Using Geographical Information Systems to Plan Fixed Route Operations or Pleasing More of the People More of the Time

Nariida Smith and Jianlin Xu

Institute of Transport Studies
A Commonwealth Key Centre of
Teaching and Research in Transport Management
The University of Sydney
AUSTRALIA

INTRODUCTION

1. In both the private and public sectors public transit routes and services have always been planned taking into account the physical conditions governing operation of the route and the potential market for the services.

2. There is nothing new about using market research to plan transit services. Transit passengers have become used to surveyors seeking their opinions or observing their movements, but market research is not limited to interviewers with a clip board. It involves the collection of both qualitative and quantitative information. Thus it encompasses a wide variety of activities including finding out the characteristics of the population in the catchment area and marketing intelligence such as what is happening in the community: will buses/trains be needed for a special event or what are competitors and complimentary services doing: an extra train is being run, can an extra bus be sent to meet it ?

3. Nor is there anything new in taking regard for route conditions either physical or due to traffic when planning routes or the services along those routes. Streets too narrow for efficient bus transit or more frequently intersections with restricted turning capacity have always constrained bus route planning. When narrow streets were replaced by wider sub-arterial roads and freeways there were still route constraint problems due to traffic conflicts.

4. Often the market and physical/traffic attributes of the route need to be considered together. Does heavy traffic frequently delay the service by ten minutes. If the passengers are elderly people travelling to the shops this may matter less than if they are workers and the delays make them late for work.

5. Even the operator of a small number of buses sometimes has to meet multiple objectives in planning the service. An extra service may mean less complaints about late services but incur extra running costs. When transit services are expected to satisfy extended objectives the task of meeting these goals, or indeed even devising suitable measures to see if they are met, becomes difficult. Increasingly transit services are expected to provide access as a community service, attract passengers away from automobiles thus limiting both the local and global effects of automobile traffic whilst at the same time they are expected to contain costs.

6. It will be argued that Geographical Information Systems (GIS) are appropriate tools for addressing complex sets of objectives whilst at the same time they can takes us back to the time when the transit company operators' understanding of the market decided a service should be started to respond to a perceived demand. Whilst that operator may not have used the terms producer or attractor the idea of collecting people at a station to transport them to their jobs in a factory area was well understood (Graham,1992). "When they put in the new estate back in those days I went out and counted the blocks and decided they'd need a bus" (bus

proprietor talking about setting up a new service 45 years ago). "A good operator knows who their passengers are and where they want to go" (same person).

7. This paper discusses the advantages of GIS in emulating the planning process for fixed route transit services, both in route design or where the routes are in place deciding the service patterns. It suggests that there are advantages in fixed route/ fixed time services which should be exploited. Moreover it suggests that GIS should enable us to extend the planning process to ensure the service satisfies a variety of chosen criteria.

DEMAND RESPONSIVE FIXED ROUTE SERVICES.

8. The benefits to flow from provision of public transport services are dependent upon people using those services. In addition where such benefits are to stem from less automobile use people must switch modes from car to public transport. The proposition by numbers of writers, for example Newman & Kenworthy (1989) that provision of a service automatically attracts users is yet to be proven. It is certainly unlikely that any service will attract patrons unless it offers to take them to places they want to go at times they want to go there.

9. The importance of choice in time and destination for the user has lead to a re categorisation of passenger transport into "personal" transport and "communal" transport Richardson(1994), This categorisation sees a taxi as offering personalised service as does the predominant personal mode automobile and also bicycle and pedestrian travel. The flexibility of personal urban transport is seen as the major attraction of the automobile. This leads to the suggestion that the best way for public transport to compete with the car is to emulate it. This argument suggests a declining proportion of total trips are now fixed route fixed scheduled journeys to work or travel along radial routes. There has been an increase in cross suburban trips for non work purposes or are undertaken outside peak hours and there are no clear "desire lines" for these trips (Australian Urban and Regional Development Review, 1994).

10. Demand responsive bus services were first trialed as "dial a bus" with limited success in the 1970's. They are now being reconsidered as it is claimed that communications means and automatic dispatching software now available make such services truly viable and more importantly less costly (Glazebrook, 1992). However even perfect technology cannot solve all the difficulties encountered by such services.

11. One of the failures of all systems trialled till now has been the difficulty in recovering costs through the fare box. A service that increases journey distance by diverting to individual callers will always increase running costs and as the number of passengers increase to meet that cost running times may be unacceptable for the passengers picked up early in the trip. Moreover a crowded small vehicle may not be perceived as offering a comfortable trip.

