A SCENARIO APPROACH TO AIRPORT EVALUATION IN REMOTE COMMUNITIES: WITH PARTICULAR REFERENCE TO THE PILBARA REGION OF NORTH-WEST AUSTRALIA

David A. HENSHER
School of Economic and Financial Studies
Macquarie University
North Ryde

Peter B. THORNTON
Airport Consulting and Construction Australia Pty Ltd (a subsidiary of
Macdonald Wagner Pty Ltd)
Sydney and Perth

ABSTRACT: *Coordinated development of aviation facilities and services is critical for geographically remote communities. Given a growing desire to improve aviation capability in the northern regions of Australia, it is necessary to have an analytical base for determining the implications of alternative configurations of air services in terms of links to be served, airport/aerodrome investment, type of flight equipment and flight frequency. In this paper we outline a method for identifying airport supply configurations to meet air service demand to and from the Pilbara region of north-west Australia. The approach emphasises minimum levels of demand required from a community in order to justify provision of air services of a given scenario. The method is influenced by the paucity of data on demand in remote communities, and the consequent risk of relying solely on demand-side forecasts of patronage levels. It is therefore particularly useful in assessing transport systems associated with remote resource development projects which are notable for the rapidity of change which they can bring. The approach has relevance to a wide range of transport applications.*

INTRODUCTION

Airports and aerodromes have a long history of contribution to the economic and social development of remote communities in Australia. In conjunction with air services they provide a critical communication medium with more populous regions. Although there have been systematic efforts to plan for coordinated airport services in major capital cities, the evolution of such facilities in sparsely populated areas has been rather piecemeal. Mixed ownership of land-side facilities and different licensing statuses, together with the changing winds of fortune in developing regions, have contributed to an hierarchy of airports often with competing offerings in relation to air services, with the resultant potential for duplication and claims on limited resources for upgradings which while serving quasi-local interests may not be in the best long-term interest of the region as a whole. There is a clear need for a procedure that can assist in the prioratising of investment strategies (including disinvestment) for a region as a whole so that both maximum efficiency and equity are achieved in the light of available resources.

This paper outlines a method to assist in investment rationalisation for airport services in remote community regions, with particular reference to the Pilbara region of north-west Australia. The novel feature of the approach is its minimal reliance on often speculative demand forecasts of airport use, with the emphasis on supply side benefit-cost criteria linked in with the minimum ridership required to justify a level of landside investment as embodied in a supply-side scenario. Demand-side forecasts are moved from centre stage to provide (ball park) assistance only in the determination of the possible realism of each considered supply-side scenario, in terms of the latter satisfying likely levels of future demand for air services. Thus the outcomes are not strongly contingent on demand-side forecasts which have an infamous history of uncertainty.

The paper is organised as follows. In the next section we outline the supply and demand side modelling approach, followed by a discussion of the empirical context in which the method has been applied to date. We then select some typical outputs of the procedure to illustrate its contribution to the rationalisation of future airport investment strategies. We conclude with a summary of the major contributions of the paper.

THE EVALUATION METHOD

The method is designed to identify airport supply configurations required to meet air service demands to and from remote communities. Determination of an 'optimal' configuration of air services requires consideration of the air network to be served, the nature of airport/ aerodrome investment, the type of flight equipment and the frequency of flight services.

At the outset we have deliberately restricted the method to be accommodated within existing data sources, since the costs of mounting new surveys would render such a method cost ineffective. Central to the approach is the analytical criterion to determine the minimum level of demand required to justify provision of air services of a given type. The criterion must be useful also as a policy tool for selecting the communities to be incorporated in the air service network, as well as a means of providing a uniform basis for equitable treatment among those that should be included and excluded.

Given that some existing sites may be upgraded while others may remain at their current status or be allowed to run down, the centre-piece of the method is the equating of monetarised net time savings resulting from an adjusted air service at a given airport (in relation to a specific route or a network) relative to existing air service at that airport, and the incremental costs of implementing the service, which includes landside and runway investment. The resulting benefit-cost criterion together with an index of association between estimated minimum ridership and predicted ridership are used to guide the rationalisation of investment strategies. The approach is sufficiently general to accommodate both efficiency (aggregate benefits and costs) and distributional effects. To apply the formal core it is necessary to specify a set of future development and population scenarios and to evaluate each accordingly.

The Supply Side Module

In low density communities the frequency of air service is a critical variable in the measure of user benefits attributable to airport investment. Savings in travel time principally result from reduced waiting times at airports due to improved headways. There is a disutility to the traveller associated with the delay due to flight scheduling. Central to our approach is a recognition of an acceptable inconvenience limit under normal schedules and an unacceptable level of inconvenience when a low level of service occurs. For sparse networks and low-density markets, the quality of service can be approximated by frequency delay, with stochastic delay accommodated in load factor adjustment. A non-linear relationship between frequency delay and headway will pick up the disutility effect in the following way:

a.   very low headways are usually associated with high levels of inconvenience, given the expectations of travellers;

b.   as headway increases, expectations are adjusted to less frequent service, increasing tolerance to delay and preparedness to accept longer wait time;

c.   there is a maximum wait under normal service conditions; thus the marginal disutility of waiting time tends to zero; and

d.   beyond a certain level of service (commonly one flight per day or 15 hours headway) disutility is expected to increase significantly. The extent of the increase will

depend on the (potential) traveller's attitude to the
offered service versus no service, and to the expectation
that the single flight will not be significantly delayed.

e.   at very infrequent levels of service the marginal disutility
     of increased headway is assumed to be zero.

The assumptions in a-e can be embodied in a disutility function of the
polynomial form in equation (1).

$$\text{Frequency delay (hours)} = H^3/A - H^2/B + H/C \qquad (1)$$

where H is the headway and A, B, C are empirical constants defining the
level of service that shapes the disutility curve. The empirical constants
used herein impose the condition that the convexity of the disutility
function begins at a headway of 1 flight per day (say 15 hours headway
ignoring sleeping hours) and a maximum acceptable waiting time of two hours
(Figure 1).   This does not mean that such low frequencies have to exist
but only that the shape of the disutility function follows from the
particular level of service.   If there is a high level of service (e.g.
8 flights per day) then we would expect the initial concave portion of
the function to apply.   A default assumption is that frequency delay
equals average headway, which is a linear relationship independent of
delay. Linking frequency delay with marginal disutility of delay
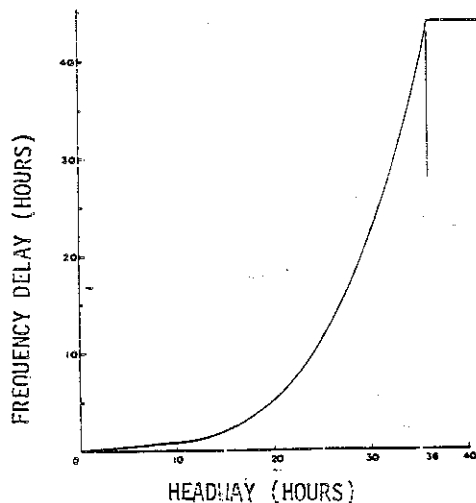produces a richer measure of the benefit to travellers of improved
services.

Figure 1.   The Waiting Disutility Function

For each planning year (including a base forecast year), we can
identify an airport pair (ij) and determine annual time savings associated
with adjusting services away from the current level.   By a suitable

weighting factor (w_{ij}) for the share of traffic from airport i to each and every airport j^{iJ} (j= 1,...,J) we can identify airport-specific time benefits. The headway of air services between each production-attraction pair (H) is a function of annual traffic levels (Y_A), defined as equation (2).

$$H_L = 15 * 365 \, L_{ij}/Y_A \tag{2}$$

where L is the load factor (average passengers per flight). Given equations (1) and (2) and the symmetry condition for airport pair weights $(w_{ij} = w_{ji})$, the adjustment in annual undiscounted benefits for airport i is :

$$\Delta B_i = Y_A V_I [\sum_{j=1}^{J} w_{ij}(\Delta INVT_{ij})] + Y_A V_0 [\sum_{j=1}^{J} w_{ij}(\Delta[\frac{H^3}{A} - \frac{H^2}{B} + \frac{H}{C}])] \tag{3}$$

where Y_A is the total number of trips into and out of airport i,

V_I is the unit value of inflight time savings (¢/person hour),

$INVT_{ij}$ is the inflight time of travel between airport production i and airport attraction j,

V_0 is the unit value of waiting time savings

and all other terms are as defined previously.

