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Evaluating Minimum Service Levels for Bus Services - Using Geographical Information Systems

by

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ABSTRACT: Under the New South Wales Passenger Transport Act 1990, each commercial contract for providing a bus service must stipulate a scale of minimum service levels. It is a means for the Government to ensure that all the residents of communities which have similar population densities receive an appropriate minimum level of services from the bus operator. It can also be viewed as a marketing tool that can be used by bus operators to increase patronage and revenue. The minimum service levels policy is based on population level, car ownership and the competing passenger transport services. The key requirement in the minimum service levels estimation procedure is to measure the spatial relationship between residential areas and transport modes under consideration.

Conventionally, the approach has been to visually inspect a paper map to extract population and car ownership statistics affected by different transport modes. Today, with GIS, this procedure can be automated and dealt with on a much larger scale, enabling results to be more accessible to end users.

This paper describes the process of enabling GIS analysis in a case study for a regional New South Wales town.

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Introduction

In planning bus service, bus operators have to balance operational and marketing objectives given the constraints imposed by Government. Operational objectives include the optimisation of net expenses while maintaining operational reliability. The marketing objective centres on maintaining market-oriented services in line with commercial and social obligations. A significant constraint is the minimum service level (MSL) requirements introduced in 1990 under the New South Wales's 1990 Passenger Transport Act. MSL's were introduced to ensure that all the residents of communities which have similar population densities receive an appropriate minimum level of services. It can also be viewed as a marketing tool that can be used by bus operators to increase patronage and revenue. Minimum service levels are determined by a series of formulae which take into account existing or planned levels of population, car ownership and competing passenger transport services.

This paper describes how a Geographical Information System (GIS) can be used to automate the determination of MSLs for a contract area. The paper is structured around four sections. Next section provides an overview of the Minimum Service Levels policy under the New South Wales's 1990 Passenger Transport Act. In section three, the implementation of the MSL estimation procedure as a GIS application is presented. It includes general discussion of the GIS approach together with the description of RouteInfo, a software package designed to implement the MSL procedure. Data from a case study of a New South Wales town are used to illustrate the development of RouteInfo. A conclusion summarises the major benefits of GIS approach.

The New South Wales's 1990 Passenger Transport Act and the Minimum Service Levels Policy

A central feature of the 1990 reform of bus operators in NSW, under the Passenger Transport Act, was the specification of minimum service levels (MSLs) as a way of ensuring that the public were availed of an acceptable level of service. The "need of the community" are specified in subsection 20(3) of the 1990 NSW Passenger Transport Act (NSW Department of Transport, 1990). To tie the "Minimum Service Levels" policy to the 1990 Act, the NSW bus industry entered into an agreement with the NSW Department of Transport (Bus and Coach Association (NSW), 1992) on a set of formula to be used in calculating MSLs. It was agreed that prior to being awarded a commercial contract, all bus operators will have their bus operations assessed to determine whether the service levels meets the requirements as formulated in the two documents. They are the "Minimum Service Levels - Metropolitan Areas" document (NSW Department of Transport, 1991a); and the "Minimum Service Levels - Non Urban Areas" document (NSW Department of Transport, 1991b).

Clause 20 of the Act states that "service levels" means (NSW Department of Transport, 1991b):

a) The periods of time during which services are to be operated; and
b) The frequency and extent of operation of services during any specified period of time.