12. Perhaps there are other attributes of the automobile that need to be emulated or exceeded to attract people to public transport. People may value a range of comfort options offered by their personal automobile, for instance air conditioning, smooth ride, comfortable seating and very importantly for some people personal space. Door to door service may be valued not because a walk trip is saved at origin or destination but simply because the door to door trip is faster.

13. Most of the comfort attributes mentioned above are more easily emulated or exceeded by a fixed route service with better quality buses or rail cars with a capacity to avoid crowding and the time attributes may well be emulated too as long as the individual services or sets of smoothly linked services run sufficiently close to travellers origins or destinations.

14. Whilst new technologies may make demand responsive services more viable other emerging technologies can make fixed route services more demand responsive. This may mean planning new routes but it might equally well mean changes in pattern of service on the existing route either in timing or stopping patterns. Since these services could also be "personalised" to an extent a less emotive categorisation might be "individual" vs "group" urban transport. This enables the virtues and values of group enterprise to be appreciated.

15. A fixed route public transport system would not then be seen as serving a diminishing market of those too young, too old, too poor or to frail to drive a motor vehicle. It should be recalled that airlines offer fixed route, fixed schedule public transport systems. This inter-urban transport offers good quality services, but that service is not door to door and cater to groups rather than an individual. These disadvantages together with some lack of personal space are happily exchanged for a high speed journey. Special interests such as those of the business traveller or tourist are still catered for in a market grouping.

PLANNING FOR EXISTING CITIES

LAND USE AND PUBLIC TRANSPORT PLANNING

16. The cities of tomorrow are predominantly the cities of today (Wachs,1994). Very few planners are presented with new greenfields sites to build new transport systems to serve new communities. Even in new satellite communities the transport must be planned to link into the existing city transport systems.

17. Thus when planning public transport services to existing cities best use of current systems and services must be considered. The best use of existing transport corridors either road or rail is very important since the acquisition new corridors when it involves acquiring land currently dedicated to other uses is expensive and disruptive. Of less importance is the continued use of existing vehicle fleets although staged replacement is usually more economically sensible than total at a time replacement and of least importance is the maintenance of existing services patterns which are proving no longer viable. This should not be interpreted as

endorsement of the practices such as restricting direct bus services and busing passengers to a station to travel out of their way just to justify continuation of a rail service. Rather it suggests encouraging land use planning for best use of existing corridors and service planning to suit existing land use needs.

18. Transport planning is now seen as integral part of urban planning. Not only must the transport system serve the land uses but now it is also accepted that land use planning should consider accommodating transport needs. Too frequently this frequently taken to mean planning higher urban housing densities to provide passengers for public transport systems. This interpretation is far too limited. Appropriate transport systems and appropriate densities /mix of land use should be part of an overall plan.

19. May (1991) suggests transport planners should be asking "what sort of city do you want?" & "how can transport policy contribute to it". He cites a policy paper prepared for the city of Birmingham giving 5 city objectives:

i. efficiency in the use of resources
ii. accessibility to jobs , goods and services
iii. environmental protection, safety and security
iv. economic regeneration
v. practicality, including financial feasibility

These objectives are broad and most if not all of the issues are relevant to public transport planning. It is also apparent that potential for conflict in objectives exists and thus there is a need to establish planning priorities.

20. Before attempting to manipulate the market for public transport systems it is important that the market demand for such systems in understood. Equally it is important that the supply side constraints of service provision be fully understood so that the cost, social and environmental effectiveness and efficiency of the service may be assessed.

21. However to quantify or indeed show the existence of social and environmental benefits of the service (plus demonstrate the access benefit or that a change of mode has limited automobile disbenefits) we need to be able to estimate the patronage for the service. A start can be made by estimating the potential for patronage of the service based on the area served.

PATRONAGE POTENTIAL

22. In the State of New South Wales in Australia the issue of patronage potential is addressed in the 1990 NSW Passenger Transport Act. (NSW Government,1990) This legislation governs provision of public bus services in NSW using a variation of a competitive franchising model. Both planning and operation are by individual operators but these operators are granted sole fixed term rights to a region. Minimum service standards are set which require the operator to cross subsidise a certain level of non peak service from profitable peak services with the aim of

eliminating direct public subsidy. Contracts are awarded, not on price ,but to the bidder who offers the best service.

