3 CHAPTER THREE: MODEL STRUCTURE

3.1 Introduction

The route cost model was developed as a Microsoft Excel spreadsheet to calculate the cost of an airline service for each given route, for a specified number of passengers, with a minimum service frequency and for a range of different aircraft modes. The structure of the model is described in this chapter in terms of the input component, the calculation component and the output component.

3.1.1 Assumptions

The following assumptions were made in developing the model:

1. The data that has been collected has been found valid and referenced accordingly.
2. Calculations for the direct operating costs, which include standing and flying costs, are calculated in the rate of hours utilized annually, while other costs like passenger fees are calculated as per unit description.
3. A Flight for this cost model is defined as a return journey, made by any given aircraft on a route, otherwise all calculations are done using sector distance using one leg of the journey.
4. Passenger demand is given as the maximum volume of passengers along the route irrespective of the direction of travel.

3.1.2 Flow chart

Figure 6 shows the flow chart, which comprises of the model that was developed. It gives the systematic layout of the calculations to be done and what information is input to give the output necessary. The model is composed of the following components:

1. The input module containing the characteristics of the route to be used, like distance, passenger numbers (section 3.2) and a data base for default values for each aircraft type like the cruising speed, (Chapter 4 and compiled in Appendix D).
2. The calculation module (section 3.3)
3. The output module (section 3.4)

