2 CHAPTER TWO: AIRLINE ROUTE COSTING

2.1 Overview

This chapter uses the literature review to highlight the different airline cost structures, in order to understand the cost breakdown. The components that will be used in the model will be discussed in this chapter. The relevant data to be collected and equations to be used will be formulated.

The rest of the chapter will elaborate on the factors that are crucial in airline management to control operating costs for the purpose of understanding airlines' route and service economics.

2.2 General structure of airline costs

2.2.1 Introduction

Doganis (1989) states that the costing of an airline service is an essential input to many decisions taken by airline managers, as to whether to run a service along a given route and whether it will be profitable. The way the costs are broken down and categorized will depend on the purpose for which they are being used.

Kane (1996) outlines the three purposes for cost information in airline planning as:

1. Airlines require an overall breakdown of their total expenditure into different cost categories as a general management and accounting tool. They need to show a general breakdown of costs to show cost trends over time, to measure the cost efficiency of particular functional areas (such as flight operations or passenger services) and ultimately to enable them to measure their operating and non- operating profits or losses.
2. An assessment of costs is essential in evaluating investments either in a new aircraft, route or service.
3. Cost identification is crucial in the development of pricing policies and pricing decisions.

2.2.2 Standard structure

Doganis (1989) states that world wide in the airline industry there tends to be a standard approach in the categorization of costs for general management use.

Airline accounts are generally divided into operating and non- operating categories, so as to identify and separate out as non- operating items all those costs and revenues not directly associated with the operation of an airline's own air services.

1) Non- operating Items

Doganis (1989), defines the ICAO breakdown for Non -Operating Items as shown below:

1) Gains or losses arising from retirement of property or equipment, both aeronautical and non-aeronautical. These arise from the difference between the depreciated book value of an item and the value that is realized, when an item is sold off.
2) Interest paid on loans, as well as any interest received from bank or other deposits.
3) All profits and losses arising from the airline's affiliated companies, some of which may be directly involved in air transport. This item, in some cases, may be important in the overall financial performance of an airline.
4) Other items which do not fall into the three previous categories, such as losses and gains arising from foreign exchange transactions or from sales of shares or securities.
5) Direct government subsidies or other government payments.

2) Operating Items

The operating items will then be grouped as those sources of income and revenue that are directly associated with running of the airline service. According to airline accounts these items are further subdivided into direct operating and indirect operating costs.

I. Direct Operating Costs

These include all those costs, which are associated with, and dependant on the type of aircraft being operated and which would change if the aircraft type were changed. Stratford (1973) divides the direct operating cost into elements including:

1. Standing Costs, including depreciation of the capital invested in flight equipment as well as the insurance and interest associated with the flight equipment.
2. Flying costs, including crew, fuel and oil, landing fees and direct maintenance and overhaul costs.
3. Other costs which would represent the special costs of significance to the particular exercise in hand.

Note:

Doganis (1989) specifically states that there are some items however, such as maintenance, administration or costs of cabin staff, which are categorized as direct costs by some airlines and as indirect costs by others. Furthermore, maintenance and overhaul costs cover not only routine maintenance and maintenance checks but also periodic overhauls and repairs. They encompass labour costs and expenses related to all grades of staff involved directly or indirectly in maintenance work. The costs of components and spare parts consumed are also included, as are the costs of workshops, maintenance hangars and offices.

II. Indirect Operating Costs

Doganis (1989), outlines that the indirect operating costs include the following:

1. Station and ground expenses, which are incurred in providing an airline's services at an airport other than the cost of landing fees and other airport charges, e.g. cost of ground handling and aircraft, passenger or freight servicing.
2. Cost of Passenger services whose largest single element is staff cost, including pay, allowances and other expenses directly related to aircraft cabin staff and other passenger service personnel. The second group consists of those costs, which relate directly to passengers like in-flight catering, and finally the premiums paid by the airline for passenger liability insurance and passenger accident insurance.
3. Ticketing, sales, commission and promotion cost; these include all expenditure, pay allowances, etc related to staff engaged in the above-mentioned activities.
4. General administrative costs; these are usually a small element of an airline's total operating costs, since overhead costs can be directly allocated to a particular activity.
5. Doganis (2001) summarizes the items, which are entailed in the operating costs in Table 1.

Table 1: Components of operating costs

Direct Operating costs	Indirect Operating costs
Cabin/ flight crew salaries and expenses	Station or ground costs
Fuel	Handling
Airport charges	Passenger Services
En route charges	Sales/ Reservations
Maintenance	Commission
Depreciation	Advertising/ Promotion
Aircraft Rentals	General Administration
Insurance	Other

Source: Doganis (2001)

2.2.3 Alternative structure

Stratford (1973) shows an alternative structure that can be used to differentiate cost components in terms of airline or aircraft, shown in Figure 1. Specific operating costs are sorted out in such a way that they enable management to minimise cost expenses in a manner that is appropriate for each component.

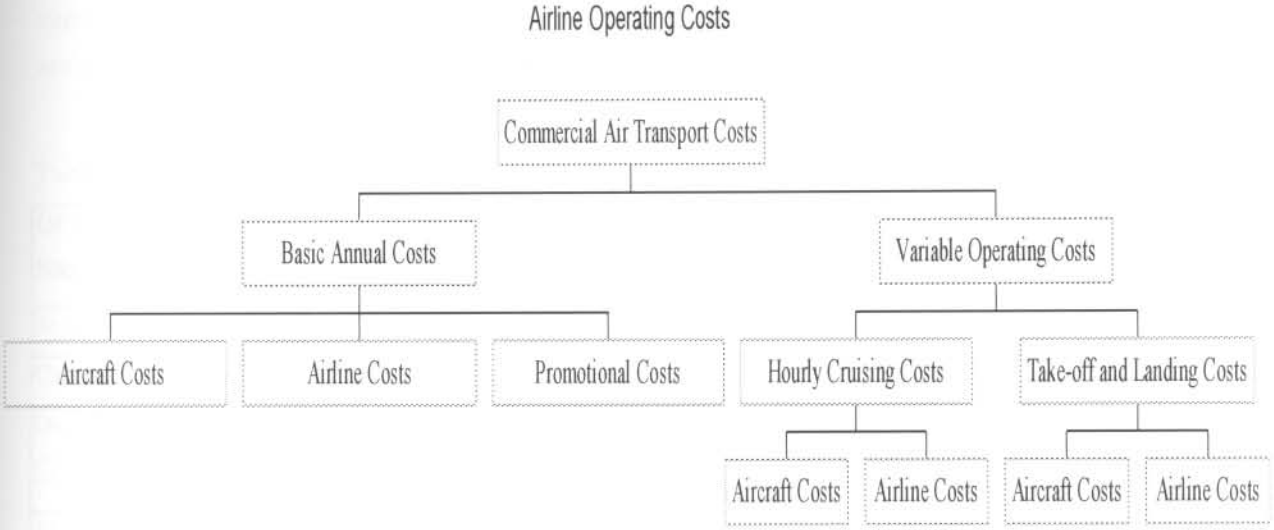

Figure 1: Flow Chart separating costs into airline and aircraft costs (Stratford, 1973)