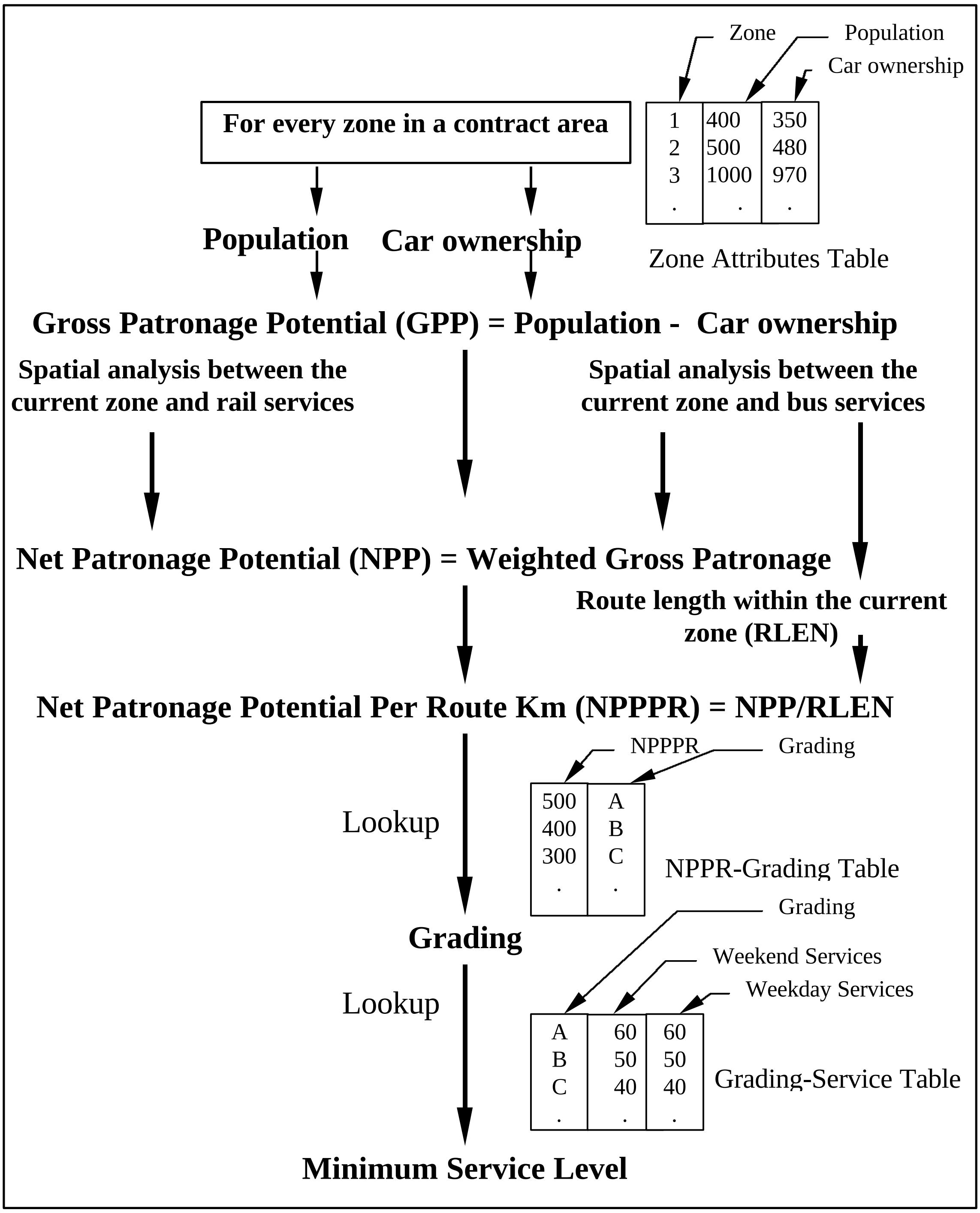

Figure 1: Flowchart of Minimum Service Levels Estimation

Subsection 20(3)(b) of the Act states that the Minimum Service Levels should be drawn up "with respect to communities which have similar population denstities and which are in other respects comparable.”. As a result, services have been divided into five categories, namely: country town; village-to-town; town-to-town; urban fringe; and urban.

Minimum service levels models were developed for each operator, using the current averages for commercially viable services, within each of these five area classifications. The minimum service levels model is based on the concept of "patronage potential" (see Figure 1). The gross patronage potential (GPP) of a region or a route is based on the population residing within the catchment area with account being taken of the effect of car onwership. Basic data types specifically required for the MSL estimation plus a wider range of information are available from different sources including Census data from Australian Bureau of Statistics and other third parties. Population and car ownership information are available from Census. Census collector district can be used as zone unit in the MSL estimation. The GPP is then weighted to take into account the effect of competing transport services being located within 400 metres of the region or route; and with account being taken of the population residing within walking distance (1.5 kilometres) of the city centre destination or a rail interchange station.

Figure 2 provides a general diagram for identifying weighting categories for any zone which is within or outside a contract area. This diagram classifies any zone according to the spatial relationships between a zone under study and the location of bus routes as well as bus and rail interchange stations.

Three different types of bus services are also considered in the MSL estimation procedure. Primary bus services operate 7 days per week, including nights, at reasonable frequency levels. A secondary bus route is one that operates during peak hours and shopping hours on Monday and Saturday only. An infrequent bus route is one that operates at infrequent intervals, usually only on weekdays (NSW Department of Transport, 1991a).

There are 14 classified and 2 unclassified categories which covers all possible combinations for any MSL estimation problem. The 2 unclassified categories are not in the scope of the MSL estimation problem. Every classified category is represented by a single letter between D to T. For example, category D zone can be interpreted as a zone which is within a contract area and unaffected by both rail and bus whereas a category J zone is within a contract area, unaffected by rail but affected by the primary bus service. The specific values of weighting factors used in calculating net patronage potential (NPP) for urban contracts are presented in Table 1.

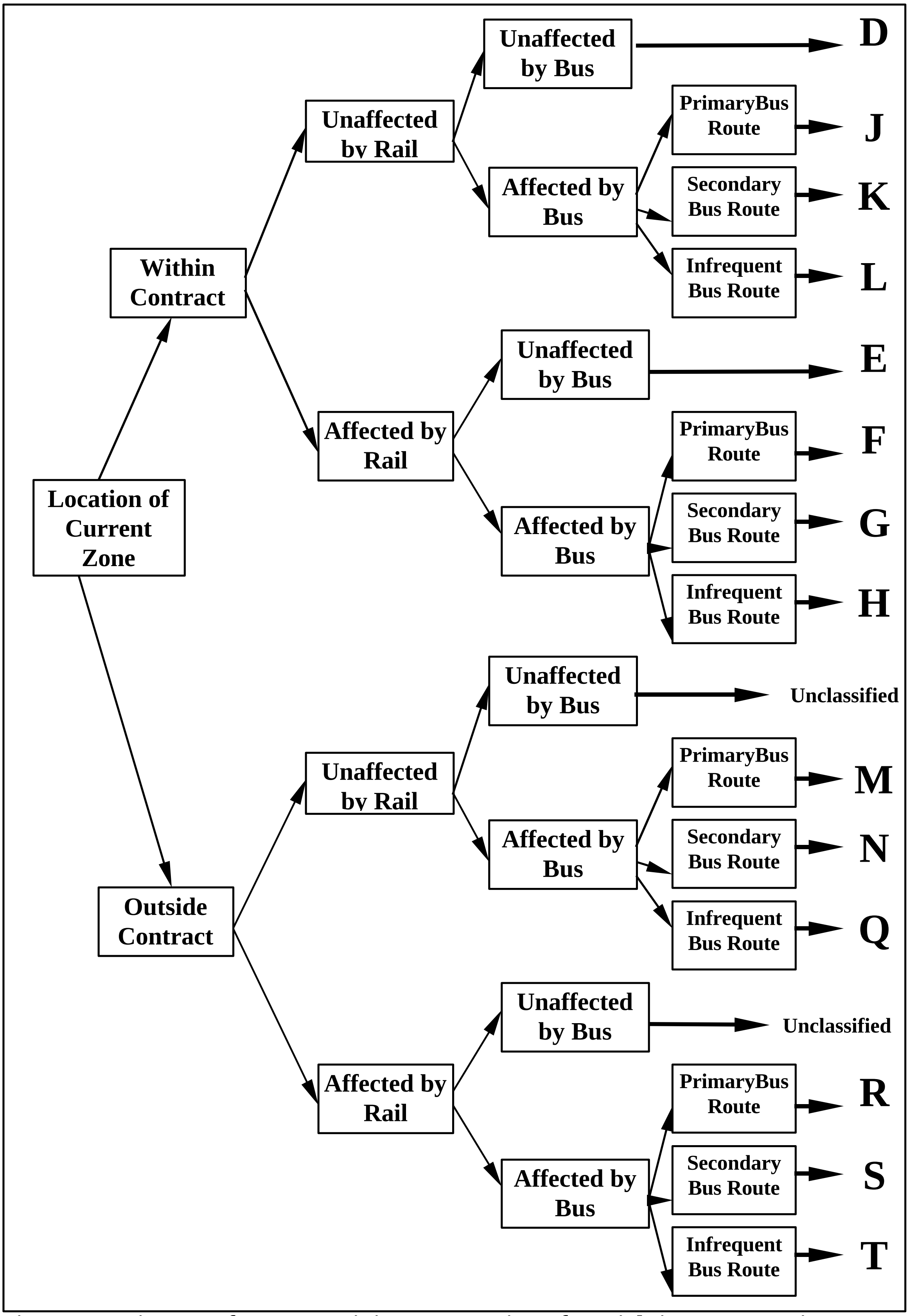

Figure 2: Diagram for Determining Categories of Weighting Factors in MSL Estimation

