Environmental Impacts Of Airports

(A study of airport development and its impact on the social, environmental, and economic well-being of the community)

By: Majid Fayazbakhsh

Department of Environmental Resources

University Of Salford

Salford - UK

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This thesis is dedicated

to all my family

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Declaration

I declare that the study presented in this thesis is the result of my own investigation. I also declare that this work has under no circumstances been submitted for any other degree.

M.Fayazbakhsh

University Of Salford

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Glossary Of Terms

AEA	Association Of European Airlines/Airports
ASK	Available Seat Kilometres
ATC	Air Traffic Control
ATK	Available Tonne Kilometres
BA	British Airways
BAA	British Airports Authority
BAB	British Airways Board
BOAC	British Overseas Air Corporations
BR	British Rail
CAA	Civil Aviation Authority (UK)
CNR	Composite Noise Rating (US Index)
COD	Chemical Oxygen Demand
CTOL	Conventional Take-Off And Landing
DOE	Department Of Environment (UK)
DOT	Department Of Transport/Transportation (UK/USA)
DTI	Department Of Trade And Industry (UK)
EEC	European Economic Community
EPA	Environmental Protection Agency (USA)
EPNL	Effective Perceived Noise Level (in decibels)
FAA	Federal Aviation Agency/Administration (USA)
FAR	Federal Aviation Regulations (USA)
GNP	Gross National Product
GWP	Global Warming Potential
HGV	Heavy Goods Vehicle
HMSO	Her Majesty's Stationery Office (UK)
Hz	Hertz Frequency Unit, 1 cycle per second

IATA	*International Air Transport Association*
ICAO	*International Civil Aviation Organisation*
ILS	*Instrument Landing System (Airfield Approach Aid)*
ITV	*Independent Television (UK)*
MAC	*Maximum Allowable Concentration*
MOT	*Ministry Of Transport (UK)*
NASA	*National Aeronautics And Space Administration*
	OR, North Atlantic/American Space Agency (USA)
NEDC	*National Economic Development Council (UK)*
NEF	*Noise Exposure Forecast (US Index)*
NNI	*Noise And Number Index (UK Index)*
NRA	*National Rivers Authority (UK)*
OECD	*Organisation For Economic Co-Operation And Development*
PNL	*Perceived Noise Level (in decibels)*
PNYA	*Port Of New York Authority*
RTOL	*Reduced Take-Off And Landing*
SEL	*Sound Exposure Level (USA)*
SFC	*Specific Fuel Consumption*
SPL	*Sound Pressure Level*
SST	*Supersonic Transport*
STOL	*Short Take-Off And Landing*
TRRL	*Transport And Road Research Laboratory (UK)*
USAF	*United States Air Force*
VASIS	*Visual Approach Slope Indicator System*
VTOL	*Vertical Take-Off And Landing*
WHO	*World Health Organisation*
WWF	*World Wide Fund*

Preface

In the last thirty years, air traffic has increased rapidly causing the need to build more and larger airports. As the aviation industry continues to expand, the need for larger and more efficient aircraft with bigger payloads over greater distances becomes inevitable. The use of larger aircraft coupled with the growing demand for air travel requires the building of more and larger airports. One of the most important factors to consider when building a new airport is the impacts it may have on the environment.

This thesis attempts to investigate the most important environmental impacts that may rise from the building of a new airport, it also discusses both the positive and the negative aspects of such impacts. It also discusses the ways and means of reducing and minimising the adverse environmental impacts. It does NOT, however, concentrate specifically on a particular airport and the contents apply to airports "in general". A "general assessment" of such environmental impacts will also be made in the final Chapter.

It should, however, be noted that, although the main aim of this thesis is to investigate the environmental impacts of airports, a considerable amount of the material in this thesis relates to "aircraft" since some of the most important environmental impacts of airports are directly caused by aircraft, for example, the problem of aircraft noise.

Chapter 1

Introduction

1.1 General Background:

Until the late 1960s, there was little concern about the harmful environmental impacts caused by the construction of airports and other public facilities. Complaints regarding environmental effects were not common and they were considered by government officials as irritants that threatened to slow down the progress of the aviation industry. A dramatic increase in both public and government concern took place in the late 1960s about the environmental impact of airports. This increased concern partly resulted from the heightened public awareness of environmental problems in general, and even more from the worsening environmental problems of airports in particular those that were coupled with the sharp increases in air travel and the introduction of the large jet aircraft [1].

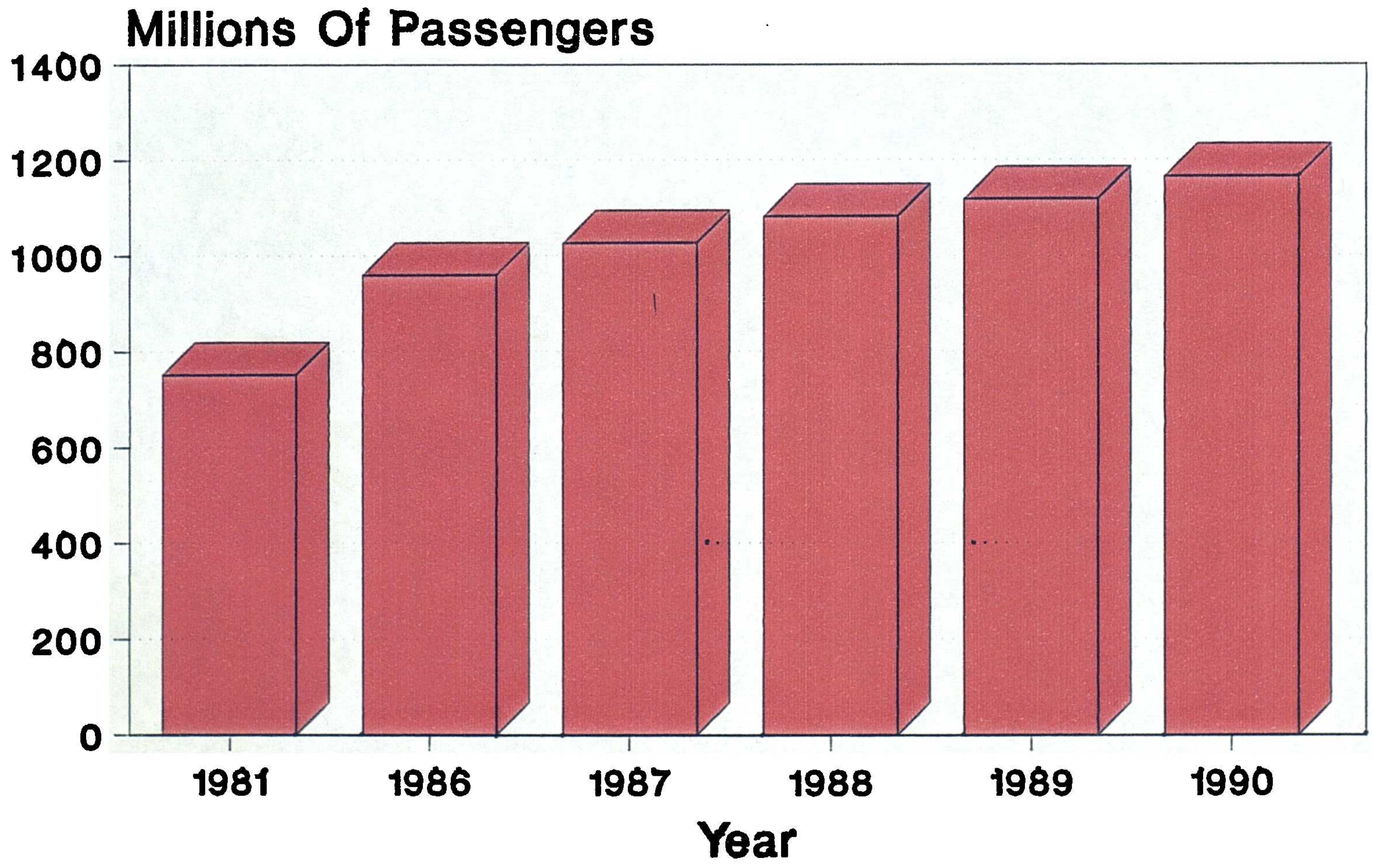
This chapter will highlight and briefly discuss the main and most important environmental issues related to airports, it will also provide the basis for discussions in the next chapters which will investigate the most concern causing and controversial environmental impacts of airports. As mentioned earlier, growth in aviation is largely responsible for the public and official concern towards the environmental problems associated with airports. It is, therefore, appropriate at this stage to briefly discuss the historic trend in air travel.

1.2 Demand For Air Travel:

Since the 1950s, the aviation industry has been growing rapidly. During the period 1950-1975, the number of air travellers worldwide doubled every five years i.e. an increase of about 15% per annum [6,17]. In the United Kingdom for example, in 1946, some 0.4 million passengers travelled to and from the UK by air. By 1978, this figure had reached 38.9 million [8], i.e. an increase of almost 100 times OR 10,000% within 32 years. In 1972, about 86% of all business trips to and from the UK, and 98% of the intercontinental business trips from the UK were made by air [13]. In general, the overwhelming majority of the UK's international passenger traffic to all areas other than the EEC is by air (86% of the 10.87 million in 1977) [7], and in 1978, 60% of overseas visitors left the United Kingdom by air while 62% of UK residents travelling abroad went by air [9].

By 1981, a total (domestic + international) of 752 million passengers were carried worldwide on scheduled air services. By 1990, this figure had almost reached 1.2 billion i.e. an increase of about 55% in nearly ten years (see Figure 1.1) [18]. The growth of air travel is, therefore, self evident. Further air traffic on charter flights and in private executive aircraft is also growing ever faster. In addition to passenger traffic, air cargo is also growing significantly at major hub airports such as London Heathrow; Paris Orly; Frankfurt Main; New York JFK; and Chicago O'Hare [28]. For instance, from 1981-1990, the total tonnage lifted worldwide

Figure 1.1: Total Passengers Carried On World Scheduled Airlines (Dom. + Int.)



Source: Author (Produced from Ref.18)

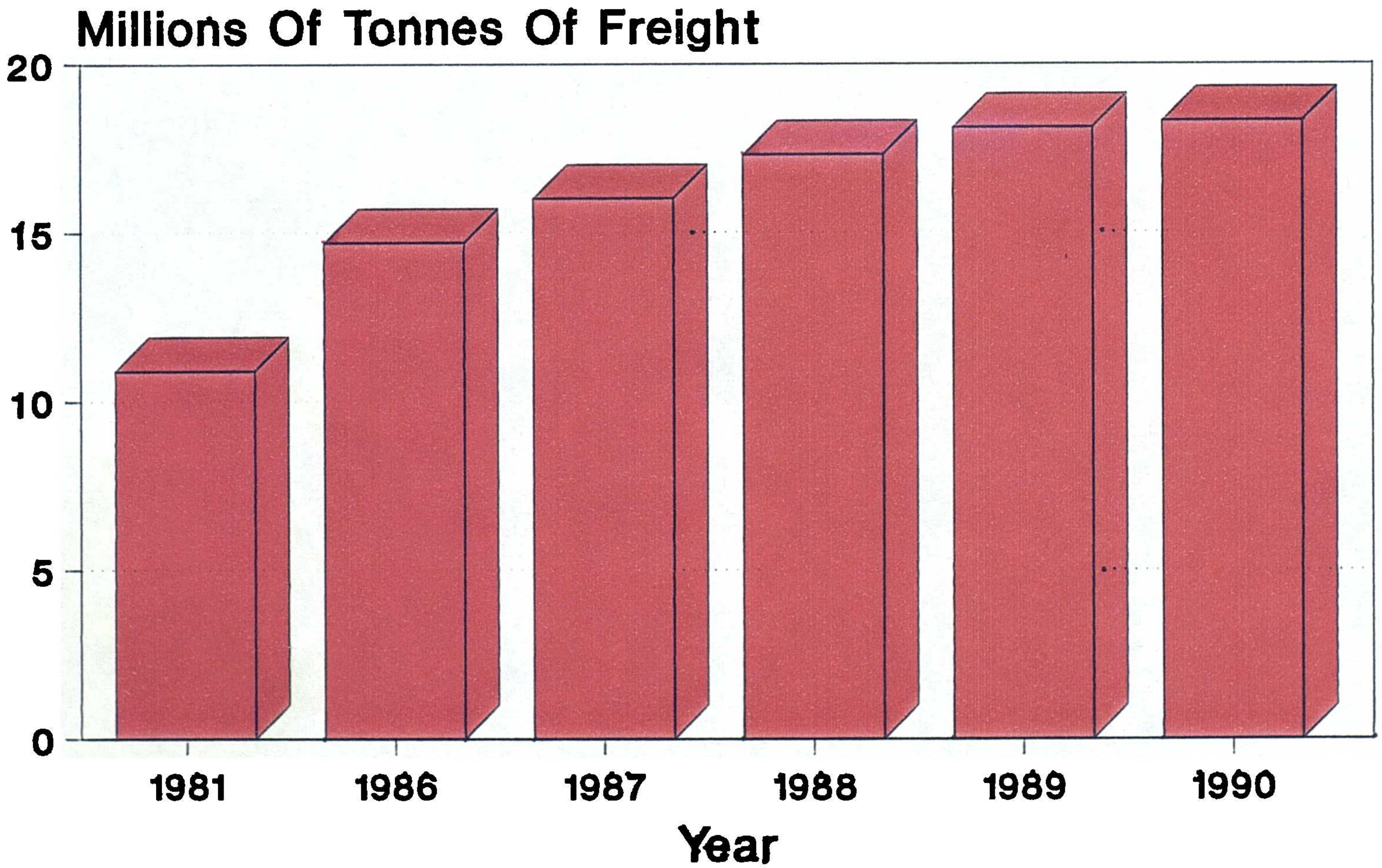
by scheduled air services increased by 68% (see Figure 1.2) [18].

Therefore, more and more cargo centres, storage houses and transfer facilities are needed at large international airports. At Manchester International for example, cargo traffic has recently grown as several new airlines have begun scheduled services. For this reason, work on phase 3 of the World Freight Terminal at Manchester was completed in early 1990s to meet the extra demand for cargo traffic [24,41]. Such increases in both passenger and cargo traffic require the need to build more and larger airports which may create more environmental impacts.

1.3 The Impacts Of An Airport On The Environment:

The construction and operation of an airport and its supporting transportation network (e.g. road and rail) like any other land use development can have a wide variety of effects. Some of these effects are desirable such as benefits to air travellers; business interests; economic activities in the region; supplying air transport needs; increased land and property values; improved aesthetics in the area by turfing and landscaping; providing easy access and egress to and from urban areas; prestige and convenience added to the area; encouraging tourism; reducing congestion at larger airports; and some are undesirable such as higher noise levels in the communities surrounding the airport; increased traffic on the

Figure 1.2: Total Freight Carried On World Scheduled Airlines (Dom. + Int.)



Source: Author (Produced from Ref.18)

local road network and additional air pollution; increased demand for local public services e.g. waste and sewage disposal; possible harm to wildlife; damage to fragile ecology and hydrology; disturbing the behaviour of wetlands; reducing the value of recreational areas through aircraft noise; and destroying the peaceful nature of the countryside [17].

Other adverse environmental effects include additional waste and water pollution; the use of energy and materials both for the construction and operation of the airport; the loss of natural resources such as minerals and special crops which may become inaccessible because of an airport [1]; community severance; vibration; visual intrusion; accidents; delays and congestion; lorry traffic causing road damage; improved lighting systems which increase security but cause more night-time operations which may create more annoyance to nearby residents [1]; the loss of residential; industrial; commercial; recreational; and agricultural land and open spaces both in rural and urban areas; demographic changes; the creation of new commercial and industrial complexes which are normally airport related and relocation of the old ones i.e. "urbanisation effects"; the destruction of the scenery and the natural environment i.e. trees; views; birds; species and soil; changes in the natural landscape and water-courses; affecting sites of special interest (historic; cultural; scientific; religious or natural beauty); competition between different modes of transport; and the general deterioration of the area and the aesthetics.

Additionally, large international airports usually become growth centres by attracting a large number of employees (possibly in thousands), thus creating a demand for housing and supporting services. Also, a number of related activities find it convenient to be near their markets and settle nearby thus, contributing to and altering the pattern of regional development. The supporting road and rail links serving an airport may also attract additional development unrelated to the airport and which, if uncontrolled, could further increase the urbanisation of the surrounding areas [17]. The following subsections will discuss the most important environmental impacts raising from airports.

1.3.1 Urbanisation Effects:

Depending on its size, an airport with its access links can have a substantial impact on the pattern of urban development. As a major employer, an airport attracts many related services and industries such as airline companies; offices; aircraft workshops; trading companies; manufacturers of high-value products that are despatched by air; distribution centres; electronic firms; warehouses; car hire agencies; fuel stations; catering firms; banks; post offices; shops; hotels; bars and restaurants; convention and exhibition centres; transport-oriented industries with national and international markets e.g. cargo handlers and freight forwarders; bus; rail; and taxi operators [17].

Similarly, airport employees and the employees of the related industries are very likely to settle in areas close to the airport thus generating further development of both secondary and tertiary activities. In this way, the airport may very considerably stimulate the growth of underdeveloped areas within a subregion. This stimulation of growth can be a positive or a negative impact depending on national and regional planning policies. If the policy is to stimulate growth in an underdeveloped area, then a new airport is very effective in doing so. If, however, the policy is to discourage urban growth, such stimulation may then have a negative impact [17].

In general, once an airport is built, it is almost permanent. Because of this, there are constraints on its location as it cannot be placed far in time or distance from its market areas. Also, for technical reasons such as problems of takeoff, landing, and visibility, airports are usually built on inexpensive and flat land near the urban periphery. On the other hand, because large investments are usually involved in both airport infrastructure and public utilities, it is therefore inevitable that the surrounding areas may become a natural focus for urban development. Unless strict controls are imposed, it is very likely that in the long run the airport subregions will become dense urbanised areas (see 1.3 earlier) [17].

It is, therefore, possible to say that, an airport may be directly responsible for the growth of both urban and rural areas through jobs and extensive roadway systems which provide accessibility to relatively undeveloped areas, and, by providing those areas with public services such as water; gas; electricity; telephone; and sewerage which can be readily used by other land uses in the "development corridors". The providing of such services together with the availability of reasonably priced land within the development corridors can easily produce population redistributions and "demographic changes" [17]. For this reason, the location of an airport needs careful considerations in the planning process.

1.3.1.1 Impact On Other Related Land Uses:

According to some research, infrastructure plays only a minor role in the process of regional development [19]. As for airports, a careful survey of the literature suggests that airports themselves may have little effect on industrial location decisions [20]. For instance, a study of 124 manufacturing firms in 1971 in the Heathrow area found almost complete indifference to the Airport as a factor in locational decisions. It should, however, be noted that, many of the firms surveyed were in the area before Heathrow became a major airport. The same study also concluded that offices and firms dealing in tertiary services placed considerably more importance on the Airport as a factor in their locational decisions [21]. This shows that, in spite of the above findings, airport subregions are often found to be favourable locations for industry and tertiary services. This is because [22]:-

a) Firms with overseas offices and markets find sites near airports "convenient" for travel by both the staff and clients;

b) Airport locations seem to have a certain "prestige" that some firms find attractive;

c) Airports are usually located near the connection of well developed road networks, which themselves attract certain industries and tertiary services such as those mentioned earlier (see 1.3.1 earlier).

Certain industries such as hotels; catering firms; car hire firms; warehouses; and cargo centres are especially important since, it is evident that, as airports grow these related services grow along with them, particularly hotels which have benefited from the upward trend in air travel. For example, in 1971, there were 18 major hotels with 3,700 rooms at Los Angeles Int. Airport i.e. an increase from 450 rooms in 1960. By the end of 1973, another 3,100 rooms were added to this number [23]. Similarly, with government assistance, Heathrow has experienced a rapid increase in hotel accommodations. The growth in hotel accommodation is also evident in the immediate surrounding of Manchester International with the opening of the new Hilton International in 1986 and the new 250 bedroom five star Sheraton which was opened near Terminal 2 in 1993 [24].

To cope with the extra capacity, Terminal 2 has brought with it a "new road connection" to the M56 spur allowing direct access to the main regional motorway network i.e. The M6 and the M1, plus a "new complete rail station" which opened in 1993 linking the Airport to the main railway network i.e. Piccadilly [26,41]. As a result, these new facilities at Manchester are likely to speed up the process of urban development within the area which shows that, the supporting infrastructure (rail and road links) is one of the more fundamental impacts of an airport on its region and subregion.

Office buildings too will grow in airport areas. For instance, from 1966-71, 12 complexes with over 9,000m^2 of office space were built within 8kms of Chicago O'Hare Airport [25]. Similarly, Olympic House which is a major new building at Manchester Airport opened in 1993 to provide office accommodation for Manchester Airport PLC (Public Limited Company); all airlines; and other tenants who operate from within the Airport [24,41]. At Stansted Airport, i.e. the Third London Airport, nearly 22,500m^2 of commercial space is used within the Airport itself plus another 9,000m^2 of office block owned by Stansted Airport Limited which is being let to airlines and related companies for up to £280/m^2. In addition, in 1990, another 7,200m^2 of new industrial units were being built by the BAA to be let to the Airport related industries such as freight and engineering companies for £75-85/m^2 [27].

Furthermore, Stansted Airport has a good road access from the M11 and M25 Motorways and a new rail link which runs directly into the Airport. On top of that, a new 250 bedroom hotel has recently opened at the Airport and another one is planned. The Airport will bring additional employment into the area and new housing is planned in Great Dunmow and Bishops Stortford. Commercial premises are also in increasing demand which may not only boost land values, but further development too [27]. The strong relationship between airports and urban development is apparent in the above examples.

1.3.2 Community Severance:

For an airport to serve efficiently, good access and egress is essential. In general, a "complete highway" will not only increase accessibility, it will also create a more desirable environment socially; economically; and aesthetically for both the user and the adjacent non-user [29]. On the other hand, the construction of a new road or a rail link may cause severance and affect people's life style by reducing the quality of their parks; emergency services (e.g. police; fire; ambulance); cultural; educational; religious; recreational; and natural environment. Further severance may be expected by the changes in the neighbourhood character and in the life style such as social habits and shopping habits; by the redevelopment of land to undesirable extent and uses; and by the changes in or the intolerable mixing of commercial; industrial; and residential activities [30].

The excessive mixing of such activities can seriously affect local economy and employment opportunities, and, in cases where a road or a rail link serving the airport has to pass through residential areas, it may cause partial or total community segregation by cutting off the residents from part or whole of their neighbourhood and property owners from part or whole of their land. The biggest impact on the community may be from [30]:-

a) Possible displacement or relocation of people and families; homes and schools; hospitals and churches and other places of social gathering; existing shopping centres but at the same time offering better facilities elsewhere;

b) Changes in the land access i.e. possible disruption and changes in both pedestrian and public transport routes and services; traffic diversions; one-way streets; turning prohibitions; and temporary or even permanent road closures; all of which will result in longer distances; increased travel times; more congestion and delays;

c) The closing of some intersecting roads and property access points which can affect both the adjoining and to a lesser extent other non-adjoining businesses by reducing their business. This reduction in business may severely affect both employment opportunities and the economic base in the community.

1.3.3 Land Take:

Large international airports and their supporting services such as maintenance areas; cargo centres; car parks; terminal buildings; filling stations; coach and rail stations; taxi ranks; plus their road and rail links altogether, require a parcel of land much larger than almost any other single land-use development [17]. For example, a Boeing 747 needs a minimum of approximately 4,200m^2 of parking space or apron area, and for the same aircraft to takeoff, a runway length of about 4kms by 60-70m width is required i.e. an area equal to around 24-28 hectares [31]. Similarly, the development of the new Terminal 2 at Manchester International is said to have taken almost 106 hectares of land [32], and the total area covered by London Heathrow is altogether around 12km^2 or 1200 hectares [33].

Such areas of land plus the land taken for the road and rail links to the airport including their ancillary services such as bridges; tunnels; intersections; roundabouts; garages; petrol and service stations; parking lots; not only can be used for more environmentally and aesthetic purposes but, as stated earlier, they also reduce the amount available for residential; commercial; industrial; agricultural; or recreational purposes such as golf courses or hunting grounds.

1.3.4 Visual Intrusion:

The so-called "visual intrusion" of a development is mainly about the visual scars and their adverse effects caused by that development on both urban and rural landscapes. Considering airports with their road and rail links, their visual intrusion may include [30]:-

a) Life in the "shadow" of an airport or its road and rail links;

b) Loss of privacy caused by the road and rail users being able to see inside houses and gardens;

c) The effect of the road and traffic on the general scene;

d) The loss of character or setting of historic buildings (e.g. Speke Hall close to Liverpool Airport).

Visual intrusion is a highly "subjective" matter and it is more a measure of quality rather than quantity which makes it difficult to directly measure and quantify. In some cases, visual intrusion may reduce house prices and for this, a figure can be calculated. Road and rail traffic to an airport may spoil the landscape or the outlook from houses by causing visual intrusion, so do other facilities such as fuel stations; garages; train stations or bus-stops. People's valuations of visual intrusion vary depending on each individual, and those who live in the more beautiful and historic areas are more likely to suffer from this impact [8,11,16].

1.3.5 Vibration:

When aircraft fly at very low altitudes, they may cause some vibration to the nearby buildings particularly during takeoff and landing. In addition to aircraft, the road and rail traffic also produce some vibration which may affect the adjacent buildings and cause structural damage. Vibration may also have psychological effects for example, fear for personal safety. As with buildings and their contents, damage is usually the main concern. The most common effects of vibration causing discomfort inside a building are the rattling of doors and windows; the shaking of the light objects; and if strong enough the shaking of the whole structure [15].

1.3.6 Construction Nuisance:

Airports depending on their size may take several years to build. Construction is in the open and may cause problems of noise and air pollution from construction plants and machinery; additional traffic into the area especially heavy goods vehicles; general mess caused by dust and mud and piles of earth and rubbish; vibration to nearby buildings; possible damage to roads and properties; difficulty in access for both people and vehicles; temporary road closures or traffic diversions; problems of security and danger; problems with telephones; gas; electricity; water and drainage which may have to be cut off temporarily.

The biggest nuisance seems to be the noise from the bulk earth moving operations [15] involving heavy machinery and equipment such as bulldozers; scrapers; tower cranes; and excavators. Other operations such as pneumatic drilling and welding are also noisy.

1.3.7 The Problem Of Noise:

The problem of aircraft noise is probably the most controversial environmental issue related to airports and over the last few years it has become an international issue. It is therefore appropriate to cover this section in detail later in Chapter Two.

1.3.8 Atmospheric Pollution:

One of the most important environmental issues related to airports is the risk of atmospheric pollution from both aircraft and particularly from the ground vehicles. The importance of the ground vehicles regarding atmospheric pollution stems from the fact that airports in general attract large volumes of road traffic. For instance, the expressway between O'Hare and

Chicago's loop completed in 1961, by 1963 had exceeded capacity estimates for 1980, and in 1988, at least 80% of all journeys to London Heathrow and 70% to London Gatwick were by road [17,34]. Such amounts of road traffic attracted by airports increases atmospheric pollution near airports. Most serious, however, is carbon monoxide which in the vicinity of large international airports has been found to have reached levels equivalent to that in dense urban traffic areas [2]. Like noise, atmospheric pollution too is a serious matter, and it will be dealt with in detail later in Chapter Three.

1.3.9 The Economic Impact:

This is the most beneficial impact of an airport and like noise and air pollution it needs detailed investigation which will be covered later in Chapter Four. A few examples will be made here in this chapter to show the economic importance of both airports and the aviation industry. For instance, in 1968 a total of £670m was earned in the United Kingdom from civil aviation and related activities [2,12]. Looking at tourism, in 1971, 64.5% of "all" visitors to the UK came by air [35]. By 1973, this figure had reached 65% and they had spent a total of £750m [36].

Airports themselves, make large sums of money from various sources such as landing fees; fees from aeronautical training of pilots and ATC officers and engineers; or rents from the airlines. The BAA for example, in 1971-72, earned £11.7m from five of its Airports. This was 31.5% of its total income which was largely made at London Heathrow where more than 74% of BAA's income came from [2]. Through airports, airlines also make large sums of money. For example, BOAC later known as British Airways earned a total of £212m in 1971-72 [2]. Other beneficial activities include aircraft manufacturing; exports and imports; employment; and insurance. For example, in 1974, over 40% of world aviation insurance was handled in London with an estimated value of £300m [2], and as with UK's trade by air, in 1972, it accounted for 15.8% of total exports and 14.3% of total imports by value of goods [36]. Heathrow for example, handled more than £2,500m of visible trade in 1973 [14].

With regards to employment, estimates show that in 1972, more than 1.5 million people were employed worldwide in civil aerospace and air transport industry half of whom were employed in the USA alone [3]. In the United Kingdom, however, in the same year, approximately 300,000 people were directly or indirectly employed in the civil aviation and related industries [4,5]. Considering the manufacturing industry of aircraft, the world market for the US commercial aircraft from 1974-85 was estimated to reach $148bn, and in the United Kingdom, the aerospace exports in 1972 reached £417.5m of which nearly half were civil aircraft engines and engine parts [2,3]. In the same year, French exports and exports of other Western European Countries reached £300m and £100m respectively [2].

Large international airports usually have immense economic impact. They may employ 10-20,000 people whose annual payrolls may reach hundreds of millions of pounds which will be spent mainly on local goods and services. Similarly, airlines and other airport services may also spend an equal amounts of money or more for the same purposes [1]. According to one estimate for example, in 1971, as much as £70m per year was being pumped by Heathrow Airport into the local communities from direct activities alone [14]. More up to date figures for London Heathrow will be given later, in Chapter Four.

As with the ADP (Aeroports De Paris) which include Paris Charles De Gaulle and Paris Orly International Airports, in 1991 they (the ADP) had based a few hundred firms with 80,000 people in direct employment, and had a turnover of FF30bn i.e. approx. £3bn. Altogether, the ADP in 1991 produced a total of 150,000 direct and indirect jobs, with an overall turnover (direct and induced) of more than FF100bn i.e. approx. £10bn or more precisely, 7% of the French GNP [37].

Another important economic benefit of aviation is the amount of "time saved" by air travel over long distances especially where a water crossing is involved for example, London to New York, or Paris to Rio de Janeiro. Through airports and aviation, major cities have become much closer together resulting in large amounts of time savings both in business and leisure trips but particularly in the shipment of goods from one place to another i.e. in the freight industry. Such savings in time are very important since time is regarded as money. For this reason, the value of time is a determining factor in any cost-benefit analysis.

