Modelling and assessment of demand-responsive passenger transport services

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Summary

An investigation of public transport options was carried out for the central Gold Coast region of Queensland, Australia, using the LITRES-2 public transport modelling system. Several road-based demand-responsive passenger transport services were modelled in combination with conventional buses, trains and taxis, under a range of assumptions about future demand. The demand-responsive options included multiple-hire taxis, “roving buses” and a “smart-shuttle” local service between railway stations and their immediate suburban localities. These were shown to be valuable and operationally credible as complements to the conventional timetabled modes. Besides substantive conclusions of this kind, the project raised some methodological issues concerned with project planning and execution, and the capabilities and usage of a modelling system such as LITRES-2.

1 Introduction

The responsibility for public transport in Australia lies with State rather than with local governments; nevertheless, many local Councils take an active interest in the provision of such services, working in consultation with State transport departments. Such was the case in the project described in this chapter. An Integrated Regional Transport Plan was prepared by the Queensland Transport Department for the south-eastern section of the State during the mid-1990s. The Integrated Plan included ambitious targets for increased usage of public transport services, and the achievement of those targets was one of the considerations leading to the initiation of a Public Transport Passenger Study by the Gold Coast City Council (GCCC) in 1997. The Passenger Transport Study included the modelling project described in this chapter, and was in turn one of the main inputs to the Gold Coast City Transport Plan, a joint undertaking of the GCCC and the Queensland Departments of Transport and Main Roads (GCCC 1998).
The main task of the Gold Coast modelling project was to assess the viability of several proposed road-based demand-responsive transport modes, which were envisaged as supplements to anticipated bus, rail and taxi services in the near and medium-term future, that is (approximately) the period 2000-2010. The work was carried out by the Commonwealth Scientific and Industrial Research Organisation (CSIRO), in collaboration with Booz Allen and Hamilton (BAH). BAH’s main role was to supply estimates of key parameters concerned with current and forecast demand, service levels and fares. BAH subsequently also used the results of the project in formulating a wider range of recommendations for the enhancement of passenger services and infrastructure (BAH 1998).

The main analytical tool used in the project was a specialised transport modelling system called LITRES-2, which embodies research carried out by the author and his CSIRO colleagues over several years (Horn 2002; see also Smith 1993, and Smith et al. 1995). No proprietary GIS software was used: all data were stored in ordinary Unix files, and all data preparation was carried out using standard Unix tools, or using editing and display programs developed as adjuncts to LITRES-2. The supplementary software includes a graphical program for browsing spatial inputs (see Figures 10.5 and 10.6); there is also a graphical version of the modelling system itself, which has proved useful in demonstrating and validating the system’s operation (see Figures 10.3 and 10.4). Besides the substantive issues under investigation, the project involved extension and refinement of the software, and an effort to assess the software’s capabilities in practice.

Section 2 of this chapter surveys urban patterns in the Gold Coast, states the objectives of the project, and introduces the transport modes under investigation. Section 3 describes the LITRES-2 modelling system and the main categories of data involved. Section 4 outlines the scenarios tested in the project and the results obtained in each case. The chapter concludes in Section 6 with a summary of substantive conclusions from the project, a discussion of methodological issues, and an assessment of LITRES-2 in comparison with alternative modelling packages.

2 Project objectives

The City of the Gold Coast comprises a stretch of Pacific seashore and estuarine hinterland commencing some 32 km. south of the Brisbane central business district, and extending another 60 km. south to Coolangatta on the New South Wales border. Figure 10.1 covers the more densely settled parts of the region, running 40 km. From north to south between Oxenford and Coolangatta. During the past fifty years the region has evolved from a collection of small farming, fishing and holiday towns, into a leading tourist destination, favoured also as a residential location by many elderly people on account of its mild climate. Substantial numbers of residents commute to work in Brisbane, and the region now houses a diversified range of industries in its own right. It is one of the fastest-growing urban areas in Australia, with a permanent resident population already exceeding 425,000.
A chain of high-density urban development (e.g. apartment buildings, hotels and other tourism facilities) follows the main north-south coastal road, concentrating especially in the north around the regional centres of Southport and Surfers Paradise. West of the coast there are extensive low-density residential areas built on the banks of estuaries and canals. This “waterfront” zone is bounded on its western edge by the Pacific Highway, which traverses regional centres at Helensvale, Nerang and Mudgeeraba, from which suburban developments extend farther westward into the foothills of the coastal ranges.

Figure 10.1  Sketch map of the Gold Coast region
The Gold Coast City Council initiated the project with the general objectives of reducing growth in car traffic and congestion, improving accessibility within the region for residents and visitors, reducing dependence on the private car and the need for new roads and parking facilities, and improving environmental sustainability. These objectives were to be pursued by increasing the range of choice, convenience and integration of the public transport system, improving the accessibility and affordability of public transport, and in general, improving the balance between private and public modes of transport (BAH 1998).