2.2.4 Towards a structure for the cost model

Table 2 summarises the cost components of Doganis (1989) and Stratford (1973) for the purposes of this study, such that all components are included. The components are divided into standing costs, flying costs and other costs, to differentiate between direct and indirect operating costs. The costs are sub-divided depending on whether the costs are fixed whether the aircraft fly or not and variable, depending on the frequency of flying of aircraft and furthermore as to whether the costs are to be allocated to the aircraft or the airline.

Table 2: Cost structure to be adopted for the model

OPERATIONAL COST BREAKDOWN	Fixed costs		Variable costs	
	Aircraft	Airline	Aircraft	Airline
Standing costs				
Capital	♦			
Depreciation	♦			
Insurance	♦			
Flying costs				
Fuel and oil			♦	
Landing Fees			♦	
Airport and en-route charges			♦	
Direct Maintenance	♦			
Crew costs	♦			
Ground Handling				♦
Other costs				
Passenger Services				♦
Sales/ reservations				♦
Ticketing, sales and promotion		♦		
General administrative costs		♦		

2.3 Components of cost

2.3.1 Utilisation

Utilisation is defined as the average period of time for which the aircraft in question is in use, measured daily, monthly or yearly in block hours. The utilisation of an aircraft is an important factor that needs to be calculated, since most of the costs incurred by the aircraft are spread over how often the aircraft is utilised.

Most aircraft have a maximum annual utilisation for which they have been designed. Stratford (1973), shows that a number of variables influence the value of the total flight utilisation, which may be achieved by an aircraft. Many of the items are inter-related, in that the utilisation has to be calculated from the block time and the number of flights a day within usable operating hours as shown below:

The number of usable hours in an operating day (H) is calculated in Equation 2-1 as:

$$\mathbf{H = nt_f + (n-1)\,t_g} \qquad \text{..............................2-1}$$

$$\mathbf{And \quad t_f = (R/V_b) + t_l} \qquad \text{..............................2-2}$$

Where	H	the usable hours in the operating day (must be <= 24hrs)
	n	the number of flights per day
	t_f	the mean flight time per route
	t_g	the average ground time at transit and terminal points
	R	the mean distance per route
	V_b	the average block speed of the aircraft
	t_l	the average time lost during take-off, climb, and descent and taxi time.

The number of flights per day for a single aircraft is:

$$\mathbf{n = \frac{H + t_g}{R/V_b + t_g + t_l}} \qquad \text{...........................2-3}$$

And annual utilisation (hrs/year)

$$\mathbf{U = D.n.t_f} \qquad \text{..............................2-4}$$

Where D the serviceable operating days in the year

The ATA (1963) method presents the detailed Direct Operating Cost Equation. The costs are calculated as a cost per aircraft statute mile (Cam); however this can be converted such that the block hour costs are inclusive of the lost time at take off and landing.

$$\textbf{Block Hour Cost} = C_{am} * V_b \qquad \text{....................2-5}$$

$$\textbf{Flight Hour Cost} = C_{am} * V_b * t_b / t_f \qquad \text{............................2-6}$$

Where C_{am} = Cost per air mile
V_b = Block speed (miles/hr)
t_b = Block time (hrs)
t_f = Flight time (hrs)

Block Speed

For uniformity of computation of block speed, the Equation 2-11 based upon a zero wind component is used:

$$V_b = R / (T_{gm} + T_{cl} + T_d + T_{cr} + T_{am}) \qquad \text{....................2-7}$$

Where V_b = Block speed in mph
R = Trip distance in statute miles
T_{gm} = Ground manoeuvre time including one minute for takeoff
T_{cl} = Time to climb including acceleration from takeoff speed to cruise speed
T_d = Time to descend including deceleration to normal approach speed
T_{am} = Time for air manoeuvre
T_{cr} = Time at cruise altitude (including traffic allowance)

$$T_{cr} = [(R + K_a) - (R_c + R_d)] / V_{cr} \qquad \text{.......................2-8}$$

R_c = Distance to climb (statute miles) including distance to accelerate from takeoff speed to climb speed.

R_d = Distance to descend (statute miles) including distance to decelerate to normal approach speed.

V_{cr} = Average true airspeed in cruise (mph)

K_a = Airway distance increment due to extra distance that may be flown during the flight time. It's usually calculated as (7 + .015D) up to D < = 1400 statute miles, and K_a = 0,02D for D >1400 statute miles.

2.3.2 Capital costs

This being a highly capital-intensive industry means, a big potion of the operating costs are spent on the costs of acquiring the aircraft. The common costs incurred include depreciation, insurance and interest

1) Depreciation

The depreciation period is defined as the period during which an airline will be charged for the expense for the flight equipment losing its value over time. Kane (1996) defines depreciation, as the expense for depreciation of airframes, aircraft engines, airframe and engine parts, and other flight equipment for the time period over which the aircraft is in use.

Doganis (1989) states that airlines tend to use straight-line depreciation over a given number of years with a residual value between 0 and 15 %. The annual depreciation charge or cost of a particular aircraft in the airline's fleet depends on the depreciation period adopted and the residual value assumed.

The hourly depreciation cost of each aircraft in any one year can be established by dividing its annual depreciation cost by the aircraft annual utilisation.

Depreciation/hr can be calculated using Equation 2-9 from Stratford (1973), which uses the linear depreciation function, shown below:

$$C_{sd} = \frac{(C_{air} + C_{eng} + C_{equ})*(1-r_v)}{L*U} \qquad \text{..................2-9}$$

Where C_{sd} is the cost per hour of the depreciation of the flight equipment

C_{air} is the cost of one furnished airframe with spares

C_{eng} is the cost of the engines installed in one airframe, and the spare engines together with the engine spares holding per airframe.