The time factor is of vital importance also at times of emergencies such as earthquake; drought and famine; flooding; fire; war and other natural disasters when urgent supplies of food; medicine and clothes; and the rapid evacuation of people are the main objects. As mentioned earlier, the economic impact of airports shall be discussed in detail with more up to date facts and figures later in Chapter Four.

1.3.10 The Use Of Energy And Materials And Environmental Contamination:

Considerable amounts of energy and materials are used by airports some of which are essential for their operation and at the same time they may contaminate the general environment particularly the waterways. Contaminants such as oils and chemicals for instance, that are used for the construction, operation, and maintenance of an airport may easily pollute the waterways and reduce the water quality. Like air pollution, water pollution is another serious environmental problem related to airports. It is therefore necessary to discuss water pollution together with the types and quantities of energy and materials used by airports, and their effects on the environment later in Chapter Five.

1.3.11 Aircraft Development:

Through airports and aviation, rises the need to develop better and more advanced aircraft which will improve the quality and efficiency of the existing services. Since 1945, aircraft have been developing continuously and at an accelerating pace with particular attention given to:- a) capacity; b) speeds. Capacity has increased from the 21 seater DC3 of the late 1940s to the current 300-350 seater jumbo-jets, and speeds have increased from about 400 to 1920km/hr by Concorde. At the same time, piston engines have been replaced by turbo-propeller and then by jet engines [6,10].

The result is that larger aircraft carry more people and cargo from A-B and faster aircraft carry people and goods from A-B in a much shorter time both of which are economically viable. Larger aircraft however, tend to be noisier than smaller ones, and reducing noise especially during takeoff is the incentive for developing quieter engines.

A good example of recent development in aircraft technology is the new Boeing 777 Jet Aircraft better known as the "21st Century Jet". About 10,000 people including 230 teams of engineers and designers worldwide have been involved in the design of this most advanced and latest passenger aircraft. The project cost around $3-4bn (£2-3bn) and the Aircraft was delivered in 1995. The Aircraft is mainly computer designed for every single part and subcontractors from Japan; Australia; Italy; UK; Canada; USA; France; and Belfast were competing for the design of each component part. Based at Seattle-USA, the Aircraft is smaller than B747 but bigger than B767 with two large powerful engines and can fly for three hours on <u>one engine alone</u> and this increases safety standards [38,41].

1.3.12 <u>Accidents:</u>

Every year the aviation industry worldwide claims many lives through accidents imposing a great social impact on the friends and relatives of the victims. For example, in 1989, there were altogether (scheduled and chartered) a total of 35 aircraft accidents worldwide claiming altogether 1,191 lives, and the corresponding figures for 1990 were 32 and 557 respectively [18].

1.3.13 <u>Impacts On The Natural Environment:</u>

The impacts of an airport on the natural environment may include:-

a) Changes in the natural landscape;
b) Changes in the local ecology;
c) Changes in the local hydrology.

a) <u>Changes In The Natural Landscape:</u>

When building a new airport or expanding the facilities of an existing one, inevitably some changes in the landscape will take place. For instance, if the existing Liverpool Speke Airport were to be expanded, part of the River Mersey would be reclaimed for building a second runway [40]. In general, the construction of an airport may include the re-routing of rivers; canals and waterways; the clear cutting of trees and possible destruction of fields and forests for runway construction and the safe landing and takeoff of aircraft; possible demolition of buildings and structures or sites of special interest (see 1.3 earlier) which may ruin the local heritage of a town or a village; possible relocation and in some cases the total removal or displacement of open spaces; leisure parks; foot paths; little country roads; and conservation areas although, both actions should be avoided to the extent possible [17].

b) <u>Changes In The Local Ecology:</u>

These changes are those affecting the living plants and animals, and other species such as the fish; the birds; or the insects. Ecological changes may result from construction activities and activities related to the daily operation of the airport and its related developments. For example, aircraft noise plus the road traffic and the people may disturb the local wildlife causing migration. Further migration may result from creating an unattractive environment for the wildlife to feed; nest; or breed near airports as they may be a hazard to aircraft [17].

Birds for example are a potential hazard to aircraft especially during takeoff and landing, and they cost the aviation industry millions of pounds each year in engineering bills and delays. In addition, birds are believed to be responsible for the crashing of, on average, one aircraft every 18 months [39] as some birds fly at heights of about 600-3,600m in flocks of up to 10,000 birds and others such as gulls for example often roost or feed in runway areas. Birds that are not detected by radar and become pests may require culling in order to prevent them from being sucked into aircraft engines [17].

During construction, activities such as clearing; grubbing; and stripping may cause sedimentation and siltation in natural waterways which may destroy the food sources of fish, and in extreme cases smothering certain species of aquatic life. Other operations such as filling; dredging; draining; excavating; the removal of the topsoil; vegetation; and forestlands; and other topographic changes may also destroy wildlife habitat and food sources causing possible extinction of some unique or non-unique flora and fauna [1,17]. The use of pesticides and herbicides at an airport may contaminate food supplies of marine life, and excessive pollution of waterways may reduce their oxygen content to the extent that aquatic life may not survive (see Chap.5) [1,17].

Similarly, excessive draining and withdrawal of ground water may greatly reduce water supplies to the wildlife or contaminate those supplies by salinity intrusion especially near coastal areas (see below - Hydrologic Impacts). Other climatic changes such as the atmospheric pollution caused by aircraft and vehicle engines or by power plants may also damage or completely destroy certain crops or species such as insects or plants (see Chap.3). It should, however, be noted that, some ecological impacts such as those on plants and animals are usually very slow in time, and they may take 10-20 years or even longer to show their effects [1,17].

c) <u>Changes In The Local Hydrology:</u>

The most common hydrologic impacts associated with airports and their related developments are flooding; changes in water movements by filling and dredging operations during construction; and salinity intrusion. Flooding may occur from excessive quantity of rain-water not being able to find its way into the ground because of the paved and impermeable surfaces such as runways; taxi ways; aprons; terminal buildings; car parks; or the hangar areas. In addition, impervious surfaces tend to increase the speed of the runoff water and this reduces its time of concentration at the manholes which, at times of high intensity rainfalls with long durations (30 mins. or more), it (the rain-water) may reach the manholes and overflow the designed capacity of drainage pipes so quickly that it may cause flooding [1].

Flooding can wash away the topsoil and other solid matter causing siltation and sedimentation, and through increasing acceleration and turbulence, it will gain erosive power and wash the soil away causing erosion all of which will reduce the water quality. Erosion and siltation may also occur in the construction period through accelerated runoff caused by the removal of the topsoil and the protective vegetation. Lack of infiltration of water into the ground caused by hard surfaces (explained earlier) may reduce and lower the water table thus reducing the amount of fresh water available to nearby residents. In the coastal areas, however, where airports are frequently built, reduced water table may increase the risk of sea water entering into fresh waters causing salinity intrusion. This intrusion by the sea water may require artificial recharging of the ground water to:-

a) Maintain fresh water supplies; and;
b) Prevent salinity intrusion [1,17].

Other hydrologic impacts may include the relocation of channels and waterways, and the draining and filling of swampy areas particularly where the ground is weak and unstable for example, near coastal areas. Such changes to the patterns of water movement may create significant local climatic changes and irreversible ecological impacts such as those discussed earlier. To summarise on the above discussion, the hydrologic impacts of an airport may include:-

a) The creation of ground water and other hydrologic imbalances;

b) The erosion and siltation of soil both during and after construction leading for instance to drainage problems;

c) The need to recharge ground water supplies which can be a long term benefit.

So far, almost every environmental impact of an airport has either been highlighted or briefly discussed here in this chapter. In the following chapters, the main and most important environmental impacts of an airport shall be discussed in detail with illustrative figures and tables.

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Chapter 2

The Problem Of Noise

2.1 Introduction:

One of the biggest environmental issues facing airports today is the problem of noise. In general, the aviation industry is one of many noise producing sources with airports being the main source of aircraft noise. To the airport planners and operators, noise has always been a problem as people have always objected to the growth and expansion of airports because of noise. For example, the recent plan for expanding Manchester Airport by building a second runway has angered local communities who claim that the scheme will bring extra noise for approximately one million people living around the Airport [1].

Noise is generally regarded as a completely negative impact of aviation and regions close to airports are highly vulnerable to it. Places such as hospitals; schools; nursing homes; colleges and residential areas are very vulnerable and sensitive to the location of airports mainly because of aircraft noise. Therefore, choosing a suitable site is very important when planning an airport.

For many years, noise has been investigated and much research and investment have gone into modifying aircraft engines and designs in order to reduce aircraft noise particularly at takeoff. Operating an aircraft will produce some noise that will disturb somebody somewhere to some degree. In the context of this thesis, the question is to what extent and how great is the noise impact from aircraft on the environment, and how much does it affect our lives. It is, however, interesting to note that some people actually enjoy listening to the sound of an aircraft taking off so long as its repetition is kept in moderation and it is taken as a leisure activity.

2.2 What Is Noise?

A common definition of noise is that it is an unwanted sound [2]. Some noises are more tolerable than others depending on their nature. Some are completely intolerable, others acceptable. Most noises are unpleasant whereas, some can be enjoyable. Music for example is a kind of sound and very enjoyable when wanted but, when it is not wanted then even music becomes only a noise. Sometimes the sound of traffic or a flying aircraft or even a passing train can be welcomed and pleasant by showing sign of life to a lonely and homebound person. But, far more often, it is a noise which is unwanted.

In general, noise is considered a nuisance since it interferes with normal activities such as sleeping; reading; talking; hearing; studying; watching television; listening to the radio or music; relaxing or concentrating. It is almost impossible to have an absolutely noise free environment. Therefore, it is unrealistic to believe that we can create an environment free from noise when even the blowing of the wind, the rustling of the leaves, the singing of the birds, and the flowing of the rivers produce some noise.

2.3 Noise And Airports:

In general, there are two types of noise related to airports. One is the noise from the actual construction of an airport, and the other which is the most important and disturbing is the noise from the running and operation of an airport i.e. the aircraft noise. Construction noise is mainly produced by additional site traffic delivering goods and materials to the site, and by heavy plants and machinery e.g. tractors; bulldozers; tower cranes; excavators; pneumatic drills; and other electrical or mechanical equipment used in the building and civil engineering operations.

The construction noise although disturbing and inconvenient for the local residents, is seen as being rather insignificant compared to aircraft noise. The larger and more complex the airport, the longer it takes to build, and therefore, the greater is the disturbance. It is, however, not within the scope of this thesis to deal with the construction noise, and the main task is to investigate the noise "after" construction.

In addition to aircraft noise which is the main cause of disturbance, the noise from the airport's road and rail traffic is yet another problem, and a brief discussion of it will be made later in this chapter. Considering aircraft noise, it varies during takeoff; cruise; and landing. The loudest noise is at takeoff when all engines apply full power to produce takeoff. It is, however, much lower at landing since a considerable reduction of power takes place at this stage. When the aircraft are cruising, the airborne noise is kept at a more constant and lower level. Also, because cruising is normally at high altitudes, the ground effect of noise at this stage is very little.

The ground operations of aircraft are also noisy. For example, when the aircraft are standing still and re-fuelling or during maintenance, they constantly produce noise for a considerable length of time. Other supporting machinery and equipment (e.g. electrical or mechanical) that are essential for running an airport also contribute to the overall problem of noise. Aircraft type is another factor that determines noise levels. Some aircraft are noisier than others mainly due to different design characteristics, engine capacities, and usage. For example, supersonic aircraft such as Concorde are much noisier than subsonic aircraft because they operate at much higher speeds. For this reason, in some countries, supersonic operations are limited to certain times of the day.

How much noise is produced from an airport depends directly on its size and level of activities. This means that the bigger and busier an airport, the bigger is the problem of noise since there is a larger number of aircraft movements (a movement is a takeoff OR a landing). London Heathrow for example, with about 74 movements per hour at peak times (1992 figures) is considered a busy and noisy Airport [37]. The proximity of the airport to the local community, the type (i.e. commercial; military; or cargo), and the time (peak or off-peak periods) of operations are also important factors. The problem of airport noise changes with time i.e. during the peak holiday season, or at weekends when more people travel and the flights are more frequent thus causing more disturbance. The economic well-being of the whole community also is important in enabling people to travel more, and this will increase the number of flights and consequently, the noise.

Noise is a problem common to all major international airports. It can make them less attractive as residential areas and leisure parks, thus allowing more airport related industries to develop around them. One advantage of noise is probably the fact that it is the reason behind creating employment in the research and engineering section for designing and developing new quieter engines. But, this small advantage against a number of disadvantages is rather insignificant. The most important environmental issues related to aircraft noise are its effects on health; social; and economic aspects. These problems shall be investigated more deeply later in this chapter.

2.4 Sources Of Aircraft Noise:

Aircraft noise is produced mechanically; aerodynamically; and above all from the engines. Mechanically, it is produced from the vibration of the whole body (i.e. the wings and the fuselage) in the landing and takeoff, and by the engine runup during maintenance and use in flight. Aerodynamically, aircraft produce noise from the flow of air over and under the wings and the fuselage at high speeds. It is, therefore, this phenomenon which makes the design of each component part important regarding the shape; size; and angles when considering aircraft noise reduction.

But, the principal noise from an aircraft is the one from the jet engines (see 2.3 earlier). Jet aircraft were introduced after the Second World War in the 1950s, and with them came the new problem of aircraft noise. In general, the larger and heavier an aircraft, the more power is needed for takeoff, therefore more noise is produced. For example, long distance jet aircraft such as the Boeing 707 or the Mc-Donnell Douglas DC8 which arrived in the late 1950s and have high jet velocities, are very noisy because of their size and the power needed to produce takeoff [22]. In a jet engine, high pressure gases at high temperatures are expanded and passed through a propulsion nozzle giving a high velocity jet [20]. It is, therefore, this high velocity jet passing through the nozzle which creates most of the engine noise, and the higher the speeds, the louder is the noise (see earlier about supersonic aircraft).

2.5 Noise Measurement:

The most common basic unit for measuring noise is the "decibel" (dB) which is the unit of sound pressure level (all sounds are atmospheric vibrations which create a pressure in the ear). The decibel is 20 times (for convenience) the log of the ratio of the measured sound pressure to a reference pressure of $20N/m^2$. This reference pressure, zero dB, is about the level of the weakest sound at 1,000Hz (a specific frequency, somewhere near the middle of the range with which we are normally concerned) which can be heard by a person with a good hearing sense in an extremely quiet location [67,68]. (note that the audible spectrum of sound is between 20-20,000Hz) [9].

An increase of 1dB is just perceptible, whereas an increase of 10dB is felt by an average listener as a doubling of loudness. It is virtually impossible to hear sound levels below 25dB except in specially insulated recording studios where a minimum of about 20dB may be achieved. The rustling of leaves is about 35dB, and the singing of birds is about 45dB. Whether or not these represent "noise" depends on one's subjective reaction to the so-called "dawn chorus" [67,68].

When combining two or more separate sounds, the decibels cannot be added directly. The increase in noise level from adding another "equal" sound is only 3dB. If, however, the additional sound is 10dB or less, then there is NO increase in the original sound level. By itself, the decibel is NOT an adequate unit for measuring noise. It ranks noises only according to their sound pressure level and does not account for the ear's decreasing response at low and high frequencies (note that the reference frequency is about 1,000Hz - see earlier). Therefore, in order to duplicate the response of the human ear, sound level meters are usually fitted with three internationally defined frequency weighting filters of A; B; and C [67,68].

Experience has shown that for measuring vehicle noise, the decibel A scale (dBA) is adequate for measuring and comparing the noise of one vehicle with another where the sources are almost identical. It can also be used to compare the noise from cars; lorries; or buses where the sources do not vary that much. When however, the sources are widely different for example, when comparing aircraft noise with road traffic noise, the dBA is NOT an adequate measure [3,4,5].

Most people have no idea how loud a sound is in dBA. For this reason, they cannot feel the significance of the numbers. To give some idea as to what the numbers mean in simple terms, Table 2.1 provides a "rough guide" to a variety of noise sources. Table 2.1 also shows that, because of the nature of the dBA unit, the dBA readings are NOT proportional to one's impression of loudness. For example, the loudest noise is about seven times the quietest and this can often be confusing since, as mentioned earlier, an increase of 10dB is equal to a doubling of loudness. Ideally, a general objective measure of noise should be applicable to all industrial and transportation noise sources, and it should be easy to measure [67,68].

Table 2.1: Noise Levels Of Some Typical Sounds

Noise Source	Sound Level dB(A)
Room in a quiet dwelling at night	32
Soft whisper at 2m	34
Clothing dept. in a large store	53
Grocery department	60
Busy restaurant or canteen	65
Typing pool (9 typewriters in use)	65
Vacuum cleaner at 3m	69
Inside small car at 30mph	70
Inside electric train	76
Ringing alarm clock at 1m	80
Loud music in large room	82
Printing press, medium size	86
Heavy diesel vehicle at 8m	90
Service rifle at ear level	160
Jet aircraft taking-off at 150m	130
Inside a foundry	100
Busy general office	65
Very still day in the country with no traffic	25

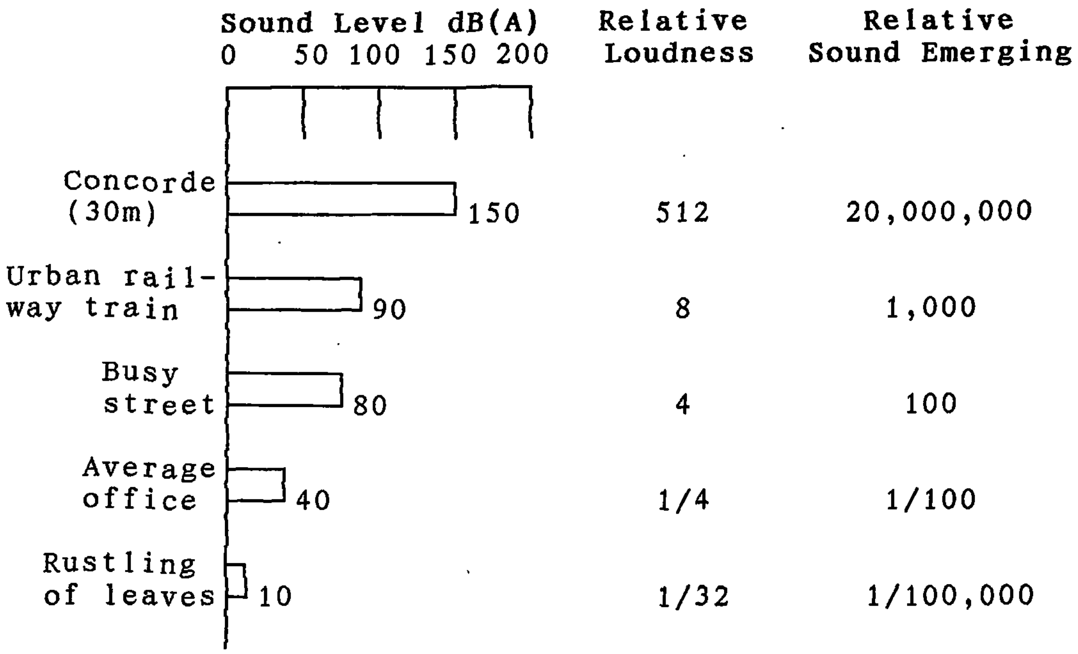
Source: Ref.8 & 67

2.6 Aircraft Noise Measurement:

Before discussing various ways of measuring aircraft noise, it is appropriate to give a general background to the subject. Air transport is the loudest and has the most disturbing noise compared to rail; road; and sea transport. Concorde is a good example. To give an idea as to how loud air transport is, Figure 2.1 compares several sources of noise together. It also shows how loud a

Concorde is compared to an urban railway train or a busy street, and that an increase of 10dBA produces a doubling of loudness (see earlier).

Figure 2.1: A Scale Of Noise And Sound



Source: Ref.9

In 1968, the ICAO having recognised the seriousness of aircraft noise particularly near airports, established some international specifications recommending the "<u>noise certification</u>" of aircraft <u>that have reached acceptable performance limits with respect to noise</u> [10]. By 1971, the ICAO produced Annex 16 on International Civil Aviation (a document containing essential international guidelines for noise control at airports in the form of standardised recommendations) [9]. Other countries developed their own parallel standards. Most notably the United States developed a set of standards through the FAA which are published in the

Federal Aviation Regulations. In some cases, these are slightly more stringent than the ICAO recommendations [11]. These recommendations however, are all designed to combat the problem of aircraft noise, and their effectiveness in doing so will be shown later in this chapter (see 2.11.9 later).

ICAO certification standards mainly relate to the noise of an aircraft on approach; standing on the runway; and on takeoff. In general, there are four categories of aircraft [9]:-

a) Subsonic jet aircraft:- air worthiness applied for before October 1977;

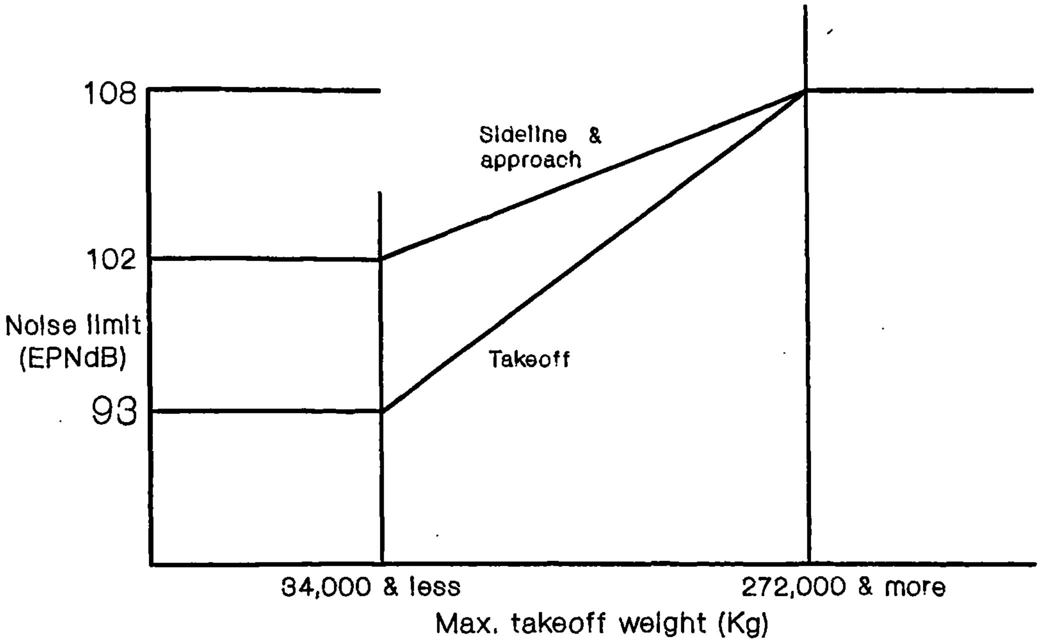
b) Subsonic jet aircraft:- air worthiness applied for on or after October 1977;

c) Propeller driven aircraft:- over 5,700kg;

d) Propeller driven aircraft:- under 5,700kg.

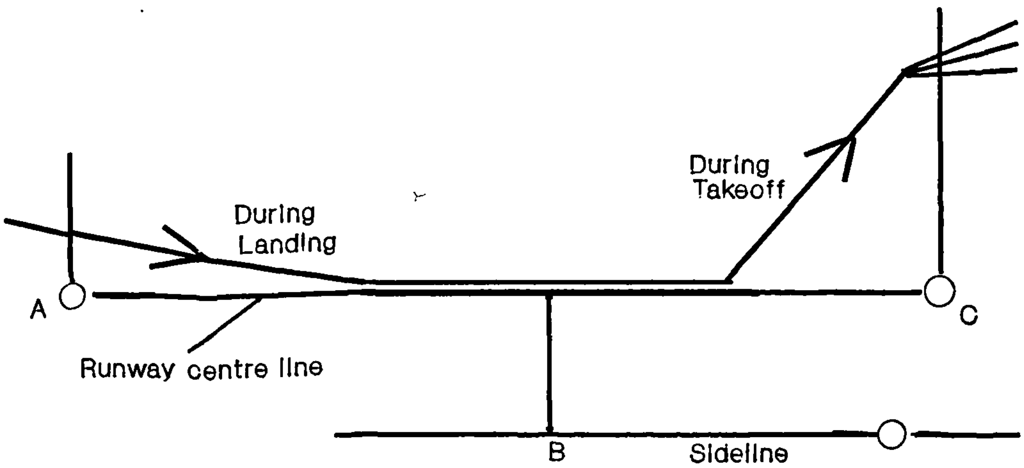
The noise certification limits set by the ICAO; FAA; CAA; and other authorities all relate to the maximum takeoff weight of aircraft. Figure 2.2 shows these limits set by the FAA taking into account the takeoff weight of the aircraft [11]. The noise limits in Figure 2.2 set by FAR Part/36 are based on fixed measuring points A; B; and C; and noise levels are calculated in EPNdB (defined later) which varies on a logarithmic scale with aircraft weight. Figure 2.3 shows the

Figure 2.2: Aircraft Noise Certification Limits - (FAA)



Source: Modified from Ref.11 (FAA)

Figure 2.3: Location Of Noise Level Measuring Points By FAR And ICAO



Note: Sideline is parallel to the runway centre line

Source: Ref.11 (FAA)

although permitted noise levels under each set of regulations are the same, there are slight differences in the locations of these measuring points which make the ICAO limits less demanding.

2.6.1 Units Of Measurement:

The response of the human ear (hearing sense) to noise is very complex. For this reason, it is not entirely correct to measure aircraft noise in dBA since intensity alone is not an accurate measure of noise disturbance. The following points are also important in the subjective response to noise:-

a) The length and duration of the sound;

b) The number of times the sound is heard i.e. number of repetitions;

c) The time of day when the noise is heard (i.e. day or night).

It is therefore necessary to use another unit of measurement which accounts for all of these factors. In the late 1960s to early 1970s, a study by JFK International Airport (New York) showed that another unit of measurement other than the dBA was needed to measure aircraft noise and so, the Perceived Noise Level (PNL) was developed [9]. The PNL includes the duration and the maximum pure tone content of the noise [8], and it is a complex summation which requires extensive computer calculation [9].

The two principal units for measuring aircraft noise (single event) in practice are:- The Effective Perceived Noise Level (EPNL), and the Sound Exposure Level (SEL). The EPNL is used for the noise certification of aircraft (Annex 16 of the ICAO), and it modifies the PNL figure for duration and the maximum pure tone (intensity) at each time increment. The EPNL therefore includes measures of sound level; frequency of occurrence (number of repetitions); and duration; and there are very complicated rules laid down for its measurement [8,9].

The SEL is the accumulation of the instantaneous sound levels measured on the dBA scale over the time during which the sound is detectable. This accumulation procedure takes note of the logarithmic nature of sound addition (i.e. a doubling of loudness with every 10dBA increase). The SEL is more commonly used by the FAA, and the EPNL by the ICAO. Both EPNL and SEL are used as the basic units for developing environmental measures of noise exposure [9]. There is, however, a relationship between the scales of measurement, and for all intents and purposes, the PNdB level of a large jet aircraft is equal to the dBA level + 12 to 15. Some sources quote 12 while others say 13, but generally speaking the range lies between 12 to 15. Both the EPNL and the SEL like the human ear take account of the middle and high rather than the low frequencies [8].

So, although there are various scales of measurement, aircraft noise is widely measured in dBA; PNdB; or EPNdB. The first being dBA, does NOT give an accurate measurement of aircraft noise to subjective response. Therefore, PNdB is used more often, or EPNdB which takes account of all the factors mentioned earlier i.e. loudness; repetition; and duration [8,9]. There are, however, other methods used for measuring aircraft noise, and these are discussed below.

2.6.1.1 The Noise And Number Index (UK):

This method known as the NNI method is used by the United Kingdom and has had limited use elsewhere. The NNI is a much simpler method of measurement compared to the methods used by other countries, and it is calculated by:-

$$NNI = \overline{PNdB} + 15 \log N - 80 \quad \text{.........(2.1)} \quad [9]$$

Where:- N = No. of occurrences of aircraft noise exceeding 80PNdB which is the peak level produced by a Boeing 707 at full power at approximately 4,000m height [9]; and;

$\overline{PNdB}$ = the logarithmic average of peak levels and is calculated by:-

$$\overline{PNdB} = 10 \log_{10} 1/N \sum_{i}^{N} 10^{PNdB/10} \quad \text{........(2.2)} \quad [13]$$

Where:- PNdB = the peak noise level for a single noise event and is equal to dBA + 13. The -80 constant is introduced to simplify the zero position of the scale so that zero NNI would correspond to zero public annoyance [8].

The NNI was established in 1963 from the studies of the Wilson Committee on the problem of aircraft noise in the vicinity of London Heathrow Airport [3]. The study found that there was a relationship between the values of NNI and annoyance level (see Figure 2.4) [12]. The NNI Index also takes account of the following factors [3]:-

a) Noise level at source;

b) Distance between the source and the receiver (receiving point);

c) Frequency of occurrence i.e. No. of repetitions in a certain time period.