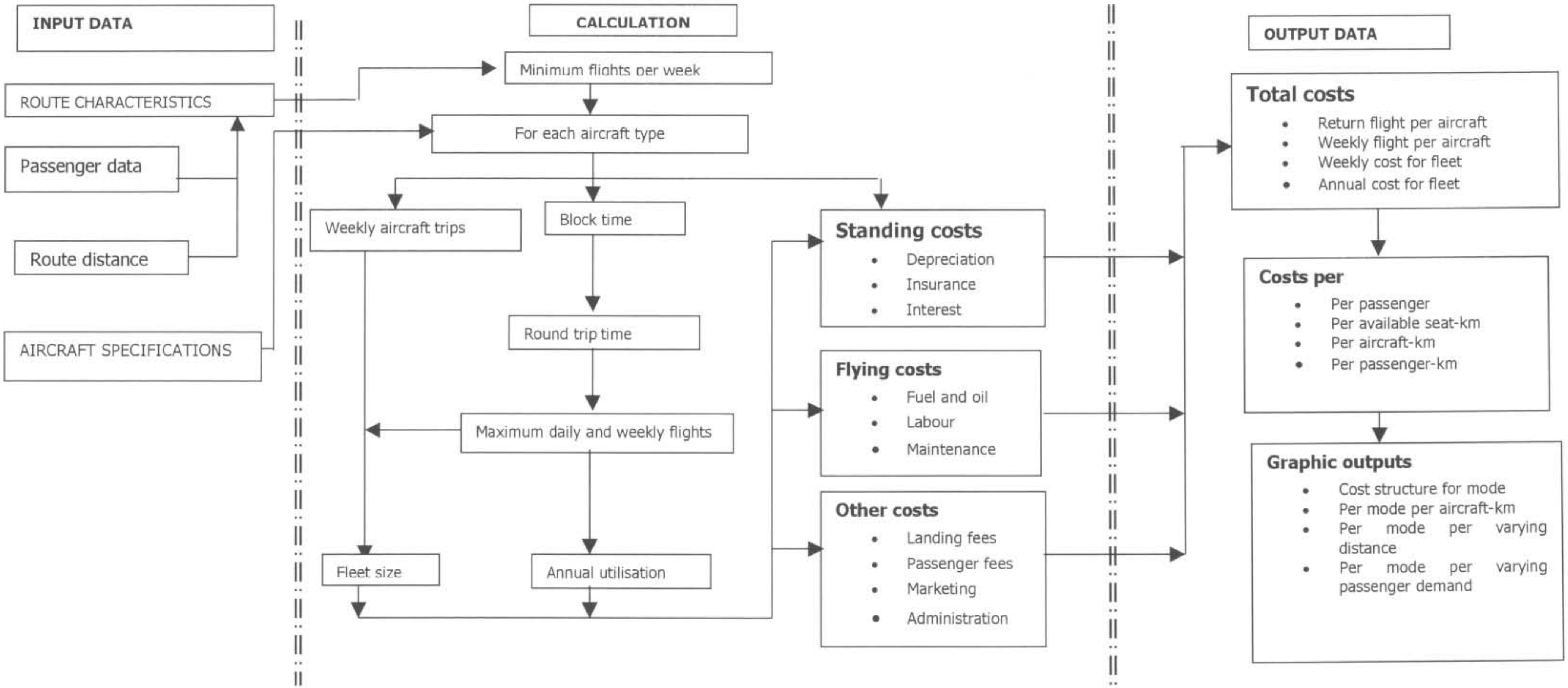


Figure 6: Model flow chart

3.2 Input module

All the data that serves as input to the model is included in the *Input Sheet*, while the aircraft default values and technical specifications are included in the *aircraft data*. The aircraft data, which includes aircraft technical characteristics like operating speed, default values, and data collected for each aircraft needed to calculate cost components is shown in Appendix D.
The user of the model can input the basic descriptors of the route, for which the cost is to be calculated. The sheet is set up in such a way that the automatic link will always have values and will use these default values, unless the model user decides to use alternative values in the "manual" cell.

3.2.1 Route description

The user of the model needs to specify the origin and destination countries, for the airline service that is being costed. Once the countries have been specified, the IATA Airport codes for the major international airports are linked automatically from the *demography* work sheet. These codes are important because, they are used to identify each airport.

Sector distance

The model user, will then be given the option of either using the automatic distance between the two specific airports, obtained by linking the *distance matrix* in a separate worksheet, or the user can input the actual distance manually.

The model will be set up in such a way, that the automatic link will always have values and will use these default values, unless values in the manual section are provided. When a value is filled in the manual section, it will be the input value used.

Passenger demand

The model assumes that the passenger volumes are equal in both directions. This demand is given in units of passengers/week. The weekly number of passengers can either be derived from the *trip distribution matrix* (See Appendix C) or input manually by the user. The time period used is a week because in the airline industry, the standard unit of time over which frequency is described is usually a week.