In preliminary discussions with the GCCC and BAH, it was decided that the analysis should concentrate on a study area measuring approximately 21 x 15km. This covers the central part of the Gold Coast region, and includes all the main regional centres mentioned earlier. In some respects the region is well served by public transport: there are high-frequency bus services along the coastal strip, and a railway line has been built from Brisbane to Helensvale, with extensions to the south under way at the time of the project. Even so, current levels of passenger transport usage are very low (GCCC 1998, Section 4.3), and the Gold Coast’s generally dispersed settlement pattern constitutes a difficult environment in which to sustain geographically comprehensive bus or rail services.

Table 10.1: Characteristics of transport modes

<table>
<thead>
<tr>
<th>Transport mode</th>
<th>Pickup and setdown</th>
<th>Advertised service</th>
<th>Routing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking</td>
<td>stop to stop</td>
<td>–</td>
<td>Euclidean or Manhattan path</td>
</tr>
<tr>
<td>Bus, Rail</td>
<td>stop to stop</td>
<td>timetabled</td>
<td>fixed</td>
</tr>
<tr>
<td>Taxi</td>
<td>door to door</td>
<td>free-range</td>
<td>demand-responsive</td>
</tr>
<tr>
<td>TaxiMulti</td>
<td>door to door</td>
<td>free-range</td>
<td>demand-responsive</td>
</tr>
<tr>
<td>RovingBus</td>
<td>stop to stop</td>
<td>free-range</td>
<td>demand-responsive</td>
</tr>
<tr>
<td>SmartShuttle</td>
<td>stop to stop</td>
<td>timetabled, stops or zones</td>
<td>demand-responsive</td>
</tr>
</tbody>
</table>

The public transport modes covered by the project included the existing bus network, the railway line with its projected extensions, and a variety of demand-responsive services. The attraction of the latter in the context of a region such as the Gold Coast is that they can be operated more flexibly than fixed-route services, and thus should be more effective in serving spatially-dispersed urban areas. They may be envisaged as variants of conventional taxi services, designed to achieve economies of scale through the use of larger, shared vehicles. The demand-responsive modes are characterised by the use of recently-developed technologies to handle communications between vehicles and a central dispatching facility, and to allow prospective travellers to make inquiries and bookings. Beyond that, their viability will often depend on the use of automated, centrally located scheduling software to obtain an effective and efficient deployment of vehicles.

The main demand-responsive modes modelled in the Gold Coast project are outlined below.
• **Taxis**: Single-hire, door-to-door taxi service. As with the other demand-responsive service modes, provision is made for advance bookings. The traditional “step-in” style of taxi service was not modelled in the Gold Coast project.

• **TaxiMulti**: multiple-hire taxis guaranteeing service within prescribed travel-time standards.

• **Roving Bus**: multiple-hire services like TaxiMulti, but picking up and setting down passengers at designated stops.

• **SmartShuttle**: a bus service based on an advertised timetable but run on demand. That is, the actual route taken by a SmartShuttle bus needs to traverse only the locations for which demand has been registered, and the service can be omitted altogether on occasions when no demand is registered. The timetabled locations may be points (e.g. bus stops), or sets of points (in areally-defined zones), or a combination of the two.

3 **Methodology**

The LITRES-2 modelling system provides a fine-grained representation of demand and transport services, with particular focus on the operational characteristics of demand-responsive modes (Horn 2002). The system’s modelling architecture is outlined below, before proceeding to the data setup and modelling strategy used in the Gold Coast project.

3.1 **Modelling framework**

LITRES-2 applies a “micro-simulation” strategy to the representation of events and processes evolving over a given period of time (some alternative approaches are discussed at the end of this chapter). By contrast with more statistically-based approaches, the parameters are all empirically based, and a formal calibration of the system is thus not required. A primary distinction between *simulation* and *control* modules (see Figure 10.2) provides a clear conceptual basis for the system, and is consistent with the intended future usage of the control modules in a real-time context. In particular, the request-brokering and journey-planning modules embody algorithms that are applicable in a public transport information system, while the fleet-scheduling module comprises procedures designed to manage bookings and deployment for a fleet of demand-responsive vehicles in real time. The simulation modules embody representations of “real world” processes, and are the source of the control systems’ knowledge of critical real-world phenomena such as passenger requirements and vehicle movements. By contrast, the role of the control modules is to influence the simulated processes, this influence being exerted by means of messages (e.g. dispatch commands) sent to the simulation modules.
The main simulation modules are demand simulators and a network simulator. The demand simulators convert pre-defined models of aggregate demand into a stream of travel-requests, which is sent to the control modules. The network simulator tracks the movements of demand-responsive vehicles through the road network, and interacts mainly with the fleet-scheduling module. Several additional simulation models (not shown in Figure 10.2) provide for the modelling of randomly-occurring contingencies, such as vehicle breakdowns and delays, and passenger bookings and no-shows. The simulation models are executed in a temporal context provided by the C++Sim toolkit (Little and McCue, 1993), which ensures that timed processes evolve in a chronologically consistent time-sequence. Outside the simulation modules, the time-sequence is manifest as time-stamps on messages sent to the control modules.