In the United Kingdom, it has become generally accepted that the NNI relates to aircraft noise as shown below [20]:-

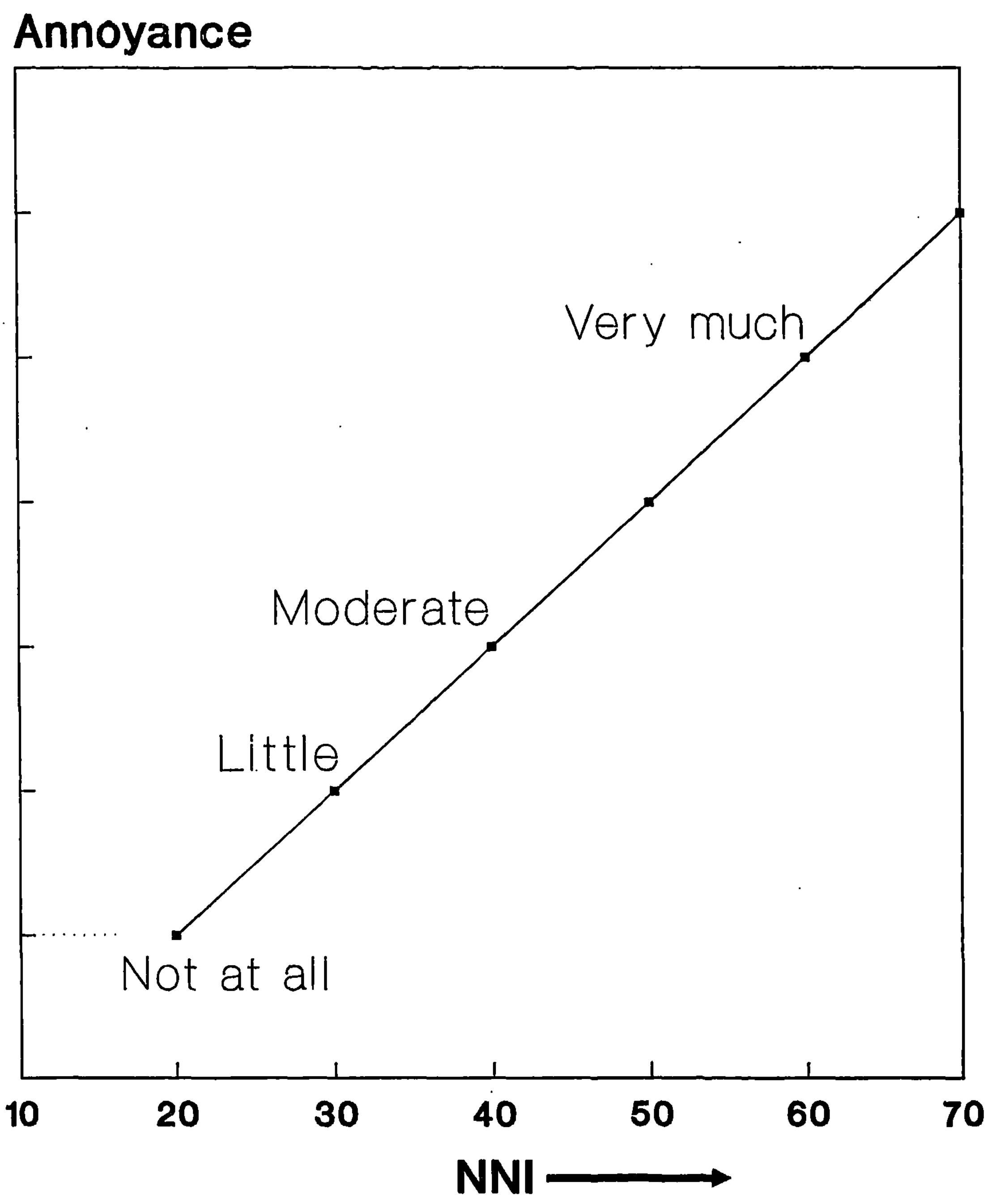
NNI = 35 —————— Low disturbance

NNI = 45 —————— Moderate disturbance

NNI = 55 —————— High disturbance

Figure 2.4 shows these values diagrammatically and confirms their general acceptance. NNI values of 65 or more are extremely disturbing or even intolerable. There are, however,

Figure 2.4: Typical Degrees Of Annoyance And The NNI



ource: Ref.12

uncertainties and doubts as to the accuracy of the NNI in assessing noise annoyance, and its precision has been questioned in the past. But, it is the method most used by airport authorities and will continue being used into the future until newer methods have developed [14,15,16,17].

The NNI does not apply to all airports particularly to small airports that deal with specialised work and have very little aircraft movement. It generally applies to major international airports and to airports such as Manchester and Liverpool as it did to Heathrow in 1961 [16]. The method is mainly used for land-use planning near airports and for assessing the eligibility of properties for the provision of sound insulation and Government grants. These grants usually use the "<u>high annoyance</u>" rating (55NNI) of the "<u>Wilson Committee Report</u>" (see 2.10 later) as the basis for payment, and the amount of payment increases as the NNI increases [20].

For example, an area which is covered by the 35NNI contour near an airport may only qualify for a 60% grant, whereas an area within the 55 or 60NNI rating would almost certainly qualify for a 100% grant. The NNI method has its limitations and weaknesses and these are:-

A) <u>Weighting:</u> i.e. it gives too much weight to the frequency of aircraft movements (no. of repetitions) and not enough to the noise of an individual aircraft [20];

B) Night-time disturbance: i.e. it does not account for the night-time movements since the NNI is based only on average daily movements of aircraft from 06.00-18.00hrs G.M.T. from mid-June to mid-September [20];

C) Ambient noise levels: i.e. it does not necessarily apply to airports that have different ambient noise levels and aircraft movements i.e. as earlier stated, it mainly applies to large international airports and not to small ones [20];

D) Non-transport movements: i.e. it does not include noise from test and training flights which are a problem to some airports [20];

E) Areas outside and beyond the 35NNI contour: i.e. noise during the flight (en route noise) and also noise from the *stacking area*. According to the Wilson Committee, the 35 NNI is a low level of annoyance therefore, people who live outside the 35NNI zone should suffer very little or no disturbance. It is, however, quite possible that people living outside the 35NNI contour but under the flight paths and within the stacking areas may experience some disturbance [20].

Nevertheless, there are some considerations being given for improving the Index especially with respect to night-time disturbance; effects of ambient noise level; and noise disturbance from non-transport movements for example leisure and training operations [16].

<u>Stacking area:</u>- Occasionally when there is heavy air traffic and runways are congested, the landing of aircraft may be delayed and aircraft have to circle around at different altitudes and distances from the airport in what are known as "<u>stacking areas</u>". This stacking can cause a significant number of aircraft circling over the same area creating unwanted noise and raising complaints. It must be remembered that stacking is done only for safety reasons and does not happen very often [20].

2.6.1.2 <u>The Noise Exposure Forecast (USA):</u>

The <u>Noise Exposure Forecast</u> (NEF) is the method used by the FAA in the USA and is given by:-

$$NEF = \overline{L_{EPN}} + 10 \log N - K \quad \ldots\ldots\ldots\ldots\ldots (2.3) \qquad [9]$$

Where $\overline{L_{EPN}}$ or $\overline{EPNdB}$ = Average Effective Perceived Noise Level and it is calculated from the individual L_{EPN} values. This is the EPNL defined previously (see 2.6.1 before), and;

K = 88 for day time (07.00-22.00) hrs;

K = 76 for night time (22.00-07.00) hrs.

And the individual L_{EPN} is:-

$$L_{EPN} = 10 \log 1/T\int_0^T 10^{0.1L(t)}dt \text{ ....(2.4) [9]}$$

Where $L_{(t)}$ = the sound level in dB(A) OR PNdB and T = 20 or 30 Seconds so that the quiet periods between aircraft movements are NOT included. The Combined 24-hour NEF is:-

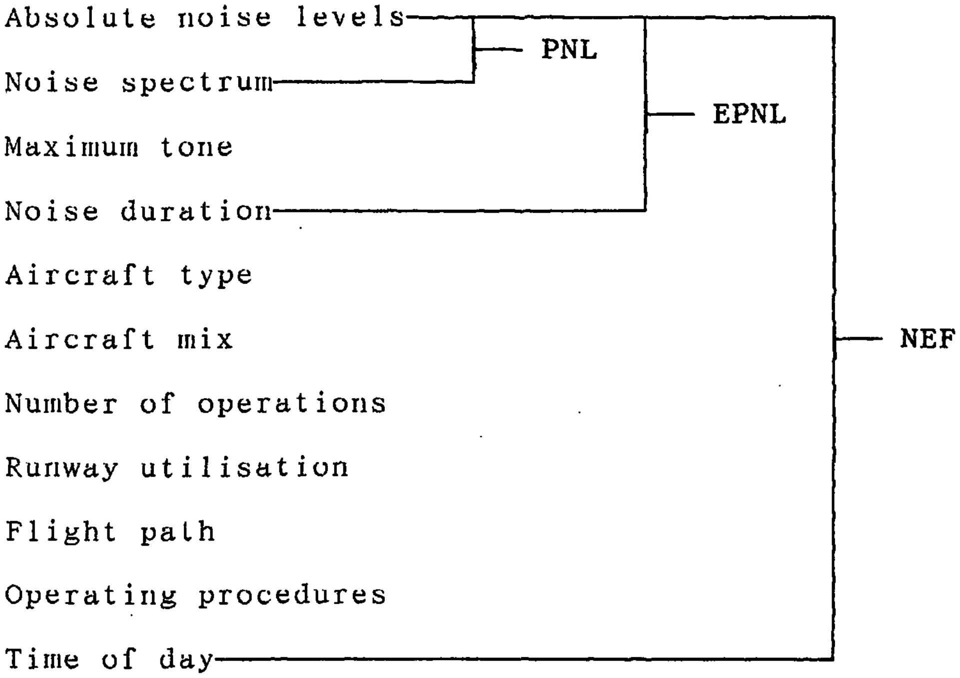
$$NEF_{day/night} = 10 \log_{10}(\text{antilog } NEF_{day}/10 + \text{antilog } NEF_{night}/10) \text{.........(2.5) [9]}$$

The NEF takes account of the effect of cumulative noise exposure on communities near airports. Studies have shown that where the NEF value is less than 30, people are not adversely affected, and in areas where it is more than 40, the environment is generally regarded undesirable by the residents [59]. Figure 2.5 shows the data required for NEF procedure [59].

2.6.1.3 Day/Night Average Sound Levels (USA):

The impact of noise cannot be assessed accurately "only" on a "single" noise event with the loudest and highest intensity. This is because there is more than one event involved in the operation of an airport. To assess the problem of noise more accurately, a "cumulative" measurement of the noise events is more precise when assessing disturbance caused to sleeping; reading; relaxing; and other activities [9]. Therefore, it is important to measure the cumulative noise events over a time

Figure 2.5: Data Required For NEF Procedure



Source: Ref.59

period. The method developed in the USA and used more recently than the previous one is the <u>Day/Night Average Sound Level</u> (DNL or L_{DN}), and is given by:-

$$L_{DN}(i,j) = SEL + 10\log(N_D + 10N_N) - 49.4 \quad ......(2.6) \quad [9]$$

Where:- N_D = No. of operations from 07.00-22.00hrs;

N_N = No. of operations from 22.00-07.00hrs;

SEL = Average Sound Exposure Level, (from individual <u>single</u> event noise levels);

i = Aircraft type and classification;

j = Operation mode i.e. takeoff <u>OR</u> landing.

Partial L_{DN} values are calculated for each significant type of noise using equation 2.6, they are then summed to evaluate the total L_{DN} value from all aircraft operations using:-

$$\text{Total } L_{DN} = 10 \log \Sigma_i \Sigma_{j(10)} L_{DN}(i,j)/10 \text{ ....(2.7)} \quad [9]$$

2.6.1.4 International Noise Exposure Reference Unit (ICAO):

This is an international method recommended by ICAO for measuring aircraft noise which takes account of the Total Noise Exposure Level (TNEL) from a succession of aircraft and is expressed in terms of the Equivalent Continuous Perceived Noise Level (ECPNL). The TNEL produced by a succession of aircraft is given by:-

$$TNEL = 10 \log \sum_{1}^{n} \text{antilog } EPNL_{(n)}/10 + 10 \log 10 \text{ ...(2.8)} \quad [9]$$

Where $EPNL_{(n)}$ = Effective Perceived Noise Level for the n^{th} event and the ECPNL is given by:-

$$ECPNL = TNEL - 10 \log T/t_0 \text{ ....(2.9)} \quad [9]$$

Where T = Total period of time under consideration in seconds and t_0 = 1 second.

When comparing the above methods, it is clear that equations 2.1; 2.3; and 2.6 for the NNI; NEF; and the DNL are all very similar in principle. It is therefore concluded that response to aircraft noise is almost the same whatever method of measurement is used.

2.7 The Effects Of Noise:

The effects of noise vary with its nature; loudness; duration; number of repetitions; and the time of day. Its effects on buildings and structures; animals; birds and other species is yet another matter. Noise in general whether from traffic; aircraft; or other sources affects humans in many ways. It affects us socially; economically; physically; and psychologically. The problem of noise and its environmental impacts in every sense are a wide area of study. It is something we have to live with regardless of the circumstances. The question is how much noise can we tolerate before it can seriously affect us.

Today, however, we are technologically advanced only to the point where we can minimise and reduce the problem of noise, but cannot cure it completely unless all activities cease. With regards to airports, as stated earlier, they are the centres for many activities other than aviation, and often generate large volumes of road traffic. For this reason, it is appropriate to discuss the effects of noise "in general" rather than concentrating on aircraft noise alone, although aircraft noise and its effects shall be discussed separately later in this chapter. The most common effects of noise in general are discussed in the following sections.

2.7.1 The Health Effects:

The effects of noise on health vary depending on the susceptibility of the person exposed to noise; the nature of the noise; or whether the individual is exposed to noise in the place of work or in home [20].

2.7.1.A <u>Auditory Effects:</u>

Auditory acuity or sharpness is defined by perception thresholds. That is, the minimum acoustic sound pressures perceived by the ear. The temporary shift of these thresholds caused by exposure to high noise levels may become permanent when exposure to noise is continued for a long time [24].

2.7.1.A.a <u>Physical Damage To The Ear And The Hearing Mechanism:</u>

The ear can be physically damaged in several ways. For example, the eardrum can be injured or ruptured by a very loud noise. A safety limit of 140dB for sounds of short duration is generally recognized [24]. When the eardrum is ruptured, it is not usually completely fatal to the hearing mechanism and it can be repaired. A very large shock wave can sometimes physically break the bones of the middle ear which transmit the sound to the lymphatic liquid in the cochlea and when this happens, instantaneous deafness can occur. Again, this damage can often be repaired by skilful surgery and by artificial replacement [23].

Unfortunately, in general, nerve cells of the human body do not regenerate once they are damaged and the total loss of the cells causes loss of hearing if the ear is exposed to high noise levels for a long period of time. Progressive deafness occurs over a life time as these cells die. This is called presbycusis which many people think is a natural phenomenon but, others think that it is partly a result of the high noise levels existing in our environment [23].

It is now clear that excessive noise can cause damage to the ear. In fact, continuous noise levels above the 85dBA region cause some damage. This damage is slow; gradual; and progressive, and is not usually noticed by the recipients until it is far too late [23]. Many people who work in high noise level industries all their lives become deaf in their old age. This subject nowadays is becoming of increasing interest in many countries because employers can now be held responsible for deafness caused to their employees merely by noise alone. It is probable that people who live in urban areas have less sensitive hearing than those who live in remote rural areas and who experience little or no industrial noise [23].

2.7.1.A.b Loss Of Hearing (Deafness):

The primary effect of noise at work is the development of industrial or occupational deafness which is a "permanent" loss of hearing caused by continuous exposure to noise. This permanent loss of hearing is a gradual process which reduces the hearing ability by damaging the cochlea of the ear (see earlier) and especially the sensitive hair cells that make up part of it.

Another type of deafness known as "blast deafness" may result from a "sudden" exposure to a very high noise level such as Concorde, and it may cause a greater damage and hearing loss than a continuous exposure to a lower level of noise for a longer period of time [20].

A sudden noise louder than 150dB can cause instantaneous damage, whereas a noise of about 120dB or more is the "threshold of pain" (the level at which the ear can physically feel the pain) in many people without necessarily causing damage unless the exposure continued for some time. The gradual loss of hearing from the continuous exposure to high noise levels is a bigger problem than that caused by a sudden noise which may create a temporary shift to the threshold of pain and after a short while returning to normal. This condition is known as the "temporary threshold shift" which occurs between 3,000 to 6,000Hz frequency and more practically at about 4,000Hz [20].

For all noise, whether steady or fluctuating, it is generally accepted that the "doubling of the exposure time" can only be tolerated if the noise level is reduced by 3dB [24]. This rule has been adopted by the international recommendation and by many other countries. The EPA of the United States has concluded that there is a risk of permanent damage to the hearing sense after 40 years of exposure to a daily L_{eq} (Equivalent Continuous Sound Level in dBA) of:-

dB(A)	No. Of Hours Exposed Per Day
75	8
78	4
81	2
84	1

Source: Ref.24

According to these figures, a continuous exposure to a noise level of 75dBA for 8 hours per day over 40 years i.e. a life-time exposure, may cause permanent damage to hearing [24]. Similarly, according to some sources, a "continuous" 4 hours exposure to an aircraft noise of 90PNdB is sufficient to cause a "temporary loss" in the threshold of auditory sensitivity by as much as 15-20dB [63].

2.7.1.A.c Occupational Deafness:

Continuous exposure to high noise levels delays the return of normal hearing back to its original level. Not only that, the threshold of hearing also becomes higher gradually and reaches a point where it does not return to normal i.e. the level that existed before continuous exposure to noise. This initial loss of hearing occurs at 4,000Hz (see earlier), and is a level higher than those normally related to speech (500-2,000Hz), and the effect is not noticed instantly. But, when sufficient loss of hearing takes place by spreading over and beyond the initial effect at 4,000Hz and starting to affect the speech frequencies, only then the person exposed may notice the problem. By this time the damage is probably irreversible [20]. For example, people who work in aircraft hangars and workshops where there are continuous high noise levels during engine testing and maintenance may experience such a problem.

2.7.1.B <u>Non-Auditory Effects:</u>

The health effects of noise vary and they may include the following:-

a) Effects on the cardiovascular system (blood circulation);
b) Neurophysiological effects (digestive system);
c) Stress and mental disturbance (psychological effects).

Although these are all adverse effects of noise on health, it is important to have sufficient reliable evidence when relating the amount of noise (dosage) to health disorders if basic standards for noise doses are to be set [24].

2.7.1.B.a <u>Cardiovascular Effects (Blood Circulation):</u>

Vasoconstriction is a "<u>startle reaction</u>" and a well documented circulatory response to noise in which the blood vessels tighten and cut down the flow of blood to various parts of the body. Adrenalin is then released into the body causing fatigue and headaches. This reaction is noticed by people startled into awakening by a noise during their sleep [25].

2.7.1.B.b Neurophysiological Effects (Digestive System):

Some evidence suggest that exposure to prolonged intense noise is significant so far as gastrointestinal conditions are concerned. Apparently, a sudden and unexpected noise can interfere with the digestive system even though the real significance of noise on digestion is not very well documented [28].

2.7.1.B.c Stress And Mental Disturbance (Psychological Effects):

It is not certain that noise and mental stress are directly related but, it is possible that noise is one factor affecting mental health. Most people know that unusual exposure to high noise levels can change their emotional responses by making them more sensitive to other matters [20]. Most Environmental Health Officers are familiar with complainants who show extreme agitation when subjected to prolonged and excessive noise. Their family relationships may be adversely affected and they break into tears when discussing the problem. Occasionally, they suggest extremes such as suicide [20].

This sensitivity is more visible in people who are concerned about the environment, are worried about air disasters and accidents, or otherwise associated noise with the possibility of some adverse effects on their lives [20]. A report by the Council of Europe in 1965 concluded that the possibility of damage to mental health caused by noise is likely to be greater in individuals suffering from nervousness [20]. Noise may also aggravate an existing neurosis or predisposition to mental stress [26]. In several investigations, minor neurotic conditions have been related to environments with high noise levels (airports for example) although other studies do not show such a relationship [20]. There is, however, no doubt that noise is related to psychiatric illness, and numerous studies strongly suggest that in certain circumstances it (noise) may be a significant factor in mental disorder [20].

2.7.2 <u>Effects On Behaviour And Activities:</u>

Undoubtedly, some normal activities of our lives will be affected by noise some of which are essential and difficult to avoid such as:-

a) Sleeping;
b) Speaking and communication;
c) Working; and;
d) Awareness of useful sounds.

2.7.2.A <u>Sleep Annoyance:</u>

One of the most obvious and disturbing effects of noise is its interference with rest or sleep which causes lack of concentration; irritability; and reduced efficiency. Sleep is a physiological necessity, and if the amount is not enough it can seriously affect our health. It is, therefore, important to look at the nature of sleep when considering its disturbance by noise since, sleep does not have a uniform pattern and varies throughout the night or day [20].

In general, sleep is in four stages. The first is the "dozing" or preliminary stage followed by three other progressively deeper stages of sleep, the deepest of which is the most beneficial. Sleep is largely affected by age and its depth becomes less with the increasing age [34]. For this reason, younger people spend most of the sleeping period in the deeper stages of sleep whereas the middle aged and elderly spend a bigger proportion of it in the dozing stage. Also, it is more difficult for elderly people to get back to sleep once awakened [20].

It is therefore this age group who complain more about noise than others since they spend more time in the dozing stage rather than the deeper stages of sleep. There is, however, a relationship between the likelihood of being woken up and the depth of sleep. Depth of sleep has been shown to be affected by a noise level of 55dBA [29]. Also, familiar and constant noises such as the television or the radio are less likely to wake people than a sudden and unusual noise such as, the sudden noise of an accident [20].

Furthermore, since the human ear continues to function and transmit sound to the brain even during sleep, it is therefore possible to be disturbed even when sleeping. For example, a person who wakes up by noise will easily notice the effects of not sleeping enough on the next day. The effects of sleep disturbance by noises that do not normally wake people are not so readily noticed. People who do not fully enjoy the benefits of the deeper sleep may show the same effects as those deprived of sleep altogether [20].

Sleep disturbance affects more women than men according to the number of complaints from males and females. People can become accustomed to noise and gain enough sleep in a noisy environment which initially made sleep impossible. Considerable variations exist amongst individuals as some people find it difficult to sleep without the background noise, or some students cannot study if their music is not playing. On the other hand, many people exposed to noise especially at night, never become accustomed to it [20]. In general, transportation systems can cause serious problems regarding sleep disturbance. Nevertheless, these disturbances are related more to the disruption of activities rather than to effects on health. Sleep is mainly disturbed in the following ways [24]:-

a) Difficulty in falling asleep;

b) Certain sleep stages being shortened;

c) Awakening;

d) Autonomic or independent/unexpected reactions.

To relate a single and specific measure as a direct cause of sleep disturbance needs some research. But, generally speaking, noise levels that increase background noise by 10 to 15dBA often cause sleep disturbance [24]. Additionally, there are three criteria related to sleep disturbance. First, extending the time needed to fall asleep which is assumed to begin at an L_{eq} of 35dBA. Second, reducing and shortening the stages of "light" sleep (stages 1 and 2) which begins at 45dBA, and thirdly, shortening the stages of "deep" sleep (stages 3 and 4) which begins to affect at around 50dBA [24].

2.7.2.B Speaking And Communication:

It is very annoying when a normal conversation becomes difficult to hear because of high noise levels since, it is important to communicate easily and accurately in most situations. Loud noises that interfere with speech can affect communication which is not only undesirable but can sometimes be dangerous. Inefficiency, and even fatal accidents may occur because of inability to transfer information and to communicate freely. For example, not being able to hear an approaching motorcycle can result in a serious accident. Road vehicles and aircraft, all generate noise some of which is loud enough to cause sufficient disruption in communication. Communication is affected by noise mainly in two ways [20]:-

a) If the level is high enough, it can make speech unintelligible (not understanding simple phrases) and warning sounds unheard or completely inaudible;

b) High noise levels which cause loss of hearing (see earlier) make the spoken word more difficult to understand and audible warning sounds incomprehensible.

The permissible background noise level that can exist before intelligibility (i.e. the percentage of simple phrases understood in a speech or conversation) is seriously affected can be measured reasonably accurately [20]. The criterion used to make such *assessment is called the* <u>*Speech*</u> <u>Interference Level</u> (SIL). How much the background noise interferes with the speech, depends on the noise level (dBA) and the distance from the speaker. As a guide, an SIL of 75dBA prohibits telephone conversation, and a 65-75dBA affects reliable communication over a distance of 0.5m even when the voice is being raised. With regards to offices, an SIL of less than 55dBA is desirable for any office communication [30].

Increasing the voice intensity (speaking louder) enables the person listening to hear the spoken word in spite of loud noises, but it is inconvenient to speak louder. Noise levels either fluctuate or stay constant, and it is suggested that, intelligibility increases more with fluctuating noise than with constant noise levels [24]. With a background noise level of more than 60dBA for two people 2m apart in order to hold a conversation, must raise their voices [24], whereas a sound of 48dBA allows normal conversation at 4m [31].

Within a home, intelligibility must be good for a soft voice and for a moderate volume television in order not to disturb neighbours. To hear the radio and television reasonably well, a maximum indoor level of 40-45dBA is normally required [32]. Also, if the bedrooms and living rooms are provided with normal sound absorption, then the noise limit for houses is approximately 45dBA [24].

In general, the masking effect or interference on conversation is defined by the relationship between the percentage of intelligibility on one side, and an acoustical or sound index on the other [24]. This means that, the higher the background noise level or the SIL, the lower is the intelligibility. This shows that these two variables are inversely proportional. For example, a jet flyover after takeoff with a level of 85 PNdB masks approximately 25 words of conversational speech, and this masking effect reduces once the aircraft gains height and is further away from the airport [62].

2.7.2.C <u>Working Performance:</u>

Noise can affect our working performance by reducing our concentration which leads to inefficiencies. Physical jobs are less affected by noise than those needing concentration. According to several studies, it has been shown that noise in the working environment can significantly affect efficiency in various ways for example [20]:-

A) The performance of a task is affected less by a familiar noise than by an unexpected and unfamiliar noise as in the case of sleep annoyance;

B) Noise levels louder than 90dB significantly increase the number of errors made particularly when the person has been working in noise for some time;

C) The number of errors made because of noise varies with the conditions of work and the state of the person i.e.:-

a) Noise increases arousal so that if people are short of sleep and are doing routine and undemanding work, it may arouse and stimulate them thus reducing errors;

b) If the work requires a state of alertness, a loud noise can make them nervous and thus increase errors.

Therefore, routine work is generally less affected by loud noise than exact or precise work which needs concentration. These conclusions are related to the achievement of tasks and are based on controlled experiments. It is, however, certain that concentration; efficiency; and output can be affected by noise at a level much lower than 90dB [20]. To what extent people's work is affected by noise depends on the individual; on the nature and duration of the noise; and on the task performed [20]. Like sleep annoyance, acoustic stimulation or disturbance activates the nervous system thus affecting task performance and causing autonomic reactions or behaviour [27].

2.7.2.D Awareness Of Useful Sounds:

Some sounds we must hear if our safety is not to be endangered e.g. a fire alarm or an approaching vehicle. Loud background noises such as the takeoff noise of an aircraft by masking useful sounds endanger our safety particularly in the case of crying children; the malfunction of equipment such as a gas fire; or the approaching traffic. Useful sounds are diverse, and this diversity makes it difficult to lay down any rules in this respect [24].

2.8 The Importance Of The Road Traffic Noise:

Although it is outside the scope of this thesis to deal with the road traffic noise, a brief discussion of it is appropriate since, as stated earlier, airports generate large volumes of road traffic which increases noise disturbance in the region. For example, it is estimated that, the building of a second runway at Manchester Airport will bring an extra 11,000 vehicles per day travelling to the Airport thus, creating more noise [36]. The problem is much greater at London Heathrow. In 1992 for example, some 40 million buses; cars; coaches; taxis; and lorries went through the Heathrow Tunnel (i.e. approximately 4,000 vehicles per hour) not to mention the underground link which is altogether separate [37].

Traffic noise is not steady. It rises and falls as each vehicle passes by and varies with the density of traffic. This fluctuation is because road traffic is made up of different types of vehicles for example heavy/light goods vehicles; buses; and motor-cycles. Also, when a vehicle is approaching, the noise level rises and reaches a peak, and then falls as the vehicle drives away making it more non-uniform [20].

Therefore, the overall noise produced by road traffic is by nature complex; irregular; and constantly changing. It also varies with time of day (peak and off-peak periods); speed; and road surface conditions (dry or wet, smooth or rough). On dry roads, noise is mainly from the engines for all vehicles until speeds of around 100km/hr are reached. But, for light weight vehicles, noise from the tyre/tarmac contact usually overcomes engine noise [38]. Since engine noise has been reduced by applying appropriate legislation, noise from the tyre/tarmac contact has become more of a problem especially with heavy goods vehicles. Also, wet conditions usually "increase" noise levels by 10dBA, thus making wet conditions more disturbing than dry conditions [20].

Furthermore, traffic noise although not as loud as aircraft noise, is repeated far more often than aircraft noise which makes it more disturbing in terms of repetitions. For example, when comparing the number of vehicles going to Heathrow (4,000veh/hr [37]) with the number of aircraft movements (74/hr [37]), traffic noise is far more disturbing than aircraft noise regarding repetitions although not so much with loudness. It affects more people in the United Kingdom than all other forms of noise combined [35]. Therefore, the more people travel, the more traffic goes to the airports thus creating more disturbance. Also, studies have shown that in most urban areas the predominant noise is the one from road traffic [3]. The most significant effects of "<u>traffic noise</u>" are those on speech and communication; sleeping; and physiological aspects.

A) <u>Speech And Communication:</u>

This is one of the most obvious forms of interference caused by traffic noise. The higher the flow of traffic, the more noise is produced creating more interference with speech communication which means peak hours are more interfering than off-peak hours. Although traffic noise is not loud enough to damage hearing, it can still affect speech communication, and disturb the pleasure of listening to the radio; music; television; and the use of gardens on a nice sunny day. The comfortable use of houses may also become limited by having to close the windows in warm weather, and some rooms may not be used for normal living because of road traffic noise [20].

B) <u>Effects On Sleep:</u>

Although there is less traffic at night, it can still cause disturbance particularly where volumes are high. Experiments have shown that a passing lorry with a noise level of 40dBA has a 5% probability of "waking up" a person, and with 70dBA this probability rises to 30% [33]. The same experiments also show that the probability of a "change" in the sleep including waking by a passing lorry at 40dBA is 10%, and at 70dBA is 60% [25,29]. Since a large number of heavy goods vehicles travel to the cargo centres near airports especially at off-peak periods, the problem of road traffic noise therefore becomes bigger for the local residents.

C) Physiological Effects:

Apparently traffic noise has no harmful effects, but its physiological effects include the "startle reaction" when exposed to a sudden and an unexpected noise [25].

2.9 Effects Of Aircraft Noise:

The main effects of aircraft noise are those on health (physical and psychological); social; and economical; and these are discussed in the following.

2.9.1 The Health Effects:

According to numerous reports, aircraft noise can affect our health physically and psychologically. For example, in a study where 600 people were exposed to aircraft noise at Munich and Hamburg

Airports, after they were examined, it was found that although no major illness such as heart circulatory disease or diabetes were caused by aircraft noise, it did, however, create nervousness and changes in their vegetative functions especially in their blood pressure [39].

Above all, the study found that 95% of the people who were disturbed or annoyed by aircraft noise during landing, never get used to it. The idea of "getting used to aircraft noise" was therefore rejected in the report. Similarly, in the United Kingdom, research has shown that people who believe noise can damage their health, tend to suffer far more from aircraft noise than those who believe the economic benefits of aviation are more important than its health effects [39]. In other words, people who look more into the negative aspects of an airport are more likely to suffer from aircraft noise than those who look more into the positive sides of aviation for example, the economic growth.

