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STATION DOMAIN AND GIS IN TRAFFIC DEMAND FORECASTING FOR URBAN RAILWAY PLANNING

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ABSTRACT: Demand predictions of traffic at railway stations play a significant role in urban railway planning. Such forecasting is important to arrange a station plaza with adequate facilities, as well as to select spacing and location of railway stations. Such forecasting process, especially in the context of urban areas, involve much spatial details at different plan levels to represent enormous and varied project and policy variables. The concept of station domain, which is defined as an area around a station with a boundary up to which the station usually attracts majority of passengers to use its services, can play a vital role in the forecasting process of railway traffic in urban areas. On the other hand, the unique ability of geographical information system (GIS) to handle complex spatial relationships and attributes make it a natural tool to use in the planning and analysis of transport systems, specifically public transport systems. This paper presents a simple methodology to forecast traffic at each railway station of a railway line incorporating the concept of station domain. This methodology utilised the beneficial features of a GIS package for efficient data management and spatial analysis. Some findings of a pilot application of the methodology on the Joban New Railway Line project, Tokyo Metropolitan Area, Japan are also demonstrated in this paper to show the potential use of the prediction process.

KEYWORDS: Urban railway, Station domain, GIS, Traffic demand forecasting.

INTRODUCTION

Urban railway, either in the form of light rail transit or rapid rail transit, is playing an increasingly major role for urban public transport and urban environment in both developed and developing countries. Planning of such railway systems has, therefore, become vital to ensure efficient public transport services. Traffic demand forecasting at railway stations plays a significant role in urban railway planning. Such forecasting is important to arrange a station plaza with adequate facilities, as well as to select spacing and location of stations. However, railway systems development, especially in the context of urban areas, involve much spatial details at different plan levels to represent enormous and varied project and policy variables.

This paper is organised in a sequential manner to demonstrate a simple methodology for traffic demand forecasting at each railway station of a railway line incorporating the concept of station domain and utilising the beneficial features of a GIS to cater spatial variability.

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TRAFFIC DEMAND FORECASTING MODELS

Various forms of forecasting models including the conventional four-step transport model (trip generation, trip distribution, modal split and traffic assignment) are often used to predict traffic demand at each railway station. Different forms of aggregate and disaggregate models are recommended, based on the extent of data availability and accuracy required for traffic forecasting. Reviews of such models are available in various literature, such as Nitta and Mori (1986), Brand (1973), Chapleau (1986), etc.

For example, Harata and Ohta (1986) examined the predictability of nested logit model to the analysis of railway station and access mode choice. The model had a three level structure, containing main mode, access mode, and station choice, respectively. The before and after data were collected by mail-survey including the residents in the survey area of three kilometers radius from a new railway station.

Preston (1991) also identified a wide range of techniques that can be used to forecast the traffic demand for new rail stations and services. The simplest and least accurate method is likely to be the Trip Rate Model and the most accurate and complicated methods are likely to he provided by disaggregate Mode Choice Models.

Considering the spatial variability of urban areas and the complexity and extensive data requirement of existing models, a simple traffic forecasting methodology is demonstrated in the following sections.

THE METHODOLOGY INCORPORATING STATION DOMAIN

Station domain and logistic curve are the two key features of the methodology for traffic demand forecasting at each railway station of a railway line. These features and the traffic demand forecasting technique are explained in this section.

Station Domain

Station Domain, in rail transport systems, can be defined as an area around a station with a boundary up to which the station usually attracts passenger (or majority of passengers) to use its services.

Such an area can he represented geometrically by Voronoi diagram (Peuquet and Marble, 1990) or. by Weighted Voronoi diagram (Okabe et al., 1994) or, can be judged from experience (for example, 500 meter around a metro station, Musso and Corazza, 1989). In determination of station domain, user choice behavior can also be reflected by introducing a multinomial logit model (Ahsan, 1994).

Furthermore, station domains can be defined depending on route and station configuration, which are explained in Fig. 1. Absolute station domains are obtained considering the station of a single railway line in one zone. On the other hand, relative station domains are obtained considering all the stations of all railway lines in one zone.