Aggregate demand for passenger transport is represented as a collection of pre-defined demand models, each associated with a particular market segment, parameters for party size (i.e. the number of people travelling together in a given journey), and a given time-period (e.g. 8:00 to 9:00 a.m.). Two types of demand model were used in the Gold Coast project. An origin-destination (OD) model is a matrix of which a given element specifies the total number of journeys from one zone to another during the period covered by the model. A source-sink (SS) model consists of an array of which a given element specifies the aggregate demand for travel from a given point to a given zone, or vice versa; such a model provides a straightforward way to represent demand associated with a major regional facility, such as a shopping complex or tourist venue, as an overlay on the more uniformly-distributed patterns associated with an OD model.
The task of a demand simulator is to disaggregate a demand model in a randomised fashion, so as to generate a stream of travel-requests: each such request refers to a person (or party of people) belonging to a particular market segment, requesting travel between a given origin and a given destination point, within a given *journey-envelope* specifying an earliest departure and a latest arrival time. As a typical example of the simulation techniques employed in LITRES-2, we shall consider the demand-simulation process for an element \((i,j)\) of a given OD model. This element specifies the total number of journeys \(k_{ij}\) to be made from zone \(i\) to zone \(j\) during the period \((t_{lo},t_{hi})\) covered by the model.

In summary, there are \(k_{ij}\) travel-requests to be generated for element \((i,j)\), consistent with the aggregate parameters mentioned above but differing from each other in a random fashion. To generate the starting-point for one such request, we refer to the bounding rectangle of zone \(i\) (i.e. the smallest rectangle enclosing all parts of the zone), with width and height \(w_i\) and \(h_i\) respectively. We use a random-number generator to obtain a pair of numbers \((p,q)\), both in the range \((0,1)\), and hence generate a point \((x,y)\), with \(x\) located at \(p.w_i\) units from the left-hand edge and \(y\) at \(q.h_i\) units from the bottom of the bounding rectangle. We check that \((x,y)\) lies within the boundaries of the zone, and if not, we obtain a new pair of random numbers and repeat the process. The same technique is used to obtain a destination point in zone \(j\) for the travel-request. The commencement-time \(t_{start}\) for the request is interpolated at random within the model period \((t_{lo},t_{hi})\); that is, given a random number \(r\) \((0 \leq r < 1)\), \(t_{start} = t_{lo} + r(t_{hi} – t_{lo})\). The end-time \(t_{term}\) is found by reference to walking-time and travel-delay parameters of the market segment \(s\) associated with the OD model: \(t_{term} = t_{lo} + w_{max_s} + t_{min_{ij}} \cdot k_{max_s}\), where \(w_{max_s}\) and \(k_{max_s}\) are obtained by uniform random interpolation in ranges specified for market segment \(s\), and \(t_{min_{ij}}\) is the shortest possible travel time by road from \(i\) to \(j\).

**Journey-planning**

The travel-requests generated by the demand modules are passed, one by one, to a *request-broker* module, whose task is to plan an optimal journey that satisfies the requirements of each incoming request. A journey consists of a sequence of one or more *legs*; a journey-leg carried by a vehicular mode is called a *trip*. A single-leg journey may be walked all the way or carried by a door-to-door vehicular service (i.e. taxi or TaxiMulti). A multi-leg journey involves a sequence such as “Walk→Bus→Train→SmartShuttle→Walk”; or more precisely, “Leave origin-point at 10:10am, walk to bus stop, catch 290A bus at 10:15am, alight at Nerang at 10:25am, take the train from Nerang to Robina at 10:30am, alight at Robina at 10:40am, take SmartShuttle at 10:45, alight at local stop at 10:50, walk to destination, arriving 10:56am”. An example is shown in Figure 10.3.
Figure 10.3  Planning a journey
The planning of multiple-leg journeys is carried out by a journey-planning module, an optimisation procedure embodying a branch-and-bound algorithm. The journey-planning process is subject to behavioural constraints specified for each market segment, such as the maximum distance that the traveller is prepared to walk at a single stretch. The availability of service is determined by timetable data, or in the case of demand-responsive modes, by reference to the fleet-scheduling module. The objective in planning a journey is to minimise the generalised cost of travel, defined as the sum of any fares, together with the imputed cost of time for the person or persons making the journey. This imputed cost is estimated using valuation factors for the various time components of the journey, namely waiting at the origin, waiting at interchanges, walking, and travelling. Travel times are estimated as follows. For a walked leg, the time is simply the length of the leg divided by the walking speed associated with the market segment associated with the traveller; while for a leg carried by a timetabled mode, the travel time is obtained from the timetable. For a leg carried by a non-timetabled mode (i.e. RovingBus, TaxiMulti or taxi), travel time is calculated by reference to the mode’s service-quality standards (see Section 3.2 below).