Since the benefits which accrue to each passenger depend on the route flown, the proportion of travellers on a one-way link, w_{ij}, is used to weight the time benefits on the link to produce a weighted average link time benefit. The headway equation (2) is then replaced by equation (4).

$$H_L = 15 * 365 \, L_{ij}/[w_{ij} \, Y_A] \tag{4}$$

Equation (3) assumes that the only user resource benefits are time savings. However, if we are also interested in the incidence of benefits, we can include savings in air fares (INVC) and other influencing non-resource adjustments (δ). So we would add into equation (3) the following:

$$Y_A [\sum_{j=1}^{J} w_{ij}(\Delta INVC)_{ij}] + Y_A V_S [\sum_{j=1}^{J} w_{ij} \Delta \delta] \tag{5}$$

The (undiscounted) annual incremental cost (IC_i) of airport provision is defined by equation (6)

$$IC_i = Y_A \sum_{j=1}^{J} [\Delta (\frac{C_{ij}}{L_{ij}} INVT_{ij})w_{ij}] + CRF * \Delta I + \Delta M \qquad (6)$$

where C_{ij} is the aircraft cost including amortisation of original costs ($/min);

   $CRF * \Delta I$ is the capital recovery factor multiplied by the change in annualised capital cost of the airport;

   ΔM is the change in annual airport maintenance costs, assumed to be 100% recoverable.

   All cost items are assumed to be constant over five-year periods, are in constant dollars of the base year and are summed over the economic life of the airport (assumed to be 20 years).

   To determine the minimum number of passengers (Y_A^S) required to justify a proposed service/facility change of a particular scenario and economic life start time we set Y_A to the unknown Y_A^S and solve equations 3 and 5 subject to $\Delta B - IC = 0$. Equations 3 and 5 can also be implemented with demand forecasts Y_A^D to obtain the traditional benefit-cost ratio.

The Demand Side Module

Demand forecasts can be used to provide one benchmark of likely patronage level (Y_A^D) which when related to the supply-determined minimum-ridership 'forecast' (Y_A^S) can be used to guide the prioritising of investment strategies. An investment strategy index (ISI_i) can be defined as equation 7.

$$ISI_i = 1 - [Y_i^S/Y_i^D] \qquad (7)$$

   An econometric aggregate city-pair model of air passenger trips is used together with a time-series of cross-sections to obtain parameter estimates for the influences on patronage levels. Since passenger forecasts associated with investment in regional and local airports will typically be required to apply to periods well into the future (up to 30 years) it is necessary to limit the set of explanatory variables to those that are relatively easy to forecast, have some commonality of trust in their future levels, and contain a subset of variables which are critical to the scenarios being considered. Examples of scenario-linked variables are travel time, air fares and particular plans for local/regional development. Thus compromise is required, given the state of forecasting, between truly explanatory models and typically descriptive models. Further discussion of the demand function is best tied in with the empirical application.

A CASE STUDY - THE PILBARA ZONE OF NORTH-WEST AUSTRALIA

Background

The Pilbara zone of Western Australia (WA) was selected in 1982 by the Department of Aviation for priority consideration as part of the National Aerodrome Plan for Australia. The general objectives are the definition of the scope and timing of aerodrome requirements for forward planning purposes and the provision of a broad strategic framework to guide the development of aerodromes and aerodrome facilities.

Historically, aviation has been of great importance to the remote regions of WA. The trend has been for the regular public transport (RPT) network to be rationalised to use larger and faster aircraft, with the consequence that small urban settlements have been dropped from the network. Air links from RPT airports to such centres have been maintained using commuter standard aircraft.

All the major aerodromes are locally or privately owned. The main urban hubs of Karratha and Port Hedland are owned and operated under the Aerodrome Local Ownership Plan (ALOP) while minor hub aerodromes such as Paraburdoo and Newman are owned and operated by Hammersley Iron Pty Ltd and Mt Newman Mining Company Pty Ltd respectively. Commonwealth owned and operated aerodromes predate the development of iron ore resources in the Pilbara. They are located at Onslow, Wittenoom, Nullagine and Marble Bar. Throughout the Pilbara there are scattered authorised landing areas (ALA's) which enable commuter standard links to be operated to remote smaller mining operations such as Pannawonica and Shay Gap.

Development of iron ore resources has been the stimulus for all significant economic growth in the zone, the establishment of infrastructure including airports and the formation of the current predominantly Fokker F28 aircraft, airline network. The current development of the hydrocarbon resources of the NW shelf is a major new addition to the Pilbara's economic base with a significant impact on the local economy of Karratha. However, despite historical prosperity and growth, which has provided a relatively stable population with on-going regional commitments, a number of events have placed considerable uncertainty on the future growth of the region. It is clear that events in the development of resources for the export market will continue to be the key factors in determining the growth of the population in the Pilbara (including its composition) which will be the single most important consideration in the determination of air service needs. While the NW shelf gas project provides a plus for regional growth it is the only known future event (subject to decisions on phasing) which is likely to cause substantial peaks in air passenger demand on top of an otherwise generally flat baseline growth. This benefit will be centred on Karratha. Mine upgrading at Port Hedland, Paraburdoo and Newman may contribute lesser peaks. These prospects have to be placed

in the context of the general decline in the profitability of the iron
ore and salt industries which have resulted in a corresponding decrease
in the rate of development and population increase. Future population
growth up to 2010 is unlikely to exceed 2 per cent per annum.

Accompanying the uncertainties in development are uncertainties
in the structure and conduct of the airlines servicing the area in the
future. The route structure (as of late 1983) for RPT's and third level
air services are shown in Figure 2, and a summary of the status of each
airport and ALA in the Pilbara zone in Table 1 together with a description
of the capabilities of aircraft used on each route (Table 2). The
relaxation of regulations and increased potential competition mean that
changes in the composition of airlines, services and aircraft are likely
to open up a Pandora's box of possible futures. The region is displaying
conditions of approximate contestability in the current phase of trans-
itional partial deregulation. All of these considerations suggest that
a scenario-approach to determining likely future airport needs is
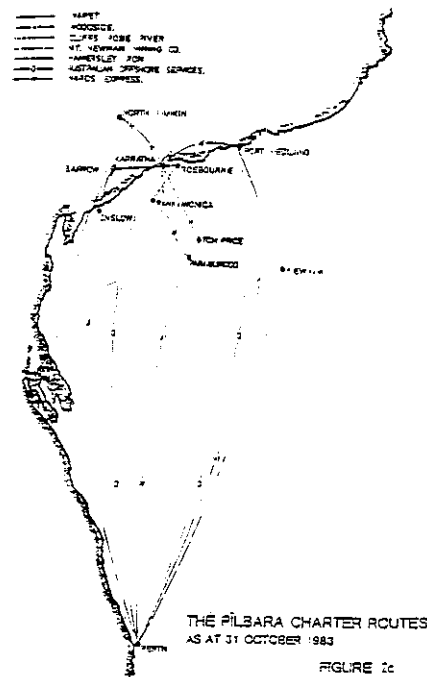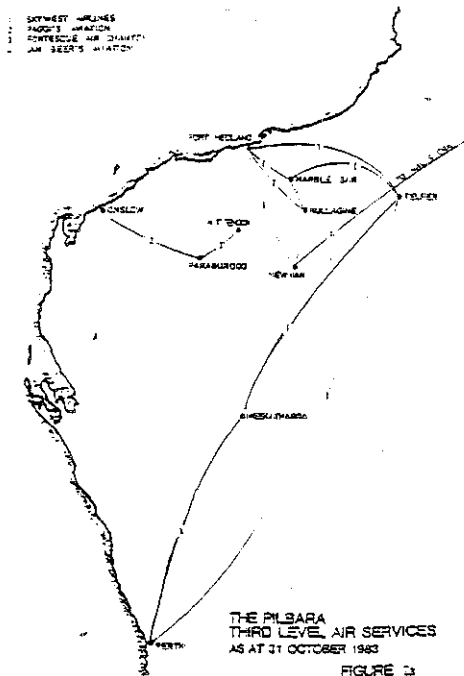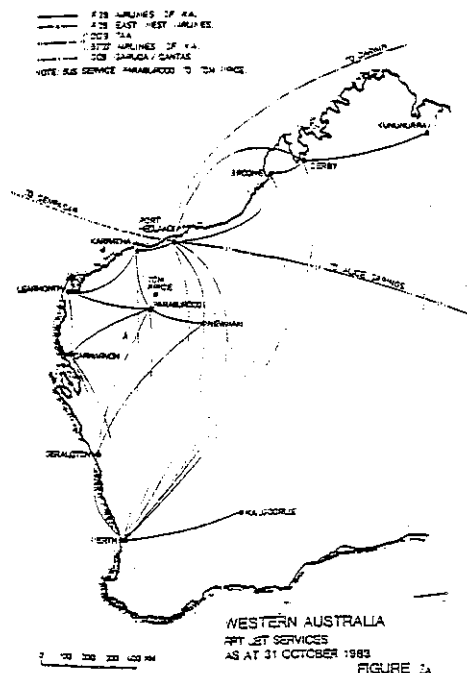desirable.