In another study near Zurich Airport, the consumption of sleeping pills by the nearby residents was found to be related to aircraft noise. The same population however, were also found NOT to have the same level of performance or behaviour in the following day, because of the disturbances caused by aircraft noise. Their performances were apparently found to be "below" normal the next day [40].

The effect of aircraft noise on the sleep of babies has also been examined, and it has been found that the reaction of babies to aircraft noise depends on how long the mothers stay in the noisy area. For instance, babies born from mothers who came to the noisy area before or during the first five months of the pregnancy, showed little or no response to the noise. Whereas, babies whose mothers came to the area in the latter part of the pregnancy, or arrived in the area after birth, showed a much greater reaction. It was therefore concluded that, the difference in reaction was because of the time difference between the periods of exposure to the noise before the birth [41].

As stated earlier, previous studies suggest that minor neurotic conditions can be related to high noise levels such as, aircraft noise (see 2.7.1.B.c earlier). For example, a study of several schools near London Heathrow showed symptoms of mild affective illness amongst teachers, whereas a community survey in Switzerland showed NO relationship between aircraft noise and minor psychiatric illness [27]. There is however, further evidence suggesting that exposure to aircraft noise in particular may be associated with an "increase" in psychiatric illness although, this does NOT mean that aircraft noise does create mental illness. Nevertheless, it is interesting to note that, a survey of admissions from the London Borough of Hounslow (near Heathrow Airport) to a local mental hospital between 1966-68 showed a much higher rate of admissions from areas of high aircraft noise than those from a relatively less noisy area both for the first and total admissions [42].

Many experts believe noise is a serious threat to public health. People repeatedly exposed to high noise levels may show more irritability; severe nervous tension; lack of concentration; and weakness to perform even simple tasks [60]. For example, a young man who was working in a company with a 75dBA background noise level (i.e. slightly above normal office level) was suffering from continuous insomnia (inability to sleep), became bad-tempered, lost his intended fiancee and overcame by his sense of failure and attempted suicide by driving his car into a tree. This incident was later seen as a pathological development in a psychopathic personality triggered by adverse environmental effects in this case, noise [64].

As for SST such as Concorde for example, sonic boom studies have shown that, they (SSTs) expose millions of people to a sound equal to that experienced under the flight path of a jet aircraft within 2.5kms of an airport [65], and, based on previous attitude surveys and paired-comparison tests, it seems that, sonic booms may have strong psychological consequences causing psychological-sociological problems with serious effects on mental health and well-being [66].

A more detailed and comprehensive study of the psychological effects of aircraft noise has been carried out by Karami (Ref.56) to which the reader is referred for a deeper understanding in this area. In this study, the Author investigates the most likely "psychological effects" of aircraft noise on the local residents living in the vicinity of Tehran International Airport [56].

2.9.2 The Social Effects:

Aircraft noise is probably the most dramatic man-made noise particularly in the vicinity of airports. During World War II, the sound of some aircraft was welcomed and popular, but became unacceptable in the Post-War years. In fact, *between 1956-58 the number of complaints* from aircraft noise near London Heathrow quadrupled. In the same period, air transport increased at around 8% [12]. By 1971, approximately 200,000 people were living around Heathrow Airport who had been moderately or seriously annoyed by the Airport noise, and the total number of people affected by aircraft noise around major and minor airports as well as air force bases in the United Kingdom is much higher [43].

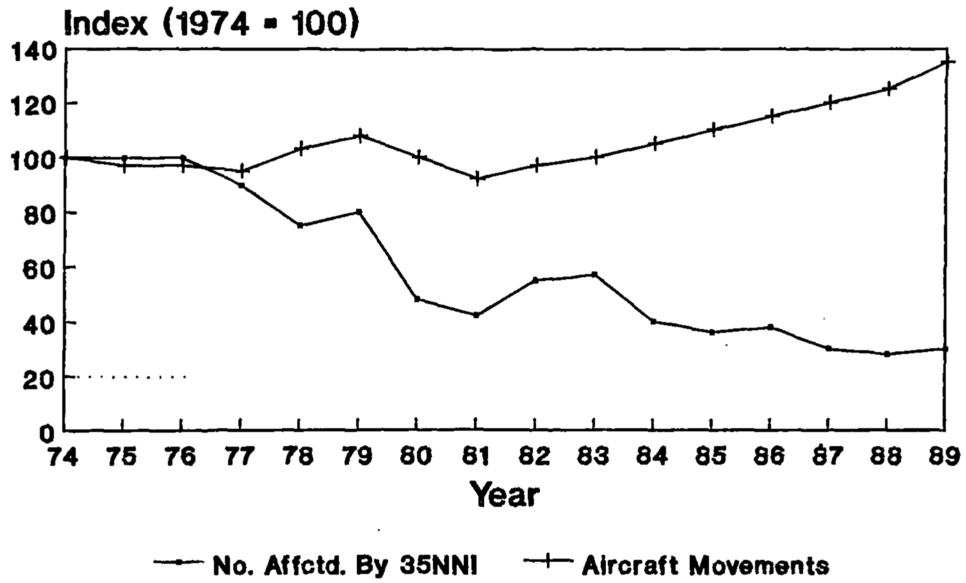
In the United States, the total area subjected to excessive aircraft noise i.e. leading to numerous complaints, grew some seven times between 1960-1970 [44]. By 1976, it was estimated that aircraft noise would seriously annoy 6 to 7 million Americans [45]. Such annoyance spreading over a long period of time can have a considerable social impact. In some extreme cases for example, people may have to leave an area because of noise, and this can have a great social impact on their lives as they become attached to their home and neighbourhood (see Chapter 1 - Community Severance).

According to the BA, the problem of aircraft noise has been reducing enormously over the last twenty years. For instance, from 1974-1989, the total number of people affected by aircraft noise in the 35NNI zone from both London Heathrow and London Gatwick Airports had dropped by 70% and 20% respectively. At the same time, aircraft movements at both Airports had increased by about 35% and 170% respectively over the same period (see Figures 2.6a and 2.6b) [19]. Therefore, whether or not the problem of aircraft noise has been reducing is a bit doubtful since, these reductions in the number of people affected may have resulted from the increasing number of aircraft movements forcing people to move out of these areas through excessive disturbance.

For example, from 1986-1988, a 12% increase in aircraft movements at Heathrow was accompanied by a 21% reduction in the number of people living in the 35NNI zone [19]. This indicates that, although people move from one area to another for various reasons, there is, apparently, a strong relationship between aircraft noise and demographic changes. This relocation of people, as stated earlier, may have great social consequences similar to those explained earlier.

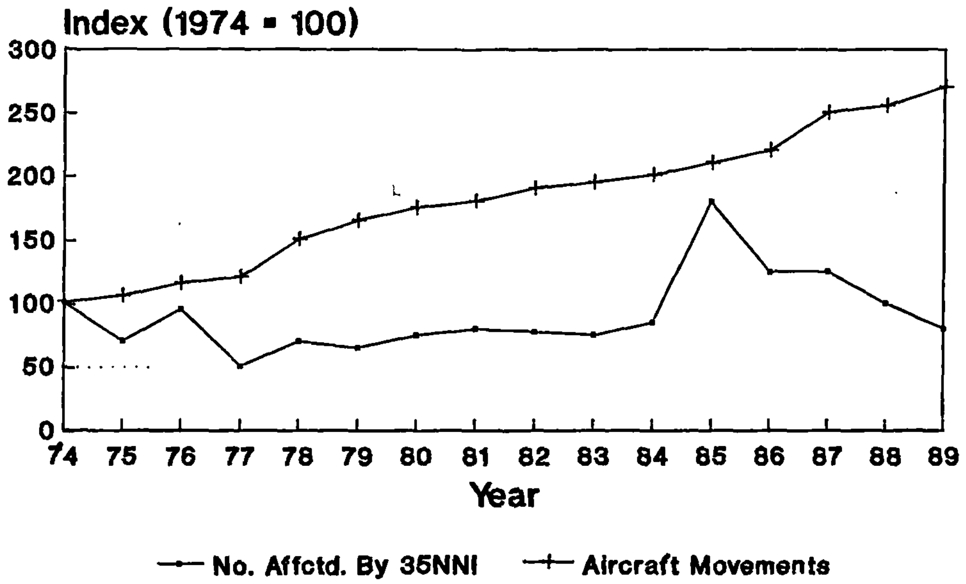
In most surveys of noise annoyance, aircraft noise runs a close second to road traffic noise in terms of the number of people affected and the extent to which they are annoyed. In

Figure 2.6a: Population Affected By Aircraft Noise - Heathrow



Source: Ref.19

Figure 2.6b: Population Affected By Aircraft Noise - Gatwick



Source: Ref.19

the United States, this situation is often reversed [43]. For example, in 1975, more than five million people were exposed to objectionable aircraft noise around US Airports, and this is not that far away from the estimate made earlier for 1976 (see 2.9.1 earlier). By 1990, this number had declined to three million, and by the year 2010, it is expected to reach as low as one million [18]. These reductions are the result of the aircraft noise reduction policy in general by the United States Government, and they confirm the statement made earlier by BA that the problem of aircraft noise has been reducing for the last twenty years.

Excessive annoyance to a large number of people may cause complaints; protests; and community actions; and in extreme cases possible litigation. In some cases, these cumulative annoyances may also reduce local house prices causing adverse economic impact (see 2.9.3 later). Complaints and community action do not really represent the extent of the actual problem. In some countries, litigation powers available show that complaints are the real sign of how strongly people feel towards noise. In other countries with different powers, a large number of social factors combine to determine the likelihood of complaints, and this makes it difficult to recommend a general criterion [24].

It should, however, be noted that, the problem of aircraft noise has been reducing over the last few years by designing better and quieter engines, and by applying a general noise reduction policy in and around airports. Nevertheless, in spite of these efforts, and the fact that the recent generation of jet aircraft are much quieter, the problem of aircraft noise will continue to exist for some time into the future, and it will continue to impose its social impacts upon communities [46,47].

2.9.3 The Economic Effects:

Although, it is usual for the economic effects of aircraft noise to be regarded as social effects, for the purpose of this thesis, it is appropriate to cover this section separately. The most noticeable economic impact of aircraft noise is its effect on house and property values. House and property values near airports can be affected by aircraft noise although, NOT in all cases. This is because some airport employees may prefer to live nearer to their work in order to save travelling time instead of living in a quiet area and having possibly twice as long to travel.

Therefore, depending on each individual and his priorities, the benefits could easily balance the costs and not affect property values at all. For example, in a case personally known to the Author, one particular employee of Manchester Airport is willing to live closer to the Airport mainly for having less distance to travel and to avoid the road traffic in spite of the aircraft noise problem.

In addition to the above, there are other factors that determine the value of a house or a property such as historic or sentimental values or other personal reasons. These factors however, usually tend to maintain the value of a property and are not affected by the airport noise. For instance, a house that has historic and sentimental values to its owner is very unlikely to lose its value even if in close proximity of an airport. Yet for an old couple who are retired with no historic attachment to their property, a quiet and peaceful area is more appealing even if not so financially beneficial. It is, therefore, because of these reasons that calculating the cost of aircraft noise becomes a difficult task.

For example, in 1970, a committee known as "The Roskill Committee" was set up to investigate the problem of aircraft noise and its effects on house prices in relation to the Third London Airport [49]. One study compared the prices of individual houses at "different" locations from Heathrow Airport, and the other compared house values on "similar" estates. The first study showed a 6% fall in house prices where the NNI value was 50, and the second showed aircraft noise at the "same" level i.e. 50NNI to have NO effect at all on house prices [49].

The Roskill Commission therefore concluded that the "similar" estates were NOT infact identical, and that the higher noise level on one estate was offset by the possession of other advantages. Neither of these studies was used in the final Roskill cost-benefit analysis, and a third study was carried out based, not on actual house prices, but on the opinions of the estate agents and professional valuers working around Heathrow and Gatwick Airports which was even less satisfactory than recording the actual selling prices of houses [49]. Table 2.2 shows the main results of the study.

Table 2.2: The Effect Of Aircraft Noise On House Prices Near Heathrow And Gatwick Airports (The Roskill Survey)

Percentage Reduction In House Prices In 1970			
Class Of Property	Noise Level (NNI)		
	35-45	45-55	55+
Heathrow			
Low priced (ave. price £3,000)	0	2.9	5.0
Med. priced (ave. price £6,000)	2.6	6.3	10.5
High priced (ave. price £10,000)	3.3	13.3	22.5
Gatwick			
Low priced (ave. price £3,000)	4.5	10.3	-
Med. priced (ave. price £6,000)	9.4	16.5	-
High priced (ave. price £10,000)	16.4	29.0	-

Source: Ref.49

By looking at Table 2.2, it is clear that the fall in house prices due to aircraft noise rises sharply with the value of the property. In other words, the more expensive the house, the more it loses its value through aircraft noise. The Table also shows that, although there is an apparent relationship between aircraft noise and property values, this relationship is NOT a fixed or uniform one, and that it varies from one area to another; from one class of property to another; and from one NNI zone to another.

For instance, in 1970, the drop in value for houses with an average price of £3,000 in the 45-55NNI zone in the Heathrow area is 2.9%, whereas the corresponding figure for the Gatwick area is 10.3% (see Table 2.2 earlier). This shows that, houses in the Gatwick area are affected to a much larger extent by aircraft noise than those in the Heathrow area for a given noise level and a given price range. The reason for this may be that the Gatwick area is more rural and middle-class than the Heathrow area; or that Gatwick is less-long established and less developed than Heathrow; or that Heathrow is much closer to the CBD (Central Business District) of London; or various other reasons such as those explained earlier.

In general, as stated earlier, it is not so easy to quantify the cost of transport noise and its effects on property values [48]. For instance, work in the area of Manchester Airport produced conflicting evidence by showing that, in spite of the aircraft noise, the desirability of the environment and its proximity to the Airport are positive advantages for air-crew and Airport employees (see earlier), and that these advantages tend to raise house prices otherwise reduced by noise [50]. Also, since airports and the more expensive housing areas are usually on the windward side of the urban areas, therefore, home buyers tend to balance the advantages of being close to an airport in terms of travel time; accessibility; and job opportunities against the disadvantage of noise; air pollution; and extra traffic congestion.

In another study by University of Salford in which nearly 3,500 dwellings in Stockport-Cheshire were investigated for price depreciation caused by aircraft noise from Manchester Airport, it was revealed that there was no variation in house prices, and that the aircraft noise had no significant impact on house values in the area [51]. In contrast, a similar study by UMIST (University of Manchester Institute of Science and Technology) produced different results in which, it was found that, the properties near Manchester Airport and the runway did not sell easily and that in some cases they did not sell [51]. These differences in the Salford and UMIST findings like those found in the Roskill survey, again demonstrate the difficulties involved in quantifying the cost of aircraft noise to the home owners.

In spite of the above findings, it is generally believed that house prices "may" rise quicker with accessibility to an airport mainly because of employment opportunities and the use of air services. At the same time, it is also believed that houses which are close to airports particularly those under the flight paths or adjacent to the main runways "may not" have the "same" rate of increase in value as those in other areas, and that their value increases at a much "lower" rate than houses in other areas [8].

Other factors that may "prevent" price depreciation through aircraft noise near airports include:- increased demand for housing near airports especially by airport employees; increased urbanisation and accessibility to the local road and rail networks as well as to the local and regional markets; proximity to friends and relatives; to schools; to work; and to the local community and neighbourhood; prestige of the area; and other social factors. Proximity to work is particularly important since, in some extreme cases for example, a buyer may even pay more for a house than the market value in order to save travelling time. On the other hand, certain factors such as fear of accidents (i.e. plane crash); vibration; and possible air pollution that are subconsciously in people's mind and perhaps to some extent exaggerated may "add" to the problem of aircraft noise and reduce house prices near airports even further.

To finalise on the above discussions, it seems that, according to the Roskill survey and other sources, expensive houses in general lose more in value than cheaper ones, and that broadly speaking, houses of all kinds in rural and country areas tend to lose more in value than those in urban areas where the noise from road traffic is already a problem [8]. Good examples of these cases are the Heathrow and Gatwick situations discussed earlier.

2.10 Response To Aircraft Noise:

Human response to noise is very complex and is conditioned by a number of factors and the interactions between those factors [6]. This is because every individual has a different social background; behaviour; personality; life style; age; family and economic structure; and above all, a different level of tolerance which makes his reaction to noise different to that of another person.

For example, noise levels that are extremely annoying to some people may cause little disturbance to others. Also, since annoyance is a state of mind resulting from noise, the reaction to noise becomes even more complex since, as stated earlier, it depends on the loudness and its temporal variations (i.e. rise and falls); on the duration; on the nature and type; and on the frequency or number of repetitions of the sound e.g. the number of take offs and landings. It (the reaction to noise) also depends on the number of people affected, and on the location i.e. the proximity to an airport, and activity of those affected.

It is, therefore, because of these reasons that to accurately predict people's response to aircraft noise on an individual basis becomes a difficult task, whereas on a community basis where large numbers of people are involved, it is much easier to make an overall assessment on a statistical basis. Very broadly speaking, response to aircraft noise or to the noise from other related sources may be one or more of the following [67,68]:-

a) Expression of annoyance;

b) Difficulty in speech communication;

c) Degradation of task performance;

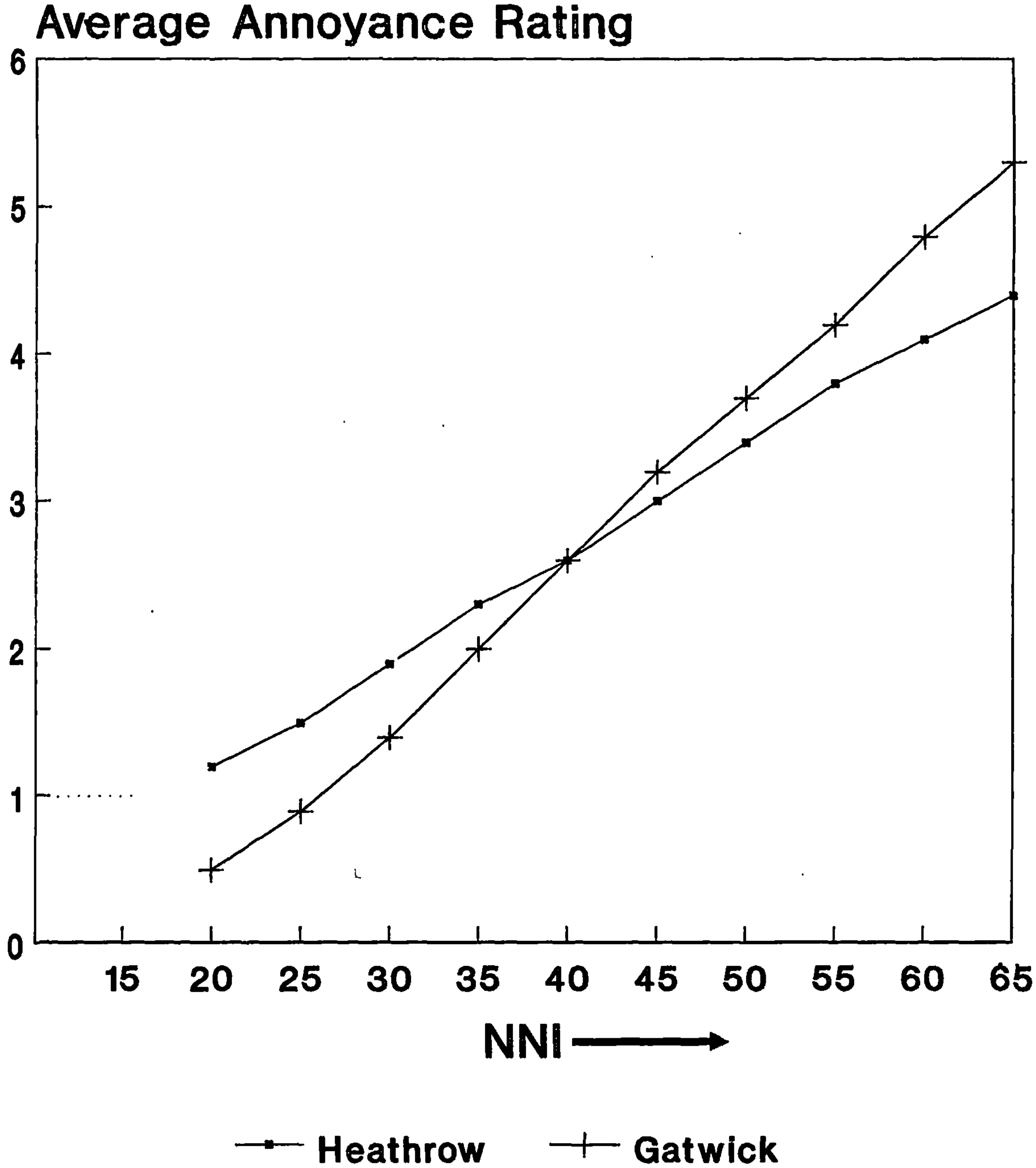
d) Interference with sleep; and;

e) The generation of stress.

In general, people's response to noise in most cases is total dissatisfaction. Also, in a study where a number of responses to the road traffic noise were investigated, it was found that, an <u>overall measure</u> of dissatisfaction described the noise nuisance more adequately than the <u>more specific</u> responses such as sleep interference or stress [7]. As for aircraft noise, according to a 1963 report by the Wilson Committee, it has been found that, in general, there is little response to noise levels below the 35NNI; moderate at about 45NNI; and very much at 60NNI and above (see 2.6.1.1 before) [12].

These figures correspond to the findings of the Wilson Committee in the areas around Heathrow and Gatwick Airports, and the response to aircraft noise from these areas is shown in Figure 2.7. In Figure 2.7, it is interesting to note that, although Heathrow is a much busier airport than Gatwick, nevertheless, aircraft noise at 40NNI and above has a greater response (disturbance) in the Gatwick area than in the Heathrow area, whereas, below 40NNI, this situation is reversed. This information not only shows the pattern of development around both Airports, it is also very useful for

Figure 2.7: The Response To Aircraft Noise From Heathrow And Gatwick Areas



Source: Ref.12

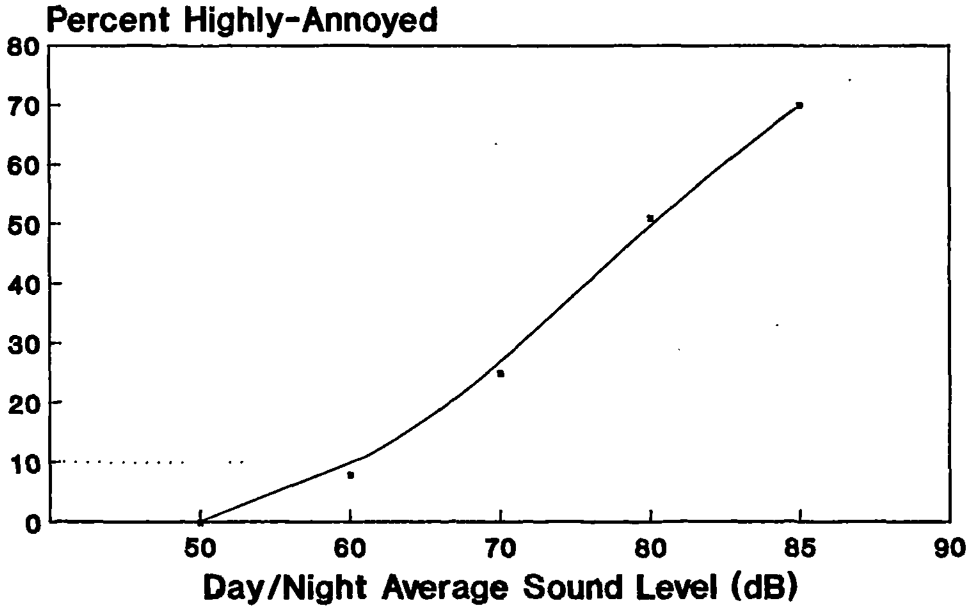
development; planning; and noise abatement policies.

As for the greater response at Gatwick, this could be for several reasons for example, the areas around Gatwick are probably more residential than industrial compared to those around Heathrow; or that the Gatwick area, as stated earlier (see 2.9.3 before), is more rural with less noise from the road traffic. In general, exposure to noise and disturbance are usually expressed in percentage terms. This means that, the percentage of people annoyed shows the severity of the noise impact (see Figures 2.8a and 2.8b).

According to Figures 2.8a and 2.8b, a very low percentage of people are highly annoyed by aircraft noise below $55L_{DN}$ and 35NNI, and at 65NNI and $80L_{DN}$, more than half the community is highly annoyed. Figure 2.8b is interesting as it shows that, even at nearly intolerable noise levels, about 10% of the people are either unaware of the noise or only occasionally disturbed. These results clearly show the variations in human response and tolerance to aircraft noise [52,53].

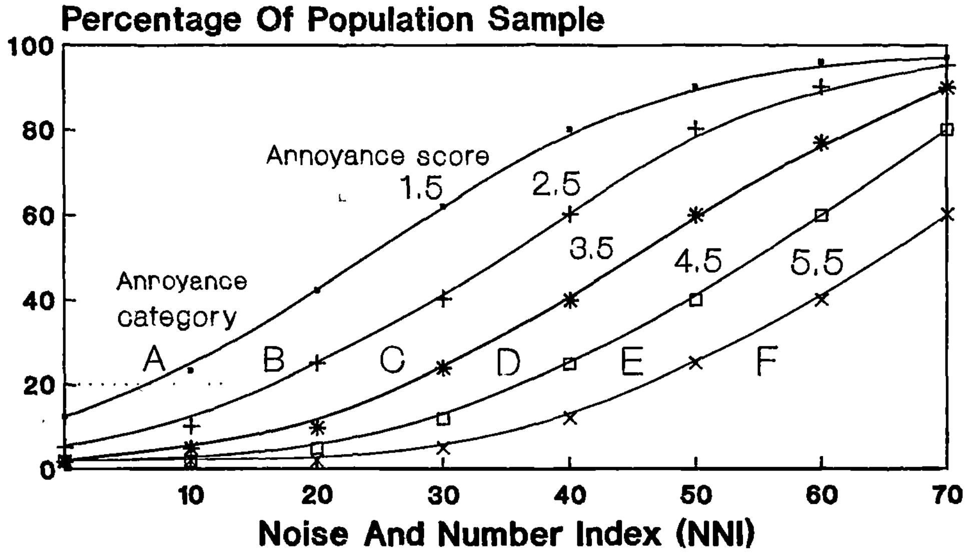
As for the response to aircraft noise during sleep, although precise quantitative data is not always readily available in this area, nevertheless, based on some laboratory experiments, it seems that people are about 10PNdB more sensitive to aircraft noise in the night-time than in the day-time, and from 01.00 to 07.00 hours or so they are about

Figure 2.8a: Degree Of Annoyance From Noise Observed In Social Surveys



Source: Ref.52

Figure 2.8b: Distribution Of Degrees Of Annoyance Due To Aircraft Noise Exposure



Note: See next page for annoyance categories
Source: Ref.53

(from Figure 2.8b)

Annoyance Category	Feelings About Aircraft Noise
A	Not annoyed:- Practically unaware of aircraft noise.
B	A little annoyed:- Occasionally disturbed.
C	Moderately annoyed:- Disturbed by vibration; interference with conversation and TV/radio sound; may be awakened at night.
D	Very annoyed:- Considers area poor because of aircraft noise; is sometimes startled and awakened at night.
E	Severely annoyed:- Finds rest and relaxation disturbed and is prevented from going to sleep; considers aircraft noise to be a major disadvantage to the area.
F	Finds noise difficult to tolerate:- Suffers severe disturbance; feels like moving away because of aircraft noise and is likely to complain.

Source: Ref.53

20PNdB less sensitive than in the night-time [61]. This reduction in their sensitivity between 01.00-07.00 hours may be due to the fact that they are in the "deep" stage of sleep between such hours. As mentioned earlier, the response to aircraft noise during sleep has been investigated more deeply by Karami (Ref.56) to which the reader is referred for more detailed information in this area.

2.11 Aircraft Noise Reduction:

Although aircraft noise cannot be suppressed entirely, there are several ways to reduce and minimise its impact. The principal methods to combat aircraft noise are:-

A) Reduction at source;

B) Reduction at the receiving point;

C) Reduction on the way (between source and the receiver).

The following sub-headings discuss the ways in which the impact of aircraft noise can be reduced.

2.11.1 Proper Planning:

Good and effective land use planning is probably the best way to reduce noise in the noise sensitive areas. For example, building an airport as far away as possible from the towns and residential areas is very effective in reducing the noise impact i.e. the further away the airport the lesser the impact. But, easy access and egress (road/rail services); travel time; costs; and civil engineering works will all impose limitations on the distance. This means that, although it is desirable to build airports as far away as possible from towns and cities, in some cases it may not be practical.

Residential areas should NOT be built near to the boundaries of an airport, and urban developments near airports should

NOT be welcomed. Factories and workshops are not particularly affected as they already have a high background noise level.

Effective land-use planning needs government legislation which means that places such as hospitals; schools; nursing homes; old people's residential homes; and housing estates should NOT be given building permission in areas with high aircraft noise levels e.g. 60NNI and above. In the United Kingdom, the DOE has set down guidelines for use in conjunction with the NNI giving recommendations for the control of development in areas affected by aircraft noise [54].

2.11.2 Aircraft And Engine Modification:

In general, wide-body aircraft are quieter than small and narrow-body aircraft because of their physical characteristics. As mentioned earlier, although aircraft produce noise by the flow of air over their fuselage and their wings (aerodynamically) which is only significant during the final stage of landing, the main problem is, the noise from the engines.

Designing better engines and aircraft mainframes can make their operation much quieter, and it is very effective in reducing noise at the source. For example, the Boeing 747; the Douglas DC10; and the Lockheed Tristar all are large and long-range jet aircraft with either the bypass type engine (i.e. a large fan at the front of the engine) OR; a ducted fan which gives them a lower fuel consumption and lower jet velocities therefore, lower noise levels [22].

The fitting of noise suppressors or "hush-kits" to the jet engines reduces noise, but it also reduces the fuel efficiency of the engines due to the extra weight and the increased drag and so increases the overall fuel consumption of the aircraft [22]. Aircraft noise can be reduced further by:-

a) Using sound absorbing materials; new exotic metals; light-weight composites and ceramics in the engines and the mainframes [18];

b) Extending the cowling around the fan and lining it with sound absorbing materials that have become lighter and much more effective over the last 15 years [18];

c) Increasing the space between the blades in the turbines by reducing the number of blades and changing their airfoil shape to reduce noisy flow of air [9,18];

d) Using low flow speeds in the fan; compressor; and in the exhaust areas of the engines [9];

e) Using the newer big-fan engines which have lower jet velocities therefore lower noise levels. For example, the KC-135 Aircraft (USAF) which are based on the civilian

Boeing 707 are replacing their old 1950s J57 engines with the new CFM56 engines. These new engines are much quieter, and they reduce maximum noise on the ground by more than 15EPNdB which reduces the area affected by noise around airports by as much as 96% during takeoff and landing [18];

f) Using quieter aircraft such as STOL or VTOL (see Glossary) which enable pilots to takeoff and land at a much steeper angle, thus reducing the area affected by noise during takeoff and landing.