**Fleet scheduling**

The LITRES-2 fleet scheduler manages the deployment of a fleet of demand-responsive vehicles, by planning each vehicle’s itinerary in response to trip-requests received over time from the request-broker. Figure 10.4 shows one such itinerary, including the vehicle’s current location and its planned pickup and setdown points (“+” and “−” respectively). A trip-request refers to a particular transport mode, and has explicit time-windows specifying early and late limits for departure from the start and arrival at the end of the trip: these limits are defined by the journey-planning module by reference to the service-quality standards pertaining to the mode. The overall objective when choosing an implementation for a trip is to produce favourable operational outcomes for the fleet operator (e.g. by minimising fuel costs). The finding of shortest-time paths between each successive pair of stops in a vehicle’s itinerary is a scheduling sub-task, and is discussed below in connection with the road network model. A distinction is made between the routes and timings planned by the scheduling module, and on the other hand the actual trajectory of a vehicle as it moves through the road network. In particular, the fleet scheduler sends dispatch commands (e.g. “Cab 99, proceed at 10:10 to location (x,y)”) to the network simulation module, which simulates the movement of each vehicle through the road network, and reports back to the scheduler when a vehicle arrives at a pickup or setdown point or is affected by an incident such as a breakdown.
3.2 Inputs and outputs

The Gold Coast project was planned as a series of scenarios, each specified as a set of inputs to a run of LITRES-2. In particular, a Base scenario provided a check of LITRES-2’s predictions against current conditions, while other scenarios were constructed as variants of the Base scenario, so as to investigate the performance of various postulated sets of passenger service options over different levels of demand.

A LITRES-2 scenario is defined by input data of the following kinds.

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**Figure 10.4  Itinerary of a demand-responsive vehicle**
a. A model of the road network is used as a basis for estimating travel times, and for routing vehicles in the fleet-scheduling and network simulation modules. The network model comprises a set of nodes and a set of directed links connecting the nodes, together with link speeds and distances. This is a format used in many commercially-available GISs, but the intensive use of network calculations has required special attention to the algorithms and storage strategies used for network calculations. For the Gold Coast project, a single speed was defined for each link and path durations were pre-calculated: subsequent extensions allow for fluctuation in link speeds over the course of a day. The techniques used to find shortest-time paths and their timings are variants of Dijkstra’s label-setting algorithm, with allowance for off-network travel between the (Euclidean) starting point of a path and a nearby network node, and vice versa at the end of the path.

b. A division of the study region into polygonally-bounded small-area units called zones provides spatial reference for demand models. Zonal decompositions are used also as bases for defining fare structures and zone-based SmartShuttle services.

c. Behavioral characteristics of travellers are defined in market segments. A market segment defines travel parameters for a particular set of travellers, such as elderly people. These parameters include a set of acceptable modes, valuations of time pertaining to generalised costs, a walking speed and a maximum walking distance. In addition, there are parameters for acceptable travel duration, and for the “notice period” between the time when travel is requested and when it is to take place.

d. As indicated earlier, aggregate demand is represented in the form of origin-destination (OD) and source-sink (SS) models, each of which is associated with a market segment, party-size parameters, and a time-range.

e. Specifications of timetabled services include locations of the points served (e.g. bus stops and railways stations), and service routes (sequences of points). The specifications for each route include a transport mode (e.g. bus), a fare structure, and a timetable.

f. Demand-responsive services are defined by specifying the vehicles in a demand-responsive fleet or fleets. Each vehicle has a passenger carrying capacity; a list of the modes offered; and an operating shift, specified as the period when the vehicle is in service, with a corresponding pair of terminal points. Associated with each demand-responsive mode are parameters specifying a fare structure, pickup and setdown times, and service quality. The service-quality standards comprise a waiting-time limit and a travel factor, the latter specifying an upper limit on the ratio of actual to minimum possible travel time: this ratio is one for single-hire taxi, and more than one in the case of the multiple-hire modes.

The main outputs from LITRES-2 are outlined below. The volume of these outputs makes them somewhat unwieldy in their raw form, and their interpretation in practice requires considerable care in the selection and examination of a smaller number of key indicators (for this purpose the outputs are now provided in a coded format, to facilitate transfer to spreadsheets).

a. Travel statistics include the total numbers of passengers carried and journey-legs completed, with average travel times, distances and costs, for the whole simulation period and for nominated time-intervals. These statistics are broken down by leg-sequence, by market segment, and by transport mode.
b. **Scheduling statistics** include the total numbers of passengers carried, with mean trip time and distance per passenger, for the demand responsive fleet(s), for each mode, and for each vehicle. As with the travel statistics, statistics are aggregated for the whole simulation period and also over nominated time-intervals. They include measures of efficiency (e.g. the ratio of travel time to the least possible travel time, relevant in the case of multiple hire modes) and of vehicle occupancy (i.e. the average number of passengers on board at any given time).

c. **Route-usage statistics** include the total numbers of passengers carried on each timetabled mode, and the totals for each route and each service run along each route, with average trip times and occupancy ratios. Again, statistics are aggregated for the whole simulation period and for nominated time-intervals.