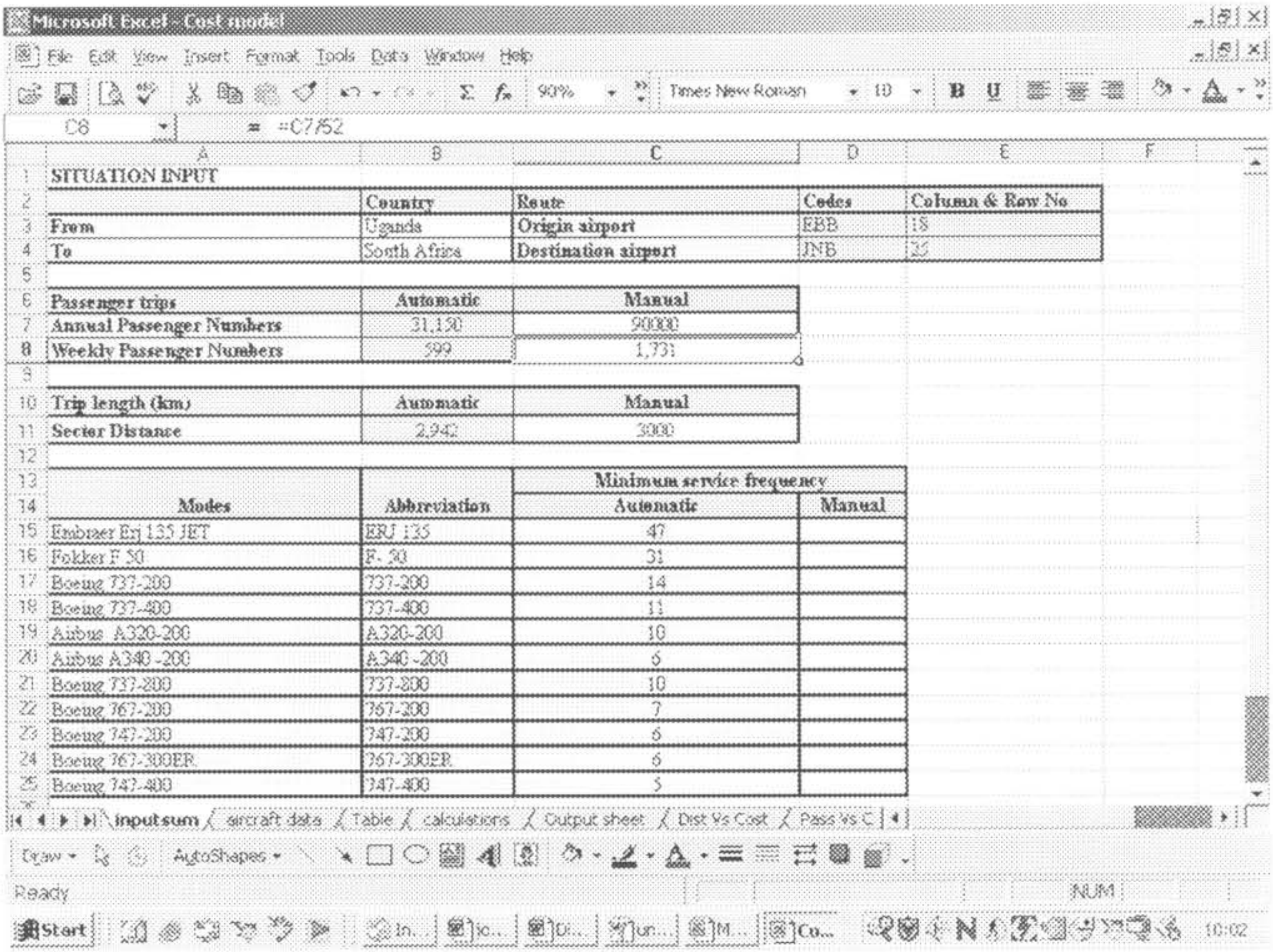
Minimum service frequency

This is defined in the model as the minimum number of flights required to meet the weekly passenger demand. There may also be a limit to the number of flights that a given route can be assigned, either according to regulations, politics or preference of the model user.

3.2.2 Africa databases

The model, in order to be applicable to the Africa situation, includes a 50 x 50 airport distance and the air passenger matrix. These sheets have been included in Appendices B and C respectively. The model will be such that it automatically picks information specific to the route characteristics that the user inserts for the route described.

Figure 7 shows an example of the input sheet for passengers travelling from Entebbe, Uganda, to Johannesburg, South Africa. The distances and passenger numbers are all input from the database. The different aircraft types used in the model are discussed in Chapter 4.



SITUATION INPUT

	Country	Route	Codes	Column & Row No
From	Uganda	Origin airport	EBB	18
To	South Africa	Destination airport	JNB	25

Passenger trips	Automatic	Manual
Annual Passenger Numbers	31,150	90000
Weekly Passenger Numbers	599	1,731

Trip length (km)	Automatic	Manual
Sector Distance	2,942	3000

Modes	Abbreviation	Minimum service frequency	
		Automatic	Manual
Embraer Erj 135 JET	ERJ 135	47	
Fokker F 50	F. 50	31	
Boeing 737-200	737-200	14	
Boeing 737-400	737-400	11	
Airbus A320-200	A320-200	10	
Airbus A340 -200	A340 -200	6	
Boeing 737-800	737-800	10	
Boeing 767-200	767-200	7	
Boeing 747-200	747-200	6	
Boeing 767-300ER	767-300ER	6	
Boeing 747-400	747-400	5	

Figure 7: Input Sheet

3.3 Calculation module

This sheet does all the calculations in the model. It compiles all the default data, input data and aircraft specifications that are necessary to calculate each cost component, for each aircraft type. Below are a description of all the components that are used in the calculation sheet, and the basis of the equations to calculate them. An extract of this worksheet is shown in Figure 8.

3.3.1 Route service characteristics

These characteristics describe the route over which the service is to be run and are used to calculate the sector flight time, frequency and utilization.