2.11.3 Runway Factors:

Certain runway factors are important in reducing noise. For example:-

a) Preferential Runways:

This is when the use of one runway is "prefered" to another runway. In general, modern transport aircraft are not usually affected by the crosswind component which means that, they can operate on a less wind oriented runway providing it will have less noise impact on the environment at large. At Schiphol Amsterdam for example, the use of one particular runway directs the noise nuisance away from the heavily populated suburbs of Amsterdam. At Los Angeles, heavier aircraft generally use only one of the two main runways, and take offs are mainly to the west over the sea in order to avoid flying over populated areas [9].

b) Runway Orientation:

This is mainly concerned with the "direction" of the runways i.e. considering all other aviation aspects (e.g. wind direction; visibility; and safety), runways should be designed and orientated in such a way that take offs and landings would be over the less populated areas to minimise the noise impact as in the case of Los Angeles (see earlier) and Athens where most take offs and landings are over the sea. Runway orientation is important in reducing noise levels particularly during taxiing; takeoff; and the landing of aircraft.

c) Runway Modification:

For example, reducing the runway length which in turn reduces runway capacity, is another effective way of reducing noise. But, since most of the revenue is from landing charges, any reduction in the runway capacity is therefore uneconomical [13].

2.11.4 Minimum Noise Routing (MNR):

These are "predetermined routes" designed to direct departing aircraft within their operational limits over less populated areas [46]. They enable the aircraft within their performing ability to takeoff safely from the runway into the appropriate airways. An airway is an air corridor about 16kms wide which is marked along the centre-line by navigational aids. Originally, MNRs were designed to reduce accidents and increase safety over urban areas by taking advantage of open spaces and avoiding densely populated areas [20]. But, this avoidance of the populated areas for safety reasons will also reduce the problem of aircraft noise in urban areas.

MNRs do <u>NOT</u> reduce aircraft noise, they only <u>minimise</u> disturbance by re-routing the aircraft to fly over the less populated areas thereby affecting less number of people. This way, smaller communities are subject to more noise by being under the busier routes, and larger communities benefit since their air corridors are avoided. Basically, MNRs move noise from the more populated to the less populated areas, and whether this is justified or not is a question to the airport operators. In the United Kingdom however, the Noise Advisory Council has twice examined the use of MNRs, and has recommended its use as being the best way to reduce the problem of aircraft noise from the whole community's viewpoint [9].

The Civil Aviation Regulations require that MNRs should be followed at major UK Airports particularly at Heathrow so that, after takeoff, every jet aircraft operates in such a way that does not produce more than 110PNdB between 07.00-23.00 hours local time, and 102PNdB between 23.00-07.00 hours local time at the designated noise monitoring points. They also require every pilot to always operate his aircraft in such a way that creates the least amount of disturbance practically possible in the immediate vicinity of airports

[21].

MNRs are not always the shortest flying routes for obvious reasons, and distances are usually stretched since pilots avoid built up areas. They (pilots) are advised to follow these routes which ensure minimum flying over populated areas although it is not always possible to do so since these routes are used only in perfect conditions of climate; visibility; and other factors that may affect the safe operation of aircraft. Also, occasionally pilots may have to alter their routes for safety reasons which are always paramount, and can further restrict the use of MNRs [20].

2.11.5 <u>Reducing Noise During Operation:</u>

The problem with aircraft noise is mainly during takeoff; landing; ground operations and engine run-up e.g. during taxiing or maintenance. The Proper handling of aircraft by pilots can significantly reduce the amount of noise particularly during takeoff and landing when the problem is at its peak. At each stage of the operation, noise can be reduced in the following ways:-

A) <u>Takeoff:</u>

The loudest noise is from takeoff when the engines apply maximum power. Where multiple runways are available, take offs should be over sparsely populated areas providing weather; wind; and other such factors permit safe operation.

Turns may be specified for take offs, and speeds may vary during takeoff to gain height, and to fly over noise sensitive areas as quickly as possible to reduce disturbance [13].

During takeoff, the noise rises sharply and extends over a wide area and then falls as the aircraft flies overhead. Therefore, at most airports, subject to safety requirements, pilots are asked to cut back on power after reaching a safe altitude (usually 300m [20]) to reduce noise in densely populated areas close to the airport. At the point of cutback noise levels can be reduced by 5PNdB [9]. Operation continues less steeply under reduced power until reaching a depopulated area when the full power climb is resumed. This way, an earlier and greater reduction in power means a stronger re-application of power further down the route [9].

Takeoff restrictions have been criticised on grounds of safety. In fact, they seem to increase noise levels at some distance away from the airport since takeoff is not as quick as possible as with no restrictions. Restricted take offs impose greater total annoyance than unrestricted since they affect areas further away from the airport which are more populated than those in the immediate vicinity [23]. This (restricted take offs) is probably another reason why the response to aircraft noise from the Heathrow area below the 40NNI zone is greater than that from the Gatwick area in the findings of the Wilson Committee (see 2.10 before - Response

To Aircraft Noise).

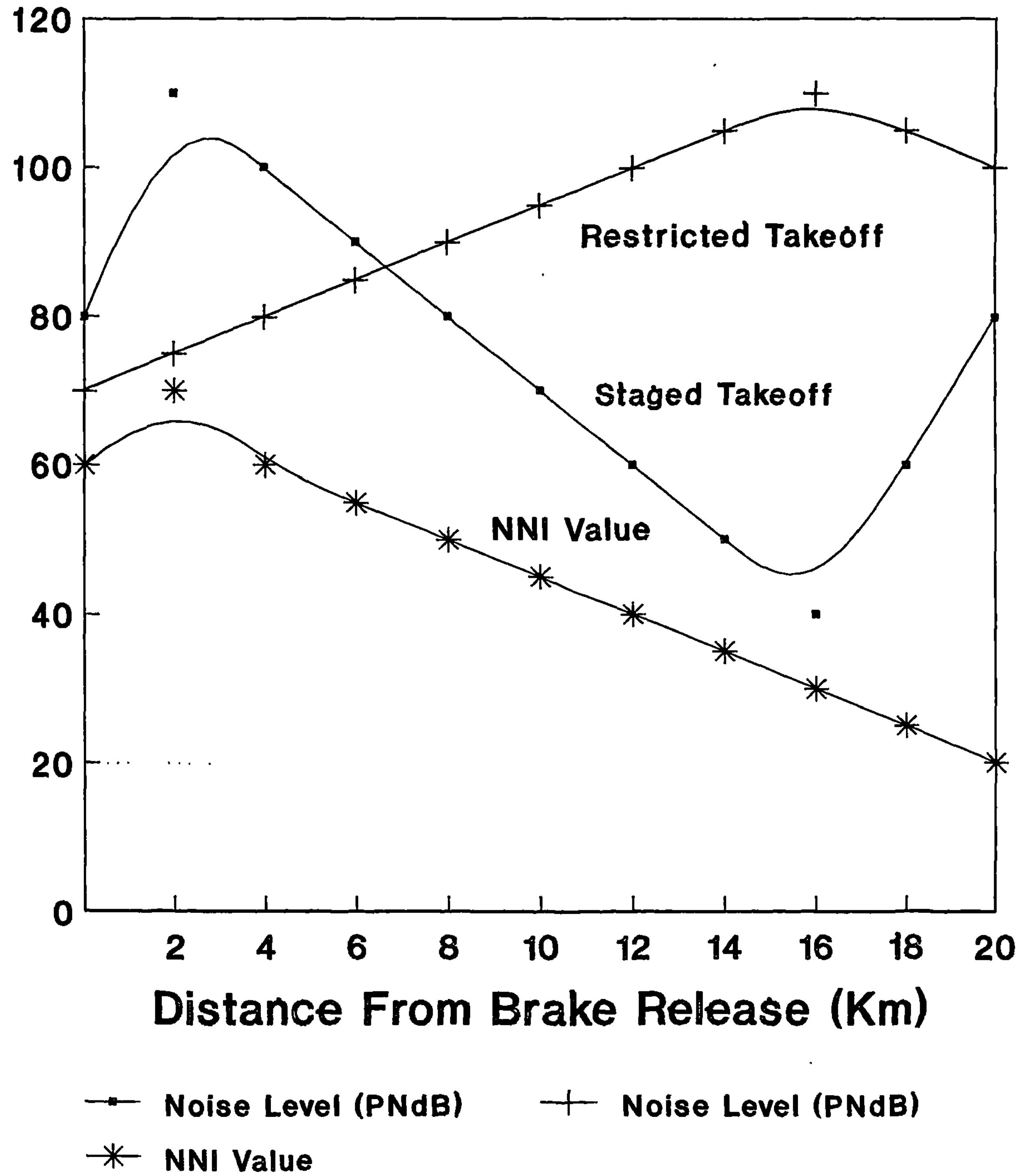
Nevertheless, following a proposal by IATA, take offs have been to some extent modified by the airlines at all major airports. For instance, the airlines apply almost full power for the first 500m of the climb, followed by a reduction in power to normal climb, and then by acceleration and flap retraction. This procedure is known as the "Staged Climb or Takeoff", and it decreases noise in the more populated areas some distance away from the airport by slightly increasing the noise in the less populated areas close to the airport [58].

This staged takeoff however, is an opposite situation to the restricted takeoff case explained earlier whereby the noise level or the NNI value decreases with the distance away from the airport (see Figure 2.9). Similarly, proper planning of Noise Abatement Procedures (NAP) on takeoff reduces noise annoyance to the whole community. For example, many airports around the World commonly use the staged climb method to reduce noise in populated areas [9].

B) Landing:

Landing noise has become more of a problem with the growth in air traffic. When aircraft are landing and throttling back, the main noise is the high-pitched whine made by the engine compressors and the use of reverse thrust (drag) during landing [12]. The rise and fall of aircraft

Figure 2.9: Noise Impact During Takeoff



Source: Author

noise during landing as it passes overhead is quicker than during takeoff. This is because the aircraft is closer to the ground for a longer distance than during takeoff, and the fact that the engines are operating at much reduced power. For this reason, and the straight path of an aircraft's landing approach, landing noise does not extend over as wide an area as during takeoff [20].

In general, the higher the flying altitude, the lower the noise level on the ground. This is because of the distance between the source and the receiver. Landing is a complicated matter since the aircraft usually fly at a relatively low altitude for some time before touch-down. This flying of the aircraft at low levels increases noise levels on the ground. Also, prior to landing, the aircraft must be stabilised and follow signals from a control tower before touch-down, and this needs a long and straight approach at low altitudes with a 3^0 angle of descent which is normally recommended for a safe landing [20].

An effective way to reduce noise on the ground during landing is to increase the height of approach or the landing height. For example, a large jet aircraft by increasing its landing height from 500 to 1,000m above ground level reduces the noise level on the ground by about 8PNdB, and by increasing its height to 1,500m, this reduction will reach to about 16PNdB [9]. The height of the approach can be increased in several ways:-

a) By <u>intercepting the runway approach glide angle of 3^0 from below</u> and descending at a steady approach speed from altitudes of about 500m and 13kms away from touch-down [8]. At Manchester Airport for example, descents below 600m until the glide angle has been intercepted are prohibited, and the Airport requires pilots to make visual approaches using VASIS (see Glossary) in order to avoid unnecessary low flying [9];

b) By <u>using a steeper than normal angle</u> for the final descent and approach. Descend is normally at 3^0 but 4^0 has also been practised [9];

c) By <u>approaching in two segments</u> with the initial descent at 5 or 6^0 flaring to 3^0 for the final approach and touch-down. This way, reductions of about 10EPNdB at 9kms, and 6EPNdB at 6kms from the runway threshold have been achieved [9]. The runway threshold is the beginning of that portion of runway usable for landing.

In addition to increasing the height of the approach, there are other methods available for reducing aircraft noise during landing and these are:-

a) By <u>reducing the flap settings and the engine power</u> which, when combined together, can achieve considerable reductions in noise. For instance, by reducing the flap settings on a B727 and a B737 from the normal 40^0 to 30^0, a reduction of 3EPNdB and 2EPNdB can be achieved respectively. Similarly, reducing the flap settings from the normal 50^0 to 40^0 on a B707 reduces noise by about 2EPNdB [9]. This process of reducing the flap settings and the engine power is known as the "Low Power/Low Drag (LP/LD) Procedure", and it has been used successfully at Frankfurt Main which has a great problem of environmental noise because of its close proximity to the urban area [57];

b) By making a Continuous Direct or Descent Approach (CDA) where the pilot uses a radar to estimate his altitude. This method prevents the use of power in a "stepped descent" which consequently reduces noise level on areas under the approach path [9].

C) Ground Run-Up And Runway Operations:

Apart from the noise produced during landing and takeoff, aircraft noise is produced also during taxiing; from the engine run-up during maintenance; and from the run-up at full power before releasing the brakes for the takeoff. On runways, aircraft noise can be reduced significantly by applying reversed thrust, although the use of thrust reversal for reducing noise should be avoided unless no other adequate source of noise reduction is available. This is because the noise produced by thrust reversal is a sudden one, and it is usually about 10dB below the takeoff noise [9]. Extensive landscaping can, however, protect airport surroundings from the noise produced by the ground operations of aircraft.

As for the hangars and maintenance areas where repairs and routine checks are carried out and engines may be running and tested for some time, they should be well insulated and built further away from the main terminal buildings. Hangars should also be screened from neighbouring residential areas either by the airport buildings and earth banks, or by other specially constructed noise barriers. The use of special mufflers which are massive silencers and placed very close to the engines is also necessary wherever possible, especially "after" a routine maintenance or check-up when the engines will be running and tested for some time. The testing of the engines should be done only at certain times and locations on the airfield, particularly if testing is being done at night [20].

2.11.6 Night-time Curfews:

Prohibiting aircraft totally from flying after certain hours of the night is very effective in reducing noise levels near airports. This is because operations (landings or take offs) even as low as one every half hour in the night may severely disturb nearby residents. This greater disturbance at night is due to the fact that, as mentioned earlier, response and sensitivity to aircraft noise are much higher in the night-time than in the day-time (see 2.10 before - Response To Aircraft Noise). It is, therefore, because of this greater sensitivity at night that night-time restrictions and curfews are very effective in reducing disturbances. Heathrow for example, imposes a total ban on all jet aircraft to take off at night-time during the summer months (April-October inclusive), and similar restrictions have been imposed also at Gatwick; Luton; and Manchester Airports [58].

Many airports around the World particularly those in Europe apply night curfews on jet flying to avoid sleep disturbances. Good examples are Zurich; Sydney; and the Orange County (John Wayne) Airport in California. Night curfews vary from one airport to another in the way that, some airports ban all operations completely and runways are effectively closed, and some may allow small propeller aircraft to operate as they are not as noisy as other aircraft [9,18].

In general, quieter aircraft are less affected by curfews and this is an advantage to cargo operators. For this reason, cargo handling is mainly during the night at major airports such as Heathrow; Orly; Main; and O'Hare where goods are being distributed worldwide, and consequently, curfews on "<u>cargo aircraft</u>" are <u>NOT</u> so intense at these Airports [8]. Heathrow for example, has a "<u>quota</u>" (fixed share) system of night-time freight movements which permits a small number of operation to take place [9]. Amsterdam; Frankfurt; and Hong Kong Airports also allow some curfew exemptions subject to certain operational and scheduling conditions by permitting noise certificated aircraft (usually all the wide-bodied aircraft) to operate. Tokyo; London; Hong Kong; and Paris are more relaxed on curfews allowing delayed flights to land, whereas Sydney has no exemption at all and operates a total 7hr curfew on all activities [9].

Where there are curfews being imposed, it is important for the airlines to consider the local time difference between each origin and destination, particularly in intercontinental flights where distances and flight times may be long. This is because, if, for example, there is a seven hour curfew uniformly applied at the main intermediate hub airports throughout the Middle and Far East, the time lost between London and Tokyo or Paris and Hong Kong may then reach to as much as 25 hours [8]. Considering "cargo" jets, they may be permitted takeoff providing there are limited numbers, but for passenger aircraft, landings are allowed "ONLY" in emergencies.

As stated earlier, night curfews reduce noise disturbance effectively, but they cause air traffic delays and congestion by congesting the terminals before and after closing down hours [8]. This congestion however, can be reduced and avoided by permitting more take offs during restricted hours. In addition, night curfews are NOT economical for the tour; airline; and airport operators since their operational capacity will be reduced. Airport operators for example will lose money through fewer landing charges. As for the type of curfews imposed, it depends on the local aviation regulations; on the location of the airport; on the local climatic conditions; and on the type (i.e. passenger or cargo) and volumes of air traffic.

2.11.7 Sound Insulation And Land Purchase:

Where noise levels are unacceptable, the use of sound absorbing materials in the construction of buildings near airports reduces noise considerably inside dwellings. For example, using a cavity between the inner and outer walls of a building reduces the noise inside effectively. Double glazed windows too are very effective especially in noise sensitive areas but cause problems of ventilation. Adequate ventilation is needed in buildings close to airports where windows are kept closed to avoid noise. The amount of insulation needed varies from one building to another depending on its type; use; and desired noise levels inside e.g. housing; schools; offices; factories; hotels; nursing homes; and hospitals.

Another factor that determines the type and the amount of insulation needed, is the "distance" between the noise source (i.e. an airport) and the receiving points (i.e. houses and buildings). In other words, it is the NNI zoning of each dwelling that determines the type and the quantity of insulation needed. In major schemes such as airports, grants are usually available to cover the cost of providing adequate insulation to buildings that may be adversely affected by aircraft noise. Each building, must qualify for such grant which is normally paid by the Government or the relevant airport authorities. Payments are either in part or in full depending on how much a dwelling is affected by the airport activities, and it is usually the responsibility of the relevant authorities to decide whether or not a dwelling is eligible for either part or full payment. Heathrow and Schiphol Airports for example, have carried out such schemes in their surrounding areas [9].

The buying and purchasing of "undeveloped" land surrounding an airport by the airport owners and operators prior to construction in order to prevent any future development is, another but expensive way to combat aircraft noise. This is a very costly and expensive way to combat noise since, large areas of land are usually bought with different prices depending on their use e.g. residential; agricultural; commercial; industrial; or recreational. The purchasing of "developed" land however, which is even more expensive, will also reduce noise disturbance particularly where the problem is intolerable. For instance, the growing pressure and complaints from nearby residents and office workers who find conditions difficult may force airport authorities into buying these properties. This again is very costly since the purchasing of homes and businesses near airports can be extremely expensive as they may cost well above the market value because of the inconveniences suffered by the seller.

Also, in some cases, for instance in the United Kingdom, a "Compulsory Purchase Order" may be needed which can make matters complicated, but depending on circumstances, it may be the only option. At Los Angeles International for example, the authorities have previously purchased many homes and businesses close to the Airport by "Mandatory Purchasing Procedures" in order to reduce aircraft noise disturbance [9].

2.11.8 Noise Monitoring:

As stated earlier, aircraft noise is monitored around airports at fixed locations known as monitoring points, and airlines must comply within the rules and regulations set by airport authorities for operational noise limits over these predetermined measuring points. The violation of these regulations may result in a warning to airlines from the authorities, and in some cases, it may lead to a fine. In cases where pilots operate above these limits, they are issued a notice, and excessive violation could ban the airline completely from using an airport [55,9].

Some airports such as Manchester for example, even offer reduced landing charges to airlines that use quieter aircraft and operate (takeoff and land) within the limits at these measuring points. These reduced landing fees tend to encourage airlines to keep noise levels low and within the set limits thus, reducing disturbances. At Manchester Airport for example, there is a 10% reduction in the landing fees offered to airlines that keep within the noise limits over the measuring points. The Airport also issues a monthly "<u>Noise Bulletin</u>" which contains a record of infringing and non-infringing airlines detailing their activities as well as encouraging them to achieve less infringement by aiming for the lowest in the ranking list. In this way, further noise reductions can be achieved within the Airport environment [55,9].

2.11.9 <u>Government Legislation (Noise Certification):</u>

Another effective way of reducing aircraft noise is government legislation for instance, the "<u>Noise Certification</u>" of aircraft (see 2.6 before - Aircraft Noise Measurement). For example, because of the growing importance of aircraft noise, the percentage of noise certificated aircraft increased from 0.5% in 1973, to 16.2% in 1979 [9]. This large increase over a period of six years, shows the effectiveness of such legislation (i.e. Noise Certification) in reducing aircraft noise.

2.12 <u>Conclusions:</u>

Airports are the centres for aviation activities where they provide the facilities to move people and goods fast. Because of this, it is impossible to run and operate an airport free from noise. The main and the most disturbing noise from an airport is the aircraft noise which tends to restrict the development of new airports, it also tends to seriously constrain the efficient operation and the economic growth of the existing ones.

In general, the problem of aircraft noise increases with the growing demand for air travel which itself stems from a healthy economy and cheaper air fares. In other words, the richer a nation, the more likely are its people to travel by air, and therefore, the more likely is the disturbance caused by aircraft noise. This disturbance, however, may be reduced by discouraging air travel through increasing the air fares but, reduced air travel may then have adverse economic impacts such as loss of revenue and tourism.

Other ways of combating aircraft noise include <u>the use of larger aircraft</u> with greater payloads which reduces total aircraft movements and consequently, ambient noise levels. <u>The use of new technology</u> in designing better and quieter engines will also help to reduce aircraft noise effectively. <u>The use of an alternative mode of transport</u> wherever possible is also effective in reducing aircraft noise but, it will have its own noise. Rail transport for example, is a good and cheaper alternative to air travel particularly for <u>short to medium range distances</u>, and for when the <u>journey time</u> is <u>NOT</u> so important. The importance of rail transport as an alternative mode of travel to air transport for reducing those adverse environmental impacts of airports shall be mentioned again later in the next chapters.

As for the road traffic noise, though it may not be as big a problem as aircraft noise, nevertheless, it cannot be ignored totally, since large volumes of road traffic are generated by airports. In addition to the engine noise, the next most disturbing noise from the road traffic is the noise from the tyre/tarmac contact which worsens in wet conditions especially with HGVs (Heavy Goods Vehicles).

Finally, aircraft noise may reduce the quality of a pleasant living and recreational environment, and it may also adversely affect both land and property values. It may also affect people mentally; physically; socially; and economically. Aircraft noise causes more disturbance during the night, and it is then that controls and reductions are most beneficial. As for the supersonic civilian aircraft such as Concorde, they have a major problem of noise, and perhaps the best way to overcome this problem is by completely banning these aircraft from flying over the skies of a nation.

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private sector, normally the company safety policy is a measure of the safety criterion, this measure has scored 100% for term contracts and for public clients using traditional contracts, while it is 75% for design and build contracts.

Experience Modification Rate (EMR) (Q13.2) as well as Occupational Safety and Housing Administration incidence rate (OSHA) (Q13.3) seem to be not familiar to the construction industry in the U.K, this was noticed during the interviews conducted, while in the USA many publications (Levitt and Parker 1976; Samelson et al 81; Samelson and Levitt 1982; Hinze and Russell 1995) have emphasised the importance of using such criteria for selection. However, this survey resulted in 0% response for the two criteria from traditional and design and build contracts, about 25% of term contract users indicated they are using the (EMR) while 33% of the respondents used (OSHA) incidence rate.

Management safety accountability (Q13.4) was used in the contracts surveyed in this study. For traditional contracts, 37% of public clients and only 15% of private clients used this criterion, while for term contracts, 67% used this criterion and 25% for design and build contracts.

Q14. Reputation

For traditional contracts 69% of public client respondents used past failures of contractors (Q14.1) as a criterion for selection, while only 33% of private clients considered this criterion. On the other hand, 100% of term contract users considered the past failures for contractor selection, 50% of design and build contract clients used the criterion for contractor selection.

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Chapter 3

Atmospheric Pollution

3.1 Introduction:

Atmospheric pollution is a global problem and its impact on the environment is a vast area of study. So far as airports are concerned, they pollute the air through aircraft and the ground support systems. Aircraft themselves are not major polluters. For example, American studies have shown that less than 2% of the national air pollution comes from commercial aircraft and comparable studies in Canada indicate an even lower figure [50]. Similarly, in 1991, independent environmental tests at Manchester Airport showed that only 1% of the atmospheric pollution was from aircraft fuel [48].

But, airports create large quantities of "local" air pollution through other sources such as the motor vehicles that are mainly petrol driven and the ground service equipment which largely use diesel engines. The main and most important sources of air pollution related to airports are discussed below.

3.2 Sources Of Air Pollution From Airports:

In addition to aircraft and the ground equipment, motor vehicles are the main sources of air pollution near airports since they are used far more intensively than the jet aircraft. For instance, as much as 25% of the pollutants emitted from all sources within the airport boundary may be from motor vehicles of the airport passengers; visitors; and employees [57].

Motor vehicles are both on the air-side of the terminals; on the aprons; and near the operational buildings; and, also, on the land side, they are in the approach or access roads; in the car parks and terminal buildings; and in the cargo areas. Motor vehicles have a much lower rate of combustion than jet engines, therefore, the amount of pollutants emitted per unit of fuel used by motor vehicles is much higher than that from the aircraft (at least ten times greater) [26]. Also, the problem of air pollution becomes even bigger by the fact that airports generate large volumes of road traffic. The following are only a few examples:-

A study of average daily emissions by motor vehicles; power plants; and jet aircraft in the Los Angeles County in 1969 produced the following results (see Table 3.1) [1]:-

Table 3.1: Average Daily Emissions Of Motor Vehicles, Power Plants, And Jet Aircraft In The L.A. County (1969)

Sources Of Air Pollution	Total Average Tonnes Of Pollutants Per Day	% Of Total
Motor vehicles	11,657	95.50
Power plants	442.0	3.60
Jet aircraft	106.0	0.87
Total	12,205	

Source: Author (Produced and modified from Ref.1)

From Table 3.1, it is clear that motor vehicles are much bigger polluters than jet aircraft. It also shows that jet aircraft have the lowest pollution level in the area which confirms the results of the American and Canadian studies mentioned earlier (see 3.1 before). The above figures are likely to have increased since 1969.

In 1971, the UK Department Of Trade and Industry (dti) prepared a report on the air pollution at London Heathrow in which it was concluded that, "the highest values came from road traffic and the taxiing of aircraft" [25]. Similarly, the US Environmental Protection Agency (EPA) had estimated that, in 1987, aircraft created only 0.5% of "all" oxides of nitrogen (NO_x) in the USA (the same as forest fires), whereas motor vehicles and HGVs accounted for 33% [46].

In 1992, some 40 million buses; cars; taxies; lorries; and coaches went through the Heathrow Tunnel [Ch.2], producing large quantities of exhaust gases and other pollutants. Also, at Manchester International, it is estimated that when the Airport is expanded, 11,000 extra vehicles per day will travel to the Airport [Ch.2] producing 200,000 tonnes of pollutants per year in the air near the Airport [3]. The contribution of the road traffic to the atmospheric pollution near airports is clearly visible in the above examples.

In addition to the road traffic, construction of an airport also pollutes the air through earth moving; excavation;

demolition; spray painting; burning of refuse; and other activities that pollute the air with dust; smoke; exhaust gases; and other pollutants. Airports also pollute the air significantly through space heating for terminal buildings; hangars; control towers; houses; offices; stores; hotels; clubs; bars; restaurants; medical treatment rooms; laundries; and dry cleaners. Residential areas which develop around airports also add to the local pollution through space heating in the winter, and through barbecues in the summer [5].

Power plants and electricity supplies to the airports also pollute the air especially if burning coal and oil to generate power. Both CO_2 (carbon dioxide) and SO_2 (sulphur dioxide) are produced. Other sources of energy for example Nuclear reactors are also potentially hazardous [5]. Similarly, manufacturing industries of goods; equipment; facilities; and the materials needed to operate airports and aircraft pollute the air via chemical plants and petroleum refineries.

The smoking of tobacco by passengers; well-wishers; and employees also produces areas of localised air pollution. For instance, some 40 million people travel through Heathrow every year (1992 figures) [2] who together with millions of well-wishers and thousands of airport staff all contribute their share of atmospheric pollution. Although the major source of atmospheric pollution in areas close to airports is still from motor vehicles, the significance of aircraft regarding air pollution is becoming more noticeable with increasing demand for air travel. Therefore, this chapter will concentrate on air pollution related mainly to aircraft and their ground support systems and equipment, and their impact on the environment.

3.3 Air Pollution From Aircraft:

Kerosene is the main fuel used worldwide by aircraft and the gases emitted from their exhausts are similar to those emitted from motor vehicles. Basically, the combustion of hydrocarbon fuels in jet engines produces carbon dioxide (CO_2); water vapour (H_2O); unburnt fuel or hydrocarbons (HC); carbon monoxide (CO); carbon particles known as smoke or soot (C); oxides of nitrogen (NO_x); and other trace particles e.g. sulphur dioxide (SO_2) [6,19,46,51].

Over the past two decades, emissions of all but NO_x have been reduced to very low levels particularly at cruise stage by developing cleaner-burner engines [46]. Aircraft mainly emit HCs when idling, and NO_x when cruising [7]. After emission, these pollutants are transformed physically or enter into chemical reactions. The amount of pollutants emitted depends on the <u>quantity of fuel used</u> and the <u>rate of emission</u> (emission factor) of each pollutant i.e. gm of pollutant per kg of fuel <u>consumed</u> [19]. The emission factor of <u>each gas</u> depends on the <u>aircraft type</u>* (i.e. subsonic; supersonic; or cargo) where in each case it would have different physical and operational characteristics (e.g. loading; altitude; speed; engine size; and fuel type); and on the stage of operations (i.e. landing; takeoff; cruising; idling; or taxiing); and on how long (i.e. hours or mins.) the engines are operated in each stage.

For example, the emission factor of NO_x increases with engine loading, and is greatest at takeoff when the engines are running at full power. But, for HCs, this situation is the opposite (see Table 3.2). Similarly, for trace elements such as sulphur, the factor may significantly vary with fuel type, and for CO_2 and H_2O, the emission factor does NOT change noticeably with factors such as aircraft type; fuel; loading; and the stage of operations [19].