23. In NSW this model was modified to award contracts to incumbent operators in the areas if they were able to meet the minimum standards. Tenders were only let where there was no suitable applicant. Moreover the operators would expect to keep their contracts if they perform well rather than be displaced by "better offers" when the contract comes up for renewal.

24. The amount of service which must be provided is dependent on the patronage grading of the area and relies on:

Area measurement:
the area within the region boundaries subtracting: unpopulated area, area within 1.5km radius of a railway station and 50% of any section of the area to be shared with another operator eg. the area 400m either side of a cross regional through route.

Population measurement : population of the region from recent statistics (if area has changed significantly a comparable region is used as proxy) again subtracting 80% of population within 1.5km of station and 50% of population near competing bus routes. This population is then weighted to take into account the car ownership in the region.

Population density = population / area
is then used to set patronage gradings for areas. Service must match the "average service levels for the time being prevailing in the industry with respect to communities which have similar population densities and which are in other respects comparable".

25. Routes must be designed
    i. to meet urban density criteria mentioned above
    ii. to offer access directly or by train connection to the Central Business District during peak hours and to the nearest regional centre with shopping (preferably with a department store) medical practice, Commonwealth Employment Service and elderly citizens facilities.
    iii. so that at no point on the route does the distance from that point to the terminus exceed the shortest road distance between those points by more than 25. (If the terrain is rugged service may be able to be reduced.)

    iv. if the age distribution of residents is markedly different from the average, service may be reduced

26. The aim of meeting the standards "for the time prevailing" hopes to ensure a level of service rising over time as the average level of service in one period becomes the minimum level of service in the next . Patronage potential is a first pass attempt at setting appropriate levels of service.

27. Whilst patronage potential can be hand calculated it obviously also lends itself to a computer application. As the patronage potential of the route must be measured with reference to a route map a geographical information package is the perfect platform for such an application.

GEOGRAPHICAL INFORMATION SYSTEMS

GIS FOR THE 1990 TRANSPORT ACT

28. Geographical information systems (GIS) are computer software packages set up to link data from one or more databases to a map. Data and maps may vary from weather data on a map of the globe to dog license data on a local council area map. In principal there is no limitation to either the databases that can be linked nor the type of map. In practice limitations are set by available information for linking the data to the map as well as, less commonly, lack of appropriate maps and/or appropriate data.

29. The GIS maps required for bus services are the street maps of the area to be served. These will usually also be applicable to rail services as most street maps show railways. The maps however seldom show even existing bus routes and these plus any planned routes must be encoded into the GIS system.

30. The usefulness of GIS for data display and understanding of area based data has lead to its ready adoption for the display of census data. This data is usually stored after census collection at census collector district level(the area covered by one census collector), to protect the privacy of individual households, whilst still providing very local data. A numbers of items from the Australian 1991 census data are now available with linked to a GIS (CDATA91, ABS 1994)

31. This census information provides most of the data required to estimate area patronage potential gradings within the terms of the 1990 Passenger Transport Act. A GIS package can also calculate the areas to be removed from the calculation or discounted because of proximity to railway stations or competing bus routes. The census data provides age profiles and car ownership details for discounting patronage potential.

32. In consideration of individual routes data about shopping centre and services locations can be specifically encoded but also may be available from other sources. The Roads and Traffic Authority of NSW holds extensive road condition and terrain databases which if linked to the GIS could provide information on ruggedness. Comparison of route distances with direct distances requires the application of specific GIS package features. The combined GIS Transport planning package TransCAD (Caliper Corp, 1990) can serve this purpose as can other GIS packages see Clement et al.,1993.

33. Thus it is already possible to use GIS to find whether a particular route or sets of routes satisfy this general set of criteria and to establish the patronage potential of

the area served. It should be clear that other databases could be used to establish whether the route satisfies a much broader set of criteria than those specified by this legislation. These could provide extra information about the area through which the route runs or the condition of the route itself. They would thus be linked into the GIS as either area or line features.

FURTHER ROUTE AND AREA CRITERIA

34. *More Market Information from the Census*:
Census data can provide information on age, work and study patterns, household composition, car ownership and income profiles for the area. It is also possible to establish the types of housing in the area. This distinguishes between areas of single person apartments and large family houses. More detailed population information can give a better indication of propensity to catch a bus or train than a simple head count.