Table 1: Weighting categories used in the MSL estimation procedure

Category	Description	Weight
D	in contract area, unaffected by both rail and bus	1.00
J	in contract area, unaffected by rail and affected by primary bus	0.50
K	in contract area, unaffected by rail and affected by secondary bus	0.70
L	in contract area, unaffected by rail and affected by infrequent bus	0.90
E	in contract area, affected by rail and unaffected by bus	0.30
F	in contract area, affected by rail and primary bus	0.15
G	in contract area, affected by rail and secondary bus	0.21
H	in contract area, affected by rail and infrequent bus	0.27
M	outside contract area, unaffected by rail and affected by primary bus	0.50
N	outside contract area, unaffected by rail and affected by secondary bus	0.30
Q	outside contract area, unaffected by rail and affected by infrequent bus	0.10
R	outside contract area, affected by rail and primary bus	0.15
S	outside contract area, affected by rail and secondary bus	0.09
T	outside contract area, affected by rail and infrequent bus	0.03

(Source: after NSW Department of Transport, 1991a)

Population density is then taken into account by measuring the net patronage potential per route kilometre. Each contract is then given a grading, based on the patronage potential and population density of the area. Within each grading, the average service frequency of existing commercial bus services was calculated during different time periods (e.g. peak-hour, shopping off-peak, nights, Saturdays, Sundays, etc.) and used as a recommended value in a lookup table.

The existing manual estimation procedure for MSL can be automated by a suitable computational process to enable the calculation to be undertaken efficiently for the contract areas which require evaluation. The three basic functions, namely database management, graphical user interface and spatial analysis functions can be readily delivered through a GIS-based computational process. A database management capability, particular the capability to import and export different database formats from different data sources as part of data preparation can be achieved in more efficient way than the current manual procedures. Instead of relying on the paper map, a graphical user interface presents a map in a digital form with a number of associated functions for zooming, querying, etc. in a more interactive mode. Spatial analysis functions can support the task of finding the spatial relationship between a contract area, bus and rail networks.

Although it remains possible to use the manual approach to estimate the MSL for any contract area, it involves visual inspection and direct measurement together with manual look up and calculation, which is time consuming and less accurate. It is time consuming because data has to be assembled, prepared and analysed manually. It is less accurate because a direct visual inspection and guess work is carried out on the paper map. The manual approach is less feasible for regularly review of the patronage potential in response to any possible change in the road network (e.g. the introduction of new road links or new local traffic control devices such as speed humps or road closures) as well as in land use development (e.g. new regional shopping centre or new sub-division for a possible increase in patronage potential level).

The practical limitations of the manual approach creates a good opportunity for testing the feasibility of using the GIS technology to implement the MSL estimation procedure.

Using GIS Approach to Implement MSL Estimation Procedure

Overview of RouteInfo - A GIS-based application

This section describes the development of RouteInfo software developed by the Institute of Transport Studies, which employs the GIS technology in implementing the MSL procedure. Since 1990, the GIS technology has been promoted and applied widely in many specialised areas of transport (Simkowitz, 1990, Patterson and Ferguson, 1990, Vonderohe, 1992a and b, Choice and Kim, 1995 Losee and Brown 1996). It is a computerised database management (DBMS) for the capture, storage, retrieval, analysis, and display of spatial data and associated information (after Simkowitz, 1990). GIS is used to support description, analysis, understanding, planning and realisation of changes in the world. It not only analyses and handles extremely large amounts of data, but also quickly performs the tasks (Caliper, 1996 and MapInfo, 1995). GIS functions could also reduce the cost of doing business that results from enhanced productivity or by sharing information, and expanded capabilities (Vonderohe, 1992a and b).

TRANSCAD, a GIS environment developed by Caliper Coporation was chosen to support the GIS functions in the development of RouteInfo. RouteInfo is an add-on MSL procedure within the TRANSCAD GIS framework. This software implementation strategy is adopted due to the fact that TRANSCAD GIS is getting more popular. Bus route planners make use of a limited range of GIS packages and would resist changing packages just to include MSL estimation. In addition, TRANSCAD was chosen as a result of an software evaluation based on the following criteria:

- graphical user interface capability,
- database management system and ,
- spatial modelling functions,
- Windows operating system with object link and embedded (OLE) capability for supporting “cut and paste” between different windows applications and for incoporating data from different sources such as free-form text, engineering drawing and photographs,
- the integration capability with transport planning functions, and
- software license cost.

Given the database, spatial analysis and graphical user interface ability, GIS is a suitable candidate for implementing the MSL procedure. The graphical user interface ability provides an important man-machine user interface. It provides the support to the other two features: database management and spatial analysis. In terms of database management, data specifically used for bus route planning and operation can be organised in layered systems. In general, GIS organises the information in a map into layers. Each layer is a group of features of the same type, such as zones, streets, bus routes, bus stops or students locations. Figure 3 shows a typical layering system.