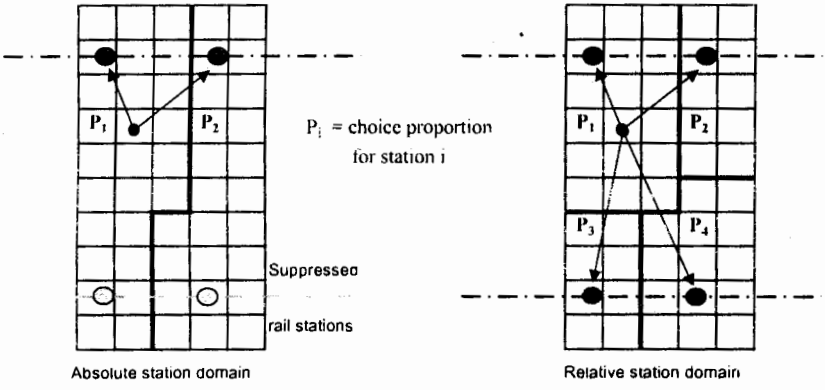

Fig 1. Absolute and Relative Station Domains

Logistic Curve

Logistic curve also known as built-up curve, in urban spatial analysis, is defined as the curve representing the proportion of developments for urban development projects with respect to time from the implementation of the projects. Most common form of expression for a logistic curve is as follows (see Fig. 2):

$$P_t = (1 + e^{(a-bt)})^{-1}$$

Where,
P_t = Proportion of built-up at time t
a = the intercept
b = the slope coefficient

Very often logistic curves are used for prediction of future population in an area, because calibration of such curves involves very easy process.

Traffic Demand Forecasting Technique

First station domains are determined for every station on the planned railway line. Both absolute and relative station domains are needed for planning judgment of facilities in station plazas and fixing priority investments. Populations for station domains are then calculated from development plans using development areas within each station domain, planned or predicted population for these development areas and the regional built-up pattern as follows:

Total population in a station domain at time t	=	Plan development areas in the station domain	*	Plan population density in development areas	*	Proportion of built-up at time t

Traffic demands for each station domain are then forecasted from multiplying this predicted population by rail trip rate per person estimated for the project area.

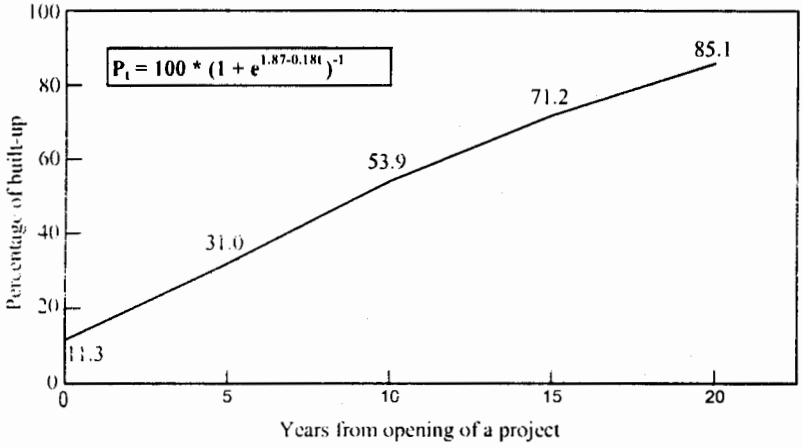

Fig 2. Average Built-up Curve for Urban Areas in Japan

INTEGRATION OF GEOGRAPHICAL INFORMATION SYSTEM

Geographical Information System (GIS) has been defined in many ways by the experts in the field. According to Schweiger (1992), "GIS is a tool that provides data base management capabilities (including capture, selection, storage, editing, querying, retrieval, and reporting functions) of spatial data, and provides the ability to perform analysis of geographic features (points, lines, and polygons) based on their explicit relationships to each other". Spatial data, which consists of both map data (such as, zone boundary, transport network, etc.) and attribute data (such as, population, employment, etc.), can be easily stored in the data base of a GIS package. There is considerable interest in integrating GIS with forecasting models to meet the requirements of advanced applications (Abel et al., 1994 and Fedra 1992).

The beneficial features of a GIS package are efficiently integrated with the methodology described in the previous section for data management and spatial analysis. Functions, such as Voronoi diagram, Poly to Grid, Aggregation and Disaggregation of information between higher and lower plan levels are widely used for the spatial analysis. Development areas are represented by GIS zones. Railway lines are represented by links and end points of each link/route for railway stations are represented by nodes.

PILOT APPLICATION OF THE METHODOLOGY

To demonstrate the potential of the methodology for traffic demand

forecasting of urban railway stations described in this paper, some graphic outputs from a pilot application are described in this section. For the study purpose, a portion of the 58.3 kilometers Joban New Railway Line project in Tokyo Metropolitan Area, Japan, was considered and SPANS, a raster-based GIS package was used for spatial data management and analysis. Some black and white figures in document format are produced for this paper from the colour photographic outputs of SPANS (for detail see Ahsan, 1994).