Minimum service frequency

These are the minimum number of passengers required to meet demand. It is calculated by dividing the passenger demand by the aircraft passenger capacity, and is found on the input sheet:

$$\text{Weekly aircraft trips} = \frac{\text{Weekly passenger Demand}}{\text{Aircraft passenger Capacity}} \qquad \text{.................... 3-1}$$

Sector distance

This sector distance is given in the *input module*, as the route length distance from origin airport to destination airport and will be used to determine the block time for the aircraft.

Block time

This is calculated as the time taken for a given aircraft mode to fly over the route length specified in the input sheet. The block time takes into consideration the lost time as the aircraft is taking off and landing and in essence described as time from "engine-on" until "engine – off". The acceleration and deceleration time losses are assumed in the time specified for take-off and landing.

Round trip time

This time is different from block time in that it includes the entire time taken for a round trip. It includes the time taken for servicing and refueling before the aircraft can take off again at both ends. The duration of this service time, is taken as standard i.e. for larger aircraft, sufficient manpower is employed to achieve the same time as for smaller aircraft.
The flight time is calculated in the model using:

Round trip time = 2 (Block time + servicing time) ………………..3-2

Maximum daily service frequency (supply)

The supply that can be offered along this route is defined as the maximum number of flights a single aircraft can fly in a day. This is determined by the block time for a route length and regulations that specify how long any aircraft can fly per day, which is included in the usable operating hours for each aircraft. Value must be rounded-off downwards i.e. 4,7 flights = 4 flights. The daily flight frequency is calculated as:

$$\text{Number of flights} = \text{Integer value of} \left[\frac{\text{Usable operating hours}}{\text{Block time + Servicing time}} \right] \quad \text{…………. 3-3.}$$

Maximum weekly service frequency

This is defined in this model as the number of flights that each aircraft can fly each week. This frequency is calculated by multiplying the maximum daily service frequency by the number of days in a week on which flying occurs. For a fixed schedule, where block time allows for only one one-way flight a day, the maximum weekly number of flights is 6 flights, as only 3 return flights per week with one aircraft are possible.

Fleet size

The fleet size, which will be needed to meet passenger demand, depends on the weekly frequency per aircraft and the standby fleet. The aircraft are assumed to be traveling the route at full capacity There is a minimum and maximum frequency that an aircraft can fly, which is determined by the number of operating hours in a day, and the length of the flight. This is necessary, such that when any of the fleet is undergoing maintenance, there is an aircraft available. A stand by fleet of 2% is meaningless in respect of a fleet of less than 50 aircraft; but it implies that external aircraft could be leased or hired to account for this extra expense.

$$\text{Fleet size} = \frac{(1+\text{standby fleet}) * \text{weekly one-way passengers}}{(\text{Aircraft capacity} * \text{maximum weekly frequency})} \quad \text{…………..3-4}$$

Utilisation

For the model, the utilisation period is considered weekly and annually for calculation of the operating costs. Weekly utilisation is calculated as the product of weekly flight frequency and block time while annual utilisation is also a product of weekly utilisation and number of weeks in a year.