Scenarios

The demand and supply side modules are 'driven' by scenarios
centred on the upgrading of aircraft equipment. Changes in aircraft
technology are related to the headway and inflight travel times (and
fare) as well as the costs of operating aircraft and airports plus
infrastructure costs. The evaluation method has been applied to an
airline network as well as a particular airport. We will illustrate
the scenario approach in two contexts,(a) the potential establishment
of a hypothetical airport X at an unspecified location in the Pilbara
in the general vicinity of Paraburdoo and Newman. The airport is
assumed to be linked to Perth and one other airport (e.g. Karratha or
Port Hedland), (b) an airline network which connects by direct link
the four major airports in the Pilbara - Karratha, Port Hedland,
Paraburdoo and Newman - to each other and to Perth. Direct links
to Darwin from Karratha and Port Hedland are included. Although the
application provides a condensed version of the actual RPT network
in the region, the method can in principle be applied to any level of
network detail subject to available data.

The airport - X and network models set out below examine the
annual passenger movements required at each of the Pilbara airports
to justify upgrading of the airport and aircraft type over the network
simultaneously or on specific routes only.

The scenarios have been evaluated for a 20-year economic life
of an airport with forecast values and discounting based on each of
four 5-year periods (up to 2010). The time streams of costs and
benefits are discounted back to 1984 present values using 10%, 12%
and 15% test social discount rates. The forecast values of variables
have been identified in dollars of the time of incurrence.

WESTERN AUSTRALIA
RPT JET SERVICES
AS AT 31 OCTOBER 1983
FIGURE 2a

THE PILBARA
THIRD LEVEL AIR SERVICES
AS AT 31 OCTOBER 1983
FIGURE 2b

THE PILBARA CHARTER ROUTES
AS AT 31 OCTOBER 1983
FIGURE 2c

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AIRPORT EVALUATION

TABLE 1   MAJOR PILBARA AIRPORTS AND ALA's (FEBRUARY 1984)

Name	Ownership	Facilities	Runways	Regular Commercial Services
KARRATHA	Roebourne Shire	Terminal, Two Hangars Control Tower, FSU, Met Office, Hydrant Refuelling, Hire Cars	1 sealed Lighting T-VASIS	AWA (F28) Skywest (Cessna 310/402)
PORT HEDLAND	Port Hedland Shire	Terminal, Four Hangars Control Tower, Fire-Rescue Station, FSU, Met Office, Hydrant Refuelling, Hire Cars	2 sealed Lighting T-VASIS	AWA (F28, B737) TAA (DC9) Garuda DC9 East-West/Skywest (F28) Skywest (Cessna 310/402)
NEWMAN	Mt Newman Mining Co	Terminal Hydrant Refuelling Hire Cars	1 sealed Lighting T-VASIS	AWA (F28) Skywest (light aircraft)
PARABURDOO	Hamersley Iron	Terminal Hydrant Refuelling Hire Cars	1 sealed Lighting T-VASIS	AWA (F28) Paggi (Partenavia) Fortescue (Partenavia) (Alternate airport for DC9/B/737)
ONSLOW	Commonwealth	Terminal	2 unsealed Emerg. Lighting	Paggi (Partenavia)
WITTENOOM	Commonwealth	Terminal	2 unsealed Lighting	Fortescue (Partenavia)
TOM PRICE	Hamersley Iron	Terminal	1 unsealed Emerg. lighting	None
ROEBOURNE	Roebourne Shire	Terminal	2 unsealed Emerg. lighting	None
MARBLE BAR	Commonwealth	Terminal	2 unsealed Emerg. Lighting	Skywest (Cessna 310/402)
NULLAGINE	Commonwealth	Terminal	1 unsealed Emerg. Lighting	Skywest (Cessna 310/402)
BARROW ISLAND (ALA)	West Australian Petroleum Pty Ltd		1 sealed Lighting	F28 (Charter)
TELFER (ALA)	Newmont Holdings Pty Ltd		1 sealed	Skywest (Cessna 310/402) Cessna Citation on charter
SHAY GAP (ALA)	Goldsworthy Mining Co.		1 unsealed	Light aircraft (charter)
GOLDSWORTHY (ALA)	Goldsworthy Mining Co.		1 unsealed	Light aircraft (charter)
WICKHAM (ALA)	Cliffs Robe River Mining Associates		1 unsealed	None
PANNAWONICA (ALA)	Cliffs Robe River Mining Associates		1 unsealed	Cessna 310 (Charter)
NORTH RANKIN (ALA)	Woodside		Helipad	Aerospatiale Puma Bell 212 (Charter)

TABLE 2   AIRCRAFT DATA (SELECTED TYPES)

Aircraft	Group No.	Manufacturer	Wing Span (m)	Length (m)	Height (m)	Passenger accommodation (excluding crew)	Typical Gross Weight (kg)	Max Range (km)	Best Cruise Speed (Mach or km/h)	Powerplant
B727-200	A	Boeing (US)	32.92	46.69	10.36	150	87,000	3 600	.8 - .84	3 P & W JT8D-15
DC9-50	B	McDonnell Douglas (US)	28.45	56.31	8.38	100-115	55 000	2 148	.76 - .80	2 P & W JT8D-11 or 15
B737-200	B	Boeing (US)	28.35	30.48	11.28	100-115	52 730	3 000	.73 - .78	2 P & W JT8D-17
F28-4000	C	Fokker (North)	23.58	27.40	8.47	65	29 480	2 093	.845	2RR Spey MK555-15
F28-4000	C	Fokker (North)	25.07	29.61	8.47	85	32 205	2 095	.845	2RR Spey MK555-15H
BAe 146-200	C	British Aerospace (UK)	26.34	28.55	8.61	100	40,597		.805	4 Lyc ALF502R-5
Citation 2	D	Cessna (US)	15.76	14.39	4.53	10	6 500	3 222	.75	2 P&C JT15D-4B
BAe Jetstream 31	D	British Aerospace (UK)	15.85	14.37	5.32	18	6,614		488	2 GA TPE331-10
Saab-Fairchild 340	D	Saab-Scania Fairchild	21.43	19.76	6.86	35	12 272		510	2 GE CT7-5A
EMB 120	D	Embraer (Brazil)	19.79	20.00	6.54	30	10 823		507	2 P&C PT7A-1
DHC Dash 8	D	De Havilland Canada	25.63	22.26	7.62	36 - 39	15 860		490	2 P&C PW120
Super King Air 200	E	Beech (US)	16.62	13.35	4.57	8 - 14	5 700		561	2 P&C PT6A-42
Cessna 402	E	Cessna (US)	13.45	11.07	3.48	8	3 114		322	2 Recip.