35. *Lifestyle Segmentation:*
Moreover other sorts off databases currently exist which link market tastes and preferences to location. Market researchers for the retailing industry use surveys and group interviews to collect "psychographic" information aiming at lifestyle segmentation, relating aspirations and tastes to particular residential neighbourhoods. This information is currently used to target direct mail advertising.

36. *Shopping Tastes & Preferences:*
In fact marketing databases are a growth industry as technology for collecting such information and processing it advances. Linking the purchases households make, and the times they make them to their personal details and home area provides a powerful niche market targeting tool. Concerns about privacy violations are met by having the shopper volunteer the information in return for points towards a shoppers reward such as free airline travel. This type of information at area level could provide specific patronage potential: such as little expected patronage for a week day service for shoppers where 95% of households shop evenings and Saturday mornings. More general "taste" attributes might be used for targeting the service: should it be advertised as "cheap" or should it be advertised as "saving the environment" ?

37. *Road & Traffic Conditions:*
Recently in a number of cities bus planning and operation has become more difficult. It has always been necessary to plan for difficult routes in narrow streets or awkward intersections. However recently in numbers of cities such difficulties have been increased by traffic calming measures. Devices aimed at slowing automobile flow also impede bus flow and road closures limit access. Road information databases can be used to estimate if the route is physically viable and at the same time provide information about average traffic flow speeds to give an estimation of trip times by time of day. Road authorities hold good quality comprehensive databases with details of road geometry and traffic conditions and regulations relating to the roadway including relevant information such as parking

restrictions. These databases are now being increasingly linked to Geographical Information Systems.

38. *Production and Attraction Site Information:*
Land uses, such as sites of entertainment facilities, factories, offices and shops are being encoded into GIS databases. Census data gives employment density by type of industry. In addition the GIS may, from other sources, include parking availability at such sites.(Repogle 1993). This type information may help produce good patronage estimates. One of the best ways to limit car travel is to restrict parking.

39. *Environmental Information:*
If the benefit from the proposed bus route or rail line is to include potential benefits due to substitution for automobile traffic from the localities served maps of noise pollution and air pollution in the area might be used to estimate the possible benefits of traffic removal. On a wider scale if the proposed new route system is predicted to cause a significant change in mode split percentage reduction in greenhouse emissions may be calculated. All such calculations are easier on a broad scale. Local air pollution reduction can be based on simply reduction in vehicles travelling through the area but is more accurate if linked to traffic reduction on particular roads as the degree of pollution is worse from congested roads. Noise pollution must be linked in the same way to particular roads.

40. *Existing Passenger Data:*
The best new potential passengers for an existing or to be extended transit service may be the current passengers. Is there potential for them to use the current service more or use new services planned? These people are an important source of latent demand since they have shown they are willing to travel on the transit service. It may be possible to encourage them to ride at other times. Researchers at CITYRAIL the NSW urban railways operator have found that the non users opinion of the rail service was three times worse than that of the users. The Australia Consumers Association magazine Choice Magazine,1994 found the same trend for non-users vs users of all public transport. Ticketing data provide information about immediate origin and destinations, time and times of travel and status such a pensioner or school child.

41. *User and Non-user Survey Data*:
More information can sometimes be deduced from ticketing data, for example a trip to the shopping centre at 11am is likely to be for shopping however to find final, rather than simply transit network destinations and purposes accurately there is no substitute for asking the passenger. Then to investigate potential for use surveys need to be extended to beyond the current passenger group. Surveys can broach the viability of alternative destinations and also provide the opportunity to elicit preferences, opinions and perceptions. It is important to remember that choices are made on the basis of perceived rather than actual service. As such data becomes available it may be linked to the GIS by either stop number or area.

42. This section began with the proposition that geographical information systems are appropriate tool for estimating the patronage potential of a bus franchise area and checking whether a planned route satisfies set criteria. Since there is an ever widening range of database information which either has been or could be linked to a GIS many different pieces of information are available to refine calculation of patronage potential or check whether a route is satisfactory for all travellers and particular niche markets of travellers. But it is reasonable to ask should we go further and ask whether a particular route or service is optimal?

BALANCING OBJECTIVES

NETWORK OPTIMISATION

43. There are numbers of papers, for example Cedar (1989), and software packages dealing with transit route and network efficiency optimisation. These start with the premise that basically the route exists to service the stops, if there are no stops along a particular section of the route the bus could drive down a parallel street. Route planning finds an optimum way of servicing those stops. This can be done by hand when operators apply incremental improvements constantly seeking to save buses or improve reliability through network solutions such as route decomposition or aggregation.