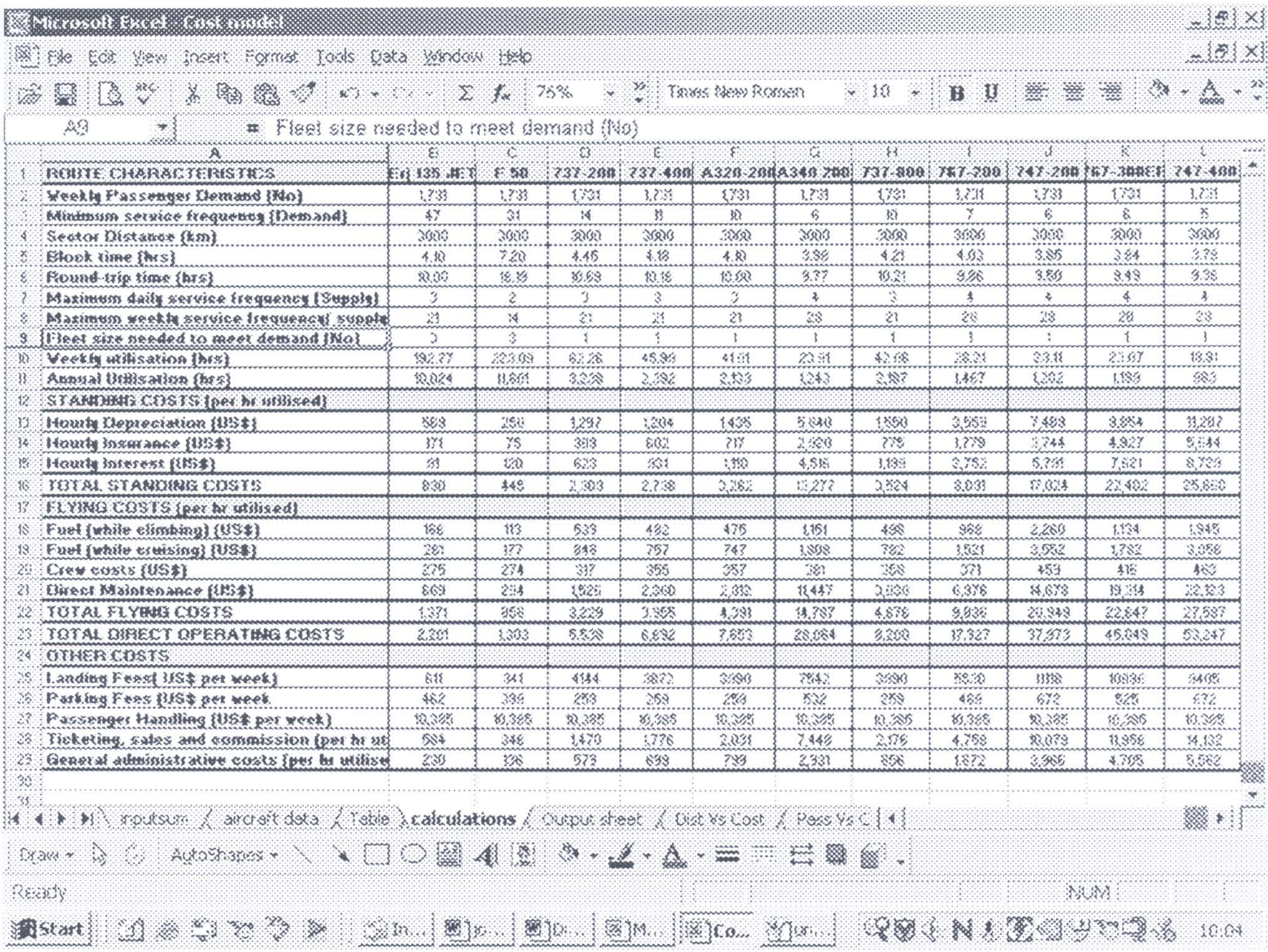
Weekly utilization (hrs / week) = No of flights / week * block hours / flight ……….. 3-5

Annual utilisation (hrs / year) = weekly utilisation *weeks / year) ……….. 3-6

3.3.2 Operating costs

The aspects that are crucial in determining the operating costs, like fuel costs, wage levels, frequency of service, average length of haul and traffic density, will all be taken into consideration in the model for a service that is supposed to run cost effectively. The equations for the cost components under flying, standing and other costs used in the model are given in Table 14.

Figure 8 gives an example of the calculation sheet that appears in the model in the order that the calculations are done in the way that has been described above. The operating costs, which include the standing, flying and other costs in the calculation sheet are calculated using the equations in Table 14 in Chapter 2. The calculations are for the input sheet shown in Figure 7.