Abbreviations:

GA - Garret
P & W - Pratt & Whitney
P&C - Pratt & Whitney Aircraft of Canada Ltd
RR - Rolls-Royce

Group Numbers:

A - Large Jet
B - Medium Jet (A)
C - Medium Jet (B)
D - Commuter Jets and Commuter Prop Jets Over 5,700 kg
E - Commuter and Other Aircraft Below 5,700 kg

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The financial variables, average weekly earnings (E), link airfare (INVC) and fuel costs (FC) were updated using a simple time extrapolation. Other variables are defined as scenario variables with their levels specified for each evaluation. Given the upgrading scenario, the particular airport and the social discount rate, the supply side output is

1. The minimum number of annual passenger movements (Y_A^S) required such that net benefits are positive.

2. At Y_A^S, the annual incremental passenger benefits and the annual incremental costs of providing the changed standard of airline service.

3. A summary of the components at the Y_A^S value, that is the dollar value of changes in inflight time, airfares, waiting time disutility, aircraft operating costs and annualised airport capital and maintenance costs.

The load factor is related to the headway. For low values of headway (i.e. frequent flights) the disutility is assumed to be very slight. In the headway range of 5 to 7 hours, the curve is flat indicating that changes in headway in this range cause little additional inconvenience (or benefit) to passengers. Beyond 10 to 15 hours headway the disutility curve steepens rapidly and at about a headway of 33-34 hours the disutility experienced by the traveller begins to exceed the actual headway. We assume that people prefer to travel between 6 a.m. and 9 p.m. (a 15-hour day), that is, a time interval between flights of slightly greater than 2 days. Beyond 33 to 34 hours the disutility experienced is assumed to be considerably greater than the actual headway. To prevent the disutility function from predicting unrealistically high values, it is assumed to be constant beyond 36 hours (about 2½ days).

The optimised level for Y_A^S can be contrasted with Y_A^D. A number of relatively simple functional forms were analysed for the dependent and explanatory variables in the demand model; however a linear generalised cost specification gave the best statistical fit and predicted airport specific passenger movements extremely well (Table 3). The demand for air travel to and from Pilbara airports, estimated on 1979-1984 annual data is strongly influenced by the population size at the production and attraction ends, the generalised cost of air travel (invehicle time, headway and airfare), and five dummy variables, the latter accounting for specific contextual effects which had a significant effect on the level of passenger movements in and out of particular airport market areas. Perth is a major hub AMA, with a population substantially larger than any of the Pilbara region AMA's. The Perth dummy variable provides a mechanism for allowing the parameter estimate of population to take two values, one value for all AMA pairs which do not involve Perth, and a value for links involving Perth. This variable must be interpreted jointly with the population variables.

The No-bus dummy variable gives an indication of the relative isolation of the AMA in terms of access by public land transport. Automobile costs and travel times were considered but excluded in this trip distribution model. They are both highly correlated with air fares (being distance linked with zero congestion) as well as automobile travel being a poor substitute for the population of air travellers. The Pilbara-Port dummy variable accounts for the diverse economic roles that Karratha and Port Hedland play. The Gold-dummy and the Karratha-growth dummy variables allow for the specific and localised upsurgences of economic activity in the early 80's in Kalgoorlie and Karratha respectively. For the period 1979-1982 the Karratha growth factor influences passenger movements over the network by 4020, -60, 5730 and 15170 trips respectively; the Gold dummy variation is 2900, 6030, 10630 and 12830 respectively. The role of these variables varies over time quite significantly in contrast to the other dummy variables which have a uniform influence on passenger movements through time.   In remote areas such as the Pilbara region the model suggests that passenger movements are driven primarily by economic activity associated with export industries. Both the Gold and Karratha growth factors required special consideration in their projection up to the year 2010. Figure 3 gives an example of the final passenger movements at Karratha in the presence and absence of the Karratha growth factor.

TABLE 3   THE DEMAND MODEL

(a) Estimated on data for the period 1979 to 1982.
Dependent variable: No. of passenger movements between i and j
(mean = 5164, s.d. 7016)

| EXPLANATORY VARIABLES	T-VALUES*	MEAN	STANDARD DEVIATION
No bus dummy (1, 0)	-2.38	0.156	0.366
Perth dummy	19.82	0.375	0.48
Karratha growth dummy (1 0)	4.77	0.031	0.175
Gold dummy (1, 0)	20.95	0.032	0.175
Pilbara port dummy (1 0)	14.07	0.063	0.244
Population at airport zone i ('00s)	3.33	111.265	155.69
Population at airport zone j ('00s) (set to zero if Perth)	3.55	110.796	155.92
Generalised Air Travel Cost ($0)	-6.56	186.56	77.39

Overall fit (R²) = .974
Standard error of estimate = 1202.54
* Estimated coefficients cannot be given for proprietary reasons.

(b) Airport-specific actual and predicted passenger movements 1982

	Actual Movements	Predicted Movements
Perth	311964	311950
Paraburdoo	23658	20673
Newman	23419	21084
Karratha	80835	87247
Port Hedland	59225	60910
Kalgoorlie	47288	47287
Geraldton	30696	30114
Carnarvon	15824	18421
Learmonth	12461	15251
Broome	24317	24562
Derby	28001	27397
Kununurra	24285	18629
Darwin	30849	29229

Data for the demand model was collected on an 'airport market area' (AMA) pair as a production-attraction specification. The AMA's are Perth, Onslow Paraburdoo/Tom Price, Newman, Wittenoom, Karratha, Pt. Hedland, Roebourne, Kalgoorlie, Geraldton, Carnarvon, Learmonth, Broome, Derby, Wyndham, Kununurra, Darwin, Bali. The full set of variables measured for each i, j or ij pair are population at i, population at j, annual passenger movements between i and j by RPT, mean gross household income, percentage of employees receiving cash in i, variability in this percentage, airfares. headway, load factor, shortest air time between i and j, longest air time between i and j, travel time by auto between i and j by shortest route, travel distance by car between i and j, dummy variables for availability of air service out of AMAi during 6am-10am, 10am-2pm, 2pm-6pm, 6pm-10pm; travel time by bus between i and j, bus fare, average household size, average number of persons per household under 18, accommodation cost if travel by car between i and j, number of hospital beds in i, total workforce, Karratha specific growth factor, number of primary, secondary, tertiary education institutions, goldmining area dummy . Onslow, Roebourne, Wittenoom and Wyndham AMA's were excluded from demand estimation because the very low passenger movements were significantly biasing parameter estimates by creating outlier effects.