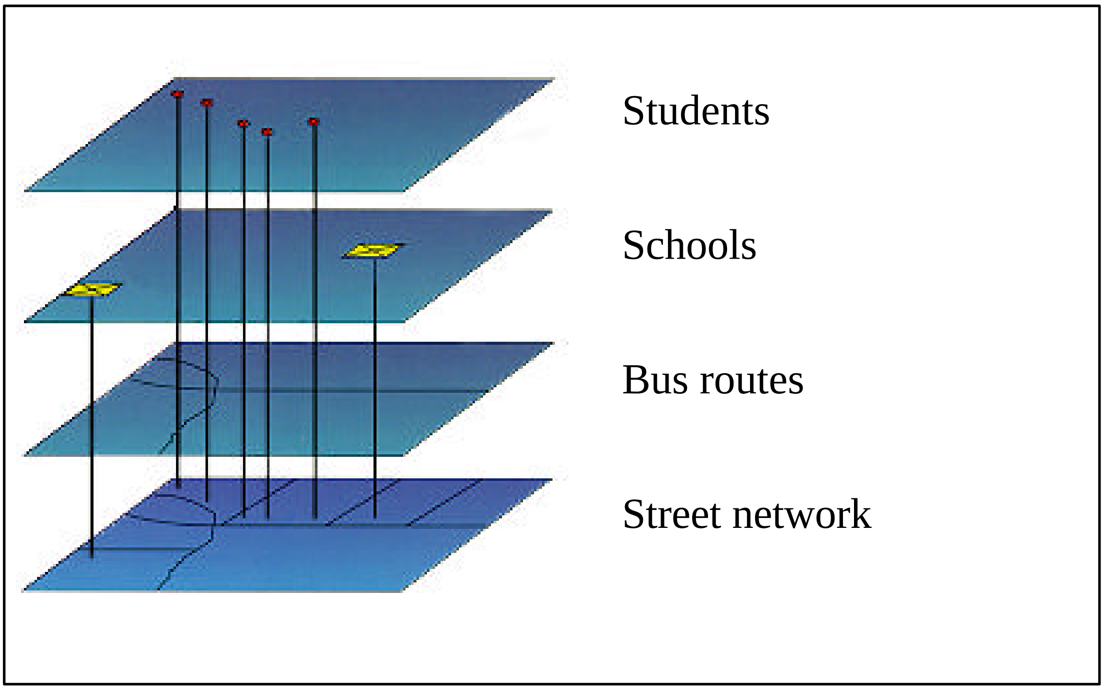

Figure 3: Layering Concept Used by GIS Approach

The user can control the contents of a map by choosing which layers to include and the order in which they should be drawn. Layers can be set so that they can be displayed automatically at certain map scales. Figure 4 shows the map of students and schools overlaying on the street network in a local area in Maitland, Hunter Valley, North of Sydney.

With the spatial analysis capability, different data sets from different layers can be overlaid or superimposed or related to each other to provide a powerful spatial analysis. In the development of RouteInfo for implementing the MSL procedure, this key feature of GIS will be used to determine the spatial relationship between contract area, rail and bus services as being outlined in Figure 2 above. Next section will focus on the description of RouteInfo in terms of its input, basic algorithm and associated output.

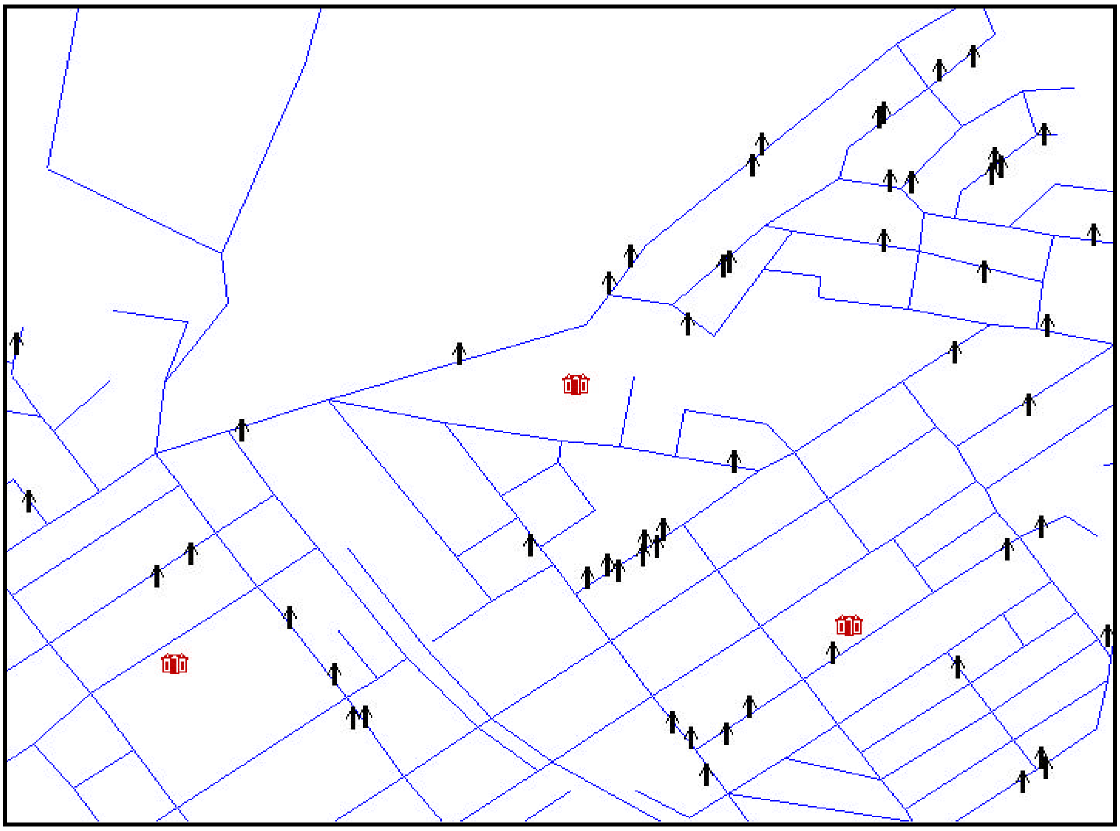

Figure 4: Map of Students and Schools overlaying on street network for A Local Area in Maitland

Description of RouteInfo

Design of the Input Data Model: Figure 5 outlines the basic input data required by a general MSL estimation procedure as implemented in RouteInfo. The following sections describe how the GIS approach in general and RouteInfo in particular can be used to structure such input data.