Table 3.2: "Estimated" Rate Of Pollutants Emitted In 1990

Aircraft Condition			Pollutant (g/kg) Of Fuel		
State	Time	Max. Engine Power	CO	HC	NO_2
Idle/taxiing	5%	5%	5.0	20.0	5.0
Approach	2%	30%	5.0	2.0	10.0
Cruise	92%	60%	0	0	20.0
Takeoff	1%	100%	0	0	40.0

Source: Ref.22 (Raper and Longhurst 1990 quoting Clarke 1986)

Figures in Table 3.2 are approximate, and they do NOT reflect on a particular type of aircraft. Therefore, some of these assumptions such as the NO_2 factor for example may seem higher than normal since:-

A) It is very difficult to measure emissions directly at cruise altitude;

B) The growing concern over air pollution especially with regards to the upper atmosphere has made engine manufacturers reluctant to reveal their information on engine pollutants especially those emitted from <u>military aircraft</u> [19]. This is because:-

a) They (military aircraft) make up for an "<u>estimated</u>" 24% (1988 figures) of total global consumption of aviation fuel [20,21] which may produce a substantial amount of atmospheric pollution particularly in the upper atmosphere;

b) They may have a greater impact per unit of fuel used [19], which means that they may have a bigger emission factor than civilian aircraft for reasons explained earlier i.e. power; speed; loading; and altitude. The "<u>low</u>" flying F-18, and the "<u>high</u>" flying Mig-27 combat aircraft are good examples especially with regards to difference in altitudes;

c) Unlike civil aircraft, their emissions are <u>NOT</u> regulated, and they may emit additional substances the effects of which on the atmosphere are <u>NOT</u> publicly known [19,21];

d) Their emission factors, and details of their operations are often kept secret [19].

Compared to other modes of transport, aircraft are the cleanest form of travel. As measured in kg of pollutants per 1,000seat-kms, jet engines produce less than half the weight of pollutants from diesel electric trains and less than a fifth from the new and improved motor vehicles that meet the strictest requirements for urban areas [26]. The early turbojets may still discharge as much as 160kg of "total" pollutant during taxiing and takeoff, but even this level is much less than the early piston-engine aircraft of the 1950s/60s [26].

Unlike road transport where emissions are largely at street level, a large proportion (80-90%) of aircraft emissions is at very high altitudes (10-12kms) [19] as they spend most of their time cruising. The remaining 10-20% is released into the lower parts of the stratosphere during takeoff; landing; and taxiing. It is, therefore, at such cruising altitudes (10 to 12kms) where emissions affect the upper atmosphere directly by contributing to the global warming [19]. At the present time, emissions of CO; soot (C); SO_2; HCs; and trace elements from jet aircraft are NOT a great concern since aircraft emissions are very small compared to ground level sources. Also, these pollutants in small quantities have very little impact at high altitudes [19].

In 1975, almost 40% of NO_x emission took place further North than 40 degrees North [24], and in 1991, 80% of global aviation took place in the Northern Hemisphere [23]. This is because air traffic is dense at latitudes 30-60 degrees North due to the US/European/North Atlantic route [19]. These figures indicate that, the more industrialised and developed thus wealthier nations of these regions have more aviation activity than the nations of the Southern Hemisphere. Today, however, there is probably a larger volume of air traffic at lower latitudes. Table 3.3 shows worldwide emissions of aircraft for 1988 by using estimates based on assumed emission factors and data from several sources including the UN.

Table 3.3: "Estimated" Global Emissions From Aircraft In 1988 (in 1,000s of tonnes)

Emission	Commercial	Military	Total
Carbon dioxide (CO_2)	125,000	41,000	166,000 *
Carbon monoxide (CO)	271.0	86.0	357.0
Smoke or Soot (C)	3.0	1.0	4.0
Nitrogen dioxide (NO_2)	1,625	513.0	2,138
Hydrocarbons (HC)	141.0	44.0	185.0
Water (H_2O)	169,000	53,000	222,000
Sulphur dioxide (SO_2)	406.0	128.0	534.0

* *In thousand tonnes of carbon*
Source: Ref.19, 21, UN (1990)

3.4 Effects Of Air Pollution From Aircraft:

The effects of pollutants from jet engines in the atmosphere vary noticeably with altitude. This means that their effects at high altitudes are different to those at ground levels mainly because:-

a) Some gases such as NO_x have a greater impact in the higher altitudes than in the lower ones;

b) The gases remain in higher altitudes for longer periods than in near ground levels since aircraft are most of the time cruising;

c) The behaviour of the gases changes noticeably with altitude because the chemistry of the atmosphere changes with altitude;

d) Certain reactions such as the formation and destruction of ozone by NO_x take place higher up in the atmosphere (10-15kms or more) [19].

In the context of this thesis, this chapter will concentrate "mainly" on the effects of aircraft pollutants at low altitudes i.e. "at ground level and on local areas around airports" as well as briefly discussing their global effects.

3.4.1 Local Effects Around Airports:

Gases and fumes emitted from aircraft engines and other ground support systems directly affect the local environment around airports by reducing the air quality. For example, a study of air pollution from aircraft in Los Angeles in early 1970s had reported that as jet aircraft grow to dominate the airport environment, there will be a decrease in the emission of other organic gases and aerosols (colloidal particles in a gas medium) [26]. Poor air quality is believed to affect human health both physically and mentally. It also affects climatic conditions as well as trees; vegetation; forests; wildlife; soil; water; rivers; buildings; and structures. In order to investigate the effects of aircraft emissions, it is necessary to discuss the effects of each gas separately.

3.4.1.1 Carbon Dioxide (CO_2):

In 1991, the aviation industry worldwide made up for 2.7% of the total carbon emitted globally from fossil fuels (coal; oil; gas) [19]. This figure is likely to increase with the increasing air travel thus emitting more CO_2 into the atmosphere. CO_2 normally exists in the air and is vital to plant life. It is a heavy, colourless, and odourless gas, and until recently has not been considerd as a pollutant because, at normal levels, it is essential in all life processes. At higher levels however (10 to 100 times higher than normal), it can accelerate human breathing and increase the effects of poisonous gases. It also increases photosynthesis by plants which take up the excess CO_2 [5,7]. Excessive CO_2 produces the so-called greenhouse effect which appears to have a Global Warming Effect (GWE) [5]. This GWE of CO_2 shall be discussed later in this chapter.

3.4.1.2 Nitrogen Oxides (NO_x):

There are three main oxides of nitrogen generally known as NO_x and they are [7]:-

a) Nitrous oxide (N_2O) which is produced naturally;

b) Nitric oxide (NO) which is emitted through combustion;

c) Nitrogen dioxide (NO_2) also emitted through combustion.

NO is relatively harmless and it is produced in much larger quantities than NO_2, but it rapidly oxidizes to NO_2. In a busy road or city centre, there is normally twice as much NO than NO_2. NO_2 concentration in city streets is usually less than 1% of the MAC (Maximum Allowable Concentration) i.e. 25ppm for NO and 5ppm for NO_2 for an industrial 8hr exposure. NO_2 is harmful with a strong smell and yellow-brown colour. It is more toxic than NO and has an odour threshold of about 200μg/m^3 [6,7,9,10,51]. The major natural sources for NO_x compounds are organic decomposition in the soil and perhaps in the ocean, and the amount of NO_x that does not react photochemically is normally removed from the air within three days [10].

Approximately 3 million metric tonnes of NO_x are emitted annually (1987) from aviation, a third of which is released in the most sensitive parts of the atmosphere between 9-13kms [20]. From there onwards, they slowly move to the higher and lower altitudes and when they reach near ground levels they normally get washed away by rain within few days. At 10,000m heights, they remain in the air for up to a year. After one year, about 37% of NO_x still remains there and once they reach 12,000m heights, they help breaking down the ozone in the stratosphere [20].

In general, aircraft are only a minor source of worldwide total level of NO_x emissions [46]. They probably make up for less than 2% of global anthropogenic NO_x emissions [19]. In a study by the US-EPA, it was shown that, in 1987, NO_x emissions by aircraft in America were only 25% of those emitted from farm machinery and rail roads [46]. The concern over NO_x is because of the way they affect the Earth's supply of ozone which is concentrated at two levels [46]:-

a) In the stratosphere;
b) Near the ground.

In simple words, there is not enough of it (ozone) higher up, too much of it lower down, and no way to even out the supply. At higher levels ozone is a life saver. It protects the Earth from the Ultraviolet radiation of the sun which harms plants; animals; and humans [7,19,46]. Most modern aircraft do not threaten this protective layer since they fly below the main concentration of ozone [46]. Near the ground, the story is different since aircraft emit more NO_x during <u>takeoff</u> than at any other stage of the flight because of the maximum power needed for the initial climb [19,46].

These ground level NO_x with the help of sunlight react with HCs to form secondary pollutants known as "oxidants" many of which are toxic. These oxidants are detrimental to biological systems, and they can destroy certain materials [51]. Some of these irritating substances (photochemicals) are better known as acrolein; aldehydes; formaldehyde; Peroxyacetyl nitrates (PAN); and possibly the carcinogen PBN (peroxybenzoyl nitrate). Hundreds of chemical reactions take place as long as there is enough supply of HC; NO; NO_2; O_3 (ozone); and sunlight where ozone keeps the oxidising process going [5,7].

NO_x also reacts with HCs and the sunlight to form ozone and smog in the troposphere and in the lower stratosphere. Direct chemical action of ozone at low levels is harmful to the biosphere. Ozone is also a health threat which affects breathing and hurts the eye [19,46]. Smog is a strong oxidant resulting from the formation of ozone and other pollutants in which NO_2 is the main ingredient. Smog damages crops and plants, it cracks rubber and irritates the eye, and most important of all, it reduces visibility causing dangers for aircraft particularly during takeoff and landing [5,7,46,51].

Los Angeles for example is famous for its "photochemical smog formation" because of its clear skies; bright sunlight periods; topography; and heavy traffic flows since it is mainly a motorcar city [51]. Studies of hospital admissions;

respiratory diseases; changes in behaviour; and car related accidents on days with high concentration of oxidants (smog) have also been reported in the Los Angeles area [17]. In the UK and in Europe, although not at Los Angeles levels, it is now widely accepted that concentrations of ozone; PAN; and visibility reducing aerosols may reach high enough levels during sunny summer periods to form smog [18].

Furthermore, nitrogen oxides are acidic and can turn into acid rain although their role in the formation of acid rain is minor. But, since aircraft account for less than 2% of global NO_x emissions (stated earlier), they are probably NOT so important in terms of acid rain [19,46].

The chemicals in NO_x can have direct harmful effect on wildlife; ecosystems; buildings; and structures [19]. Considering the effects of NO_x on human health, little information is available on this subject since NO_x concentration in the air is very low although, they do have adverse effects particularly in the long term [6,51]. So far, the EPA has not yet chosen to regulate emissions of NO_x by aircraft even though environmentalists outside USA are putting on pressure for a reduction in the emissions of NO_x from all sources [46].

3.4.1.3 Carbon Monoxide (CO):

This is a colourless; odourless; tasteless; and lethal gas (at high concentrations) resulting from the incomplete combustion of carbon materials particularly from petrol in internal combustion engines. As much as 80% of the World's CO emission is from motor vehicles (petrol driven) [5], and if this amount were evenly spread over the lower atmosphere, it would increase the CO content in the air by 0.03ppm (parts per million) per year [5]. This increase is very significant because:-

a) CO is a very stable gas and may remain unchanged for several years. For example, in an experiment, a mixture of CO and O (Oxygen) under exposure to sunlight did NOT change even after seven years [5];

b) A carbon monoxide content of 1% in air can be fatal and death from CO poisoning is quite common [7].

Almost one-third of the CO content in the air is from vehicle exhausts [6]. CO concentrations of 10-70mg/m^3 (ppm) are common in busy streets, whereas 120mg/m^3 or more are considered dangerous and it has a tolerance level of 50mg/m^3 for an industrial 8hr period [7]. In addition to vehicle exhausts, CO is found to a large extent in cigarette smoke and can readily oxidise to CO_2 (a product of complete combustion) [7].

The absorption of CO and its reaction with haemoglobin of the blood is dangerous and well known. How much CO is absorbed depends on the CO content of the air; on the length of exposure; and on the individual's activity (e.g. resting or working hard). Apparently, CO has no permanent effects, nor does it cause any severe physical discomfort [6,51]. Although, its effects cannot be totally ignored since a small amount of carboxyl-haemoglobin (COH_b) in the blood may temporarily affect mental ability [52]. This situation however may only occur in still weather in traffic jams, and even then, only if the subject has been working hard for an hour [6,51].

According to Schulte, COH_b levels in the blood below 5% reduce perception, and above 5% the effects are more severe [53]. Table 3.4 shows the effects of COH_b in the blood at various doses. Most people are not usually aware of any discomfort from CO at the existing levels, but, policemen; taxi drivers; traffic wardens; and car park attendants may experience some form of discomfort by spending more time in areas with busy traffic. CO from vehicles is unlikely to be a medical danger unless it has unsuspected synergistic effects. Although, a small number of people may object to CO as they may be particularly susceptible to its minor effects [4,6,51].

CO dissipates quickly otherwise it would be a bigger problem if its levels were increasing (for reasons <u>a</u> and <u>b</u> stated earlier), and there is no evidence that its levels are increasing [6,51]. According to Jaffe, the rate of oxidation of CO in the lower atmosphere is very slow which is a problem

Table 3.4: Effects Of COH_b In The Blood For Different Levels Of CO In The Air (Assuming Full Absorption)

CO Content In The Air (ppm)	Equivalent COH_b In The Blood (%)	Effects On An Average Person
63	10	None
125	20	Tightness across the forehead, possible slight headache, dilation of the cutaneous blood vessels
188	30	Headache and throbbing in the temples
250	40	Severe headache, weakness, dizziness, dimness of vision, nausea, vomiting and collapse
313	50	Same as above, greater possibility of collapse, syncope and increased pulse and respiratory rates
375	60	Syncope, increased pulse rate, coma, intermittent convulsions and Cheyne-Stokes respiration
438	70	Coma, intermittent convulsions, depressed heart action and respiratory rate, and possible death
500	80	Weak pulse, slow respirations, respiratory failure and death within a few hours
563	90	Death in less than an hour
570	90+	Death within a few minutes

Source: Author (Produced and modified from Ref.51)

for its removal [54], and little is really known about the removal of CO from the atmosphere. This deadly and very stable gas can be exterminated by [5,51]:-

a) Eventually escaping into the general atmosphere;

b) Oxidising to CO_2;

c) Being used by the bacteria in the general atmosphere e.g. the soil bacteria.

3.4.1.4 Smoke Or Soot (C):

Very fine "particles of carbon" are emitted from the incomplete combustion of fuel in the form of smoke. Diesel engines particularly have this problem. By itself, smoke is not regarded a health hazard. But, the carbon particles form a haze and absorb sulphur dioxide and nitrogen oxides which may damage the lungs [14,15]. It is now considered that smoke may even be a more important medical problem than has previously been suspected since it contains potentially harmful substances such as pyrene; fluorene; anthracene; coronene; and the carcinogenic 3-4 benzpyrene [4,7].

Unlike other pollutants, smoke is clearly visible and therefore very objectionable to the general public who tend to link it to other pollutants. It is a potential cause of dirt and damage and can be measured with the help of instruments. It usually becomes invisible when mixed and diluted with air. Due to the small size of the particles, in many ways it behaves like a gas with the same penetration power and sticks to the facade of the buildings and does not wash away with rain unless the stone is slightly soluble or very smooth [6,7,51].

Thus, the appearance of the buildings and structures near an airport e.g. hotels; motels; bridges; may deteriorate by the smoke from the road traffic and the aircraft by forming a layer of dirt on surfaces. This deterioration is costly since buildings and structures must be cleaned from time to time. Smoke remains in the air on average for about one or two days, and a decrease in smoke particles in the air increases the number of sunshine hours and visibility which, as stated earlier, is very important for the safe landing and takeoff of aircraft. A good example of this increased visibility in the air is evident in Manchester-UK [7].

3.4.1.5 Hydrocarbons (unburnt fuel) (HC):

Unburnt fuel is emitted into the air from the evaporation of fuel in the fuel tank and the carburettor. The hydrocarbons in the exhaust gases also contain unburnt fuel. The constituents of petrol are not generally toxic but some of them in high doses can have small anaesthetic effects. There are over 100 compounds emitted from the exhaust gases most of which are hydrocarbons. A large proportion of aldehydes are also produced which are irritating to eyes and the respiratory system, and they can be smelt even in very small doses [6,51].

Furthermore, HCs include a number of polynuclear aromatic compounds which remain in the air for some time (as long as twenty years has been suggested). The importance of these compounds is that some of them such as benzpyrene (mentioned earlier) are carcinogenic, and that the extent of health hazard for the proportions of such compounds present in the air needs some investigation. Like NO_x, HCs help in the formation of ozone in the troposphere, but "in global terms", aircraft emit very small amount of HC which is considered to be negligible [5,6,19,51].

The importance of the ground vehicles associated with airports, and their contributions to air pollution were discussed earlier in this chapter. In addition to the large volumes of road traffic that are generated by airports, a large number of ground vehicles are also operated by airlines and they too add to the problem of air pollution. British Airways for example, operates a large fleet of ground vehicles at London Heathrow which increase local air pollution level (see the case study at the end of this chapter). Like aircraft, these ground vehicles also have different emission rates at each stage of their operations (see Table 3.5). From Table 3.5, it is clear that, although diesel engines do not perform the same as petrol engines, but they are much cleaner than petrol engines particularly in HCs.

3.4.1.6 Sulphur Dioxide (SO_2):

During the combustion process, the sulphur in kerosene oxidises to SO_2 which, in the presence of moisture becomes acidic, and is one of the main

Table 3.5: Composition Of Vehicle Exhaust Gases
(in "parts per million" by volume)

Fuel Type	Pollutant	Idling	Accln.	Cruise	Decln.
Petrol	CO	69,000	29,000	27,000	39,000
	HCs	5,300	1,600	1,000	10,000
	NOx	30.0	1,020	650.0	20.0
	Aldehydes	30.0	20.0	10.0	290.0
Diesel	CO	trace	1,000	trace	trace
	HCs	400.0	200.0	100.0	300.0
	NOx	60.0	350.0	240.0	30.0
	Aldehydes	10.0	20.0	10.0	30.0

Source: Ref.16

ingredients of acid rain. It has an important role in atmospheric processes for instance, cloud formation. The sulphur content of kerosene varies, but it is normally around 0.3% by weight. This means that, aircraft's contribution to the total global emission of sulphur is negligible although, no other source injects sulphur directly into the atmosphere at high altitudes [19]. SO_2 is a colourless and extremely irritating substance, and it is particularly harmful to the respiratory system [56].

3.4.1.7 <u>Water (H_2O):</u>

Water is initially emitted in the form of steam from the combustion of hydrocarbon fuels in the jet engines. It will then condense to form water vapour and is mainly involved in the weather processes that take place mostly below 4,000m [20]. According to Egli, water vapour from jet exhaust is more harmful at high altitudes (global effects) than at the lower ones [20]. These high-altitude effects of water will be discussed later in this chapter.

3.4.1.8 Lead Compounds:

The major source of lead pollution from an airport is the ground vehicles on and off the airport. For instance, in 1991, in addition to other airlines, 12% of the British Airways ground fleet alone at London Heathrow used leaded petrol [42]. Lead is added to petrol in order to improve engine performance. A litre of petrol normally contains about 0.4gm of lead, and between 25-50% of this is emitted into the air in the form of lead halide and oxide [6,11]. Lead concentration in typical city streets is about 2-4μg/m^3 which is 20 times or more than in rural areas whereas, the MAC for a 3hr daily exposure to lead is 200μg/m^3 [4,6].

In the UK, some 7,000 tonnes of lead are emitted every year (1981 figures) from petrol engines mostly as fine particles [51]. Studies have shown that, the presence of a motorway interchange with heavy traffic similar to those near London Heathrow increases local lead levels in the air from about 1μg/m^3 to between 2-3μg/m^3 [13]. Other places of heavy traffic such as the Heathrow Tunnel and Car Parks; Cargo Centre; Taxi Ranks and Bus Stations usually have high concentration of lead compounds. Increased levels of lead in the air may cause toxic doses reaching certain food products via biological or food chains. Lead is poisonous, and it enters the body through the mouth and the nose by eating; drinking; and breathing. Far more lead is ingested than inhaled, but inhaled lead is much better absorbed than lead ingested. Lead poisoning is quite common, and disturbance of the gastro-intestinal system known as "lead colic" is the most common form of lead poisoning which includes excessive tiredness; headaches; lack of appetite; nausea; and muscular pains [6,51].

This type of poisoning (lead colic) however, may only occur if the lead level in the blood is over 80µg/100ml of blood. This is not very likely since, studies of lead levels in the blood have shown that, even near a motorway interchange where there is a substantial amount of lead in the air, the blood lead maxima for a group of children and adults did NOT exceed 35µg/100ml (most were much lower), except for a lead worker whose level was 62µg/100ml [12,13]. Lead accumulation in the body even at small doses of 2-3µg/m^3 has a more subtle harmful effect than the type of poisoning described earlier, and its compounds are more likely to affect children by reducing their IQ, as well as affecting their performance and behaviour [7,51].

3.4.1.9 Other Particulate Matter:

Particulate matter is any solid or liquid material smaller than 500 microns (µ) and dispersed in the air. An average annual particulate matter concentration of 75µg/m^3 may have the same adverse effect on human health as a maximum 24hr level of 260µg/m^3, if it occurred only once a year [57]. In addition to exhaust gases, other particulates include rubber lining and asbestos dust from the brake linings and the clutch plates [6,51]. Rubber lining and asbestos dust are common with ground vehicles and with aircraft particularly at touch-down.

The number of aircraft movements (take offs and landings), and the landing gear arrangement (i.e. No. of wheels) also contribute to the extent of such pollution. Extensive exposure to asbestos dust is harmful and causes asbestosis which may be carcinogenic. For the time being, the amount of asbestos dust and rubber lining that is produced by aircraft during takeoff and landing is too small to be a health hazard [6,51], but the growing demand for air travel and expansion of the existing airports may, through increasing air and particularly road traffic, rise such pollution to high local levels.

3.4.2 Global Effects:

In global terms, aircraft emissions are relatively small in proportion compared to other sources [3.1]. The importance rises from emissions at high altitudes because, as mentioned earlier, as much as 80-90% of aircraft emissions take place at cruising altitudes (10-12kms) [3.3]. In the upper atmosphere, aircraft emissions do NOT behave uniformly and they may have a non-linear effect. For example, the effect of NO_x on the production of ozone will NOT double with every doubling of NO_x emission, and this non-linearity can produce large errors in atmospheric modelling [19]. Some of the more important global effects of aircraft emissions are discussed below.

Considering aircraft in general are not big polluters, they may however have a "possible significant impact" on the global warming especially with regards to CO_2. In 1990, approximately 604mt of CO_2 were emitted by aircraft worldwide which makes up for 2.3% of the total anthropogenic CO_2 emissions [19]. The concern over CO_2 is that, it remains in the air for at least several centuries, and has a direct Global Warming Potential (GWP) [8,19]. The increase of CO_2 in the air produces a greenhouse effect [3.4.1.1] which may increase global temperatures by 1 or 2^0C if the CO_2 level is doubled [7]. Also, if the use of combustion processes from all sources continues to rise at the current rate, this temperature rise is likely to occur before the mid 21st century [7]. As with aircraft, based on 1990 figures, about 1.3% of the future global warming caused by anthropogenic emissions of CO_2 alone, may be from aircraft [19].

In addition to CO_2, aircraft emissions are likely to increase both the NO_x and the water content in the stratosphere considerably. Since the concentration of NO_x and water in the stratosphere is extremely low (water being almost non-existent), this increase may therefore alter the "natural balance" of atmospheric processes [7,19]. For example, estimates show that, a fleet of 500 supersonic jets flying for 7hrs/day at altitudes of up to 20kms, may increase stratospheric water by some 10%, and up to 60% in some regions with significant addition to some particulates such as soot and sulphates [19]. These estimates however, <u>do NOT specify</u> the <u>time period</u> (i.e. <u>number</u> of days, weeks, months) over which this increase in the stratospheric water takes place.

Increased water content in the air may increase humidity especially along the flight corridors where there is more traffic. According to Held, an aircraft flying at 12kms altitude, increases humidity by 40% in a corridor 150m high and 1km wide [24]. Such an increase may produce clouds unless rapid dispersion of water took place [19]. At high altitudes i.e. 9,000m and above, the air is usually very cold (between -40 to -80^{0}C). At such low temperatures, the water vapour emitted from aircraft freezes and turns into ice crystals. These ice crystals will later turn into artificial clouds known as "<u>cirrus clouds</u>" [20]. Therefore, assuming 5,000 aircraft are in the air with an average speed of 800km/hr, and 50% making contrails which last on average for about 2 hours over a width of 1km, the total amount of contrails will then be:-

$$\underline{5{,}000 \times 800 \times 0.5 \times 2 \times 1 = 4{,}000{,}000\text{km}^2}$$

i.e. an area almost 10 times the size of England. Dividing this figure by the area of the region in which most of these aircraft are operating, we find an 8-16% increase in the cirrus clouds in the North American-Atlantic-Europe area, or about one twentieth of this (0.4-0.8%) for the world [49]. This is "NOT negligible" since, calculations have shown that, a 2% increase in the cirrus clouds, increases the Earth's temperature by 1^0C [20].

Considering NO_x, it turns into ozone in the lower stratosphere [3.4.1.2] where ozone absorbs the heat radiation from the Earth. Since the heat from the ground is reflected back to the Earth [20], the ozone formed in this way may therefore add to the global warming and cancel out any reduction in warming from the removal of methane (CH_4) [23]. Methane, which has a high GWP is reduced (by about 1%) by the hydroxyl atoms that are produced by NO_x [23]. NO_x also helps the removal of chlorine gas (Cl_2) which reduces ozone (O_3) to oxygen (O_2) and is a problem in the stratosphere. The removal of both Cl_2 and CH_4 probably do not significantly alter the overall warming effect of the additional ozone [19].

At higher altitudes (15kms or more), No_x destroys ozone and this is important since, as mentioned before, ozone protects the Earth from the damaging Ultraviolet radiation of the sun [3.4.1.2]. It is therefore clear that, the effect of NO_x in the atmosphere changes with altitude, and in both cases (i.e. at low and high altitudes), the effect is detrimental. It is, however, worth mentioning that, only the supersonic aircraft such as Concorde fly at such high altitudes (15-20kms), and since they have a very small share of the market compared to the subsonic share, their impact on the high altitude (stratospheric) ozone is not that significant [7,19].

At high altitudes, NO_x also reacts with the water vapour in the atmosphere to form nitric acid (HNO_3) which will then crystallise and turn into nitric acid clouds in the polar stratosphere where the temperature is about -80^{0}C (i.e. at 12 to 22kms altitudes). These nitric acid clouds, like those produced by the water vapour mentioned earlier, also help break down the so-called "<u>ozone layer</u>" mainly in the polar regions, and this is how the well-known "<u>ozone hole</u>" is formed [20]. In this process, the water vapour (ice crystals) <u>increases</u> the rate of ozone destruction by NO_x, and this shows the importance of water vapour in the formation of ozone holes. Since, indirectly, ozone is vital for the continuation to life, over the recent years, protection of the ozone layer has become vitally important [7,19].

In terms of ozone formation and global warming, Johnson and Henshaw suggest that, the GWP of NO_x from aircraft at high altitudes is <u>50 times greater</u> than that at ground level [23]. This is because most of the ozone forms at cruise altitude where it has maximum effect. Like CO_2, ozone has a high GWP, and as much as 10-20% of the tropospheric ozone may be from aircraft [19]. For instance, according to a 1990 "estimate", aircraft may contribute between 28% and 4.6% to the total global warming over 20 to 500 years time respectively [19,23]. These figures indicate that, the effect of aircraft emissions <u>decreases</u> as they (gases) stay <u>longer</u> in the air.

Also, the warming effect of aircraft emissions is "<u>probably</u>" greater at mid-northern latitudes (30^0-60^0 North) because of the heavy Euro-American-North Atlantic routes (see 3.3 before) although, according to Johnson, NO_x emission has a greater "<u>proportionate effect</u>" in the Southern hemisphere because of the differences in the atmospheric circulation [23]. As for the total global warming effect of aircraft emissions, Johnson and Henshaw also estimated that aircraft will be responsible for 0.01^0C of the total global warming between 1990 and the year 2000 [23].

Nowadays, the subject of global warming is causing great concern particularly with regards to the rising water levels. In the South Pacific for example, villages and islands may be entirely destroyed from the rising water level caused by global warming. People living in these villages may be severely affected by losing their home; land; and property [30]. Having discussed the main impacts of atmospheric pollution related to airports, it seems appropriate to briefly discuss other aspects of air pollution.

3.4.3 <u>Health Effects:</u>

Another important aspect of atmospheric pollution is the health effects some of which are discussed below. For example, construction of an airport involves extensive amounts of earth works and excavation during which, inhaling dust and other particles by the workers and nearby residents may cause pneumoconiosis that includes silicosis i.e. a progressive inflammation of the lungs which once they react to the common substance silica apparently cannot be arrested; asbestosis; and other forms of reticulinosis in which particles destroy many times their volume of lung [7].

The amount of damage caused to a person depends on the concentration of a gas or a particle, and on the exposure time. Some gases such as "smoke" or SO_2, have a more synergistic effect than when they act individually. As for SO_2, it penetrates more effectively than other gases, and high concentrations of SO_2 "alone" may not be capable of causing disease. Particles larger than 2µm in size are unlikely to penetrate the body's biological defences in order to reach the lungs [5,7].

As mentioned in the earlier sections, illnesses such as sore throats; eye and nose irritation; respiratory tract; headaches; breathlessness; vomiting; lack of appetite; and nausea are commonly related to air pollution. More serious illnesses such as asthma; tuberculosis; chronic interstitial pneumonia; bronchitis; and emphysema that are normally associated together are all forms of chronic respiratory diseases causing breathlessness. In such cases, the heart works harder to obtain oxygen supply and this puts more strain on the Cardiorespiratory System which may result in a cardiovascular death [5]. Lung cancer too is another fatal disease that may develop from polluted air through HCs. Although lung cancer is to a large extent smoking related, but scientists believe that some cases may develop from polluted air [5,28].

Atmospheric pollution given the right conditions can be fatal. For instance, the infamous 1952 smog disaster of London killed 4,000 people and increased deaths from bronchitis by a factor of 10, influenza by 7, pneumonia by 5, tuberculosis by 4.5, respiratory diseases by 6, heart diseases by 3, and lung cancer by 2 [31]. The problem with air pollution is not only the immediate effects, but the secondary and long-term chronic effects that are equally harmful. For example, skin related diseases some of which may cause skin cancer have been developed in the past through poor air quality [27].