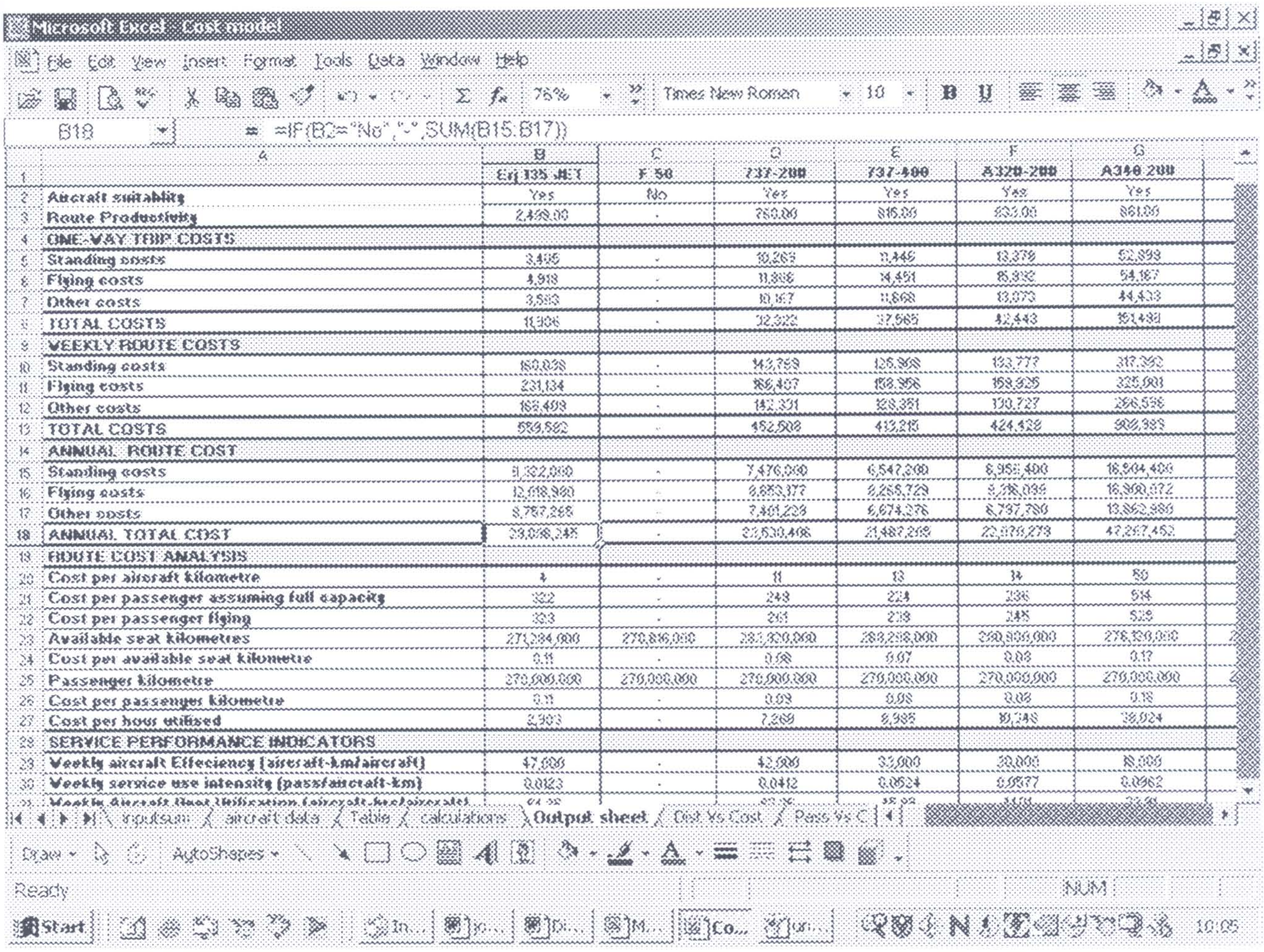


ROUTE CHARACTERISTICS	ERJ 135 JET	F 50	737-200	737-400	A320-200	A340 200	737-800	767-200	747-200	767-300ER	747-400
Weekly Passenger Demand (No)	1,731	1,731	1,731	1,731	1,731	1,731	1,731	1,731	1,731	1,731	1,731
Minimum service frequency (Demand)	47	31	14	11	10	6	10	7	6	6	5
Sector Distance (km)	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
Block time (hrs)	4.10	7.20	4.45	4.18	4.10	3.86	4.21	4.03	3.85	3.84	3.78
Round-trip time (hrs)	10.00	16.19	10.69	10.16	10.60	9.77	10.21	9.96	9.50	9.49	9.36
Maximum daily service frequency (Supply)	3	2	3	3	3	4	3	4	4	4	4
Maximum weekly service frequency(supply	21	14	21	21	21	28	21	28	28	28	28
Fleet size needed to meet demand (No)	3	3	1	1	1	1	1	1	1	1	1
Weekly utilisation (hrs)	192.77	223.09	62.26	45.98	41.91	23.91	42.68	28.31	23.11	21.67	18.91
Annual Utilisation (hrs)	10,024	11,601	3,238	2,392	2,133	1,243	2,187	1,467	1,202	1,139	983
STANDING COSTS (per hr utilised)											
Hourly Depreciation (US$)	583	250	1,297	1,204	1,435	5,840	1,550	3,569	7,483	9,854	11,287
Hourly Insurance (US$)	171	75	383	602	717	2,920	779	1,779	3,744	4,927	5,844
Hourly Interest (US$)	81	120	623	931	1,110	4,516	1,189	2,752	5,791	7,621	8,729
TOTAL STANDING COSTS	830	445	2,303	2,738	3,262	13,277	3,524	8,031	17,024	22,402	25,860
FLYING COSTS (per hr utilised)											
Fuel (while climbing) (US$)	168	113	539	482	476	1,161	498	968	2,260	1,134	1,945
Fuel (while cruising) (US$)	281	177	848	757	747	1,808	782	1,521	3,952	1,782	3,058
Crew costs (US$)	275	274	317	355	357	381	358	371	459	416	463
Direct Maintenance (US$)	669	294	1,525	2,360	2,812	11,447	3,036	6,376	14,678	19,314	22,323
TOTAL FLYING COSTS	1,371	858	3,229	3,955	4,391	14,787	4,676	9,836	20,349	22,647	27,587
TOTAL DIRECT OPERATING COSTS	2,201	1,303	5,530	6,692	7,653	28,064	8,200	17,327	37,373	45,049	53,247
OTHER COSTS											
Landing Fees(US$ per week)	611	341	4144	3872	3690	7842	3690	5830	[illegible]	10936	9408
Parking Fees (US$ per week	462	399	253	259	258	532	259	469	672	525	672
Passenger Handling (US$ per week)	10,385	10,385	10,385	10,385	10,385	10,385	10,385	10,385	10,385	10,385	10,385