44. Minimum path algorithms can serve the same purpose, calculated either by hand or with a computer. These methods generally work in one of two ways: you draw a set of possible routes and the computer estimates performance or it draws suitable combinations with their performance levels such as costs and likely ridership.

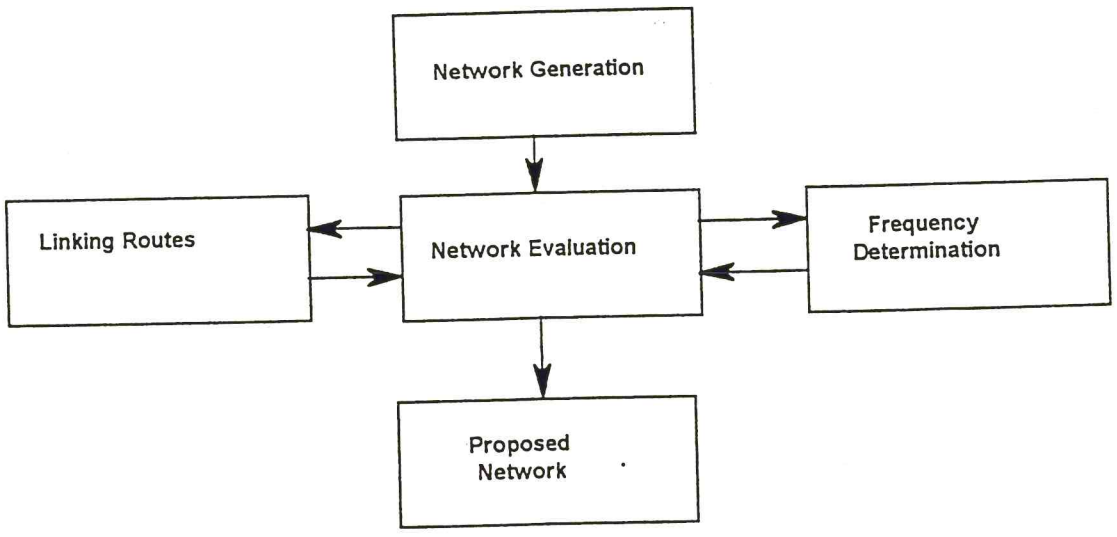

Fig. 1 - General network optimisation

45. The software package will usually
    (a). identify shortest paths between stops (called nodes in network design)
    (b) derive feasible routes
    (c) work out transfers to reach disconnected stops
    (d) produce all feasible routes as a matrix
    (e) select solutions based on some minimum eg minimum cost.
    (f). estimate who will catch the service 'assignment of passenger demand'
    (g) iteratively select the best combination of e and f

Note the minimum in (e) can be a mixed criteria objective function such as :

MIN {(Passenger hrs —min passenger hrs)÷(passenger waiting hrs)÷(empty seat hrs)}

INTERACTIVE NETWORK PLANNING

46. Existing systems such as VIPS (Volvo Transit Systems - Interactive Planning System) - for the computerised analysis and rationalisation of public transport systems, can be used to evaluate overall network strategies. In such an interactive system planners and computers work together to:
    - compile and analyse existing network data
    - creates trip matrices from survey data
    - compare large numbers of possible network solutions
    - determine the best 'interplay' between different public transit modes
    - optimise frequency
    - optimise number of vehicles to provide service
    - study effect of different fare structures
    - produces environmental information - energy consumption/noise pollution
    - calculate exact costs and income for competing proposals

The basis for such systems is a simulation model for passenger assignment based on current travel data

MORE, LESS OR BOTH

WHEN MORE INFORMATION IS NEEDED

47. Although this form of transport planning is wide ranging its costs and income results may still be too limited for planners in today's cities. If evaluation of a current or planned transport service is to be viewed from a cost benefit viewpoint a wider range costs and benefits may need to be included. Social benefits such as equity for all sections of the community and access to essential services may have values which needed to be considered in weighing up the cost of providing a service.