C_{equ} is the equipment (including radio and radar) installed together with the spares holding of equipment per airframe.

r_v is the residual value as a proportion of the fully equipped aircraft and spares after the assumed life period (L years).

U is the average utilisation per aircraft in revenue block hours/year.

The Air Transport Association (ATA, 1963) states that the depreciation of the capital value of an aircraft is dependent to a large degree on the individual airline and the world economic and competitive conditions.

For the purposes of this formula, the depreciation periods in years (L) and the residual value for the aircraft and its components according to the ATA, are given in Table 3.

Table 3: Depreciation and residual values for different aircraft types

Aircraft Types	Depreciation Period (yrs)	Residual Value (%)
Subsonic Turbine Engine Aircraft	12	0
Supersonic Aircraft	15	0

Source: ATA (1963)

Note to Table 3: Financial accounting practice normally recognizes a residual value, however the amount is usually nominal. These values are applicable to complete aircraft, including the engines and all spares (ATA method).

Under the ATA (1963) method, the equation used to calculate depreciation in costs in US$ per air mile (Cam) of the total aircraft including spares is given in Equation 2-10

$$C_{am} = (1.1C_{total} + 0.3\,Ne\,C_{eng}/\ (L^{*}\,U^{*}\,V_b) \qquad \text{..................2-10}$$

Where: C_{total} = Total aircraft cost including engines (US$)

C_{eng}= Cost of one engine (US$)

N_e = Number of engines

L = Depreciation period (years)

U = Annual utilisation - block hours/year

V_b= Average block speed of the aircraft (miles/h)

According to Doganis (2001), the economic life of an aircraft was formerly dependent on the strength and technical life of their various components and was unlikely to be affected by any new leaps forward in aircraft technology, that might make them obsolescent. But with time, in response to these two factors and to their worsening financial performance, airlines throughout the world changed. Doganis states that at the moment, airlines have tended to lengthen the depreciation period of their large wide-bodied jets to 14-16 years with a residual value of around 10 percent. For smaller short-haul aircraft the depreciation period is shorter, generally 8-10 years.

2) Interest

Interest rate is simply defined as the cost of borrowing money; it is given as a percentage value that is applied to the outstanding loan. The airline industry being highly capital intensive means that this component should be included. The interest rate is set depending on the economic conditions i.e.

inflation, bank lending rates, forex rates, etc in the country where the loan is acquired.

Since this study is cutting across various countries with widely varying economic conditions, an interest rate chosen should be representative of majority of the African countries, i.e. the rate at which Development banks, or the World Bank lends money. This value would be more representative than the rates at which financial lending institutions like commercial banks lend money to an individual.

3) Insurance

Insurance is an annual amount of money paid each year, in case of any risks that may be incurred to the aircraft during its service life. These include fire, hijacking, theft, etc.

Doganis (1989) states that the insurance of the flight equipment shows that the insurance premium paid by an airline for each aircraft is calculated as a percentage of the full replacement price.

The annual premium may range between 1,5-3% depending on the airline, the number of aircraft it has insured, and the geographical areas in which the aircraft operates. The annual premium is converted into an hourly insurance cost by dividing it by the projected annual aircraft utilisation that is defined as the total number of block hours that each aircraft is expected to fly during the year.

Stratford (1973) shows that it is standard practice to make an allowance for insurance as part of standing costs of operation, since these costs are high. Thus the cost insurance per hour (C_{ins}) on the total cost of equipped aircraft and spares, at a rate of x percent, and annual utilisation U is given by:

$$\mathbf{C_{ins} = (x * C_{total}) / U} \quad \text{.................... 2-11}$$

Where: C_{total} =Total cost of aircraft, engine and equipment.

X = Annual insurance premium rate

The insured value rate is assumed to cover 100% of the initial price of the complete aircraft

$$C_{am} = (\text{Rate/US\$ Value})\ (\text{Aircraft Cost}) /\ (\text{Utilisation})$$

$$\mathbf{C_{am} = IRa * C_{total}\ /\ (U * V_b)} \quad \text{.................... 2-12}$$

Where: IRa = Rate per US$ value

C_{total} = Total aircraft cost including engines (US$)

U = Annual utilisation - Block hours/year

V_b = Block speed (air miles/h)

2.3.3 Fuel and oil

Doganis (1989) states fuel as another major element in the cost of flight operations. The consumption of fuel varies considerably from route to route in relation to the sector length, the aircraft weight, wind conditions, cruise altitude and so on. Thus the hourly fuel cost tends to be even more of an approximation on a route-by-route basis. Fuel costs include all relevant taxes levied by the specific government.

The ATA (1963) method refers to the amount of fuel needed by the aircraft during the block time, as the block fuel whereby block fuel is comprised of the following components, all of which use varying amounts of fuel, and the summation of which will be the block fuel:

$$F_b = F_{gm} + F_{am} + F_{cl} + F_{cr} + F_d \qquad \text{..................2-13}$$

Where F_b = Block fuel in US gallons

F_{gm} = Ground manoeuvre fuel based on fuel required from engine on to take –off at runway assumed to be 14 minutes + 1 minute at takeoff thrust or power.

F_{cl} = Fuel to climb to cruise altitude including that required for acceleration to climb speed.

F_{cr} = Fuel consumed at cruise altitude (including fuel consumed in 20 statute mile traffic allowance and allowance for airway distance increment Ka).

F_{am} = Six minutes allowed for air manouveur from cruise altitude to altitude when aircraft begins descent.

F_d = Fuel required to descend including deceleration to normal approach speed.

Reserve Fuel

The reserve fuel is the amount of extra fuel besides block fuel in the tank that should be used for emergency procedures. The ATA (1963) method also elaborates on reserve fuel depending on the distance and type of aircraft. The emergency procedures are in excess of minimum Federal Aviation Regulations and are representative of airline operational practices. This excess is not related to safety requirements. The maneuvers specified in this study will only look at those for international flights within Africa and not domestic flights within countries.

Reserve fuel is needed to perform the following maneuvers, for international flights:

(1) Fly for 99% maximum range of aircraft, for 10% of trip airtime at normal cruise altitude, plus the fuel flow for end of cruise taking into account landing weight at specific speed.