Recent scientific findings have caused public concern about the risk of skin cancer from ozone depletion that is now occurring in mid-latitudes, and is extending from the winter into the summer months [29]. In 1992, COMARE (Committee on Medical Aspects of Radiation in the Environment - UK) reported a recent 50% increase in the incidence of malignant melanoma in England and Wales. A total of 1,827 cases were recorded in 1980, rising to 2,635 in 1986. The more common but seldom fatal forms of cancer grouped as non-melanotic skin cancers increased from 19,000 to over 25,000 cases in the same period [29].

The committee therefore believes that, there is sufficient evidence to show that the incidence of skin cancer is related to exposure to UV radiation caused by ozone depletion, and that the relationship between UV exposure and malignant melanoma needs more investigation. As a result, in 1992, the National Radiological Protection Board was operating three UV monitoring stations in order to establish a more comprehensive monitoring network across the country [29].

3.4.4 Climatic Effects:

Atmospheric pollution reduces the amount of sunlight considerably which can be noticed by comparing a clear with an unclear day. On average, polluted city atmospheres receive 10 to 20% less sunlight than their surrounding rural areas 10-20kms outside, and in the UK, it is estimated that 25-55% of daylight is lost through smoke alone from November to March (winter months) [5,7,55]. The UV radiation is also lost by about 5% in the summer and 30% in the winter whereas, in the UK, on the gloomier winter days as much as 90% of all radiation is lost [7,32]. Lack of sunlight and UV radiation which are essential in the production of "Vitamin D" in the human body may cause general ill-health; tuberculosis; and rickets disease (bowlegged and pigeon-breasted) which at one time was very common in the smoky industrial Midlands of the UK [5,7].

Air pollution also produces fog and smoke which always produce the poorest visibility. Poor visibility is a danger to the landing of aircraft since they require a 1km clear visibility before touch-down [7]. In general, high levels of air pollution reduce visibility and vice-versa. For example, a measurement for Cincinnati-USA showed observed visibilities of about 16; 9; and 6kms corresponding to a 100; 200; and 300μg/m^3 of a particulate pollutant respectively [33]. The build up and congestion of heavy traffic near airports is therefore hazardous with respect to fog (winter in particular), and this may be another reason why airports are located well outside city boundaries.

Air pollution affects the climate locally; regionally; and globally. Local effects are usually sensed readily, whereas global effects are more disguised. On the global scale for example, a 1% decrease in solar radiation could reduce the mean annual temperature of the Earth by about 0.8°C (1.4°F) [34]. This reduction may seem very little until one realizes that, the last ice-age was brought about by a temperature drop of only 2-3°C (4-5°F) [5].

3.4.5 Effects On Vegetation:

The effects of atmospheric pollution on vegetation are yet another matter. Smoke for instance is particularly harmful to plants, and in some cases they are destroyed. Some plants such as radishes for example lose between 50 to 90% of their growth in a polluted atmosphere, and others such as cotton; beans; lettuce; tomatoes; grapes; citrus; and several pine species are particularly susceptible to smog damage [5,7]. Research in Canada for example has shown that, lucerne (a plant similar to clover used for feeding animals) was injured by as little as 0.3ppm; barley by 0.8ppm of SO_2 concentration; and with over 1ppm, large proportions of the foliage and fruit were destroyed [7]. In areas with high levels of pollutants especially with SO_2, immunity can also develop since, experiments in Liverpool have shown that there is a strain of rye grass which has adjusted to the high levels of SO_2 and has thrived [7].

3.4.6 Economic Effects:

Air pollution in general has many adverse economic effects. The following examples although NOT directly airport related, do demonstrate the economic costs of atmospheric pollution "in general" some of which "may" well have risen "indirectly" from an airport. After the 1952 London disaster, the Beaver Report of 1954 estimated a total economic loss from air pollution of £250m/year which includes neither the health costs nor the estimated loss of 50 million working days through illness and deficiency [35]. Assuming the population of UK was 40 million at that time, this means a cost of over £6.0/head/annum. The cost items are usually laundry; painting and decorating; cleaning and depreciation of buildings and structures other than houses; corrosion of metals; damage to textiles and other goods.

In terms of the national economy, the total economic losses to the UK from air pollution in 1972 was nearly £410m. Costs associated with social health and amenity were as much as £1,200m i.e. £21/head of population [7]. Similarly, in the USA, the total cost of air pollution in 1966 was estimated to be between $2-12bn/year depending on what is included in the estimates [36]. Although health costs are not usually included in such estimates, they do however, inflict the biggest cost on the economy. For instance, in 1951, chronic bronchitis caused the loss of 26.6 million working days amongst the insured population of the UK [5]. Assuming that average earnings were £4.0 per day at the time, the total loss would then be £106.4m, and if, 20% were directly caused by air pollution, then the loss would still be high i.e. over £21m. In 1992, there were 500,000 children suffering from air pollution related asthma resulting in the loss of 2.5 million school days in the United Kingdom alone [37].

With regards to agriculture, in 1951, an ozone related leaf spot disease hit the tobacco growers in Connecticut-USA, and in 1957, the Connecticut farmers lost an estimated $1m worth of cigar wrapper leaf. Whether or not these incidents have been related, there is a strong possibility that the latter may have resulted from the former. Also, in 1959, a single smog weekend resulted in the loss of $6m [39], and in 1968, the total damage to crops from air pollution in the USA was estimated to be $500m per year a quarter of which is paid by the smog-ridden California alone [40].

So far as buildings and properties are concerned, studies in St.Louis-USA (1967) showed a drop of $245 in house values for every increase of 0.5mg of SO_3/100cm^2/day [38]. Also, in 1979 the London Boroughs Association estimated that they were spending over £1m/year to repair damage to buildings in Central London caused by "acid rain". Today however, this figure is much higher because of inflation and traffic growth [7].

Considering transportation, "extra" costs from air pollution are inevitable. Fog related traffic delays; flight cancellations; accidents; and the employing of extra personnel are only a few examples of such additional costs. For instance, according to the British Transport Commission, a foggy day costs them approximately an "extra" £2,500 (1972 figures) to pay for extra personnel [5]. Similarly, in 1958, the British European Airways lost about £200,000 within three months from flight cancellations caused by thick fog [5]. The above paragraphs clearly show the economic disadvantages of air pollution.

3.5 Air Pollution Reduction:

There are several ways to reduce air pollution from an airport and these are discussed below. With regards to the ground vehicles, the use of unleaded petrol on and off the airport is very effective in reducing lead levels particularly near airports where there are generally large volumes of road traffic. For example, the

British Airways ground transport at London Heathrow for their 1991-92 commercial; management; and sales vehicles away from the Airport used 81% unleaded and 19% leaded for their "petrol only" vehicles [42]. Today, almost every "new" vehicle uses unleaded petrol although a large number still use leaded especially the older ones. The use of new vehicles and their regular maintenance therefore reduce the overall air pollution.

On the land-side, a good and effective public transport system feeding the airport particularly rail reduces air pollution considerably near airports. Access and egress to the airports should be provided more by means of rails wherever possible than by roads in order to reduce air pollution. A well-planned and comprehensive traffic management scheme that minimises traffic congestion and delays near airports effectively reduces air pollution in the nearby areas. For instance, by restricting the use of certain routes and by diverting the traffic away from residential areas in order to create a free-flow condition especially at peak hours, further reductions in air pollution can be achieved.

The building of access roads in order to avoid bottlenecks and unnecessary stops by the road traffic near airports is also useful in reducing local air pollution levels. Wherever possible, car parks; heating or power plants; and other sources of air pollution should be separated and located downwind from locations accessible to the general public [56]. Expensive parking charges at the airports may also discourage the use of private vehicles and reduce air pollution. The placing of roads in cuttings is also effective. For example, in 1983, the TRRL (see glossary) in a study of atmospheric pollution from vehicle emissions near the tunnel portal at London Heathrow, concluded that, the level of pollutants measured at ground level near the cutting (i.e. a 7m deep cutting into which the highway runs) were lower than expected. This indicates that, placing roads in cuttings reduces pollution levels in the surrounding areas [44].

On the air-side, good siting and proper planning of airports by suitably locating them 20-30kms away from towns and cities and by providing buffer zones between the airports and the communities help reduce air pollution in the local areas. In the planning stage however, considerations must be given to wind forces and directions; topography; proximity to the city; local climate; and other important variables. The proper design and construction and the correct use of airfields (runways; taxi ways; aprons) in order to reduce congestion; taxiing; and idling times help reduce aircraft emissions at ground level. Reducing taxiing time is particularly important since exhaust gases are largely emitted during taxiing [26].

Emission control of sources (e.g. heat and power) in the airport infrastructure also reduces air pollution. One way to control emissions is by using modern equipment. For example, in 1993, Manchester Airport installed a new Combined Heat and Power station (CHP) for its terminal 2 project which is the first of its kind at a UK airport, and, it is estimated that this new facility will emit 50,000 tonnes less CO_2 and SO_2 per year into the atmosphere compared to the amount emitted by the old system [45,58].

So far as aircraft themselves are concerned, the use of new technology in designing new improved engines helps reduce air pollution. New advanced designs for instance have reduced emissions from the first fan-jets of the 1960s to the more recent high by-pass fan types where a 40% reduction in the weight of the pollutants per unit weight of fuel "burnt" has been achieved [26]. New designs should emphasise more on reducing current emission rates, and at the same time, maintaining the required power and fuel efficiency. For example, the new GE90 which is one of the world's largest and most powerful engines is designed to emit 33% less NO_x per passenger mile [46].

Like noise, legislation concerning ambient air quality, and the setting of standards on emission levels by both airport and airline operators also helps to reduce air pollution. Currently, some countries are beginning to use standards recommended by ICAO around 1980 concerning emission levels at takeoff. Sweden has gone even further by taxing the airlines on emissions in all phases of flight. Some engine manufacturers such as GE (General Electric); Boeing; and CFM International meet all current standards for air pollution [46].

The proper operation of aircraft and the correct flight management by the pilots on and off the ground also help reduce emission levels. For instance, improving the ground manoeuvring techniques OR reducing the number of engines during taxiing help reduce emission levels although, it is doubtful that taxiing on a reduced number of engines is actually a feasible method of reducing air pollution [26]. Engine conditions (old or new) and their regular maintenance are other important factors in reducing aircraft emissions.

As with noise, air pollution too is a big problem with supersonic aircraft. Concorde for example, pollutes the air five times more than the subsonic aircraft especially with NO_x. Reducing the number of supersonic flights therefore reduces air pollution, and if fuel is injected in a special way, less amount of pollutants will be emitted from the aircraft [43].

3.6 Emissions From British Airways Fleet - A Case Study:

3.6.1 Emissions In The Air:

In 1991-92, British Airways (BA) flying operations produced some 12 million tonnes of CO_2 per annum [42]. Tables 3.6 and 3.7 show emissions from the worldwide flying operations of BA and the Caledonian Airways fleet.

Table 3.6: British Airways Emissions From Worldwide Flying Operations

	Total tonnes per year		Passengers (g/ASK)		Freight (g/ATK)	
	89-90	90-91	89-90	90-91	89-90	90-91
Fuel	3,490,000	3,560,000	38.0	38.0	272.0	268.0
CO_2	10,760,000	10,980,000	118.0	118.0	839.0	827.0
H_2O	4,860,000	4,960,000	53.0	53.0	379.0	374.0
Unburnt HCs	6,400	6,470	0	0	1.0	0
CO	40,800	15,700	0	0	1.0	1.0
NO_x	n/a	40,200	n/a	0	n/a	3.0
SO_2	20,900	21,300	0	0	2.0	2.0

__Note:__ values do __NOT__ include Concorde, auxiliary power units, ground running and fuel jettisoning.
Source: Internal British Airways Data and Warren Spring Lab. 1992, (Ref.42).

Table 3.7: Caledonian Airways Emissions From Worldwide Flying Operations

	1989 - 90 tonnes per year	1990 - 91 tonnes per year
Fuel	54,000	54,700
Carbon dioxide	165,000	169,000
Water	75,200	76,600
Hydrocarbons	270.0	224.0
Carbon monoxide	739.0	580.0
Nitrogen oxides	642.0	n/a
Sulphur dioxide	324.0	330.0

Source: Internal British Airways Data and Warren Spring Lab., 1992, (Ref.42).

3.6.2 Emissions On The Ground:

In 1991, BA used about 6,000 ground equipment vehicles at Heathrow of which, 2,255 were NOT fuelled, and the remaining vehicles produced altogether approximately 345 tonnes of CO_x (Oxides of Carbon) and 630 tonnes of HCs which made up for about 2% and 8% of the CO_x and HCs emitted by the entire (worldwide) BA's flying operations respectively (see Table 3.8) [42]. These figures should be compared with the overall fuel consumption of the HC fuelled vehicles which emit some 20,000 tonnes of CO_2 per year, i.e. less than 0.2% of the emissions from the aircraft fleet. The amount of CO_2 emitted in generating power for the electric vehicle fleet would not significantly alter this figure [42].

3.6.3 Fuel Jettisoning:

Occasionally when an emergency landing situation occurs, the aircraft may have to dump some quantity of fuel in order to reduce their weight to a safe landing weight. This dumping OR jettisoning of the excess fuel, may cause a severe HC pollution, and it is a decision made by the pilot. Such action cannot be banned since, in the emergency cases, it is an absolute requirement in reducing the landing weight for safety reasons. The safe landing weight for many aircraft does NOT require fuel jettisoning as they may not be equipped to carry out such an operation [42].

Fuel jettisoning for any other reason than an emergency needs

Table 3.8: British Airways Ground Transport At Heathrow (Fuel, Energy, And Emissions) 1990-91

Vehicle Type	1*	2*	3*	4*	5*	6*	
Fuel Used	Gasoil	Dsl.	Petrol Leaded	Petrol Unld.	Elec.	Unfld.	Total
No.of vehicles	1,415	125	683.0	556.0	659.0	2,255	5,693
% of fleet	25.0	2.0	12.0	9.0	12.0	39.0	
Tonnes of fuel used	3,645	492	442.0	759.0			
Fleet bulk fuel consumption (%)	68.0	9.0	8.0	15.0			
Ave. engine size (lit.)	5.10	5.40	1.50	1.80			
Specific fuel consumption (g/MJ)	64.0	64.0	n/a	n/a			
Energy input/m (MJ/m)	125.0	133	6.80	8.50			
Energy input/hr (MJ/hr)	760.0	814	n/a	n/a			
Emission Factors (g/MJ)							
NO_x	4.0	4.0	0.23	0.23			
CO	2.4	2.4	4.68	4.68			
HC	0.6	0.6	0.55	0.55			
Emission Quantities (tonnes per year)							
NO_x	230.0	30.7	3.40	5.80			270.0
CO_x	138.0	18.4	69.5	119.5			345.0
HCs	346.0	46.0	87.6	151.0			631.0

** See overleaf for vehicle types*

__Note:__ Emissions data derived from development and engine manufacturers and Warren Spring Lab. Reports.

Source: British Airways (Ref.42)

* *Vehicle Type-Examples (from Table 3.8):-*

1 Airside diesel equipment e.g. tugs, crew coaches, minibuses and landrovers.*
2 Taxed, landside diesel vehicles, passenger coaches and cars.*
3 Petrol powered cars and light commercial vehicles.*
4 Light commercial vehicles and management cars.*
5 Baggage trucks, fork-lifts, pallet movers, and floor cleaners.*
6 Baggage trailers, tow bars and wheelchairs.*

authorization from the Flight Management, and there were no such cases (other than emergency) for BA during 1990-91. Safety precautions must be taken when jettisoning fuel, and details of how to undertake such operation are usually available in the operating manuals. The time; the place; and the estimated quantity of fuel for each incident must be entered in the Flight Crew Report. Table 3.9 shows BA's recent fuel jettisoning incidents in which, the 63 recorded cases have resulted from the entire (worldwide) BA fleet of over 250,000 flights per annum [42].

3.7 Worldwide Emissions From The Aviation Industry:

The amount of gases emitted by the aviation industry worldwide and their environmental effects are shown in Table 3.10.

3.8 Conclusions:

Atmospheric pollution is a worldwide problem a third (33%) of which in 1992, was from the USA alone [41]. As cities expand and air travel increases, airports also expand with them. For instance, Manchester International has

Table 3.9: BA's Overall Fuel Jettisoning Incidents

Date	Estimated Qty. (tonnes)	Number Of Incidents	Number Of Incidents (no qty. available)
Aug 1990	n/a	-	4
Sep 1990	n/a	-	6
Oct 1990	14.0	1	3
Nov 1990	146.0	3	0
Dec 1990	137.0	2	1
Jan 1991	136.0	4	0
Feb 1991	141.0	3	0
Mar 1991	221.0	6	0
Apr 1991	87.0	2	3
May 1991	10.0	1	1
Jun 1991	121.0	2	2
Jul 1991	57.0	2	0
Aug 1991	20.0	1	0
Sep 1991	83.0	2	2
Oct 1991	157.0	5	1
Nov 1991	112.0	4	0
Dec 1991	107.0	2	0
Total	1,549	40	23

Source: Internal British Airways Data (Ref.42).

Table 3.10: "<u>Estimated</u>" Worldwide Emissions From The Aviation Industry (1991-92)

Emission	Environmental Effects	Approximate Emissions (millions of tonnes)	
		Commercial Aviation	Worldwide (fossil fuels)
NO_x	Acid rain, ozone formation at cruise altitudes, low level smog and ozone	1.6	69 (1)
HCs	Low level smog and ozone	0.4	57 (1)
CO	Toxic	0.9	193 (1)
CO_2	Stable, Greenhouse effect by absorbing and reflecting infrared radiation	500-600	20,000 (2)
SO_2	Acid rain	1.1	110 (1)
H_2O	Greenhouse effect by absorbing and reflecting infrared radiation	200-300	7,900 (2)
Smoke	Nuisance, effects depend on composition	negligible	n/a

(1) OECD Secretariat estimates (for 1980), from OECD Environmental Data 1989.

(2) Derived from BP Statistical Review of Energy, 1991.

<u>*Note:*</u> *a) Aviation figures from AEA estimates except for* NO_x *(Egli, Chimia 44, 369-371, 1990).*

b) Other emissions, mainly from paints and cleaning solvents are associated with aircraft maintenance and also from ground transport supporting the airline's operation.

Source: Ref.42

built a second terminal and London Heathrow is planning for a second runway and a fifth terminal. A second International Airport is also under construction at Tehran to meet the extra demand in air travel. Increased air traffic and larger planes create more congestion and in-line queuing both on the ground and within the airports waiting corridors which is a waste of fuel energy, passengers time and money, and the public's air.

In general, growth in aviation, will increase air pollution from airports. Therefore, the busier an airport, the greater is its resulting air pollution. Even at the busiest airports, most of the air pollution and the adverse "local" air quality is from the "ground vehicles" and NOT from the aircraft emissions. This is because, private cars; taxis; buses and coaches; lorries and freight transport emit much larger quantities of gases than the airliners. For instance, in 1983, a detailed study of air quality near Gatwick Airport (UK) concluded that, the Airport did NOT significantly contribute more to the ground-level concentrations of air pollutants than other sources in the surrounding area, and, that the possible sources of NO and CO over and above the background levels in the area were from the Airport's car parks and the associated minor roads [47].

Air pollution from an airport affects the local; regional; and the global environments. Furthermore, aircraft emissions have a more serious and long-term effect at high altitudes than at the ground levels. Also, in spite of the fact that the aviation industry contributes <u>very little</u> (1-2%) to the <u>overall global warming</u>, it is becoming more alarming because of the growth in the aviation industry and the likely increase in the future.

Expensive air fares (less travelling); higher load factors; higher fuel prices; fuel replacement; <u>more use of the rail transportation</u> particularly over short to medium range distances (see Chapter 2); the use of new advanced telecommunication systems so as to avoid flying for business meetings and conferences (see Chapter 2); and a change in the overall human attitude by <u>respecting</u> the environment are all the positive steps for reducing levels of atmospheric pollution.

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Chapter 4

The Economic Impact

4.1 Introduction:

Airports in general are centres which generate large sums of money into the local; regional; and national economy through various activities such as sales of goods and duty-free; post offices; car hire; car parking; shops; restaurants and bars; fuel stations; freight forwarders; coach; rail; and taxi operators; leisure flying; banking; insurance; hotels; entertainment; warehousing; air cargo and air mail handling. In general, the bigger and busier an airport, the larger is the amount of revenue generated.

Large international airports usually have substantial amounts of commercial activities. For example, at Amsterdam Schiphol Airport, 25% of all passengers passing through the Airport in 1984 made use of the shopping facilities. And, the duty-free area at London Heathrow in 1980 generated a turnover of $60,000/m^2 compared with the $15,000/m^2 for the world's most successful department store [4]. The main source of income at airports other than commercial activities is from landing and takeoff fees; aircraft parking charges; airport taxes or passenger charges; aircraft servicing and maintenance charges; training; and other services [4].

The economic worth of an airport to its local and regional industries such as employment; exports and imports; aircraft manufacturing; airline and airport operators; tourism; air travel (business and holiday); and other related services (see earlier) is immense. For this reason, some airports are regarded as national assets. London Heathrow for example is acknowledged as a national asset to the UK's economy [1]. This is because, in 1991, the Airport employed over 50,000 people; handled 1,000 flights per day; plus 600,000 tonnes of cargo; and 5,000,000 consignments per year [48].

Such scales of activities help the UK's economy and the balance of payments significantly. Considering passenger and cargo traffic, they are, probably the two most beneficial activities resulting from operating an airport. For instance, the tourist industry in countries such as Greece; Spain; and Portugal is the largest source of foreign exchange [4]. The export and import of goods by air is also growing rapidly which boosts the overall economy. This chapter will discuss the main and most important economic benefits that may result from building and operating an airport.

4.2 Employment:

One of the most important economic impacts of an airport is the number of jobs created. Depending on their size (domestic/international); capacity; type (scheduled; charter; general aviation); and their level of activities, airports are generally a major source of employment and their services are labour intensive. Large intercontinental airports such as Heathrow; LAX (Los Angeles Int.); and

Frankfurt where activities are high have immense economic impact [Chap.1].

At Heathrow for example, in 1991, more than 77,000 people were directly or indirectly employed by the Airport [20]. And, in 1990, a study carried out by Liverpool Polytechnic revealed that if the existing Airport at Liverpool were to expand and become "a major international airport" with all the necessary facilities such as additional terminal buildings and runways; hangars and maintenance areas; cargo centres; shops; restaurants and bars; car parks and fuel stations; and the supporting road and rail links, up to 200,000 jobs would be created [13].

This figure, although it is much higher than the number employed by Heathrow, it includes the direct; indirect; and tertiary jobs that will be created before; during; and after construction (see 4.2.1 below - Types Of Employment) with a multiplier effect (see 4.2.3 later - The Multiplier Effect). This is because, jobs related to airports vary according to their type; location (on-site/off-site); duration; and the stage of time i.e. before; during; and after construction. The types and nature of employment related to airports are discussed below.

4.2.1 Types Of Employment:

Depending on its size, the construction and operation of an airport is a huge task involving many different skills and professions. Some airports including their rail and road links may take up to ten years to build. These jobs vary from short term to long term; skilled to semi and non-skilled; local to regional and national; direct to indirect and induced. Employment is mainly in three stages:-

A) <u>Before construction</u> involving planners; engineers; designers; architects and landscape architects for planning; feasibility studies; and designing the facilities. These jobs are skilled; short-term; local to regional and national; and sometimes international;

B) <u>During construction</u> involving contractors; sub-contractors; builders; civil; mechanical; electrical; electronic and hi-tech engineers and consultants. These jobs are skilled to semi-skilled; short to medium term; local to regional; national; and occasionally international;

C) <u>After construction</u> involving airport and airline operators; cargo handlers; security; police; firemen; doctors and nurses; ambulances; Government departments; transport (rail/road) operators and other commercial services e.g. banks; shops; restaurants; and car parks. These jobs vary from skilled to semi and non-skilled, and they are usually long-term; local; regional; and sometimes national. Skilled jobs in particular, may sometimes be less available within the area as there may be a shortage of skilled employees within the airport region.

The most important stage of employment is the jobs created after the construction of an airport. These jobs are usually long-term and permanent, and they are an important source of income in both the local and regional economy. These jobs are classified as:-

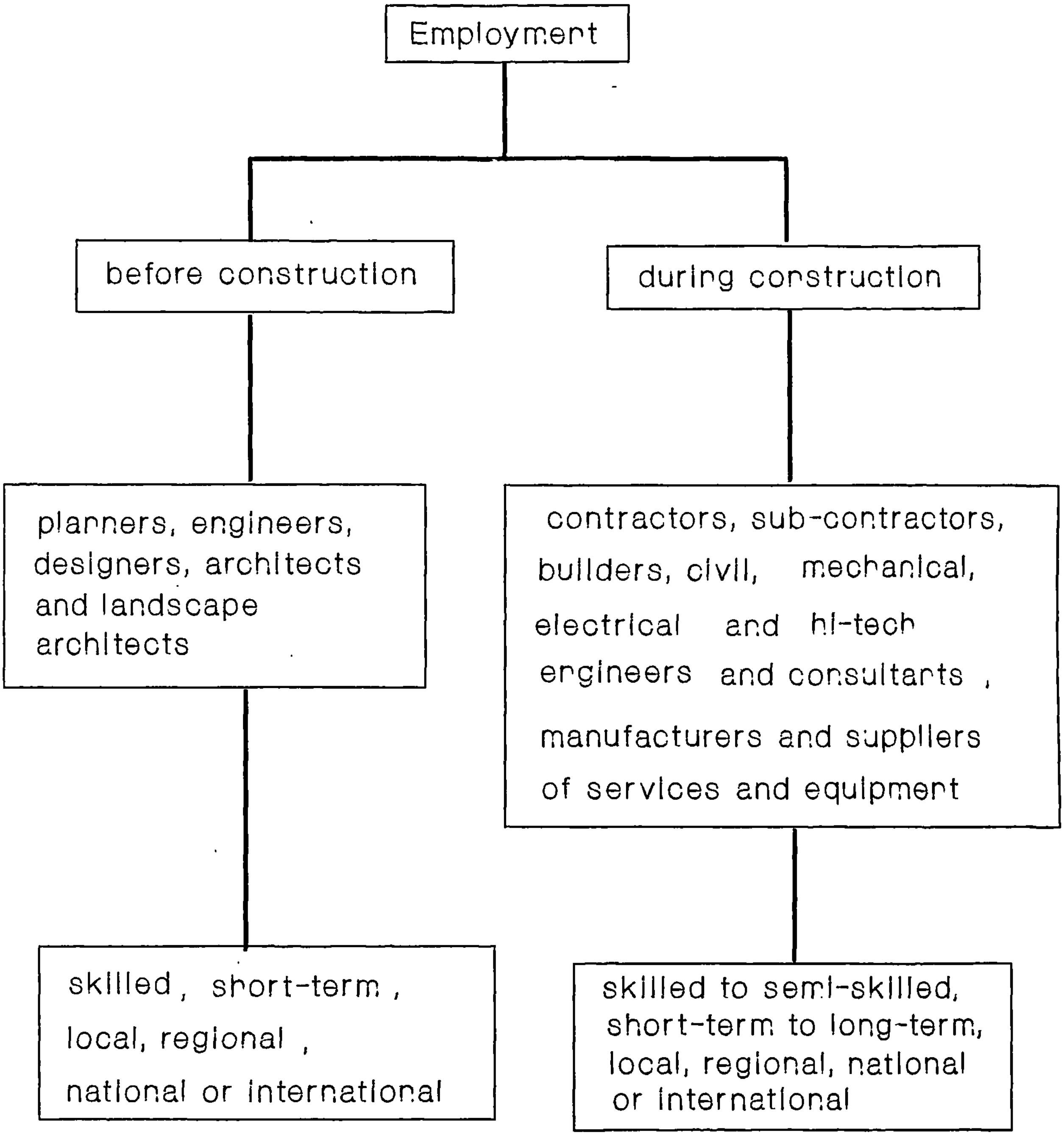
a) Direct or primary i.e. jobs that are directly involved in the aviation side of the airport for example ATCs; pilots; and ground engineers;

b) Indirect or secondary i.e. jobs that are involved in the non-aviation side, but are created to serve the airport; the airlines; and the passengers for example airline operators; banks; and shops;

c) Induced or tertiary i.e. jobs that are created to serve the needs of those who are directly OR indirectly dependent on (families included) the airport for example laundries; grocery stores and supermarkets. These are the jobs that would not have otherwise occurred had the airport not been there.

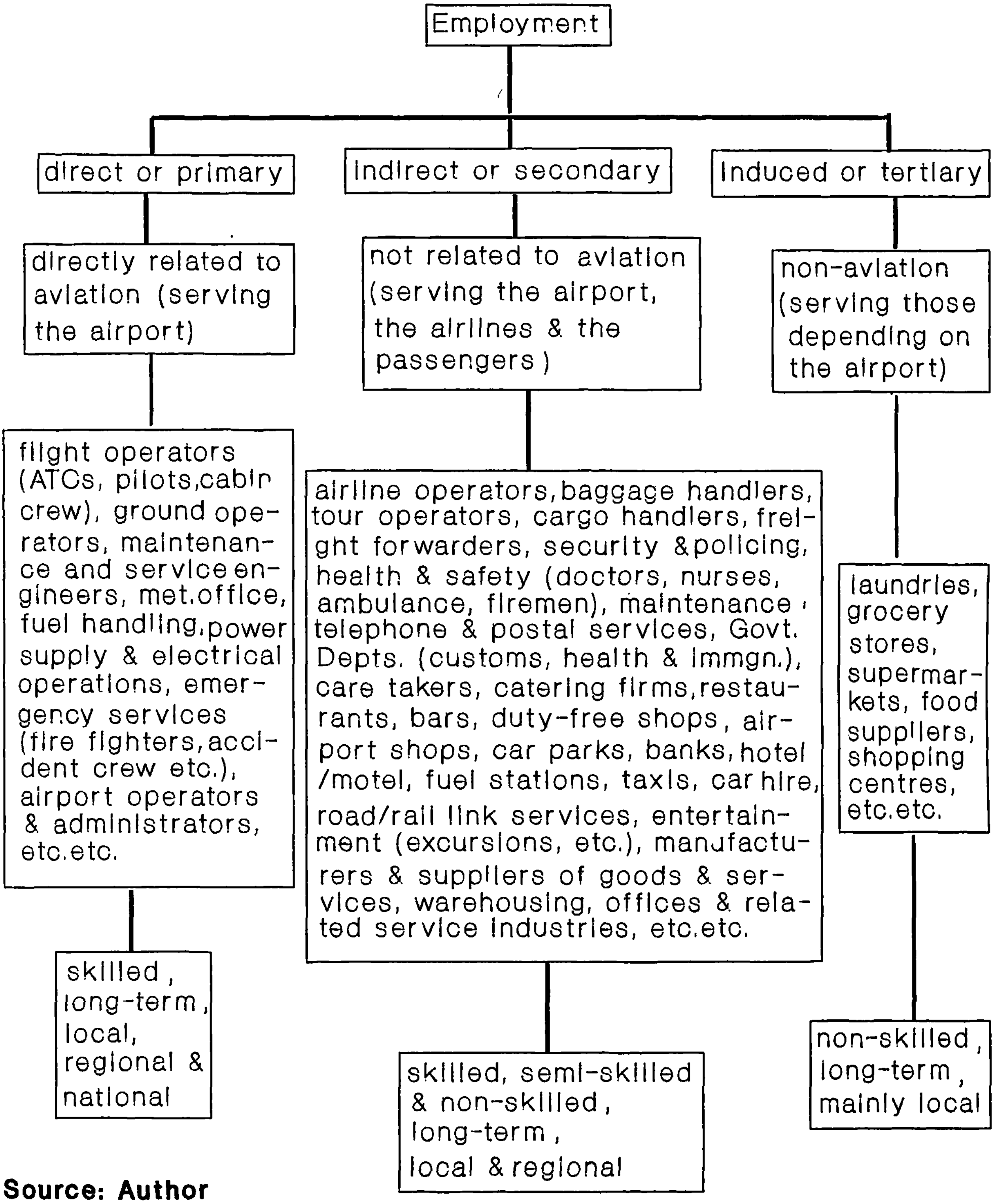
See Figures 4.1 and 4.2 for the employment trees of an airport before; during; and after construction.