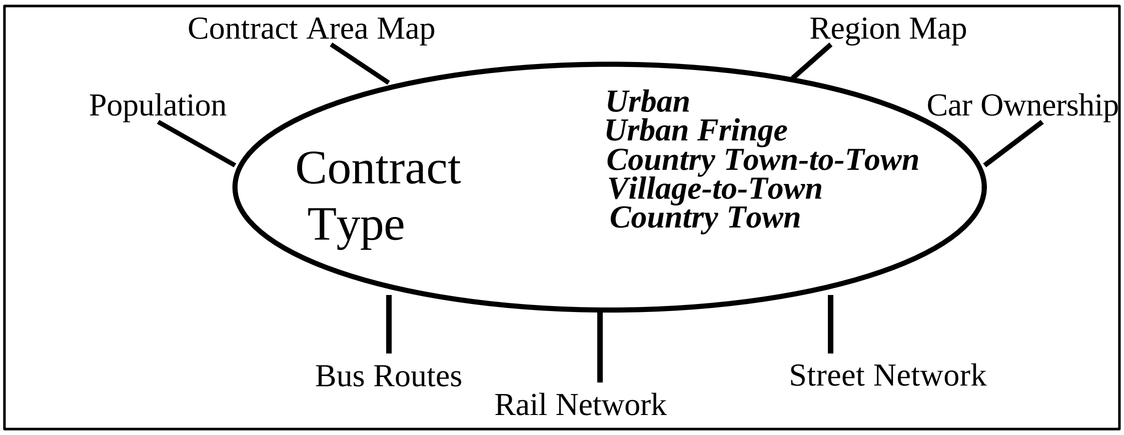

Figure 5: Basic contract types and input data required by RouteInfo MSL Estimation Program

From the GIS viewpoint, there are two basic types of information: geographic (or spatial) information, and the associated non graphic information. From the MSL perspective, boundaries of region and contract areas, street, bus, and river networks are geographic information. Non graphic information associated with geographic information particularly the contract area and region boundaries include population, car ownership and journey-to-work trip data (optional). This information is represented as database tables (see Figure 6).

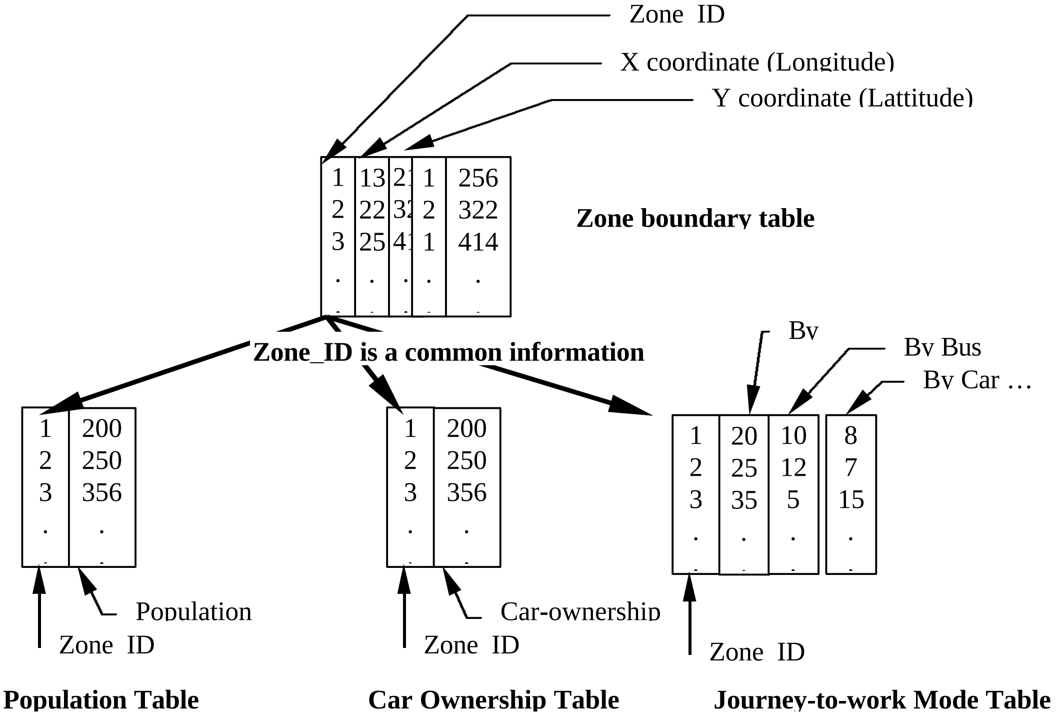

Figure 6: Data model for MSL Estimation Problem

A table is a collection of data about a specific topic. As shown on Figure 6, the population table contains information about the population of zones in a contract area and the zone table contains information only about the coordinate data for every zone in contract area. Using a separate table for every topic eliminates duplicate data, which makes data storage more effiecient and reduces data-entry errors. Tables organise data into columns (called fields) and rows (called records). The use of a common field among different tables allows for joining any number of tables together.

Basic algorithms for determining the spatial relationship in the MSL estimation procedure: The main challenge in the MSL estimation procedure is to categorise every zone in the contract area according to the spatial relationship between the contract area, bus and rail services. The algorithm involves the use of a two stage approach (see Figure 7) which employs the GIS spatial analysis functions and the combining set operation functions. The GIS spatial analysis functions (ie. TRANSCAD functions) are used to relate the contract area, and bus and rail services based on their spatial locations.