(2) Exercise a missed approach and climb out at the destination airport, fly to an alternate airport 174 statute miles distant.

(3) Hold for 30 minutes at alternate airport at 15,000 feet altitude.

(4) Descend and land at alternate airport.

Fuel consumption

Block fuel calculated in Equation 2-14, is the amount of fuel used up at the block time, as a product of fuel consumption given in terms of volume (US gal/hr) in Equation 2-15. The weight of fuel being consumed at climbing, descending and cruising is determined by the following factors; engine thrust, Specific fuel consumption (SFC), and the number of engines, using the formula in Equation 2-16. Airliners.net (2004) in discussions quotes that the fuel consumed at cruise is dependent on cruise thrust and cruise SFC, while the fuel at climbing, also depends on climbing thrust and the engine SFC. The volume of fuel consumed can then be obtained by dividing the weight of fuel consumed by the fuel density, in Equation 2-15.

$$\mathbf{F_b = F_v \text{ x } t_b} \qquad \text{....................2-14}$$

$$\mathbf{F_v = F_w / F_d} \qquad \text{.................... 2-15}$$

$$\mathbf{F_w = SFC \text{ x } T \text{ x } N_e} \qquad \text{.................... 2-16}$$

Where F_b= Block Fuel (US gal)
F_v= hourly consumption of fuel (volume) (US gal/hr)
F_w = Hourly Consumption of fuel (weight) (Ib/hr)
F_d =Fuel Density (Ib/US gal)
SFC = Specific fuel Consumption (Ib/Ibfhr)
T = Thrust at (Ibf)
N_e = Number of Engines

Oil consumption

Oil consumption is negligible, so rather than calculate it on a route basis an hourly figure for oil consumption for an engine type, for a given number of engines for the aircraft flying a sector, for the given block time is used

A volume ratio of fuel to oil is specified for the proper operation of an aircraft engine, and will be applied in the model to calculate the volume of oil consumed per block hour. The two data sources that give a fuel: oil ratio is given in Table 4, and the default ratio that will be used in the model will be specified

Table 4: Fuel to oil ratio

Engine	Fuel: oil ratio	% Lubricant mix	Data Source

Simjet miniature	25:1	4	Rolls Royce (2003)
Aj/TJT-3000	20:1	5	Turbine design (2002)

Turbo jet technologies ratio will be used because it is specified for an actual turbo jet engine being used in the market today, while the Simjet is an engine used for miniature jets. This implies that for whatever volume of fuel is consumed per block hour, a 20: 1 ratio will be used to calculate the volume of oil, in US gallons that will be changed to quart by multiplying it by 4.

The ATA (1963) formula for calculating cost of fuel and oil per air mile is stated below, assuming the factor 1.02 in equation 2-17 caters for the 2% factor of reserve fuel.

$$\mathbf{C_{am} = 1{,}02 * (F_b * C_{ft} + N_e * 0{,}135 * C_{ct} * t_b) / D} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 2\text{-}17$$

Where: F_b = Block fuel Volume (US gal)

C_{ft} = Cost of Fuel per US gallon

C_{ct} = Cost of oil for turbine engines consumed per flight hour (US\$/US gal)

Ne = Number of engines installed

D = Sector Distance

This formula will be altered and converted to cost per block hour, in order to be applied.

$$\mathbf{C_{ah} = 1{,}02\ (V_f * C_{ft} + 0,\ 135 * C_{ot} * V_o)} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 2\text{-}18$$

Where: V_f= Block fuel Volume (US gal/hr)

C_{ft} = Cost of Fuel per US gallon

C_{ot} = Cost of oil for turbine engines per quart

V_o= Block oil Volume (US gal/hr) = (1/20) * V_f

Fuel and oil prices

Emery (2002) states that fuel, especially in the African aviation industry, is still an important operating cost for airlines and currently makes up about 10 percent of direct operating costs. Furthermore, he states that the price of jet fuel fluctuates according to world oil prices and currently the price is about 80 US cents per US gallon.

The difference in percentage make up of fuel prices in the world to day could be attributed to many changes in supply, demand, market prices and the availability on the world market.

Emery (2002) states that for aviation in Africa, fluctuations in the home currency of each country, and government taxes, can have a significant impact on profit since fuel is paid in US dollars.

The particular concern in Africa is airport location, IATA has set up a fuel trade panel whose duties are to ensure reliable fuel supply at all international airports and minimise taxes and user charges on aviation fuel. Table 5 shows what elements, are comprised in the cost of fuel:

Table 5: Aviation fuel make-up cost

Cost	US cents/ US gallon	Notes
Fuel	80	Varies by distance from refinery or sea
Government Taxes	5	Varies
Fee for storage facility throughout	2	Much less at large storage facilities
Hydrant Use fee	0,5	
Into-plane fuel loading (refueller charges)	2	
Total in-plane cost	**89,5**	

Source: Emery 2002

Turbo-jet Technologies (2002), gives the cost of oil used in turbo jet engines; the price of oil is given in units of US$/quart as 0,233. The price to be used per US$ per US gallon will be 0,932 for the model.

2.3.4 Airport and en-route charges

Stratford (1973), states that the landing fee is an item included as a direct operating expense and is of significance in actual and comparative aircraft cost estimates. The fees are based on the gross weight of the aircraft, but a number of exceptions to this exist and international flights and short sector flights are in some cases liable to special rates.

Doganis (1989) adds that airport charges normally include two elements; a landing fee and a passenger charge; the former relating to the weight of the aircraft and the latter relating to the number of passengers disembarking from an aircraft. Most airports presently collect a fee directly from the passengers, termed the airport tax on departures and is included in the fare paid. The landing fee is usually paid directly to the airport by the airline as a separate charge. Kane (1996) states that the airport landing fees and rents worldwide have been rising at four times the rate of inflation in recent years, due to the fact that the airline industry has become a popular means of travel over the years.

Doganis (1989), states that en-route navigation charges serve to cover the cost of traffic control and navigational and other aids. They are imposed by civil aviation authorities and are related to the weight of the aircraft and the distance flown over a country's airspace. Thus these levies are in essence a direct cost since they vary with the type of aircraft flown and distance travelled.

2.3.5 Crew costs

The flight crew costs include all costs associated with the flight and cabin crew including allowances, pensions, salaries, etc. They usually are the largest element in operating expenses. Doganis (1989), states that they can be calculated either on a route -by-route basis or are expressed as an hourly cost per aircraft type.