Ticketing, sales and commission (per hr ut	584	348	1,470	1,776	2,031	7,448	2,176	4,758	10,079	11,958	14,132
General administrative costs (per hr utilise	230	136	573	698	799	2,331	856	1,872	3,966	4,795	5,582

Figure 8 Calculation sheet for model

3.4 Output module

The output sheet, in Figure 9, gives the overall performance indicators for the service that has been specified, for each aircraft type. It gives the overall indicators that will be used to determine the costs for the route specified.



	Erj 135 JET	F 50	737-200	737-400	A320-200	A340 200
Aircraft suitability	Yes	No	Yes	Yes	Yes	Yes
Route Productivity	2,459.00	-	760.00	816.00	833.00	861.00
ONE-WAY TRIP COSTS						
Standing costs	3,405	-	10,263	11,446	13,379	52,893
Flying costs	4,918	-	11,888	14,451	15,932	54,167
Other costs	3,593	-	10,167	11,868	13,073	44,433
TOTAL COSTS	11,936	-	32,322	37,565	42,443	151,493
WEEKLY ROUTE COSTS						
Standing costs	160,038	-	143,769	125,908	133,777	317,392
Flying costs	231,134	-	166,407	158,956	159,925	325,003
Other costs	168,409	-	142,331	128,351	130,727	266,596
TOTAL COSTS	559,582	-	452,508	413,215	424,428	908,993
ANNUAL ROUTE COST						
Standing costs	8,322,000	-	7,476,000	6,547,200	6,956,400	16,504,400
Flying costs	12,018,980	-	8,653,377	8,265,729	8,316,036	16,900,072
Other costs	8,757,268	-	7,401,228	6,674,276	6,797,780	13,862,980
ANNUAL TOTAL COST	29,098,248	-	23,530,406	21,487,269	22,070,273	47,267,452
ROUTE COST ANALYSIS						
Cost per aircraft kilometre	4	-	11	13	14	50
Cost per passenger assuming full capacity	322	-	248	224	236	514
Cost per passenger flying	333	-	261	239	245	529
Available seat kilometres	271,284,000	270,816,000	283,920,000	283,298,000	280,800,000	278,320,000
Cost per available seat kilometre	0.11	-	0.08	0.07	0.08	0.17
Passenger kilometre	270,000,000	270,000,000	270,000,000	270,000,000	270,000,000	270,000,000
Cost per passenger kilometre	0.11	-	0.09	0.08	0.08	0.18
Cost per hour utilised	2,303	-	7,269	8,985	10,248	38,024
SERVICE PERFORMANCE INDICATORS						
Weekly aircraft Effeciency (aircraft-km/aircraft)	47,000	-	42,000	33,000	30,000	18,000
Weekly service use intensity (pass/aircraft-km)	0.0123	-	0.0412	0.0524	0.0577	0.0962