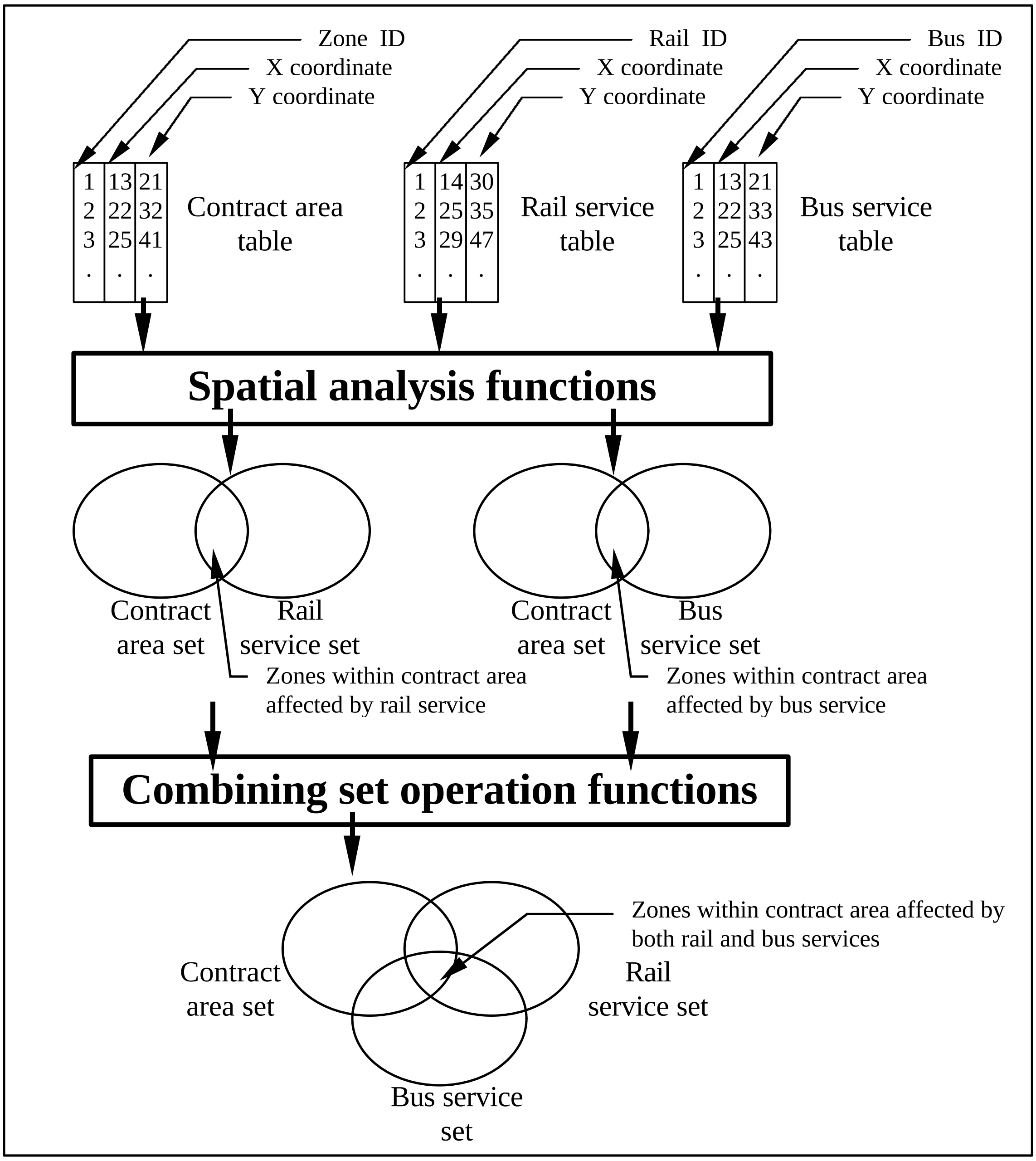

Figure 7: Basic Algorithms for determining the spatial relationship in the MSL Estimation Procedure

The output from this first stage contains two relation spaces. With the first one, the relationship between the contract area and rail service can be evaluated (e.g. zones within contract area are or are not affected by rail service). In the second relation space, the relationship between contract area and bus service can be evaluated (e.g. zones within contract area are or are not affected by the bus service). In order to combine these two relation spaces into new sets (e.g. zones affected by both rail and bus services), the combining set operation functions are used.

Output Data from Case Studies:

RouteInfo has been used to evaluate the five commercial contracts for providing bus services in Maitland region (see Figure 8). These services are operated by Blue Ribbon Coach and Travel. The source of information in terms of population and car ownership level was Census data via CDATA91.

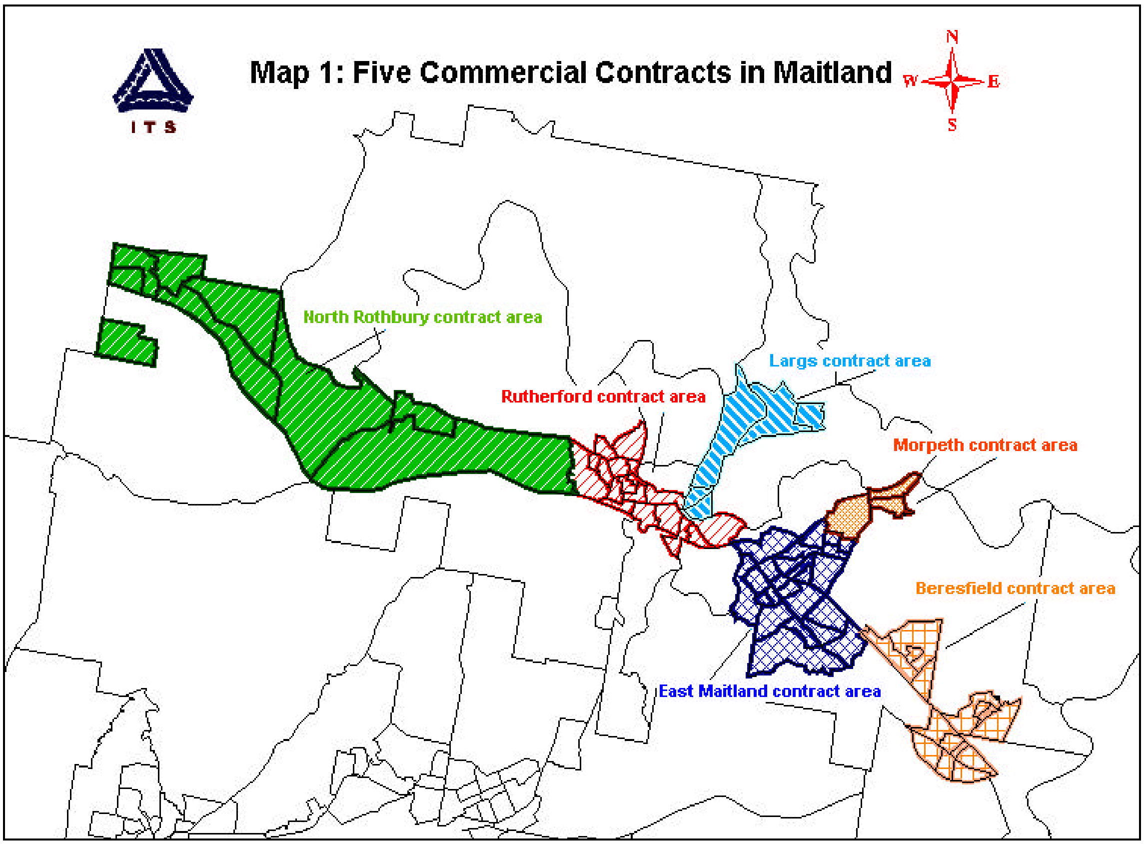

Figure 8: Case Studies of RouteInfo

Table 5 provides a summary of the MSL evaluation for the five commercial contracts in Maitland region.