The latter case will be adopted for this study and calculated by multiplying the hourly flight crew costs of the aircraft type being operated on the route by the block time for the route

In 1963, the ATA derived costs from a review of several representative crew contracts. Based on this review, yearly rates of pay were arrived at which were used with welfare, training, travel expense, and crew utilisation factors to produce the crew cost equations shown in Table 6 (ATA, 1963).

Table 6: Flight crew cost equations (ATA, 1963) (US$/air-mile)

Engine Type	**Domestic Subsonic Aircraft**		**International Planes**
	Two-Man Crew	**Three-Man Crew**	**Three-man crew**
Turbo Jet	[0,00005 ToGWmax + 100] / V_b	[0,00005 (ToGWmax + 135] / V_b	[0,00005 ToGWmax + 200] / V_b
Turbo Prop	[0,00005ToGWmax+ 63] / V_b	[0,00005 (ToGWmax+ 98] / V_b	**For each additional member**
			+ [35] / V_b

Source: ATA 1963

Where C_{am}= Costs per air statute mile in US$
$ToGW_{max}$= Maximum certificated take-off Gross Weight (lb)
V_b= Block Speed (mph)

The equations from ATA are based on speed in statute miles per hour and the ToGWmax in pounds, whereas the units for the model will be metric units. The crew cost equation values of speed will have to be changed to km per hour and the weight to be converted to kilograms. The crew cost equation that will be used in the model is shown in Table 7:

Table 7: Crew costs per hour (US$/flight hour)

Engine Type	**International Planes**
	Three-man crew
Turbo Jet	[0,0000225ToGWmax + 200]
	For each additional member
	+ [35]

2.3.6 Maintenance

The term "maintenance" as presented in the ATA method includes labour and material costs for inspection, servicing, and overhaul of the airframe and it's accessories, engines, propellers, instruments, radio, etc.

There are two well-established procedures being used for the maintenance of aircraft, namely periodic and progressive. The use of either of these procedures is dependent on the policy set forth by the individual airlines and generally the costs will be approximately the same. All equations have been quoted as given by ATA that had no derivations of them.

The ATA remarked that the close study of operating statistics shows that the average cost of maintenance may be fairly represented as a function of weight, thrust, and flight cycles. Table 8 summarizes the equations to calculate maintenance and Table 9 compiles the items used to calculate maintenance and their respective equations:

Table 8: Maintenance costs equations (US$/air mile)

Maintenance costs	Cost per air mile
Labour - Aircraft	$C_{am} = (KF_{Ha} * t_f + KF_{Ca}) * R_L /(Vb * T_b)$
Labour - Engine	$C_{am} = (KF_{He} * t_f + KF_{Ce}) * R_L / (V_b * T_b)$
Material - Aircraft	$C_{am} = (CF_{Ha} * t_f + CF_{Ca}) / (Vb * T_b)$
Material - Engine	$C_{am} = (CF_{He} * t_f + CF_{Ce}) / (V_b * T_b)$

Source: ATA (1963)

Where: R_L = Labour rate (US$/block hr)
W_a = Basic empty weight of the aircraft less engines (Ib)
V_b = Aircraft speed (mph)
T_b= Block time (hr)
t_f= Flight time (hr)
$C_{air=}$ Cost of complete aircraft less engines (US$)
T = Maximum certificated takeoff thrust (Ibf)
N_e = Number of engines

Table 9: Equation components

Item	Equation	Units
CF_{Ha}	3,08 C_{air}/106	Material cost (US$/flight hour)
CF_{Ca}	6,24 C_{air}/106	Material Cost (US$/flight cycle)
KF_{Ce}	(0,3 + 0,03 T/103)	Labour man-hours per flight cycle
KF_{Ha}	(0,6 + 0,027 T/ 103)	Labour man-hours per flight hour
KF_{Ce}	0,05 * Wa / 1000 + 6, 630 / (Wa/1000 + 120)	Labour man-hours per flight cycle (jets and turboprop)
KF_{He}	(0,65 + 0,03 T/103)	Labour man-hours per flight hour (turboprop)

Source: ATA 1963

Notes to Table 9: Labour - Aircraft (Excluding engines only). Material - Aircraft (Excluding engines only). Calculations of which are shown in Table 10.Labour and material- Engine (includes bare engine, engine fuel control, thrust reverse, exhaust nozzle systems, and augmentor systems, gear box but excludes the propeller on turboprop engines). The labour rate, in case used will be acquired appropriately for Africa's case.

Table 10: Material costs for aircraft

Types	Material cost per flight cycle (CF_{Ce})	Material cost per flight hour (CF_{He})
Subsonic aircraft	0,02 N_e C_{eng}	0,25 Ne Ce

Source: ATA 1963

Where; N_e = Number of engines
C_{eng}= Cost of one engine

According to all the maintenance equations that have been developed, there is a need for factors like labour rate, which varies significantly between African countries depending on the economic situation. In the literature review, maintenance of the aircraft is related to depreciation, which relates to the capital cost of the aircraft

2.3.7 Percentage allocation of costs

Table 11 gives the summaries of the percentage structures found in the stated references. Kane (1996) gives the Department of Transport (US) structure while the ICAO structure is given by Doganis (1989).

Kane (1996), states that labour costs are common to nearly all of those categories. When looked at as a whole, labour accounts for 35% of the airlines' operating expenses and 75% of its controllable costs. Fuel is another major cost item (about 15% of total expenses). So are travel agents' commissions (about 10%). Commissions have been one of the fastest rising airline costs since deregulation, when they accounted for less than 5% of total costs. Another rapidly rising cost has been airport landing fees and rents, which have been rising at four times the rate of inflation in recent years. For world's airlines, user charges, which include airport charges and en-route facility charges, account for nearly 5 % of their total costs.

The difference in the percentage of allocation costs, between 1989 and 1996 is due to different operating structures between the Department of Transport of the US government and the international airline body ICAO. This would explain the different allocation of sub-components of operating costs, in different operating environments; ICAO takes into account all international member airlines and arrived at a general average structure.