Figure 9: Output Sheet

3.4.1 Mode selection

Technical specifications are given that determine whether or not a given aircraft is equipped to fly over a given sector distance. The specifications that determine this are the maximum range over which any given aircraft can fly. These two conditions will determine what modes can be selected. In the output, only the values for those modes that are appropriate are provided.

3.4.2 Route productivity

Vuchic (1981) states that the route productivity is defined as the time efficiency within which work is performed. The cost per route productivity (cost / aircraft-km/hr) reflects the difference in speed at which the service is operated, in any of the above stated units. It is calculated in the model as the product of the fleet size of aircraft on a given route and the average cruising speed. In the model it is calculated as:

$$\text{Cost per Route Productivity} = \frac{\text{Cost / hour}}{\text{Fleet size x Average speed of aircraft}} \quad \text{.....................} \; 3\text{-}7$$

3.4.3 Cost components

For this study, the costs are to be calculated for the different aircraft for each of the parameters below:

- Costs for a round trip
- Weekly cost per aircraft, based on the frequency to meet demand
- Weekly cost of route
- Annual cost of route

In order to evaluate the cost of providing the airline service along a route, it is necessary to calculate the following parameters:

- Annual aircraft-km
- Annual available seat-km
- Annual passenger - km
- Route productivity (seat-km / hr)

In the model, the following five cost indicators are calculated using these parameters:

- Cost / passenger-km
- Cost / aircraft-km
- Cost / seat-km
- Cost / passenger
- Cost / aircraft-km / hr

3.4.4 Cost per passenger-km

Passenger-km is the utilised output of a transport service, a performance indicator, giving a measure of utilisation of the transport service. Passenger-km is the product of the number of passengers carried and the route length during the specified time. The cost per passenger-km, is calculated as follows:

$$\text{Cost / passenger-km} = \frac{\text{Cost per given time period}}{\text{Passengers x km (for same time period)}} \qquad \text{............3-8}$$

3.4.5 Cost per available seat-km

The available seat-km represents the total quantity of service offered on the route and is defined as the product of annual aircraft-km and the aircraft capacity. Available seats in Equation 3-8 represent the passenger capacity for any given aircraft. The cost / available seat-km is a measure of the cost of providing the total quantity of service. This is calculated as follows:

$$\text{Cost / available seat-km} = \frac{\text{Costs per given time period}}{\text{Available seats x km (for same time period)}} \qquad \text{........................ 3-9}$$

3.4.6 Cost per aircraft-km

Aircraft-km is defined as the total distance flown by all the aircraft in the fleet, during a given time period. The costs per aircraft-km give a measure of how suited a specific aircraft is for the given route. It is calculated as:

$$\text{Cost /aircraft-km (for a time period)} = \frac{\text{Operating costs for the time period}}{\text{Aircraft-km travelled (for the same time period)}} \qquad \text{...........3-10}$$

3.4.7 Cost per passenger travelling

Cost/passenger travelling is calculated as the total operating costs for a given service, along a route as a measure of how many people are using the service. It should be noted that passenger demand is seasonal; as such different costs could be determined for different periods of operation. These costs are calculated as:

$$\text{Cost per passenger travelling} = \frac{\text{Operating costs for service over the time period}}{\text{Number of passengers in the same time period}} \qquad \text{......3-11}$$