Table 5: Summary of MSL Evaluation for Five Commercial Contracts in Maitland by RouteInfo

Contract Area	Contract Type	Service Route Length (km)	Net Patronage Potential	Net Patronage Potential Per Route Km	Grading
Rutherford	Urban	14	3473	248	**C2**
East Maitland	Urban	21	5700	271	**B2**
Beresfield	Urban fringe	15	2794	186	**B2**
Morpeth	Urban fringe	5	865	173	**D**
North Rothbury	Urban fringe	24	1688	70	**C2**

The MSL evaluation for the first contract on Table 5 (Rutherford contract area) is described in detail.

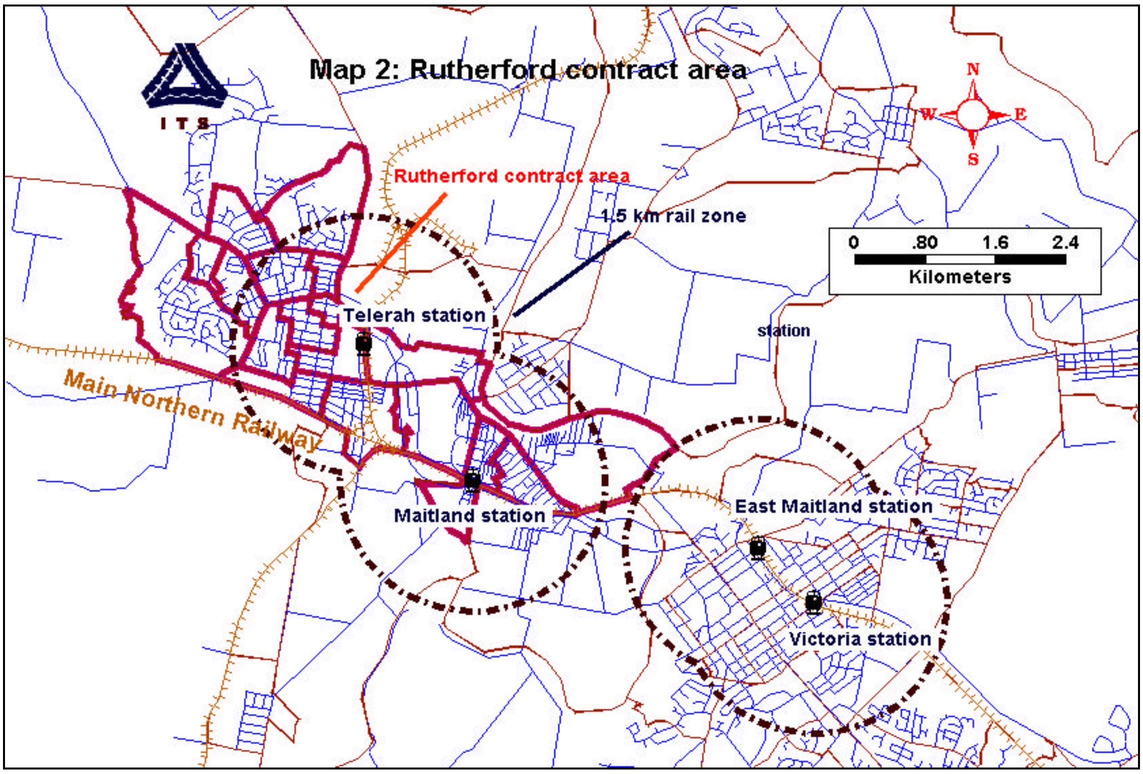

Figure 9: Map of Rutherford contract area superimposed by railway stations, 1.5 km rail interchange, railway lines and street network

Figure 9 displays the boundary of Rutherford contract area superimposed by four layers of information. They are railway stations, 1.5 km rail interchange, railway lines and street network. The output from RouteInfo is a set of files consisting of the MSL estimation summary result, patronage potential estimation results and 14 files detailing zones and associated attributes according to 14 different categories as specified in Table 1 or Figure 1 above. Table 2 presents a typical MSL estimation summary result for a selected contract area in Maitland NSW. As shown on this figure, given the contract name and contract type, the output are presented in the order of net patronage potential, net patronage potential per route kilometre, grading and recommended MSL frequencies table.

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Table 2: Typical MSL estimation summary report

ROUTEINFO Minimum Service Level Evaluation - Summary Report

Contract Type: **Urban services**

Net Patronage Potential: **3473**

Net Patronage Potential Per Route Km: **248**

Grading **C2**

MSL Frequencies Table

Time Period	Minimum No.of Journeys Required
Weekdays	
600 - 830	30
830 - 1530	60
1530 - 1830	30
1830 - 2000	60
2000 - 2130	-
2130 - 2330	-
Fridays only	-
2330 - 0030	-
Saturdays	-
0600 - 0830	-
0830 - 1730	60
1730 - 1930	-
1930 - 0030	-
Sundays & Holidays	-
0800 - 1800	-
1800 - 2200	-

RouteInfo can present the patronage potential estimation report in the form of Table 3. Net patronage potential calculation is presented by zone category together with the associated weight value for each category. The description of different categories has been presented in Table 1.

Table 3: Net Patronage Potential (NPP) Evaluation Report

No.	Category	Weight	Number of zones	GPP	AGPP	NPP
(1)	(2)	(3)	(4)	(5)	(6)	(7) = (6)*(3)
1	D	1.00	8	3376	2195.49	2195.49
2	J	0.50	0	0.00	0.00	0.00
3	K	0.70	0	0.00	0.00	0.00
4	L	0.90	0	0.00	0.00	0.00
5	E	0.30	17	6164	4258.52	1277.56
6	F	0.15	0	0.00	0.00	0.00
7	G	0.21	0	0.00	0.00	0.00
8	H	0.27	0	0.00	0.00	0.00
						3473.05

This level of detail will help bus planners in identifying any significant factor for a contract area in terms of its spatial relationship with competing bus and rail services. The report in Table 3 reveals that the zones in this contract area are classified as among two key categories (D and E). Eight zones are unaffected by both rail and bus services (category D) . RouteInfo also found that there are seventeen zones in category E (ie. affected by rail and but not affected by competing bus services). Category D zones contribute a gross patronage potential value (GPP) at 3376 (see Column 5 Table 3). This GPP value was estimated directly as the sum of population minus number of cars per zone for every zone in this category. The adjusted gross patronage potential value (AGPP) took the GPP value as an input and adjusted this value according to the percentage of zonal area which are not affected by the 1.5 km rail interchange area and the other competing bus services. The final column on Table 3 shows the net patronage potential value (NPP) which is the AGPP multiplied by the weighting factor listed under column 3 of Table 3. The description of weighting factor for different categories has been presented in Table 1.