Table 11: Percentage distribution of operating Costs

Operating costs	**Scheduled airlines of ICAO, 1982 After Doganis (1989)**	**Dept of Transportation US After Kane (1996)**
Direct Operating Costs		
Flight operations	41,7	28
Flight crew salaries / expenses	(7,3)	
Fuel and oil	(27,2)	
Air port and en-route fees	(4,7)	
Insurance and aircraft rentals	(2,5)	
Maintenance and Overhaul	9,8	11
Depreciation and Amortisation	6,8	6
Total DOC	**58,4**	**45**
Indirect Operating Costs		
Station to ground	10,8	25
Passenger services	9,1	
Ticketing, sales and promotion	15,5	18
General and administration	6,1	12
Total IOC	**41,6**	**55**
Total Operating costs	**100,0**	**100**

Sales, ticketing and promotion charges

Doganis (1989) relates the sales, ticketing and promotion charges to those engaged in ticketing sales and promotion activities as well as all office and accommodation costs arising throughout these activities. The costs of advertising, marketing promotion, commission or fees paid to agencies for ticket sales also fall under this category.

In Table 11, Doganis (1989) shows that the percentage of costs that are allocated to ticketing, sales and commissions, amount to 15,5% of indirect operating cost. The ratio of percentages of ticketing, sales (15,5%) to direct operating costs (58,4%) can be used to calculate the item.

General administration

In Table 11, Doganis (1989) gives the percentage that administration contributes to 6,1% of airline indirect operating costs. The ratio of percentages of general administration (6,1%) to direct operating costs (58,4%) will be used to calculate the cost for general administration.

Maintenance

Table 11 shows the relationship between the costs of components from Department of Transport (US) (Kane, 1996) and ICAO (Doganis, 1989). The more detailed ICAO data from international member airlines reflects that insurance and maintenance amount to 2,5% and 9,8% respectively of the total operating cost of an airline service. This percentage ratio between insurance that is easily calculated, will be used to obtain the value for maintenance.

Stratford (1973) also shows the parameters and their economic units to be used in quantifying the costs in Table 12. The unit system that is quoted in the references is quite old so it will be used when quoting values and figures from references.

For the purposes of this study, the metric system will be adopted.

Table 12: Economic units to quantify costs

COST ITEM	UNITS
Cruise performance data	
First cost of complete aircraft Engine type, number and first cost	$
Spares cost per aircraft	
Airframe	$
Engine	$
Radio/ Equipment	$
Maximum all-up weight	Ib
Basic operating weight with/ without special equipment	Ib
Annual utilisation	Flight Hours/aircraft hours/block hours
Depreciation Period	Years
Residual Value	%
Insurance rate of flight equipment	% Per annum
Interest on Capital	% Per annum
Basis of engineering costs	
A) Airframe engineering costs	$ Per block hour
B) Engine maintenance and overhaul costs	Man hours per annum
c) Equipment and component overhaul, mean attained period between engine overhauls	Hours
Maintenance labour rate	$/ Direct man-hour
Crew costs (No. in crew)	$/ Annum
Crew Utilisation	Hours/annum
Fuel costs	$ Per flying hour
Landing fees	$ Per landing

Source: Stratford (1973)

Notes to Table 12: Kilograms will be used instead of pounds for weight. Costs in US$ will be given in block hours not in terms of labour hours

2.4 Aspects that determine route costing

2.4.1 Management control of costs

Doganis (1989) states that the variable operating costs, which may represent about 50 percent of total operating costs, which are broadly determined by the level of supply, that is the volume of output are decided upon by the management. This statement implies that management decisions in some of these variable operating cost components has an impact on the costs. Some of the components over which management has control, are outlined below.

2.4.2 Prevailing wage levels

Doganis (1989) states that labour costs have become a point of focus, because they have become the largest single cost element varying in extent from 15 - 40 percent. In addition, it is a major factor differentiating one airline's unit costs from another.

Hanlon (1999) states that the importance of labour costs in the overall cost structure of an airline is dependent on the interplay of two groups of factors, those relating to the relative costs of labour and those that determine the productivity of the labour. In other words labour costs depend on the unit cost of labour as an input and the amount of that labour that is required to produce a unit of output.

2.4.3 Fuel prices

The price of aviation fuel at any airport depends partly on the companies supplying the fuel and partly on the government concerned. Prices for fuel worldwide differ in distribution and handling costs, foreign exchange rates, etc. (Doganis, 1989)

Table 13 is an extract from Doganis (1989) that shows the fuel prices for different continents extracted from ICAO (1984b). He also states that the price of fuel is crucial for airlines since on any particular route it may represent as much as 40 percent of operating costs, though overall it accounts for one of the biggest potion of the total operating costs of many airlines.

Table 13: Fuel prices on international scheduled services 1982

Route Group	**Average fuel or oil price paid. (US cents per US gallon)**	**Index (North America = 100)**
Africa	163,9	184
South America	127,2	142
Asia/Pacific	118,8	133
Europe	117,0	131
North America	89,3	100

Source: Doganis (1989)

For the Africa situation, in Table 13, the price of fuel is 163, 9 while in Table 5 the price per US gallon is 89,5, this change is attributed to the year in which the data was collected. Table 13 quotes 1982 prices while the price in Table 5 is a 2002 quotation, which would be more representative.

2.4.4 Route traffic density

The main determinant of unit cost is route traffic density. In this context, density can be measured as the ratio of traffic to network size; i.e. passenger miles divide by unduplicated route mileage, or passenger miles divided by the number of cities served.

Doganis (2001) states that economies from route traffic density arise because greater density enables the airline to use larger aircraft. These are more efficient with lower costs per seat mile and/ or to operate at higher service frequencies, consequently at higher seat load factors, which lead to lower cost per passenger mile.

2.4.5 Average sector length

Kane (1996) defines the sector length as the overall physical length of the route in miles. The greater the number of miles produced on a certain route by a given aircraft will tend to decrease the per-mile cost of operating the aircraft. The fixed cost, for a given flight will remain fixed regardless of the total miles flown. This fixed cost, spread over more miles, will result in lower fixed cost per mile.

Hanlon (1999) also states that higher block speeds and better fuel economies are achieved on longer routes. The hyperbolic relationship between unit cost and sector length, shown in Figure 2, is a fundamental characteristic of airline economics, and the airlines with the lowest cost per seat mile are those operating large aircraft over long sectors.