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FORECAST PASSENGER MOVEMENTS AT KARRATHA
FIGURE 3
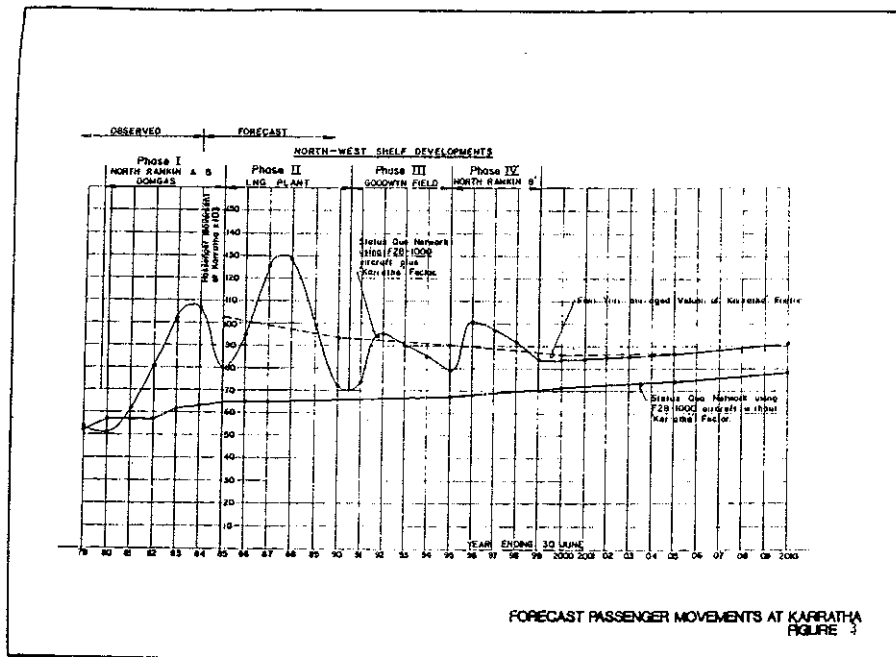
SUPPLY SIDE MODELS

Airport 'X'

Developments in the energy, mining and/or tourist industries in the Pilbara could cause a rapid change in demand for air services at one of the small centres not currently served by RPT or at a location at which an entire new town is to be constructed. To examine this type of effect, a model known as the 'Airport X' model has been devised.

This model assumes the establishment of a hypothetical airport at an unspecified location in the Pilbara in the region of Paraburdoo and Newman. Airport 'X' is assumed to be linked to Perth and one other airport assumed to be either Karratha or Port Hedland. The 'Airport X' model forms a simple air network which can be used as a planning tool for determining the annual passenger movements (Y_A^S) required to justify a particular airport configuration at as yet unknown sites.

The results of the Supply Side analysis carried out for Airport X are given in Figure 4 and Table 4. Figure 4 shows the relationship between average annual net benefits and passenger movements at Airport X for five upgrading scenarios:

- Commuter to F28-1000;
- F28-1000 to F28-4000;
- F28-1000 to DC9;
- F28-4000 to DC9;
- DC9 to B727.

AIRPORT EVALUATION

Table 4 shows that about 35,750 passenger movements would be
required at Airport X to justify upgrading to the standard of an
airport capable of handling F28-1000 aircraft when the following
conditions apply:

> All links are upgraded simultaneously;
> Social discount rate (SDR) of 10% and 100% value of time (VOT)
> Perth weighting 80%;
> Airport X - Perth load factor 75%; Airport X - Karratha/
> Port Hedland load factor 50%; (except for commuter scenario
> which assumes 100% load factor on both links).

For the same set of conditions, Figure 4 suggests that not until
passenger movements exceed 88,000 would further equipment upgrading to
a wholly F28-4000 aircraft fleet be justified and at this level all net
benefits would be distributed to the airline operator. However, it is
clear from Table 4 that upgrading from F28-1000 to DC9 would be
justified at or about 95,000 passenger movements and while the net
benefits would still be distributed to the airline operators, the
incremental benefits from reduced invehicle time and reduced airfares
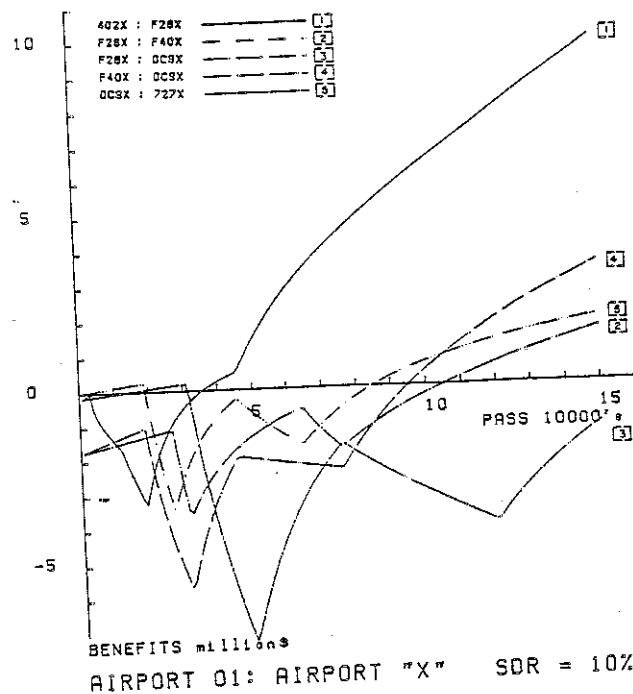would lessen the costs incurred by passengers. This latter scenario

Figure 4. Airport X Supply Side Evaluation

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TABLE 4   COSTS AND BENEFITS FOR UPGRADING SCENARIOS AT THE Y_A^S LEVEL

AIRPORT: AIRPORT X   MODEL: AIRPORT X MODEL

Upgrading Scenario	Annual Incremental Passenger Benefits $'s						Annual Incremental Service Costs $'s	
	Annual Passenger Movements Y_A^S	Change in Air Travel Time ($)	Change in Airfares ($)	Change in Headway ($)	Total	Change in Aircraft Operating Costs ($)	Change in Annual Incremental Air-port Capital & Maintenance Costs ($)	Total ($)
1 Commuter to F28-1000	35 756	182.438	2 618 979	-2.259 185	541,732 ($15.15/pass)	321 540	229 169	541 709
2. F28-1000 to F28-4000	84.928	0	0	-1 190 166	-1,190,166 (-$14.01/pass)	-1 190.166	0	-1.190.166
3 F28-1000 to DC9	95.189	72.799	1 495 355	-1.840.114	-271,999 (-$2.86/pass)	-2,120.468	1.745 524	-271 959
4 F28-4000 to DC9	105.245	80 489	1.653.325	-744 076	989,738 ($9.40/pass)	-756 788	1 746.524	989 737
5. DC9 to B727	172 273	42 305	1 078 445	-1.878.968	-758,218 (-$4.40/pass)	-910.068	151.838	-758 230

Notes: 1.   All amounts in 1984 $'s.
         2.   All amounts are annual incremental costs/benefits between scenario levels
         3.   SDR 10%.

would incur an annual airport capital and maintenance investment of about $1,750,000 over the assumed 20 year life of the airport whereas the former incurs none as F28-4000 aircraft can operate from the same airport as F28-1000 aircraft.

The passenger movements required to justify further upgrading from DC9 to B727 aircraft, at about 172,300, are sufficiently great as to rule out the possibility of this size of aircraft currently being justified at any location for which the Airport X model is a planning representative.

The Airport X model, being a relatively simple network but representative of the long-short links operated by aircraft servicing the Pilbara from Perth, provides an opportunity to examine the sensitivity of the value of Y_A^S to changes in variables which form the Supply Side model's data base.