4  The case study

The Base and other scenarios were planned in advance, and then adjusted and extended in the course of the project. The most demanding and time-consuming task was to fine-tune the considerable range of data inputs in the Base scenario, so as to obtain a credible match between model outputs and known conditions (Horn et al. 1998). The simulations themselves incurred little real delay: the run time for each scenario was generally between 20 to 40 minutes, on a Sun UltraSparc workstation.

4.1  The Base scenario

An eclectic approach was required in the preparation of the Base scenario, involving the use of sources whose applicability to the project was often somewhat indirect. Outlined below are the main sources for the data categories described earlier, and the adjustments applied to them in preparing the Base scenario.

*The road network.* The GCCC provided a road network dataset covering nearly all roads in the region, and comprising 4,166 nodes and 9,472 links. This was somewhat excessive in terms of the computational resources available; furthermore, it included a great deal of geometric detail which would be irrelevant to the analysis carried out by LITRES-2. The network was therefore reduced in size through the application of a filtering program, followed by manual correction of a few remaining anomalies. The filtering program was developed especially for this purpose. It removed “superfluous” dead-end links (i.e. each link to a node with no other links inward or outward), and “superfluous” intermediate nodes (i.e. each node with exactly one inward and one outward link). Aggregate distances were preserved in this process (e.g. where a chain of links representing a curved section of road was reduced to a single link). The reduced network comprises 1,686 nodes and 4,515 links, and is illustrated in Figure 10.5.
**Figure 10.5 The road network**

Link speeds were defined initially by applying speed limits corresponding with the road classifications provided with the network. These speeds were then systematically scaled down in the light of a preliminary simulation of taxi system performance, and ground speed checks carried out by BAH. For off-network vehicular travel, a uniform speed of 25 kph was assumed.

**Zones.** A zonal division of the study region was needed to provide spatial reference for bus fares and demand models. The zones were defined as those used by the Surfside Bus Company in determining fares, with unpopulated areas removed. These excisions – mainly in the estuarine parts of the region – were made in order to minimise distortions in the representation of demand, which is assumed within LITRES-2 to be distributed uniformly within each zone.
Market segments. BAH identified six market segments as a basis for modelling demand. The market segments may be characterised informally as follows.

- **Mainstream**: regular users of public transport when service is readily available.
- **Captive old and captive young**: people who have no real alternative to public transport.
- **Tourists**: tourists who choose to use public transport.
- **Car-oriented**: people who currently travel by car but may decide to switch to public transport if service of sufficiently high quality is available.
- **Rail commuters**: people who live within the corridor served by the railway and its planned extensions, and are likely to commute by train to workplaces in Brisbane.

Demand models. Estimates of current demand were obtained from a variety of sources (BAH 1998). Demand specifically associated with regional attractors (e.g. shopping malls, casinos, and funfairs) was modelled in the form of source-sink models, using estimates from economic studies of these facilities. Other demand was modelled in several series of origin-destination matrices, specified (as for the source-sink models) at hourly intervals over a 24-hour period (notionally a weekday). These OD series were compiled by GCCC staff from the Surfside Bus Company’s fare-collection data, Queensland Rail passenger data, and estimates of private car journeys from the SKM road traffic study mentioned earlier. The Base demand amounted to 21,148 travel-requests (31,722 travellers) during a 24-hour period. In temporal terms the patterns of demand were generally similar to those seen in other metropolitan areas, but with smaller peaks around the start and end of the conventional working day, and with a continuation of activity into the evening (or the early morning, in some of the entertainment districts).

Timetabled transport services. The geographic locations of bus stops and railway stations were digitised, and a small proportion of them were designated as interchange points for transfer on multi-leg journeys (this restriction proved to be unnecessary, since subsequent testing yielded very similar results with transfer allowed at every bus stop). The published timetables were transcribed and then elaborated, as follows. First, each route was defined as a bi-directional pair (e.g. an advertised north-south route 290 yielded two routes, 290N and 290S); second, variant routes implied by the timetables (e.g. with skip-stop service during peak periods) were generated explicitly; third, arrival times at stops without explicitly advertised times were interpolated in proportion to distances along the routes; and fourth, services on the projected extension of the railway line were extrapolated from existing timetables. Figure 10.6 shows a snapshot of the graphical browser, with a list of the routes connecting a designated pair of bus stops shown in the right-hand panel, and with one of those routes highlighted on the main map display window.
Figure 10.6  Bus and rail routes

