using the total tonnage of freight by county and municipality in GD to Hong Kong. The tonnage is based on estimates prepared by the Port Cargo Forecast disaggregated by sub-region, essentially at municipality level in the Pearl River Delta area and more globally in the outer areas of GD Province.

33. The split of road eligible cargo by road between goods vehicles and container trucks is based on the existing pattern obtained from surveys and statistics. It is also assumed that the degree of containerization will increase slightly with time to reflect higher operational efficiency. The road freight in tonnage derived from the above mode split function is then converted to goods vehicle and container truck trips using average loading factors obtained from statistics and surveys.
34. According to administrative records, the proportion of empty goods vehicle trips leaving and arriving Hong Kong in 2007 was 58% and 23% respectively. To estimate the total freight vehicle trips crossing the boundary, the model has adopted a slightly decreasing proportion of empty vehicle trips. By applying a gravity model, taking into account operating cost, journey time, toll charges and the capacity of each control point, the goods vehicles and container trucks are distributed between Mainland and Hong Kong zones to produce corresponding daily vehicle matrices.

35. Finally, the various vehicle matrices, together with the private car and coach/bus trip matrices estimated from the PTM, are assigned to the highway network using generalized cost and the ‘minimum path’ rule. The output of the CBTM is the total vehicle flow, including private cars, coach/bus, goods vehicles and container trucks by control point by direction and by design year.

Other sources of information

36. Apart from the series of Cross-boundary Survey, PlanD also conducts ad hoc dedicated survey to collection information on cross-boundary travel. For example, there was considerable growth in the use of private cars for cross-boundary travel in recent years. The annual growth rate was 21% between 1997 and 2007. PlanD therefore conducted a "Survey on Propensity to Use Private Cars to Cross the Boundary" in 2005 to explore the travel characteristics of these cross-boundary private car movements and the underlying factors that affect their usage to facilitate estimation of the latent demand of private car usage.

37. As mentioned above, there is an increasing trend of Hong Kong people working and/or living in the Mainland. It is therefore important for PlanD to know the number and socio-economic characteristics of these people, such as their geographical distribution, age and sex profiles. However, since these people are living outside Hong Kong and are quite mobile, it is difficult to obtain information on them. The Cross-boundary Travel Surveys are not able to estimate the number of
these people since those seldom/never cross the boundary could not be captured by this means.

38. PlanD has been exploring different methods in the past few years. One of the sources is through household surveys in Hong Kong. At the request of PlanD, C&SD has conducted several rounds of thematic household surveys on Hong Kong people's experience of and aspirations for taking up residence in the Mainland.

39. The major limitation of the thematic household surveys is that they could not capture Hong Kong people who had taken up residence in the Mainland but who usually stayed in Hong Kong for only a short period of time or who did not have a usual home base in Hong Kong.

40. To overcome this limitation, PlanD has been cooperating with statistical agencies in the Mainland to conduct surveys in the Mainland to collect information on Hong Kong people living there. Since Hong Kong people living in the Mainland constitutes only a tiny proportion of the population there and a complete frame is not available, this kind of surveys is costly and the results are subject to many limitations. A recent example is the "Survey on Hong Kong People Living in Shenzhen". This Survey comprises two stages: (a) Stage 1 to construct a frame of Hong Kong people living in Shenzhen mainly through administrative records; (b) Stage 2 to collect more detailed information on their socio-economic characteristics through a sample household survey.

41. To obtain a complete picture of Hong Kong living in the Mainland, C&SD is also exploring with China's National Bureau of Statistics to cover Hong Kong people in the 2010 Population Census of the Mainland.

42. Recognizing the importance of information on cross-boundary matters in planning and the need to collate, share and exchange this information with neighbouring areas, PlanD has recently initiated a joint study with three neighbouring cities (Shenzhen, Macao, Zhuhai) of Hong Kong to explore how to share planning information of common interest.

**Conclusion**
Statistics are crucial in cross-boundary transport planning, especially in an ever-changing city like Hong Kong. Both quantitative and qualitative data are important ingredients to projection results. Although data available now have largely met the purpose, the PlanD continually develops means to improve the system: from launching proprietary surveys to initiating joint study with neighbouring cities.
Annex A

Cross-boundary Transport Model (CBTM) Structure

Hong Kong Domestic Transport Model

Local Loaded Networks

Guangdong Loaded Networks

Planning Data

Highways Networks

Freight Model

Goods Vehicle and Container Vehicle Demand Matrices

Highway Loading by Crossing Point

Highway Loaded Network

Public Transport Networks

Private Vehicle Model

Private Vehicle Demand Matrix

Total Public Transport Demand

Modal Split

Through Train, Boundary Train, Bus, Ferry Person Matrices

Public Transport Loading

Bus Vehicle Flows

Cost Elasticity Model

Public Transport Model

Highways Model

PRIVATE

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