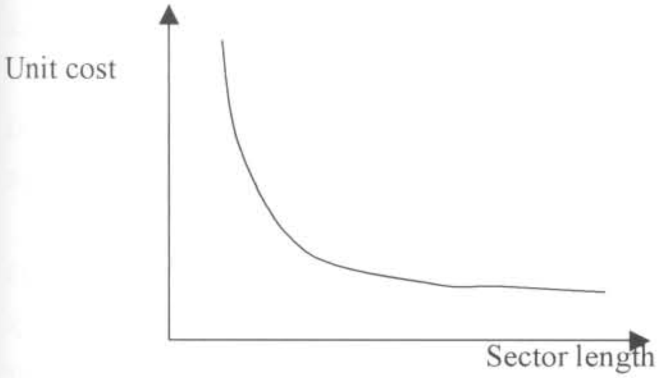

Figure 2: Hyperbolic relationship between unit cost and sector length

Doganis (2001) finds that for each aircraft type, the longer the sector length, which can be flown the lower the direct operating cost per available seat-mile, a relationship similar to the one shown Figure 2.

2.4.6 Average length of haul

The average length of haul is the average distance flown by passengers over an air carrier route. A route may be a thousand miles long, but if the average passenger disembarks after two hundred miles, his vacated seat may well remain empty for the remainder of the flight. Kane (1996) states that this can of course be prevented by non-stop flights, but these are not always possible especially if the air carriers must also serve intermediate points along the route.

Doganis (2001), states that many costs associated with sales, ticketing and the handling of passengers are related to the number of passengers rather than to the distance that each passenger travels with the airline on a particular journey. In other words, a passenger who buys a single ticket and travels 3 000km on an airline network will cost less to an airline than three separate passengers each traveling 1 000km. In the latter case, each of the three will impose individual ticketing and handling costs and the airline may have to pay a separate airport charge for each.

2.4.7 Load factors

Kane (1996) defines load factor as the percentage that revenue passenger-miles are of the seat-miles provided. A break-even load factor is computed for an aircraft type over any given route. It is equal to the percentage of the aircraft, which must be filled by passengers or other traffic in order for the airline to cover its direct operating costs for the flight. This point must obviously be reached before a profit can be achieved.

2.4.8 Aircraft type and characteristics

Doganis (1989) shows the influence of different aircraft characteristics that affect costs. Aircraft size, speed and range together determine a productivity curve of an aircraft and hence its unit cost.

From an economic point of view, the most important factors are the size of the aircraft; it's cruising speed and the range or distance, which that aircraft can fly with a full payload. The significance of size, speed and range is reinforced, in that taken together they determine the hourly productivity of an aircraft, which in turn also affects unit costs. As a general rule, the larger the aircraft the lower will be it's direct operating costs per unit of output (i.e. per tonne - km available or per seat- km).

Aircraft speed, through its effect on the hourly productivity of an aircraft, affects unit cost. Hourly productivity of an aircraft is the product of the payload and the speed, the greater the aircraft cruising speed the greater will be its output per hour.

Aircraft are designed to cater for particular traffic densities and sector lengths. Therefore, each aircraft type has different take-off and range characteristics and these in turn influence unit costs (See Chapter 5).

2.4.9 Route competition

Kane (1996) states that competition on the route due to other airlines or transport modes produces better airline service in the public interest. But in situations where there is not enough air traffic to support the airlines serving a route, it creates un-profitability because competition among these airlines leads to addition of expensive perks to attract the market. Competition for given routes is commonly caused by:

1. Creation of new air carriers
2. New routes of existing airlines into areas already being served by other airlines
3. Mergers of airline companies or route consolidations that monoplise market on routes and set minimum fares.

2.4.10 Frequency of services

High frequencies provide airlines with greater flexibility in schedule planning, thereby enabling them to increase aircraft and crew utilisation. Doganis (2001) states that airlines operating at low frequencies face the problem of what to do with their aircraft when they have completed the first round. Antolini (2002) states that on long haul routes high frequencies also enable airlines to reduce the length and cost of crew stopovers.

2.4.11 Demand for air travel

The three fundamental factors affecting passenger demand are incomes, fares and service levels. Broad estimates of aggregate elasticities imply that demand is highly elastic with respect to economic growth and fares and relatively inelastic with respect to service levels.
The components of air travel demand are co-related as shown in Figure 3:

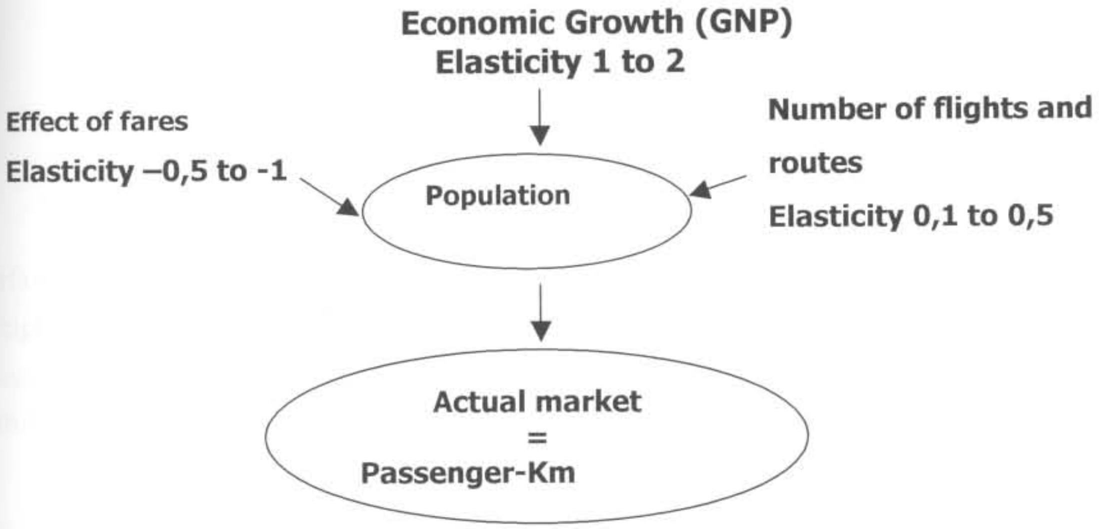

Figure 3: Factors affecting demand for air travel (Source: Hanlon, 1999)

Hanlon (1999) shows that the high-income elasticity can be seen in the short-term series relationship between economic activity and air travel demand. Although air travel tends to grow faster than GDP, it still follows very closely the cyclical pattern in GDP.