Demand-responsive services. About 220 taxis currently operate in the wider Gold Coast region, under the aegis of Regent Taxis Limited. Some of the drivers specialise in traditional “step-in” service from cab-ranks, and some – with larger vehicles – specialise in multiple-hire work from specially designated cab-ranks; most drivers however rely mainly on Regent’s central dispatching centre for most of their work (Horn et al. 1999). The simulation involved a taxi fleet about half the size of the actual Regent fleet, reflecting the approximate proportion of taxi activity encompassed by the study region. As with the timetabled modes, service details and fares for taxis were matched to existing conditions as closely as possible. The new demand-responsive services (TaxiMulti, RovingBus, and SmartShuttle) were conceived as intermediate in terms of service quality and fares between taxis and buses. The fare structure in each case was defined as a base fare and a distance-based component, with group discounts for parties of two or more people.
4.2 Future transport scenarios

Low, Medium and High demand scenarios were constructed by scaling up demand from the Base scenario to represent (notionally) the range of conditions possible in the study region within the next decade. Different scaling factors were applied to the various demand components, yielding estimates of 42,291, 53,997 and 65,799 passengers respectively for the three scenarios, compared with 31,722 in the Base scenario. To avoid excessive optimism regarding the prospects for new transport services, the analysis focussed mainly on the Low demand scenario. A more extensive study might well encompass a wider range of possibilities in this respect, for example with geographical differentiation in the rates of growth in demand.

Fixed-route services

The assumptions in the future scenarios regarding rail, bus and taxi services were the same as those in the Base scenario. As might be expected, the simulations indicated that bus usage would increase substantially under increasing demand. In fact, there is probably scope for augmentation of bus services and routes in some areas: an investigation of such possibilities was beyond the scope of the project, but – with the Base scenario already available – would require little additional effort.

Multiple-hire services

Demand-responsive services were modelled in each scenario as a single fleet of vehicles, with each vehicle dedicated to a single mode. The Low, Medium and High demand scenarios included 40, 60 and 80 mini-buses respectively, divided equally between TaxiMulti and RovingBus service. The simulations showed these vehicles carrying several passengers for much of the time, although they were rarely close to their maximum carrying capacity (see Figure 10.7). High occupancy ratios are obviously desirable from a fleet operator’s point of view, but saturation of fleet capacity prevents additional passengers from using the fleet; thus if the fleet were larger, it might be chosen by passengers who currently use other modes. Consequently the simulated patronage of multiple-hire services in the main scenarios does not fully reflect the attractiveness of these services to the travelling public, a deduction that was borne out by supplementary simulations with larger fleet sizes. More generally, the “carrying capacity” of a fleet is a somewhat ambiguous concept, since “heavily-loaded” or “saturated” conditions are characterised by a gradual decline – rather than a complete disappearance – in the additional trips that can be accepted under marginal increases in demand: the limit, where no further passengers can be accepted, is arbitrary, fluctuating over time and sensitive to arbitrary variations in current fleet deployment. A reasonably precise estimate of fleet capacity may be obtained however by allowing a progressive stretching of service standards under saturated conditions (Horn et al. 1999, Horn 2002).
Results from the Low demand scenario (see Figure 10.8) indicate that the TaxiMulti and RovingBus services should generate gross earnings per vehicle greater than those obtainable from single-hire taxis, and carry roughly twice as many passengers, provided that fleet sizes are matched to demand as discussed above. These and other results also suggest that trips on multiple-hire modes are on average comparatively long. The trip-makers highlighted here presumably are those who wish to travel between extremities of the region, and are deterred from using alternative services by their unavailability or excessive slowness; thus the multiple-hire modes may be particularly useful in spatially dispersed conditions.
Analyses of usage for RovingBus and TaxiMulti suggested how these modes might be managed in practice. For example, given the temporal patterns illustrated in Figure 10.9, an adequate service might be maintained by replacing RovingBus with TaxiMulti late at night, the latter perhaps run with a fleet reduced to one-third its daytime size. It may be observed also that although each vehicle was assumed to be able to accommodate 11 passengers in the Low, Medium and High demand scenarios, the actual occupancies rarely reached this level (see Figure 10.7). A separate series of tests indicated that with capacity reduced to seven passengers per vehicle, the reductions in fleet performance and fleet-wide carrying capacity would be fairly small (of course this ignores less tangible considerations such as the sense of crowding that passengers would experience under pervasively nearly-full conditions).
Figure 10.9  Trips by TaxiMulti and RovingBus services under Low demand
As indicated earlier, a SmartShuttle service is advertised in the form of a timetable, but the actual routes taken by vehicles are defined on demand. A “feeder” role was envisaged for SmartShuttle in the Gold Coast, with vehicles plying between local railway stations and their residential catchment areas. The following account concerns a series of tests focussed on the new Nerang railway station and its catchment area, which was divided into five SmartShuttle zones. One SmartShuttle vehicle was provided per zone, and timetables were designed in coordination with the railway timetable so that (notionally) each vehicle could tour its zone between visits of the mainline train, generally at 30-minute intervals. For comparison, an approximately equivalent set of fixed-route bus services was designed for the same area.