Fig. 2 represents the average built-up curve for the urban areas in Japan. Using the percentage built-up from the curve and relevant development plans along the Joban New Railway Line, population density distributions along the railway line were predicted. With the help of Voronoi diagram function of GIS, changes in absolute and relative station domains along the new railway line, considering with and without the project condition, were determined. Total populations within each station domain were then calculated and multiplied by the rail trip rate to forecast the traffic demand for each new station. For understanding of the potential of the forecasting technique, Fig. 3 shows some relative station domains along the Joban New Railway Line and predicted population densities for 500m square grids in those station domains for the years 2000, 2010 and 2020, along with the population density distribution for the year 1985 as base year.

RELEVANCE TO BANGLADESH

Rapid rise in population along with increased and versatile urban land use patterns have generated considerable travel demand in the major cities, especially in Dhaka, the Capital city of Bangladesh (Ahsan, 1990). The passenger component of the city travel demand in Dhaka will continue to rise sharply with the continued growth of population in the foreseeable future.

At present, the population of Dhaka city is about 10 million with a growth rate of nearly 8%. Dhaka's urban problems have reached a crisis level including intolerable environmental pollution from road traffic and road traffic congestion. To overcome such problems, planning for rail transit system in Dhaka is already in progress. Moreover, services on the Dhaka-Narayangonj railway line are also planned to meet the growing urban travel demand. The simple methodology explained in this paper can be of some help to the planners and engineers engaged in such development plans.

CONCLUSION

This paper presents a GIS integrated simple methodology to forecast traffic demand at each railway station of a railway line incorporating the concept of station domain. Logistic curve and planned population in the development areas are used for the determination of populations within station domains for different periods. The outputs of the pilot application clearly reveal the potential of the technique for practical

application. As this technique demands less data volume compared to forecasting models, its application would be suitable for a developing country like Bangladesh.

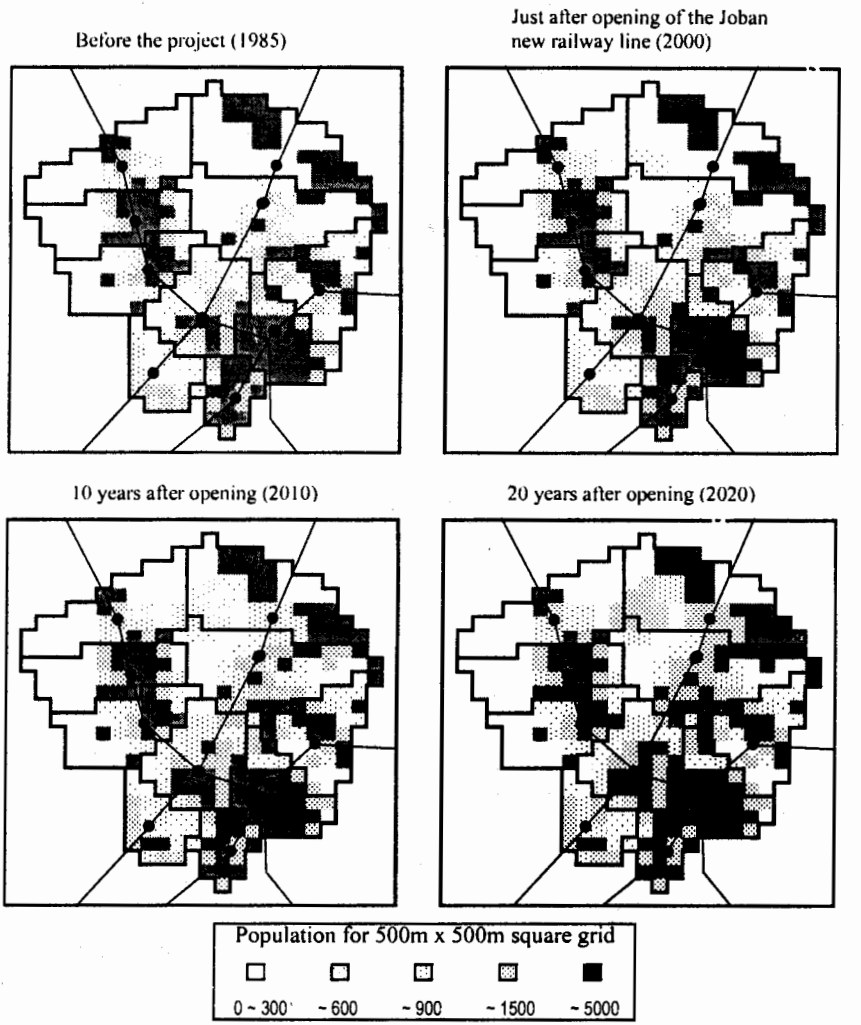

Fig 3. Population Density Changes in Station Domains Estimated by Built-up Curve

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