Figure 5 presents the results of varying the proportions of the Perth traffic within the total passenger movements at Airport X. The notable features are:

  . The highly sensitive relationship between the proportion of Perth traffic and Y_A^S;

  . The dramatic peaks in Y_A^S for Perth weightings of 95% - 85% for all scenarios other than commuter to F28-1000;

  . The relatively close Y_A^S values required to justify upgrading to DC9 as opposed to F28-4000 from F28-1000 for Perth weighting in the range 85% - 80%;   and

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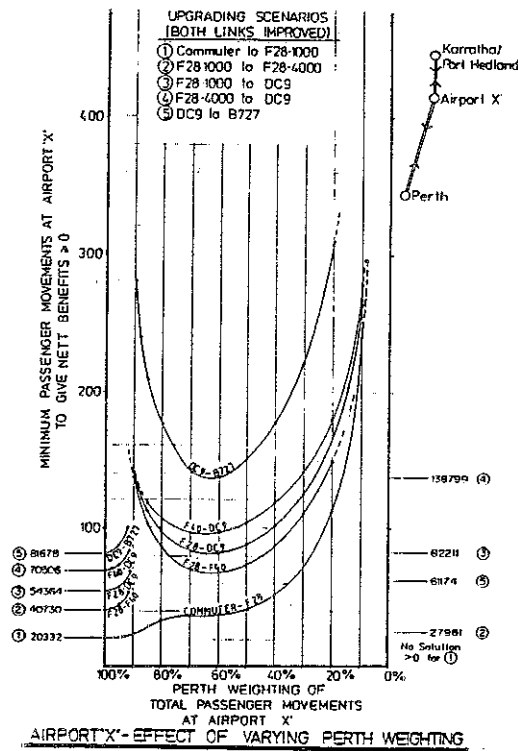
Figure 5. Effect of the Perth Hub

Because historically Perth weightings for Pilbara airports are approximately in the range 95% to 75%, the F28-1000 is well suited to the long-short link nature of a Pilbara networking operation. This is due to the relatively insensitive nature of the relationship between Y_X^2 and the Perth weighting in the range 95% to 75% for the commuter to F28-1000 upgrading scenario. By contrast all further upgrading scenarios are highly sensitive in this range.

Tables 5 and 6 present the results of sensitivity tests in which both the SDR and the value of time (VOT), for invehicle and waiting time are varied for the upgrading scenarios:

   ‚ Commuter to F28-1000;
   ‚ F28-1000 to DC9.

TABLE 5   AIRPORT X MODEL: SENSITIVITY OF Y_A^S TO CHANGES IN VOT
          AND SDR:COMMUTER TO F28-1000 UPGRADING SCENARIO

		Value of Time (VOT)			Annualised Average Incremental Airport Capital & Maintenance Costs ($)
		75% VOT	Base VOT	125% VOT	
SDR	10%	28,719	35,756	43,754	229,169
	12%	28,848	36,222	44,129	227,031
	15%	25,067	37,023	44,759	224,615

TABLE 6   AIRPORT X MODEL: SENSITIVITY OF Y_A^S TO CHANGES IN VOT
          AND SDR:F28-1000 TO DC9 UPGRADING SCENARIO

		Value of Time (VOT)			Annualised Average Incremental Airport Capital & Maintenance Costs ($)
		75% VOT	Base VOT	125% VOT	
SDR	10%	89,514	95,190	99,517	1,746,524
	12%	90,524	95,771	100,078	1,539,151
	15%	91,523	96,723	100,995	1,304,774

'Network' Model Analysis

     This model is based on an airline network with direct links
between all four major airports in the Pilbara - Karratha, Port Hedland,
Paraburdoo and Newman - to each other and to Perth.   In the case of
Karratha and Port Hedland direct links to Darwin are also included.
This model provides a condensed version of the actual RPT network in
Pilbara.   The importance of network effects on transport costs and
hence scale and scope economies has been strongly supported in recent
empirical studies (Wang and Friedlaender 1984, 1985, Johnson 1985).

     The purpose of this model is to examine the minimum annual
passenger movements (Y_A^S) which would be required at each of the Pilbara
airports to justify introduction of various different aircraft types
on routes to and from these airports.   This provides a useful assess-
ment of the network effects that exist in Western Australia and of the
differences that exist between the four major airports in the Pilbara.

     The Network model can also be used to examine not only the net
benefits and benefit/cost ratios which occur at specific airports, but
also for the Pilbara airport system as a whole.   These can be computed
to forecast passenger movements at each airport.

AIRPORT EVALUATION

The scenarios examined in the Network model are:

" Commuter to F28;
" F28 to DC9;
" DC9 to B727.

In addition two further scenarios were considered in which upgrading occurred only on specific routes:

" S4 - DC9/F28 mixed system with DC9 on PER-KTA-PRW and PER-PHE-DRW routes and F28 on the remainder.

" S5 - DC9/F28/Commuter mixed system with DC9 as in S4, PER-ZNE and PER-PBO and F28 with commuter on intra-Pilbara port links.

The F28 scenarios used averaged data which reflected the current mix of small passenger jet aircraft being used by East-West and Ansett WA on the Pilbara routes (i.e. F28-1000, F28-4000 and BAC-146). In the final form of the Network model each link appears only once to avoid double counting of benefits and costs in the system as a whole. As a result cross linkages between the Pilbara ports have to be assigned to one port only. To determine which port such links should be assigned to, the principle adopted is that a link is assigned to the airport which determined the standard of equipment which can be operated on the link.

The following hierarchy was assumed: Port Hedland > Karratha > Newman/Paraburdoo. Consequently, the following linkages were adopted:

" Port Hedland linked to Perth and Darwin
" Karratha linked to Perth, Darwin and Port Hedland
" Newman linked to Port Hedland, Karratha and Perth
" Paraburdoo linked to Karratha, Port Hedland and Perth

The Network model assumes that all links are upgraded/downgraded simultaneously; the SDR is 10%, the base VOT is used, and the weights attached to total passenger movements are:

From/To	KTA	PHE	ZHE	PBO	PER	DRW
Karratha	0	.03	0	0	.45	.02
Port Hedland	0	0	0	0	.37	.13
Newman	.05	.07	0	0	.38	0
Paraburdoo	.06	.02	0	0	.42	0

Average Annual Load Factors on Network Model Links (as percentages of seats available) are:

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	KTA	PHE	ZNE	PBO	PER	DRW
KTA	0	42	72	42	77	50
PHE	42	0	62	38	67	50
ZNE	72	62	0	55	75	0
PBO	42	38	55	0	60	0
PER	77	67	75	60	0	0
DRW	50	50	0	0	0	0

Source: Department of Aviation records.

Using the Network model established in this configuration, each of the four Pilbara airports was investigated to determine the minimum ridership Y_A^S required to justify each of the upgrading scenarios considered and the values of the various components of the benefit-cost equation; and the shape of the net benefits curve in the range 0-150,000 passenger movements for each of the upgrading scenarios.

Example 1:   Karratha

Figure 6 shows that for Karratha, upgrading from commuter standard to F28 would be justified for a total annual passenger movements of about 25,000 with further substantial incremental net benefits distributed to the passengers.   However, net benefits, distributed initially to the airline operator, are generated once total annual passenger movements exceed about 46,600 in the case of the scenario for F28 upgrading to DC9.   This scenario involves an annual incremental airport cost of about $1.15 million per annum over the twenty year economic life of the facility.   Upgrading further to B727 standard is calculated to be justified at about 72,000 annual passenger movements, but again the net benefits are initially distributed to the airline operator.   Sensitivity analysis (Table 8) shows that only minor variations occur for variation in the SDR value, but quite significant variations occur for changes in the value of time.

TABLE 8   NETWORK MODEL - KARRATHA: SENSITIVITY OF Y_A^S TO CHANGES IN
            VOT AND SDR
            F28 to DC9 Upgrading Scenario

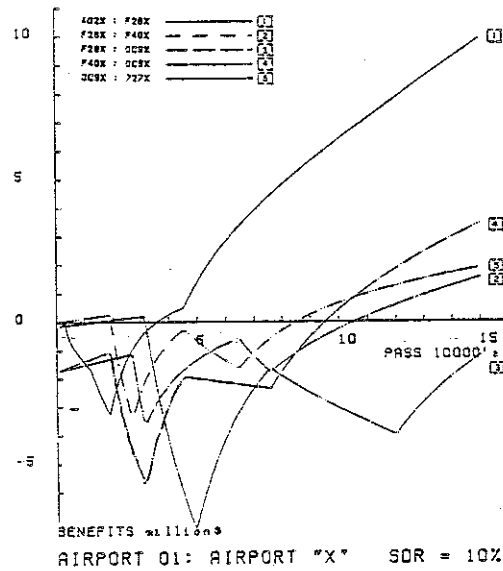|		Value of Time (VOT)			Annualised Average Incremental Airport Capital & Maintenance Costs ($)
		75% VOT	Base VOT	125% VOT	
SDR	10%	44,378	46,891	48,394	1,144,429
	12%	45,045	47,218	48,990	1,030,695
	15%	46,166	48,268	45,587	902,150

AIRPORT 01: AIRPORT "X"   SDR = 10%

Figure 6.   Network (Karratha) Supply Side Evaluation

Example 2: Paraburdoo

Commuter to F28 upgrading is found to be justified at around 25,800 annual passenger movements. Net benefits are initially achieved at a Y_A^S value of about 49,000. As disutility effects on the low passenger volume links come into play, net benefits diminish and become slightly negative.   At around 107,000 passenger movements the net benefits curve becomes positive again.   Similar effects occur for the DC9 to B727 upgrading scenario (Figure 7).