48. As mentioned earlier frequently a wide range of environmental benefits stemming from public transport as a substitute for private automobile use may need to be included in assessing overall benefit. Government legislation such as the Intermodal Surface Transport Efficiency Act (ISTEA, 1991) in the USA may require such assessments. Externalities to be considered include local issues relating to health such as air pollution with smog build up imposing health costs, noise pollution and accidents, and issues relating to the efficient functioning of the city such as traffic congestion. Government policy may also need to take account global issues of atmospheric warming, due to greenhouse gas emissions, possibly precipitating climate change and/or conservation of non-renewable energy sources.

49. Whether assessing benefit gained or disbenefit avoided it is clearly necessary to have good estimates of expected patronage and often also the percentage of those journeys which would have been undertaken by car in the absence of the service. Current travel matrix data cannot always supply this, especially if based on origins and destinations on an existing transit system but even if based on transport survey ODs.

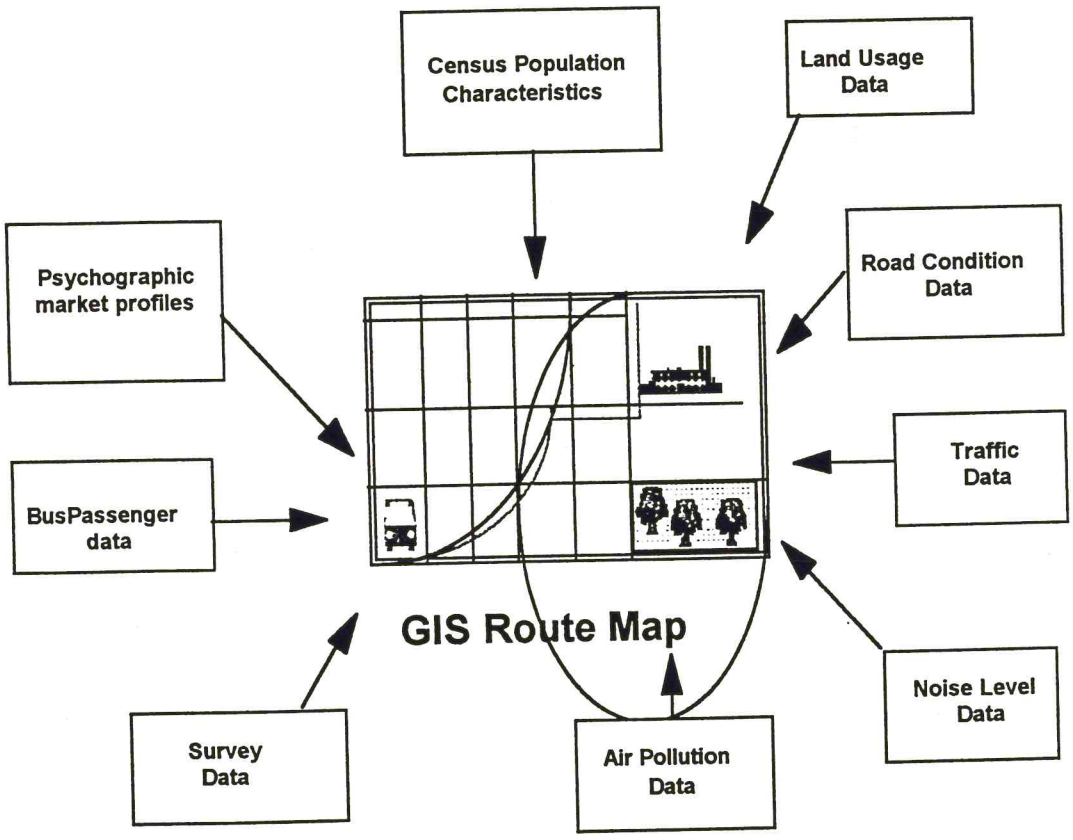

Fig. 2 - Examples of databases linked in a GIS

50. Unfortunately optimising travel by people is not a easy as optimising the dispatch of parcels. There is a growing recognition that behavioural data covering peoples perceptions and preferences is needed to predicting response to transport alternatives. Activities rather then travel per se needs to be considered to allow for

both substitution of activities and constraints of activities. A couple of simple examples point to the importance of the activity rather than simply the destination. Current travel data may note people converging on destination A and assume it is it important to continue the high operating cost transit service to A however if travel is to a cinema at A demand might be met by a more cost efficient service to a cinema at B in the opposite direction. Equally the activity to be carried out may limit the applicability of a bus or train service for the trip for instance a tradesman may need a van to carry tools to the job. To account for these sort of variables a more comprehensive planning approach is needed.