Two series of simulations were run to test these arrangements, one with SmartShuttle feeders and one with buses, the level of service in each case being held constant while the “rail commuter” component of demand was scaled up incrementally from the Base scenario. These simulations showed that the SmartShuttle vehicles could serve nearly all prospective passengers under Base scenario assumptions while satisfying the journey-planning conditions discussed in Section 3 above; by contrast, fixed-route buses would leave about 8% of travellers beyond walking distance. With multipliers of 100 - 500% applied to Base commuter demand, the proportion of requests that could be feasibly satisfied by SmartShuttle would decline steadily from 100% to 85%; the simulations suggested that the corresponding proportion for buses would be approximately constant across the same range of demand. On closer examination, however, it became apparent that the latter figure significantly overstated the performance of buses, which LITRES-2 currently models in less detail than demand-responsive vehicles; in particular, no allowance is made for passenger-capacity constraints or for delays incurred when picking up and setting down passengers. Thus on local routes and under moderate demand, small buses running in SmartShuttle mode would almost certainly be more convenient for travellers than the same vehicles run in conventional fixed-route mode.

**Mode usage by market segment**

Figure 10.10 shows aggregate mode choice results for each market segment in the Low demand scenario. In summary, *car-converts* are relatively heavy taxi users because they place high value on their own time. *Tourists* are heavy bus users, their activities being concentrated in the coastal strip where the bus service is frequent and convenient. The *captive old* are willing to walk only short distances, and so are the heaviest users of TaxiMulti.
5 Conclusions

5.1 Effectiveness of transport services

The effectiveness of the new demand-responsive service modes as demonstrated in the project has led to a recommendation that they be implemented on a pilot basis (GCCC 1998, Section 5). The recommendation has not so far been implemented, presumably due to reluctance on the part of the Queensland Government to commit the substantial resources that would be required. In general however, the project confirmed the benefits of a co-ordinated, multi-modal array of transport services. Those benefits were apparent in the way that the various modes complemented each other with respect to service quality, geographic coverage and market segments: even RovingBus and taxi, which are closely related in logistical terms, were mutually competitive only to a marginal extent.

Multiple hiring of vehicles in demand-responsive fleets was shown to be effective in terms of service quality, fleet economics and market share. It appears that TaxiMulti and RovingBus may best cater to longer journey-legs for which bus services are either unavailable or too slow to meet travellers’ requirements, while taxis are more suited to shorter legs. SmartShuttle was investigated only to a limited extent, but as a feeder to railway stations and other regional interchanges, this mode appears to have advantages over a conventional scheduled bus service.

A critical requirement for TaxiMulti and RovingBus is the achievement of reasonably high occupancies in order to obtain substantial economies of scale over conventional taxi services. Occupancy rates in turn are directly sensitive to the travel factor, which defines the maximum allowable deviation from direct routing (see Section 3.2 above, and Rawling et al. 1995). Increasing the travel factor above the value of 130% assumed in the Gold Coast project would provide broader time-windows and hence greater flexibility for scheduling, making it easier to achieve high vehicle occupancies. This would be a desirable outcome, but a reduction in fares might then be needed to compensate travellers for longer travelling times.
Taxi services were not a major concern in the Gold Coast project reported here, but were investigated more thoroughly in a related study that concentrated on the Regent taxi fleet over its full geographical range (Horn et al. 1999). That study was concerned mainly with operational issues such as the balance between phone bookings and traditional “step-in” services at cab-ranks, the impact of advance notice of on carrying capacity and waiting times, and temporal staggering of shift changeovers. The availability of historical booking records made data preparation much easier than in the wider-ranging project reported here; the methodology was also more straightforward, since the focus was on individual initiatives and changes, rather than broader combinations of assumptions and proposals like those discussed elsewhere in this chapter.

5.2 Methodological considerations

Data preparation and validation

For CSIRO and its collaborators the most difficult challenges posed by the Gold Coast project were those arising in the preparation of a credible Base scenario, especially with respect to data items – market-segment parameters, demand models, and road speeds – defining behavioural characteristics of transport system users. Here there was no alternative but to make the most of whatever data sources were available, often in an indirect way or by reference to prior experience in other locations. The empirical foundation of the project cannot therefore be regarded as definitive, and the conclusions are best seen as indicative rather than strictly predictive. Even so, detailed examination of Base scenario outcomes, and sensitivity analyses of key variables (Horn et al. 1998), showed a satisfying conformity with known aspects of transport system operation.