Sensitivity testing (Table 9) for variations in both the SDR and the VOT once again show that variation in the VOT changes Y_A^S quite significantly, but not changes in the SDR.

TABLE 9   NETWORK MODEL - PARABURDOO: SENSITIVITY OF Y_A^S
CHANGES IN VOT AND SDR
Commuter to F28 Upgrading Scenario

		Value of Time (VOT)			Annualised Average Incremental Airport Capital & Maintenance Costs ($)
		75% VOT	Base VOT	125% VOT	
SDR	10%	22,640	25,855	30,363	229,169
	12%	22,881	26,400	31,202	227,032
	15%	23,617	27,368	32,737	224,615

TABLE 7   COSTS AND BENEFITS FOR UPGRADING SCENARIOS AT THE Y_A^S LEVEL

AIRPORT: KARRATHA   MODEL: NETWORK MODEL

Upgrading Scenario	Annual incremental Passenger Benefits $'s						Annual Incremental Service Costs $'s	
	Annual Passenger Movements Y_A^S	Change in Air Travel Time ($)	Change in Airfares ($)	Change in Headway ($)	Total ($)	Change in Aircraft Operating Costs ($)	Change in Annual incremental Airport Capital & Maintenance Costs ($)	Total ($)
1. Commuter to F28	25,061	214,276	2,223,126	-1,381,600	1,057,803 ($42.21/pass)	155,010	902,777	1,057,787
2. F28 to DC9	46,591	47,433	610,957	-835,704	-177,314 (-$3.81/pass)	-1,321,772	1,144,429	-177,343
3. DC9 to B727	71,904	24,468	1,251,698	-1,460,258	-184,091 (-$2.56/pass)	-559,972	375,866	-184,106

Notes: 1. All amounts in 1984 $'s.
        2. All amounts are annual incremental costs/benefits between scenario levels.
        3. SDR 10%.

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HENSHER AND THORNTON
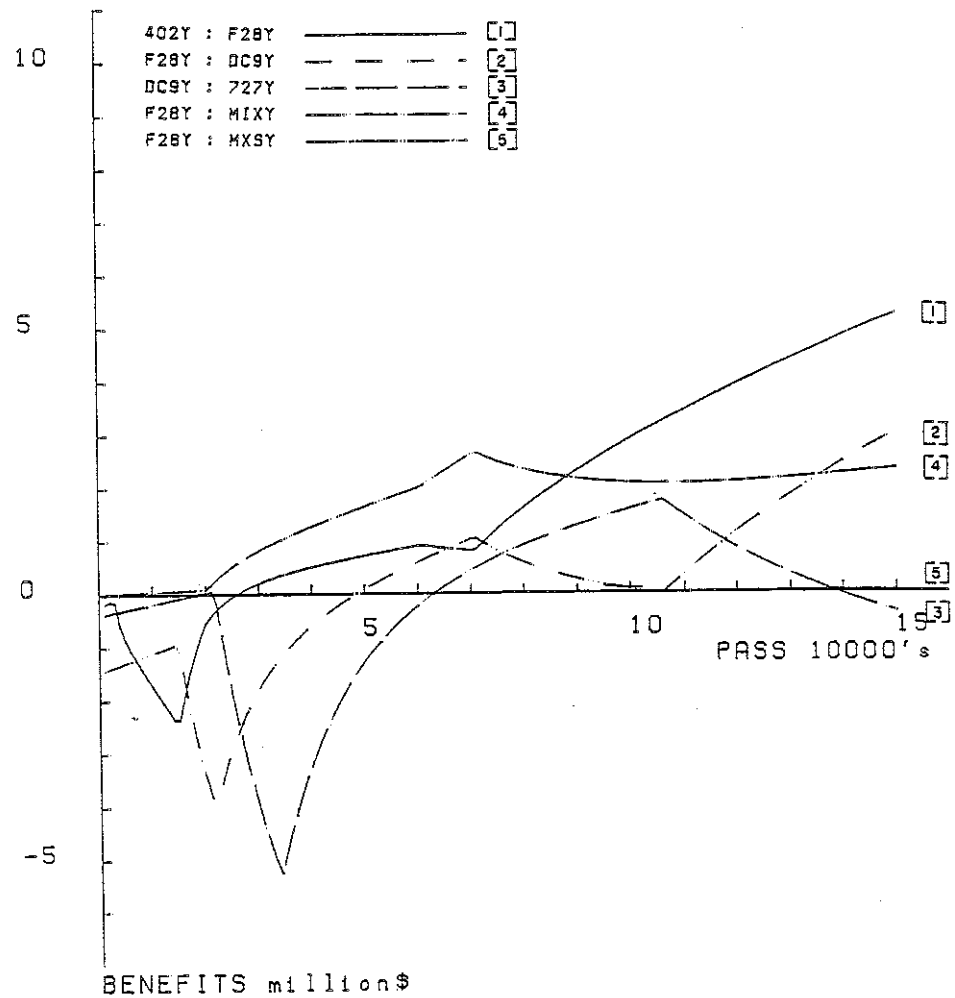
Figure 7. Network (Paraburdoo) Supply Side Evaluation

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DEMAND FORECASTS AND MINIMUM RIDERSHIP

The current 'status quo' in the Pilbara is an airport network served by a mixture of small jet aircraft, namely the F28-1000, F28-4000 and BAe-146 aircraft types. The following figures show the forecast status quo traffic for each port (a) and the number of passenger movements required to justify upgrading from commuter to F28 standard (b).

	Karratha	Port Hedland	Newman	Paraburdoo
(a) 1985 Forecast (Y_A^D)	93,000	53,000	26,000	23,000
(b) Y_A^S Network	25,061	43,106	93,482	25,855
Investment Strategy Index (ISI)	0.731	0.187	-2.595	-0.124

Whereas Karratha, in particular, and Port Hedland easily justify their F28 standard air services, the forecast passenger movements at Paraburdoo and Newman fall short of the level assessed in the Supply Side model to justify their current status as F28 airports.

In the case of Paraburdoo, forecast passenger movements are slightly below the required Y_A^S value. However, a considerable difference exists in the case of Newman. This is primarily attributable to the influence of the proportion of passenger movements on the Perth and Port Hedland/Karratha links.

There is, therefore some analytical evidence to support the argument that networking is necessary to provide the level of service currently available to Newman and Paraburdoo. The Karratha-Paraburdoo combination appears to generate sufficient passengers to justify the route as a network, while the Port Hedland-Newman combination appears to be a less certain situation.

Links having small proportions of the total passenger movements at an airport have a significant effect in increasing the number of passenger movements required to generate net benefits. If, as shown in the Airport X both Newman and Paraburdoo's passengers travelled exclusively to/from Perth then they would both probably be justifiable as F28 standard airports. However, in practice the local links from Newman/Paraburdoo to/from Port Hedland/Karratha are probably supported by the through traffic from/to Perth. It should be noted that such through traffic on these routes suffer costs in the form of long trip times. These effects have not been accounted for in this analysis. Further, the status of Newman and Paraburdoo as F28 standard airports is the result of other unquantified factors such as industrial agreements

which guaranteed the provision of jet RPT services connecting Perth to these remote centres.