Small Changes needing Market Information

51. At the same time application of full interactive network planning package may be seen as excessive when either small service changes or single new routes are being planned. The cost of acquiring and running a large scale computer planning system could not be justified within the overall budget for the exercise. Thus a **less complex** and less expensive approach is needed.

52. In addition the travel data necessary for passenger assignment models may not be available at a local level. If a service already exists in the area some passenger boarding data and, less frequently ,passenger alighting data may be available. Local area travel data is rarely available at sufficiently disaggregate level in the detail required for planning: trip ODs by purpose and time of day unless specific local area surveys have been carried out. Even if the assignment data is available it still lacks the full market information needed. Information about passenger travel to destinations currently served or even information relating to current travel patterns may not necessarily uncover the potential for carriage on a new service.

OPTIMISING OR SATISFICING ?

53. The equation for route optimisation showed a multi objective function with 3 terms but when all the required criteria in terms of market potential or environmental advantage are included the optimisation function could have 13 or even 23 criteria. Rather than express such a function in units of time monetary value would be a more reasonable common unit. It would be possible to translate time to its dollar value using a values of time and value of externalities such as clean air by perhaps willingness to pay techniques.

54. But even if the objective function could be expressed in common units and a method of solution found by a numerical grid search technique, it is quite likely that on such a complex service may have numbers of local minima rather than a global minimum. All solutions found in such a seemingly objective process would still be subject to the valuation procedures used to convert the objectives to monetary values. Thus while the concept of a global benefit attributable to a planned service is attractive it is not simple to estimate.

55. A practical alternative is to consider replacing the concept of a generally optimised solution with a **satisfying solution**. Practical local knowledge and requirements can be used set required standards on any set of criteria the local community and transit organisation together deem appropriate. Since each objective can now be assessed individually the problems of assigning a dollar value to objectives is avoided. Environmental objectives such as clean air can be difficult to value and community perceptions of issues such as safety and access are even more problematic. Actual safety may be measured in terms of crime or injury but fear of accident or injury is more difficult to cost.

56. A computer application built on a GIS system is easily able to incorporate a set of required standards for both the transit route and the area it serves. Criteria are linked as appropriate to either the area the route serves or the route itself. Then the physical route is incrementally adjusted and its service pattern planned to fit the criteria. It is envisaged that most users would find basic census data of value in estimating the patronage potential of the area and thus estimating the service frequency and stopping patterns. It is also envisaged that the physical viability of the route would be a minimum criteria - it must be possible to run the service around the planned route. Additional databases could be linked into the system as required and the criteria to be satisfied incorporated at the same time.

57. Whilst setting such multiple criteria to be satisfied by a route or service may sound daunting, in practice numbers of criteria related to operation such as the limits to circuitous routes in the NSW 1990 Passenger Transport Act are already used in planning. Minimum passenger waiting times and minimum numbers of standees are set be transit operators. At the same time external bodies such as environmental protection agencies set standards of noise or air pollution allowed plus targets noise and pollution reduction.

58. As the level of complexity of the application increases demand forecasting equations may be incorporated to estimate the travellers diverted from automobile travel due to the new or improved service. Numbers of such diversions would then used as appropriate to estimate the noise or air pollution avoided by the mode switch and those estimates compared with set targets.

59. Whilst such an application involves initial estimation of relatively complex models the advantage of a GIS satisfying approach is that it can be of value on a number of levels and be transparent for users with little mathematical understanding. Transparency is to be valued in planning processes in an era of increasing community consultation. GIS output as maps on a computer screen or on paper can display the route performance against sets of criteria .

60. Is this the best route possible or is this the best service pattern possible ? Such a system doesn't give an answer but perhaps that answer isn't as important as it first seems if all the benefits sought from the service on the route are derived.

CONCLUSIONS

61. Improvements to the environment in cities should aim to make best use of existing infrastructure. This is particularly true for transit routes where there is considerable sunk cost in corridors. However best use of the corridor does not imply continuation of existing services without consideration of their appropriateness for current needs.

62. A city by definition exploits the advantage of people living as a group rather than as isolated individuals. It therefore makes sense to have some of its passenger transport needs cater for by group oriented public transit systems. One of the most important requirements of any transport system is reliability and in passenger transport visibility "knowing it is there" is also an important concern. A fixed route / fixed time public transport system offers these advantages.