Details of calculation for different categories in Table 3 can then be shown in a more detailed in Tables 4 and 5. Every row on these tables represents the information for a specific zone/cencus collention district. The first three columns of these tables show the zone/cencus collention district identification number, the total population and total number of vehicles, respectively. The next three columns represent the percentage of zonal area which are affected or not affected by 1.5 km rail interchange area, competing bus area and the combined effect rail and bus weighting, respectively. For category D zone (Table 4) the RWeight and BWeight are calculated as the percentage of zonal area that are not overlapped by 1.5 km rail interchange area and competing bus area, respectively. For category E zone (Table 5) the RWeight and BWeight are calculated as the percentage of zonal area that are overlapped by 1.5 km rail interchange area and competing bus area, respectively. As an example, zone with CD = 1110704, it has 41% (RWeight value in Table 4) and 59% (RWeight value in Table 5) of its area not overlapped and overlapped by 1.5 km rail interchange area, respectively.

Table 4: Detail of Category D

CD	TOTAL_POPU	TOTAL_VEHS	RWeight	BWeight	RBWeight	GPP	AGPP
(1)	(2)	(3)	(4)	(5)	(6) = (4) * (5)	(7) = (2) - (3)	(8) = (6) * (7)
1110503	494	204	1.00	1.00	1.00	290.00	290.00
1110502	1030	425	0.95	1.00	0.95	605.00	573.27
1110704	488	205	0.41	1.00	0.41	283.00	116.56
1110506	1107	455	0.74	1.00	0.74	652.00	479.49
1110501	797	295	0.62	1.00	0.62	502.00	311.20
1110606	474	197	0.06	1.00	0.06	277.00	16.36
1110504	805	436	1.00	1.00	1.00	369.00	368.61
1110505	741	343	0.10	1.00	0.10	398.00	40.00
							2195.49

Table 5: Detail of Category E

CD	TOTAL_POPU	TOTAL_VEHS	RWeight	BWeight	RBWeight	GPP	AGPP
(1)	(2)	(3)	(4)	(5)	(6) = (4) * (5)	(7) = (2) - (3)	(8) = (6) * (7)
1110704	488	205	0.59	1.00	0.59	283.00	166.44
1110602	447	164	1.00	1.00	1.00	283.00	283.00
1110608	569	202	1.00	1.00	1.00	367.00	367.00
1110706	274	79	1.00	1.00	1.00	195.00	195.00
1110705	532	166	1.00	1.00	1.00	366.00	366.00
1110607	870	387	1.00	1.00	1.00	483.00	483.00
1110501	797	295	0.38	1.00	0.38	502.00	190.80
1110505	741	343	0.90	1.00	0.90	398.00	358.00
1110506	1107	455	0.26	1.00	0.26	652.00	172.51
1110507	388	183	1.00	1.00	1.00	205.00	205.00
1110603	336	160	1.00	1.00	1.00	176.00	176.00
1110605	395	166	1.00	1.00	1.00	229.00	229.00
1110606	474	197	0.94	1.00	0.94	277.00	260.64
1110502	1030	425	0.05	1.00	0.05	605.00	31.73
1110610	740	286	1.00	1.00	1.00	454.00	454.00
1110604	600	280	1.00	1.00	1.00	320.00	320.00
1110504	805	436	0.00	1.00	0.00	369.00	0.39
							4258.52

Every zone in the contract area is grouped under different categories based on their proximity to bus routes and the rail network. Zones in each category are stored in a database table. These tables are exported to comma delimited text files. They can also be automatically opened by Microsoft Excel spreadsheet package. For completeness, Table 6 presents a description of these files.

Table 6: List of onput data files from RouteInfo MSL Estimation Program

File name	Description
innr_nb	zones within contract area not affected by both rail and bus
innr_ybp	zones within contract area not affected by rail and affected by primary bus service
innr_ybs	zones within contract area not affected by rail and affected by secondary bus service
innr_ybi	zones within contract area not affected by rail and affected by infrequent bus service
inyr_nb	zones within contract area affected by rail and not affected by bus
inyr_ybp	zones within contract area affected by rail and primary bus service
inyr_ybs	zones within contract area affected by rail and secondary bus service
inyr_ybi	zones within contract area affected by rail and infrequent bus service
outnr_ybp	zones outside contract area not affected by rail and affected by primary bus service
outnr_ybs	zones outside contract area not affected by rail and affected by secondary bus service
outnr_ybi	zones outside contract area not affected by rail and affected by infrequent bus service
outyr_ybp	zones outside contract area affected by rail and primary bus service
outyr_ybs	zones outside contract area affected by rail and secondary bus service
outyr_ybi	zones outside contract area affected by rail and infrequent bus service

Conclusion

This paper reports a research and development project relating to the bus planning task. It reviews the 1990 New South Wales Passenger Transport Act with paricular reference to the minimum service level (MSL) policy and recommended procedures. The paper discusses the need for a system with three basic functions: the graphical user interface, database management and spatial analysis. Time consuming and less accurate results represent practical limitations of the manual approach. RouteInfo system which employs the GIS approach has been developed to automate the MSL procedure.

RouteInfo offers many benefits for individual bus operators. It has been specifically developed to serve the bus route planning task. Planning information such as up-to-date boundaries, bus routes, street maps, demographics, etc. which are important to the planning task are often misplaced or scattered across different organisations. Bus operators can subscribe to ITS's RouteInfo and use it as a framework within which all planning information is stored and used.

RouteInfo helps bus operators in answering the following frequently asked questions in the planning of a bus route:

- Where can I get the information about my service areas such as boundaries, street maps, and demographics?
- How can I plan a new bus route or extend an existing one to a new sub-division area?
- How do I estimate how many potential passengers there are in my service area or even in a new area that I plan to service?
- How many bus runs do I have to operate to comply with minimum service requirements?

RouteInfo is an extendable route planning tool. It is currently fully operational for determining minimum service levels; and is being extended to cover school bus routing which requires a multi-objective approach so that the service can be evaluated in term of both efficiency and equity (Bowerman et. al., 1995).

Acknowledgments

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