In upgrading to DC9 standard over the network the following passenger movements have been determined from a) the Demand Forecast Model and b) the Supply Side Network Model.

	Karratha	Port Hedland	Newman	Paraburdoo
(a) 1985 Forecast (Y_A^D)	95,000	63,000	33,430*	30,500*
(b) Y_A^S (Network)	46,551	71,578	65,627	63,000

* Year 2000 forecasts includes TAA once weekly DC9 service.

Karratha easily generates sufficient passenger movements to justify upgrading to DC9 standard while Port Hedland also exceeds its Y_A^S criterion. Newman and Paraburdoo clearly do not generate sufficient passenger movements for all services into and out of them or all links to be DC9 standard. Similar comments apply to the DC9 to B727 upgrading scenario. For Newman and Paraburdoo they cannot justify further upgrading to a standard higher than F28-1000. In order to support passenger movements on the intra Pilbara links even at this level, network or 'through' traffic is required to justify their status.

In the event of mine upgrading at Newman occurring between 1987 and 1988 the additional passenger movements generated could be easily accommodated by reductions in headways, without the need for upgrading to a larger aircraft type. The same probably applies to the case where Area C or West Angelas is developed in 1990 and is serviced through Newman, although it is possible that the proportion of Perth traffic could increase sufficiently to reduce the Y_A^S level at which further upgrading is justifiable.

Consequently, from consideration of forecast passenger movements and Y_A^S values, it appears that if a single standard airport system and hence single equivalent aircraft type service is desired to the Pilbara, the appropriate standard is F28. This, however, does not necessarily result in the system which offers the maximum potential net benefits in economic terms over the whole Pilbara Network as is demonstrated below in Network Benefit - Cost Assessment.

NETWORK BENEFIT - COST ASSESSMENT

The Supply Side analysis described above examined both past and future airport developments in the Pilbara by assessing the minimum passenger movements at each of the Pilbara airports required to justify various levels of air service ranging from commuter to B727 standard.

Another means of examining whether a scenario is advantageous is to examine the incremental net benefits and costs which occur for a given scenario at the levels of demand forecast. By examining such benefits and costs at each of the Pilbara airports and summing them, it is possible then to assess the effect on the Network as a whole.

From the preceding discussion options for adjustments from the status quo in the Pilbara Network worthy of examination are:

I   Introduce DC9 standard services to and between all Pilbara airports;

II   Introduce DC9 standard services on the Perth-Karratha-Darwin and Perth-Port Hedland-Darwin routes with the remainder of the Network remaining as an F28 standard.

III Introduce DC9 standard services on the Perth-Karratha-Darwin and Perth-Port Hedland-Darwin routes, keep the Perth-Newman/Paraburdoo routes as F28 and introduce commuter standard services on the intra Pilbara airport routes.

The Demand forecast model (Table 3) provides, for each airport, the future passenger movements associated with the links included in the Network Model. These forecasts are included in equations 3 and 5 together with the values of the components of the benefit and cost to determine the system net benefits and benefit-cost ratio for the scenario in question. Table 10 illustrates the results of an analysis of this type for one scenario which was found to generate the maximum system net benefits and benefit-cost ratio of those considered.

Examination of Table 10 shows that:

- The Network overall has a positive benefit-cost ratio as do each of the Pilbara airports when considered individually.

- The principal benefits at Karratha and Port Hedland are from reductions in DOC and in airfares.

- The principal benefits at Newman and Paraburdoo stem from increased frequency of service on the intra Pilbara routes, i.e. a reduction in headway and thus, disutility.

In carrying out these analyses the *actual* upgrading to DC9 standard already completed at Port Hedland was included. In practice, however, the cost of this upgrading ($1.66m in Table 10) can be regarded as sunk and, as far as determining the future course of action at Port Hedland, eliminated from calculations. The average annual net benefits for the system become $9.4 million and the benefit-cost ratio becomes 9.2.

TABLE 10   AVERAGE ANNUAL INCREMENTAL COSTS AND BENEFITS FOR NETWORK
            MODEL UPGRADED FROM ALL LINKS AS F28 SERVICES TO DC9 ON
            PER-KTA-DRW AND PER-PHE-DRW, F28 on PER-PBD and PER-ZNE
            WITH ALL INTRA-PILBARA LINKS DOWN-GRADED TO COMMUTER

	Karratha	Port Hedland	Newman	Paraburdoo
Approximate 1985 total forecast passenger movements (Y_A^D)	93,000	99,000	26,000	23,000
Incremental Benefits based on Y_A^D:				
Invehicle time changes (IVT)	0.09	0.11	-0.01	-0.005
Fare changes (IVC)	1.22	1.35	-0.03	-0.004
Wait time disutility changes (WTD)	1.24	-0.68	0.83	0.25
Operating cost changes (DOC)	2.72	3.23	0.10	0.12
	5.27	4.01	0.89	0.61
Incremental Costs based on Y_A^D				
Airport investment and maintenance changes	1.14	1.66	0.0	0.0

Average Annual Incremental System Net Benefits = 10.531 - 2.8 = 7.73m
                                  Benefit/Cost Ratio   3.76

Notes: 1. Includes Perth-Darwin through traffic as if Port Hedland
            traffic
        2. Based on SDR of 10%
        3. 20 year economic life

        As the Supply Side analysis adopts a social cost-benefit
approach and is concerned with the incidence of benefits particularly
in regard to the users of the service, airfare savings were included.
However, in strict resource benefit-cost analysis terms fare savings
not resulting from generated traffic should not be included.   This
adjustment has the effect of reducing the system average annual net
benefits from $9.4 million to $6.85 million and the benefit-cost ratio
from 9.2 to 7.0.

CONCLUSIONS

1. The method outlined has been structured to provide an internal
    validity check on one of the most critical influences on investment
    strategy, forecasting demand, which is prone to enormous levels of
    error.   This is particularly the case in remote areas where rates
    of change can alter dramatically with the establishment, and in
    the winding down of major resource projects.

2. By deriving information from two sources, forecast demand and
   minimum ridership, and then relating them through the investment
   strategy index, it is possible to place confidence limits on the
   benefit-cost ratios which can also be derived. The approach can
   be applied at an airport-specific or network level.

3. A major benefit of the approach is that it can be applied using
   data predominantly available from regulatory authorities and
   existing sources. Consequently, extensive and detailed social
   surveys are not required.

4. The method itself does not require a large range of variables,
   particularly those which might be considered 'soft' data e.g.
   value of time, disutility. Thus it is not unduly onerous to
   examine the sensitivity of the model to such variables.

5. The structure of the model is such that it can be used not only
   to compute minimum ridership, but also benefits and costs at
   forecast ridership levels.

6. By adopting a scenario approach, a wide range of possible
   alternatives, whether improvements to single airport(s) within
   a network or changes of equipment on several routes, can be
   evaluated. This approach makes the general method attractive to
   a wide range of transport applications e.g. rural road planning,
   inter-island shipping, inter-city rail. The basic framework
   exists with the model to extend it to more complex issues such as
   other inter-urban transport investment issues.

7. The method demonstrated its potential and power in the Pilbara
   Zone Study recently completed by ACCA. Areas for further
   development would include research on the functional form of the
   disutility curve and a more sophisticated approach to dealing
   with hierarchies within networks.

8. *Although the Pilbara Zone Study was not specifically concerned
   with deregulation, the structure of the model and scenario approach
   enables a wide range of deregulatory issues to be examined e.g.
   changing services, introduction of competitive services, new
   routes, changed aircraft types, lower fares and the like.*

   The method enables an assessment of the incidence of benefits
and costs to be examined. It also enables the validity of earlier
decisions to be examined. Consequently, the outputs of the method
can provide highly relevant information on the asset value of public
properties.

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