2.4.12 Marketing effect

Marketing expenditure serves two functions. One is to increase the airline's share of passenger demand and the other is to make that demand less price elastic. Figure 4 shows the original demand curve (D_1) before anything is spent on marketing. On this schedule, if the fare charged by the airline is P_1, the number of passengers carried by the airline is Q_1. Following a marketing campaign, the demand curve shifts to the right and acquires a steeper slope (D_2). The rightward shift allows an increased number of passengers Q_3 to be attracted to the service at original price or the steeper slope enables the airline to raise the fare to P_2 and still have a substantial increase in passengers to Q_2.

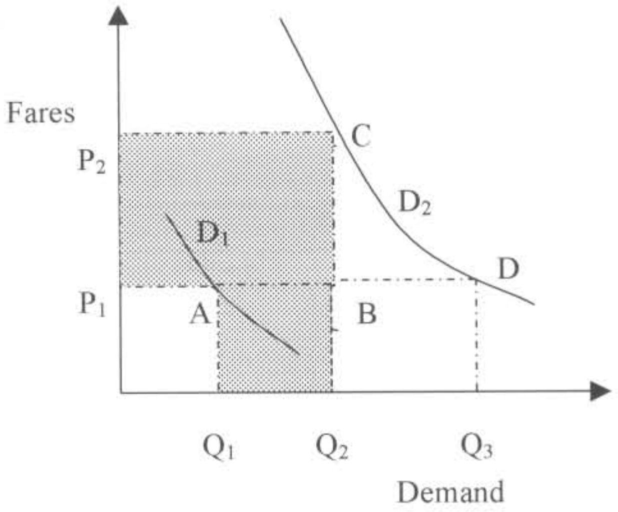

Figure 4: Demand curve for passenger demand (Source: Hanlon, 1999)

Hanlon (1999), concludes that the airline benefits both from an increase in passengers and from a higher fare per passenger; its total gain in revenue is either $(P_2-P_1)*Q_2 + (Q_2-Q_1)*P_1$ if the fares are increased or $P_1*(Q_3-Q_1)$ if the fares are kept the same. So long as this additional revenue is greater than the costs associated with the marketing campaign, the airline increases its profit.

2.5 Summary

From the literature it is evident that the structure shown in Figure 5, depicting the cost components, is the most logical method of developing the model. The operating cost component equations that are used in the model are classified as standing, flying and other costs.

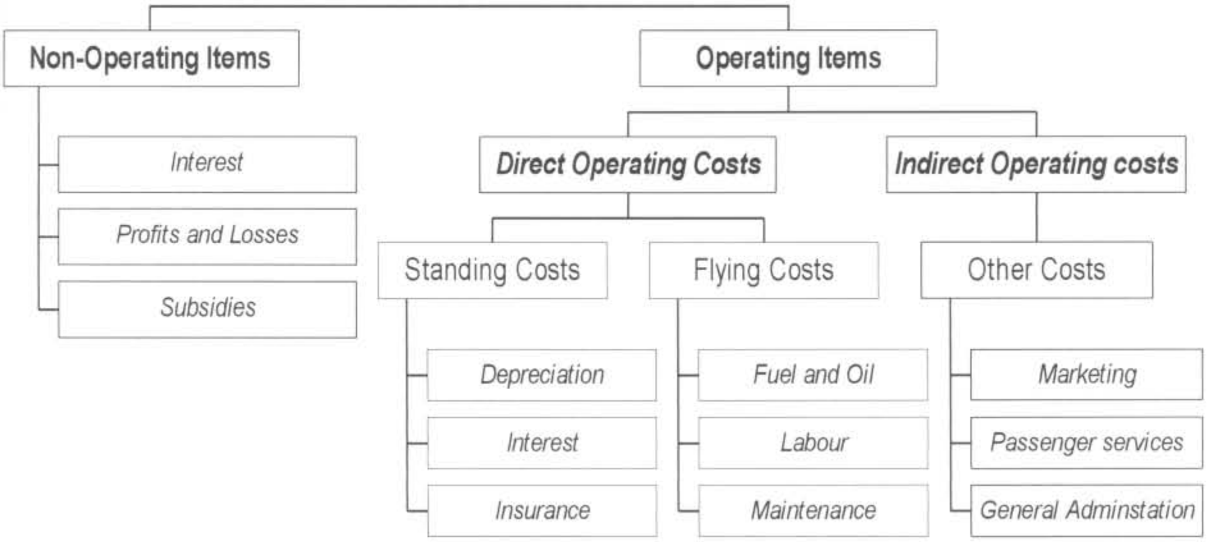

Figure 5: Airline and aircraft cost components

The operating cost component equations derived from the literature, that will be used in the model are classified as standing, flying and other costs. The equations to be used in the model are given in Table 14.

Table 14: Equations used for cost model components

COMPONENTS	EQUATIONS	Parameters
Standing costs (per hour utilised)		C_{total} = total cost of aircraft +engine
Hourly Depreciation	$C_{total}\ (1-r_v)/L * U$	r_v= residual value (%)
Hourly Insurance	$X * C_{total}/U$	U= annual utilisation (hrs)
Hourly Interest	$i * C_{total}/U\ [1-((1-r_v)(L-1))/2L]$	I =annual interest rate (%)
Flying costs (per hour utilised)		L = life (years)
Fuel and oil (cruising & air manoeuvre)	$C_{ah} = 1.02\ (V_f * C_{ft} + 0{,}135 * C_{ot} * V_o)$	X =annual insurance rate
Direct Maintenance	9,8 / 2,5 ratio of insurance costs	C_{ft} = cost of fuel (US$/US gal)
Crew costs (3-man crew)	[0,000225ToGWmax + 200]	C_{ot} = cost of oil (US$/quart)
Additional members	+[35]	V_f =Fuel volume consumed at cruising/ climbing (US gal/hr)
Other costs		V_o = Oil Volume consumed at climbing/cruising (quart/hr)
Landing Fees per aircraft	Charges per weight * ToGWmax	ToGWmax = max Take off weight (kg))
Parking Fees per aircraft	Charges per weight* ToGWmax	Tb = block time (hrs)
Passenger Handling per passenger	Charges per Passenger * No of passengers	Vb = block speed (km/h)
Ticketing, sales and commission	15,5% of operating costs	
General administrative costs	6, 1% of operating costs	

The aspects of operating costs that are key to lowering the variable operating costs include minimum and maximum frequency of flights, average sector length, block time, and the route traffic density. These will have to be analysed specifically in the model so as to design for an optimum service along a route.