63. Fixed route services can be made demand responsive by tailoring the route and service to meet the market requirements of the area they serve and tailoring the route to provide an efficient service taking into account the route geometry and traffic conditions. If a superior service in some respects to the alternative of private automobile is offered some mode switch could be expected. The effect of decreases in automobile traffic may then be assessed in terms of environmental advantage. At the same time the use of the service may confer social advantages in term of equity and access.

64. Transit services have always had to serve a range of objectives and that range is now widening. Geographical Information Systems provide an efficient means for linking sets of diverse measures regarding the physical characteristics of the route, its patronage potential, the features of the area it serves including social needs and the community's environmental envelope. These can be linked to the route map either as area features eg population or line features eg road width.

65. A planning package built around a GIS provides a means of assess the existing and planned route and service performance against multiple objectives and allows adjustment of the route as a satisfying rather than optimising process. Such a package could be useful at levels of complexity which vary from assessing the suitable frequency of service in an area based on potential travellers and checking whether the bus could actually traverse a single route to an encompassing system wide model with passenger demand equations based on behavioural and activity models.

66. Transparency to the user is a GIS feature. This can aid community consultation and allow people from all areas of the transit organisation to understand and contribute to the planning process. A wide variety of experience and expertise can thus be brought to the planning process and a sense of "ownership" of the route services promoted. The service is thus is provided with a group of "marketers" within the organisation and in the local community.

67. Bus examples have predominated in this paper because the authors are currently building a multiple objective satisfying system for urban bus routes. However most of what has been said would apply equally to railway or indeed to light rail services. Relevant physical track information such as grade and expected speed would then replace road databases.

68. Fixed route/fixed time transit services still have a role to play in our future cities especially as society recognises the overall welfare of the individual may sometimes be best served by group services. Improvements in technologies such as GIS should be harnessed to the planning of fixed route public transit services to please more of the people more of the time.

REFERENCES

Australian Bureau of Statistics (1994) CDATA91, CD-Rom release, ABS and Peripheral Systems.

Australian Urban and Regional Development Review (1995) *Timetabling for Tomorrow, An Agenda for Public Tranport in Australia*, Strategy Paper #2, Canberra.

Australian Consumers Association (1994), Survey of Public Transport Service, *Choice Magazine*, September, 1994

Caliper Corp(1990) *TransCAD* Transportation Workstation Software version 2.0, Caliper Corporation Newton, MA USA.

Cedar, A and Israeli, Y(1989) Designing Transit Routes at the Network Level, Proceedings of the IEEE Conference on Vehicle Navigation and Information Systems, Toronto, Canada, September 11-14, 1989

Clement, S.J, Affum, J.K. and Taylor, M.A.P (1993) A User's Guide to GIS Software Packages for Transport Planning Purposes, *Papers of the Australasian Transport Research Forum 1993*, Volume 18, Part 1

Glazebrook and Associates (1992), Sydney at the Crossroads, *New Land Use and Transport Options*, Planning Research Centre Monograph #34, Sydney University, July 1992

Graham, R.(1992) Commercially Viable Bus Services are encouraged by Legislation in N.S.W., AUSTRALIA, *Proceedings of the Second International Conference on Competition and Ownership in Land Passenger Transport*, Tampere, Finland, June 1991

ISTEA (1991), Intermodal Surface Transportation Efficiency Act (1991) US Congress

May A.D.(1991), Integrated Transport Strategies: A New Approach to Urban Transport Policy in the UK, *Transport Reviews*, June

Newman, P.W.G. & Kenworthy, J.R.(1992) Transit Oriented Urban Villages - Design Solution for the 90s, *Urban Futures*, Vol 2, No 1, February

New South Wales Government (1990) The Passenger Transport Act 1990 No.39, NSW Government Publications Service

New South Wales Government (1990) The Passenger Transport Act 1990 No.39 - Regulations, NSW Government Publications Service.

Repogle, M (1993) Improving transportation modelling for air quality and long-range planning, Paper to the USA Transportation Research Board Conference, Washington, January

Richardson, A (1994) Submission to the Australian Urban and Regional Development Review re: Urban Public Transport Futures

Wachs, M (1994) The Future City: its Changing Role & Prospects. Transportation Research Board and National Research Council (eds) *Decennial Census Data for Transportation Planning*, Proceedings of a Conference, Irvine, California, March 13-16, 1994, National Academy Press, Washington D.C.