Apart from these substantive concerns, the effort involved in data preparation constituted a large proportion of that invested in the project as a whole, and it seems clear that an effort of this kind might be difficult to justify in a once-off consultancy exercise. Conversely, however, the project suggests a framework within which public authorities might accumulate information on transport demand and system usage, the long-term benefits in this respect lying in the ease with which new proposals can be investigated once a suitable database is established.
Investigative strategy

Some other methodological issues were concerned with the relations between modelling – the central task of the project – and other phases of the planning process. In a naïve view, design or planning may regarded as proceeding in a linear sequence from the enunciation of a problem (e.g. as a set of objectives and conditions), to the formulation of a proposal (e.g. by proposing new transport services), to assessing the implications of that proposal (e.g. by means of a LITRES-2 simulation), and then to evaluating those implications (e.g. by interpreting simulation outcomes). But in any substantial planning exercise it can be expected that there will be backtrakings or feedback cycles to complicate a simple sequence like this, and it must be admitted that the extent of these complications was underestimated when the Gold Coast project was planned. The lesson here is that modelling should not be treated as an isolated task: although the broad outlines of transport options could be sketched in advance, the development of those options as credible proposals was intertwined with the modelling process and with the interpretation of its outputs.

For example, the main simulations of multiple-hire demand-responsive services involved the testing of a small number of proposals, each comprising specifications of fleet size, the carrying capacities of vehicles, the fares to be charged, service-quality standards, and so on. In fact these proposals themselves emerged from a preliminary series of simulation runs, in which a range of plausible values was explored for each of the main parameters. There was a similarly close relationship between design and simulation in the tests of SmartShuttle feeder services, which involved the additional design task of formulating “benchmark” bus services for comparative purposes.

A further point concerns the criteria applied in assessing simulation outcomes. Besides convenience, accessibility, and so on, it emerged during the course of the project that the clients believed that new passenger services should be able to operate with little or no public subsidy. The desire for operationally attractive performance entailed considerable effort in tuning the various proposals, and led to the exploration of demand-responsive services on a smaller scale than might have been undertaken otherwise. In retrospect, the rationale for this approach seems questionable, given the emphasis elsewhere on the benefits of consistency and integration in the provision of transport services. Operational viability is certainly a significant planning consideration, but to require that demand-responsive services should be fully self-supporting could prejudice their availability at the lower end of the socio-economic spectrum. It would be unfortunate indeed if an effort to modernise transport services were to involve the relegation of traditional fixed-route modes to a second-class or “safety-net” role.
Modelling tools

Experience in the Gold Coast project shows that effective usage of LITRES-2 requires a considerable level of interpretive intelligence, as indeed with any modelling system of comparable scope. This is illustrated by the counter-intuitive results encountered in the SmartShuttle tests, which highlighted an anomaly in the level of detail applied to fixed-schedule as opposed to demand-responsive vehicles (see Section 4 above). The anomaly can be removed by applying the same operational constraints and detailed simulation to buses as to demand-responsive vehicles, and further attention might be given also to the system’s representation of passenger behaviour (Horn 2000). In addition, an interface between LITRES-2 and a GIS might facilitate the preparation of input data and the analysis of modelling outputs.

There appears to be no immediate prospect of overcoming LITRES-2’s reliance on external estimates of passenger transport demand (Horn 2002). In this respect it is interesting to contrast the micro-simulation approach adopted in LITRES-2 (see also Tong and Wong 1999), with network-equilibrium models such as EMME/2, in which probabilistic methods are used to estimate the distribution of all journeys, including those made by private car (Spiess and Florian 1989). From a planning perspective, the main differences between the two approaches have to do with granularity and scope: where the equilibrium models are coarse-grained and comprehensive, micro-simulation is typically fine-grained and specialised (consider for example the practical difficulties attending a micro-simulation of all road traffic).

It is interesting also to consider the use of GIS buffering capabilities in estimating “catchment areas” and latent demand in the vicinity of transport routes, bus stops, railways stations and so on. This is clearly pertinent to analyses concerned with accessibility, especially where bus or rail routes are to be planned in conformity with official standards (e.g. maximum walking distances to bus stops). But accessibility by itself must be reckoned a weak indicator of transport system quality, since it is concerned merely with identifying the transport services that are physically available to people in a given area, rather than the services that those people are likely to use in practice. This criticism applies even to some interesting recent research involving the generalisation of temporal and operational aspects of accessibility (O’Sullivan et al. 2000).

The foregoing discussion has highlighted some strengths and weaknesses of LITRES-2 in the context of projects such as the one described in this chapter. In summary, LITRES-2 emerges as a very suitable means for assessing passenger transport operations and performance, with unique capabilities with respect to demand-responsive services. Considerable effort must be devoted to data collection and validation; nevertheless, once that investment is made, it is possible to explore a wide range of passenger transport planning options, to a level of detail that is not available elsewhere.

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GCCC (Gold Coast City Council) 1998. Gold Coast City Transport Plan.