Figure 4.1: Airport Employment "Before And During" Construction



Source: Author

Figure 4.2: Airport Employment "After" Construction



Source: Author

4.2.2 Effects Of Employment:

Airports in general are considered a major source of employment and income in the local and regional economy. Large intercontinental airports can create as many as 90-100,000 jobs [54]. For example, in 1991, a total of 173,100 direct and indirect jobs were provided by New York's JFK International Airport. In the same year, the Airport contributed some $15.8bn per annum to the economy of New York/New Jersey region, $4.8bn of which was in wages and salaries [21].

Before and during the construction, many *firms of* contractors; sub-contractors; consultants; and engineers *may* have to come from outside the airport region as there may be a shortage of skilled or non-skilled jobs in the area. Therefore, most of their wages and salaries will be spent outside the region helping the national economy [54]. Semi and non-skilled jobs are usually more available in the region, whereas skilled jobs depending on the degree of skill required are not always so readily available within the region. So, the lesser the degree of skill required, the more the availability of the workforce.

The main concern however, is the economic worth of an airport to its local and regional communities after construction. A very important economic benefit is the fact that the employees and their dependents spend the bulk of their income in the region which will increase regional income and income and financial activities. For example, an economic impact study of Lambert-St.Louis-USA showed that, in 1990, the Airport employed 19,200 people and injected $3.9bn/annum into the local economy [28].

Large international airports by attracting many thousands of people (families included) through primary; secondary; and tertiary employment and the related industries, are bound to increase the demand for housing; for public and transport services; and for other commercial; secondary; or tertiary activities in the airport sub-region [Chap.1 - Urbanisation Effects]. This rising demand for housing will therefore affect property values in the area. Prices may go up as there may be a <u>shortage</u> of houses "particularly in areas closer to the airport", since a large majority of airport employees may prefer to live nearer to the airport in order to save travelling time and cost. Therefore, areas closer to the airport will "<u>probably</u>" have a higher rate of increase in value than those outside the airport subregion, say 15-20kms away. So, it is true to say that, the <u>closer</u> is an area to an airport, the <u>higher</u> is the <u>demand</u> for housing which means that, the <u>higher</u> is the <u>rates of increase</u> in the property values in those areas [54].

It should, however, be noted that, although noise and additional traffic may be a deterrent for moving nearer to an airport, but the choice as to wether to tolerate noise or save travelling time and cost, is entirely a personal matter (see Chapter 2 - Section 2.9.3 - The Economic Effects).

Employees who move into the airport region will create a vacuum both in housing and labour markets in the areas and towns they left. This means that, there will be a surplus of houses available in those areas which may cause a reduction in house prices unless there was a shortage of houses in first place. Also, a shortage of skilled and non-skilled labour may occur in these areas which at the time of labour shortages can have a negative effect. The result will be higher wages and prices as well as a reduction in the income and revenue in these areas [54].

Compared to other jobs, airports tend to pay higher salaries [55]. For this reason, people tend to move from one area to another for better opportunities which may put other business at a great disadvantage in competing for workers and sometimes they may have to move away from the airport area. This shift from one place to another shows that airports can easily affect the employment structure of a region [56]. It also shows that, although airports may have a positive impact in their local and regional economy, but they can have a negative impact elsewhere.

The economic advantage of airports can also be felt at times of economic recession and unemployment where many people can be employed from local and regional areas to build and operate an airport. For example, if a second "runway" at

Manchester Airport were to be built, it is estimated that an extra 50,000 new jobs will be created in the region [33]. This would include 20,000 employed directly in aviation and airport related services, and the remaining 30,000 in secondary and tertiary employment. This means that, for every job within the Airport, there will be 1.5 jobs outside the Airport. In other words, the Airport has a "multiplier effect" of 1.5 with respect to employment. Also, the 50,000 new jobs are in addition to the short-term construction workers [52,34]. Therefore, at times of economic hardship, construction and expansion of an airport can be economically beneficial.

4.2.3 The Multiplier Effect:

Airports have a multiplying effect in the number of people; number of jobs; and in the amount of revenue generated in a region. For example, for a given airport with a total direct employment of 50,000 people and a multiplier effect of 3.5 in population, 2.5 in employment and revenue, the result will be an increase in the population, in the number of jobs, and in the amount of revenue generated as shown below:-

50,000 x 3.5 = 175,000 people moving into the region
50,000 x 2.5 = 125,000 jobs created.

Assuming an average wage of about £8,000/annum/employee, then the total income into the region from the airport would be:-

50,000 x £8,000 = £400m/annum

with a multiplier of 2.5, the total annual increase in revenue would be:-

£400m x 2.5 = £1,000m/annum

The above figures clearly show the economic and demographic significance of an airport, and they can be used as an argument for justifying the building of an airport in a region that needs development [53,57]. It should, however, be noted that, the <u>employment multiplier</u> accounts <u>only</u> for the <u>new jobs</u> and <u>NOT</u> for the <u>shifts</u> from one job to another i.e. those jobs that would <u>NOT</u> have otherwise occurred (indirect and service sector jobs) [54].

The multiplier effect is an important concept in any land-use planning and development with airports being no exception. Its size being X; Y; or Z (decided by the planners and decision makers) will depend directly on the size and the level of activities of the airport i.e. the bigger and busier an airport, the greater is its multiplying effect in population movements; jobs; and revenue. Although it is easier to measure and assess the direct on-site employment of an airport, it is more difficult and complex to measure its indirect secondary and tertiary jobs. This difficulty may create inaccuracies by <u>over or under estimating</u> the <u>total</u> number of jobs induced by the airport [54].

The size of the multiplier has always been subject to argument amongst planners and decision makers although, it will undoubtedly, be substantial for a large airport [51]. Nevertheless, several studies have attempted to trace the multiplier effect of large airports. For example, in 1971, a study of Chicago O'Hare Airport estimated that 30,000 <u>additional</u> jobs would be created from the Airport in the metropolitan area. This means 30,000 people working <u>outside</u> the Airport would <u>depend directly</u> on the Airport and its services for their livelihood [50].

Similarly, in the same year (1971), a study of Los Angeles International estimated an airport workforce of 37,000 with another 64,500 employed in indirect and secondary jobs [57]. Furthermore, estimates showed that for every direct and indirect airport related job, there were an additional 1.5 jobs in the service sector [57]. More recent and up to date data on LAX and Chicago Airports will be shown later in Table 4.1.

In general, the multiplier effect seems to be more local and sub-regional than regional since, it appears that, an airport's impact on its regional employment <u>decreases</u> with <u>distance</u> from the site itself [49]. The following section shows airport employment at some of the busiest international airports.

4.2.4 Airport Employment Worldwide:

Millions of people are employed directly or indirectly by various airports around the world. The economic significance of these airports in their regions regarding employment is clearly evident. Table 4.1 shows employment figures at some of the busiest and largest international airports around the world.

Table 4.1: Airport Employment Around The World

Airport	Numbers Employed			Year
	Direct	Indirect	Total	
London Heathrow	52,272	25,000	77,272	1991
London Gatwick	3,051	20,128	23,179	1995
Manchester Int.	14,000	#50,000	64,000	1995
Amsterdam Schiphol	1,900	31,000	*80,000	1990
Frankfurt Main	11,293	51,400	62,693	1990
Paris Ch.D.Gaul./Orly	----	----	150,000	1991
Rome Leon.Da Vinci	6,900	22,000	28,900	1992
Flughafen Wien Vienna	1,800	8,200	10,000	1990
Flughafen Zurich	17,631	----	17,631	1990
Madrid Barajas	1,000	10,000	11,000	1991
Athens International	12,000	----	12,000	1991
Tokyo Narita	720	32,000	32,720	1991
Hong Kong Int.	22,400	----	22,400	1991
Singapore Changi	----	----	17,000	1991
New York JFK	40,500	173,100	213,600	1991
Los Angeles LAX	50,000	378,000	428,000	1991
Atlanta Hartsfield	----	----	36,000	1988
Chicago O'Hare	53,750	189,530	243,270	1991
Rio de Janiero Galeao	1,141	20,000	21,141	1991
Sydney Kingsfd. Smith	20,500	22,500	43,000	1991
Montreal Int.	23,900	24,300	48,200	1987

Note: Figures for direct employment show on-site employment in most cases.
----Data not available
#Off-site aviation and non-aviation related
**Includes tertiary employment*
Source: Author (Individual Airport Authorities - Personal Communication) & Ref.27 for Atlanta

Looking at Table 4.1, it can be seen that, the employment figures at each airport vary considerably particularly with regards to direct employment. This is because each airport has a different employment and administrative structure. For instance, at some airports, ONLY those who work on site and in aviation related jobs, and are paid directly by the airport are considered to be direct employees for example ATCs; ground engineers; and safety inspectors. Whereas, at other airports, those who work on site but NOT in aviation related jobs and are NOT paid by the airport may still be considered as direct employees only because their jobs are created directly by the airport such as airline operators; flight crews; immigration and customs officers. So, depending on the employment structure/policy of an airport, the factors which determine the number of direct and indirect employees of an airport are:-

a) On-site employment;
b) Off-site employment;
c) Aviation related employment;
d) Non-aviation related employment;
e) Directly employed and paid by the airport;
f) NOT employed and paid by the airport.

It should, however, be noted that, the data in Table 4.1 is provided by each individual airport according to its own employment structure, and that the differences in the direct employment figures are because of the reasons explained above i.e. different employment structure at each airport.

4.3 Housing Markets And Land Values:

Airports in general, through their urbanisation effects and increased accessibility tend to increase land values in the immediate corridor of the improvement [40]. Also, at a time of rapid urbanisation, it is expected that the airport with its road and rail links would accelerate and improve the overall development in that sector of the region i.e. the development corridors [54]. Such improvements are bound to affect both property and land values in areas around the airport. Considering property values, factors affecting their markets near airports are [54]:-

a) Noise; proximity to airport is important i.e. houses in the 35NNI zone and above have a "greater rate of depreciation" than houses in comparable areas elsewhere [Chapter 2 - Section 2.9.3];

b) Travel time to and from work especially for airport employees, most of whom tend to live near to their work;

c) Desirability of living near airports as they tend to be in prestigious areas;

d) Lack of amenities in areas near airports.

All the above factors influence the rise and fall of the housing markets and the individual's preference and priority is also important. Some airport employees in some cases may even pay above the market value for a house nearer to the airport so that they can save travelling time. Thus, considerable pressure on the local housing market is inevitable. The effects on house values were discussed earlier in this chapter (see 4.2.2 before).

As with the land values, they vary according to whether agricultural; residential; recreational; *commercial*; or industrial. According to the North American experience, airports by themselves do NOT have a negative impact on land values. For instance, in the early 1940s when land was assembled for Chicago's O'Hare, the average price of land was about $1,000 per hectare, whereas in 1967, the average price was $247,000 per hectare [39].

Land values around Los Angeles International were estimated at about $300,000 per hectare in 1966, and a study of the Salt Lake City Airport reported that land values were increasing at a rate of 8% per annum [32]. Between 1965 and 1975, land prices around Washington's Dulles Airport had increased by 5-6 times even though the Airport was located in a rural area [54]. A good and more recent example is probably Stansted Airport better known as the "Third London Airport".

Stansted Airport is located in Essex-England, and in 1991, it opened a new international terminal capable of handling 8 million passengers per year. This new terminal will have a major effect on the rental value of commercial property and property values are expected to soar. Towns such as Cambridge; Hertford; Welwyn Garden City; Stevenage; Chelmsford; Harlow; and Braintree which are all on the M11 (motorway) corridor will no doubt benefit from the growth of Stansted [29].

For the time being, rents in the area do not fully reflect the influence of the Airport expansion, but they are expected to rise from £200-280/m^2 in 1990, to £270/m^2 and more once the expansion is completed [29]. This data implies that, although <u>in general</u>, there is <u>NOT</u> a <u>definite relationship</u> between airports and land values, it can be expected that, apart from lack of amenities, land around airports is desirable enough to force the competing land users to bid prices up substantially which clearly shows the economic good of the Airport.

4.4 <u>Tourism:</u>

In the last few years, passenger travel has expanded spectacularly. By the year 2000, tourism is said to become the world's largest industry. In 1991, 600 million people worldwide travelled as tourists [5]. By providing about 1 in 15 jobs worldwide, it can claim to be the largest industry in the world, and is expected to grow at least at the same rate as air transport. According to the World

Tourism Organisation, a "tourist" is defined as anyone travelling for pleasure; professional; educational; health; or other motives. By this definition, all British Airways passengers are "tourists" and some 60% of its passenger revenue is from tourists travelling for pleasure purposes. In 1992, British Airways Tour Operator provided more than 600,000 holidays per year and their charter airline Caledonian Airways carried over 1,344,000 passengers per year [6].

Total "world arrivals" expanded from 160 million in 1970 to 430 million in 1990 which is an increase of 169% in two decades with an average growth rate of 5.1% per year. Also, receipts from tourism worldwide from the same period rose from $18bn to nearly $250bn excluding those received from domestic tourism and fare payments to carriers. According to the World Travel and Tourism Council, in 1992, travel and tourism in Western Europe accounted for some 6% of GNP and provided 9.6% of employment [45].

In the United Kingdom, the tourism industry has grown strongly during the last decade. Tourist spending (including domestic tourism) accounts for nearly 4% of GNP, and in 1990 totalled £25.2bn. It is widely accepted that tourism is one of UK's largest industries by employing 1.6 million people including the self employed which is more than the health service and now, probably more than the construction industry. It is also one of the fastest growing industries where in the second half of the 1980s tourism was creating some 44,000 new jobs in the UK every year [45].

The UK is the world's fifth largest market for overseas visitors after the USA; Spain; France; and Italy. In 1990, 18 million people visited the UK, 12.8 million of whom arrived by air and the remaining 5.2 million by sea. Altogether, they spent nearly £8bn, £6.5bn of which was spent by "air travellers" and the rest by the sea travellers. As for the "UK travellers abroad", in the same year, over 31 million people travelled overseas with over 21 million travelling by air and about 10 million by sea. The total expenditure by these travellers abroad were £7.8bn for air and £2.1bn for sea, making a total of nearly £10bn spent overseas by UK visitors in 1990 [45,46].

These figures show the importance of tourism particularly to the air market with Western Europe (EC only) having the biggest number of visitors travelling to and from the UK. This however, (i.e. the no. of visitors) for a small island such as UK with a climate neither Mediterranean nor suitable for winter sports, is a notable achievement.

Domestic tourists, although less evident are more important for the UK than foreign ones. In 1990, UK residents made 96 million domestic trips (with at least one night away from home) 61% of which were for holidays and they spent a total of £10.5bn. It is estimated that day trippers spent a further

£5bn, in addition, UK carriers received £1.9bn. The Gulf War together with world recession have altered the statistics for 1991 by hitting travel and tourism particularly hard [45].

According to the British Tourist Authority (BTA), the number of overseas visitors will grow by about 5% per year to some 27 million by the year 2000 which is 9 million more than in 1990. Most of the extra tourists will be from Southern Europe and North America (USA and Canada), although the Far East and Eastern Europe will have the fastest growth rates [45]. Consequently, accommodation and travel; restaurants; transport services; shopping; entertainment; site seeing; arts and museums will all benefit financially from overseas and domestic tourism.

Although the number of package holidays dropped by 12% between 1989 and 1990, the overseas holiday business continues to grow. For instance, Thompson, UK's largest tour operator, aimed to sell 100,000 holidays to Florida in 1991 and also to increase its programmes to Kenya; Thailand; and Egypt. Florida however, has taken over many traditional Mediterranean resorts in the top ten list. The Company is also trying to improve its image by carrying out environmental audits of its hotels, and by contributing to certain conservation groups. As with the fuel costs, they are also important in the holiday business. For this reason, Thompson restricted 1990's price increase by buying 675 million litres of aviation fuel in advance [7].

Another advantage of tourism is the exchange of cultural heritage between the people of different countries which is normally very educational. The main reasons behind encouraging tourism are cheaper air fares and holidays mixed with higher incomes although, factors such as travel time; cost; distance; and comfort may still have a discouraging effect on air travel. Nevertheless, through tourism, airports will continue to benefit the world economy by pumping huge sums of money into most economic centres around the world.

4.5 Growth Of Civil Aviation:

Air transportation is still the fastest growing mode and it seems that this situation is unlikely to change. From 1960-1980, the average growth rate of air passenger traffic in the United States was 8.7% and worldwide 10% [2]. Even during the difficult period of 1974-1980 due to increased oil prices, the average annual growth rate for the world was 7.7% [3]. In the 1980s however, significant changes took place in the air transport industry so that, in 1989, scheduled services worldwide carried about 1.1 billion passengers with 24% of them on international flights [8].

From 1986-91, passenger numbers increased by 5% per annum. The greatest growth is in international transport with an increase of 8% per annum from 1984-89. The growth in passenger-kms had averaged to 7% per annum from 1986-91 as compared to passengers carried at 5%. The average length of journey has therefore increased at about 2% per annum. At the same time, the average growth rate of passengers carried and passenger-kms from 1986-91 had been faster than over the past ten years (1981-91) which shows the rise in the growth trend. Over the same period of 1986-91, the passenger load factor for <u>scheduled</u> services has increased slightly from 66% to 68%, and with the load factor for <u>chartered</u> services running at around 90%, therefore, the overall passenger load factor for 1991 was about 70% [8].

Studies made by IATA; ICAO; and companies such as Deutsche Airbus, have predicted that the demand for air transport will nearly double by about 2005 and continue to grow strongly thereafter. This means a growth rate of between 5-7% per annum [8]. As the international economic and cultural interchange grows, so will the demand for more international travel. Aviation is a growth industry providing an increasingly important contribution to the UK economy. For instance, the number of UK terminal passengers has increased from 45 million in 1976 to 75 million in 1986 and is forecast to grow to 80-100 million by the end of the century [9].

At almost every airport the main consideration is passenger traffic. Nevertheless, at many of the larger airports, cargo traffic is becoming increasingly important mainly because cargo traffic continues to overtake passenger flows in terms of growth rate [4]. At UK Airports for example, between 1978 and 1988, air cargo had increased from 660,000 to 881,000 tonnes per year which is an increase of almost 33% in ten years [9]. Such rises in demand for both passenger and cargo traffic require adequate and well targeted investment in the airport infrastructure.

London Heathrow for example, which opened in 1946 as one runway and a village of tents, is now the world's busiest international airport with an aircraft movement of 1 every 49 seconds at peak times [1]. Seventy commercial airlines flying to 200 destinations [10] make Heathrow the main gateway both present and future of the UK to the rest of the world. In 1992, it handled over 40 million passengers per year, and at acceptable conditions, it is believed that it can handle up to 50 million people which is its limit [1].

At present, with all the four terminals working, the Airport is approaching its full capacity, and by 2005 it may reach up to 65 million passengers per year. Such numbers will no doubt saturate Heathrow's runway capacity, and the alternative is either a terminal 5 or nothing, even though an extra 20-25 million passengers are expected to use Heathrow in the next few years. The proposed Terminal 5 will cost the BAA nearly £1bn taking Heathrow into the 21st century [1]. All around the Airport, commercial property values have boomed. Stockley Park, once a 142 hectare rubbish tip, houses Fujitsu; Toshiba; Tandem; Glaxo; and BP. Now Hounslow Council has agreed to a further 13 hectare of offices on the gravel pits at Bedfont Lakes, and IBM is moving building in the Green

Green Belt [10].

In 1991, Europe's first purpose-built hub-style airline terminal opened for business at Birmingham International Airport. Eurohub, the £60m second terminal at Birmingham will be the centre of an expanding European air route network and will initially handle more than 600 scheduled flights in and out of the city each week to more than 25 destinations in the UK and Europe [11].

In West Germany, Lufthansa is also planning to operate scheduled flights to both East and West Berlin by running eight daily flights to Tegel (West Berlin) from Cologne and Bonn, and four daily from Frankfurt; Stuttgart; Munich; Dusseldorf; and Hamburg. Flights from Nuremburg; Bremen; and Muenster are planned for later. International flights from Tegel would serve London; Milan; and Zurich, while Schoenefeld (East Berlin) would connect to Warsaw; Athens; Brussels; Rome; and Istanbul. Intercontinental destinations include New York; Tokyo; Peking; and Singapore [13].

In the first half of 1990, passenger-kms on all scheduled services run by the 21 members of AEA (Association of European Airlines) was up by 10% on the same period of 1989. Of this, European traffic had increased by 12.4%, and an above average growth was witnessed on the North-Atlantic route. Freight carryings at the same time were up by about 5% overall [13].

With trade barriers coming down in the European Community, more business travel will penetrate into the heart of Europe. The air ways will act as the arteries of business in the EEC, and a large increase in the European air travel is predicted for the coming decade. KLM (Royal Dutch Airlines) for example flies to 158 cities worldwide with more international routes than even British Airways. Its link with America's Northwest Airlines and its "open skies" agreement with the US has given it the right to fly into any American city. They have built an alliance with other regional airlines which helped them carry 17% more passengers in 1992 than in 1991 in spite of the general recession in air travel [14].

KLM, with its KLM Cityhopper subsidiary and its 14.9% stake in Air UK, has put 23 British regional Airports from Aberdeen to Southampton, and from Norwich to Cardiff in direct touch with Amsterdam, which is regarded by KLM as the gateway to Europe. These connections make it very convenient for the British business travellers to fly direct from the main cities of the UK to the European central hub at Schiphol without having to go anywhere near London. From Schiphol onwards, there are direct links to almost every major European city. Schiphol is said to be Europe's fifth largest airport by handling 16.5 million passengers in 1992 [14].

From 1987-92, the passenger load factor at Schiphol increased by 40%, where a third of all passengers went through transit and changed planes to other destinations. The Airport provides services to 100 European cities and almost 90 countries around the world. A new extension to the west of the existing terminal opened in 1993 which increased passenger capacity to around 27 million. By the year 2003, the Airport authorities are hoping to handle 30 million passengers per year [14,58].

In the United States however, its newest and biggest Airport opened in 1992 in Pittsburgh-Pennsylvania. It covers approximately $50km^2$ and has 100 boarding gates arranged in an X astride runways which will save airlines £8m/year in taxiing fuel. Pittsburgh International, cost £625m and took five years to build; it has 104 stores and restaurants; more than 17,000 car parking spaces; and claims to be "the airport of the future" [15]. Also, in 1993, Denver-Colorado was due to open the world's biggest Airport with much more of everything a plane or a passenger may need, but the project was delayed and it finally opened in 1995. The Airport covers an area of approximately $140km^2$, with 12 runways and 206 gates at a cost of £2.5bn [15,59].

Apart from Pittsburgh and Denver, nearly 90 of the US biggest Airports have already started or are planning extensive improvements in spite of the current recession when fewer people are flying and many in the airline industry are going bankrupt. The FAA had projected that, by the year 2000, the number of passengers using American Airports would have soared to 820 million. The FAA has now revised it down to 706 million, but the industry's analysts say that 600 million or under is more realistic [15].

This aerodrome drive has been encouraged by new legislation passed in 1990 that allows a tax of up to £1.80 on every departing passenger to pay for improvements. On top of that, the authorities seem to view airports not only as a public need or an economic asset, but as an emblem of civic status and prestige. Pittsburg was once the grungy steel capital of the US, but having the nation's biggest airport even if "temporarily" updates its new image as a modern post-industrial city [15].

Denver however, whose prestige will be even more enhanced by opening the world's most ambitious airport has been financed like Pittsburg with bonds and approved by public referendum even when the present Airport operates a third under capacity. Also, since construction started, the FAA has reduced passenger estimates by 40%. United Airlines, the biggest tenant estimates that its costs will quadruple to about £12.0 per passenger at the new Airport, and Continental, the other major carrier out of Denver is already operating under the bankruptcy laws. Nevertheless, in spite of all these economic set backs, the world's biggest Airport did, as stated earlier, open at Denver in 1995 [15,59].

Considering the future growth of air transport, Boeing forecasts that, at an average increase of 5.5% per annum, the current market will almost double by the year 2000, and rise by 250% by 2005. The annual available seat-kms will more than double from 3,040 in 1990 to 6,400 billion by 2005 which, according to a Boeing forecast, will mean that world airlines will be buying about $626bn worth of new jet liners, with $186bn going for replacement of retiring aircraft, and $440bn to accommodate growth. Some $200 billion has already gone into the 1990 order backlog [13].

This shows that, there is an apparent need for some 9,935 aircraft of which 34% will be short range, 25% medium range, and 41% long range. To meet this demand, all the three large aircraft manufacturers are boosting their production capacity. In 1990, Boeing planned to deliver 381 aircraft, increasing this to around 500 by the mid 1990s [13]. The above statements clearly show the economic importance of the growth in both aviation and the aircraft manufacturing industry. Tables 4.2; 4.3a; 4.3b; 4.4a; and 4.4b show the recent air traffic pattern at some major international airports around the world in a ranking order.

Table 4.2: Traffic At Some Major International Airports (Domestic + International) In 1990

City - Airport	Tot. Pass. (Dep + Arr) (millions)	Tot. Cargo (Ld + Unld) (1000 tons)	Tot. Mail (Ld + Unld) (1000 tons)
Chicago O'Hare	59.9	748.8	237.9
Los Angeles Int.	45.8	1,025.0	139.9
London Heathrow	*54.1	*1,000.0	*82.0
New York JFK	29.8	1,207.3	115.1
Frankfurt Main	28.7	1,083.5	142.1
Paris Orly	24.3	254.5	33.4
Paris Ch.De Gaulle	22.5	617.9	29.5
London Gatwick	*22.4	*232.1	*4.3
Tokyo Narita	19.2	1,361.2	29.1
Toronto Pearson	19.0	320.0	no data
Hong Kong Int.	18.7	801.9	23.2
Rome Fiumicino	17.8	237.5	no data
Madrid Barajas	15.8	220.9	28.8
Amsterdam Schiphol	14.9	585.0	25.4
Singapore Changi	14.4	620.7	8.7
Zurich Zuerich	12.3	255.5	15.7
Sydney Kingsford	11.2	249.3	20.0
Manchester Int.	*15.0	*75.6	*6.6
Athens Athinai	10.0	88.0	8.8
Cairo Int.	7.1	103.1	no data
Rio de Jan. Galeao	5.6	140.0	2.6
Vienna Schwechat	5.5	57.9	6.7
Tehran Mehrabad	5.2	67.7	5.0

**1995 figures*
Source: Ref.24, 25 (ICAO) & 26 (Individual Airports)

Table 4.3a: Airports Having World's Highest Commercial Traffic Volume In 1990 Ranking By "Total" Passengers Embarked + Disembarked

City-Airport	Number In 000,s	% Change From 1989	Rank Order 1989	Rank Order 1990
Chicago-O'Hare	59 936	1.4	1	1
Dallas-Dallas/Ft.Worth	48 515	2.0	2	2
Atlanta-Hartsfield	48 025	10.9	4	3
Los Angeles-Los Ang.Intl.	45 810	1.9	3	4
London-Heathrow	42 647	7.7	5	5
Tokyo-Haneda Intl.	40 233	10.0	6	6
San Francisco-San Fr.Intl.	31 060	3.9	8	7
New York-JFK	29 787	-1.8	7	8
Frankfurt-Frankfurt/Main	28 713	11.0	10	9
Denver-Stapleton	27 433	-0.5	9	10
Miami-Miami Intl.	25 837	10.5	12	11
Paris-Orly	24 330	0.9	11	12
Osaka-Osaka Intl.	23 512	7.5	16	13
Honolulu-Honolulu Intl.	23 368	3.3	14	14
Boston-Logan	22 936	3.0	15	15
New York-La Guardia	22 754	-1.7	13	16
Detroit-Metropolitan	22 585	5.1	17	17
Paris-Charles De Gaulle	22 506	11.0	20	18
New York-Newark	22 255	6.3	19	19
London-Gatwick	21 047	-0.5	18	20
Minneapolis-Minn./St.Paul	20 381	5.1	22	21
St.Louis-Lambert	20 066	0.3	21	22
Tokyo-New Narita Intl.	19 257	13.4	26	23
Toronto-Pearson	19 050	0.3	23	24
Orlando-Orlando Intl.	18 398	6.8	24	25

Source: Ref.25 (ICAO)

Table 4.3b: Airports Having World's Highest Commercial Traffic Volume In 1990 Ranking By "International" Passengers Embarked + Disembarked

City-Airport	Number In 000,s	% Change From 1989	Rank Order 1989	Rank Order 1990
London-Heathrow	35 250	8.6	1	1
Frankfurt-Frankfurt/Main	21 860	11.9	3	2
Paris-Charles De Gaulle	20 875	14.2	4	3
London-Gatwick	19 650	-0.9	2	4
Hong Kong-Hong Kong Intl.	18 688	15.3	6	5
Tokyo-New Narita Intl.	18 312	13.5	7	6
New York-JFK	18 100	0.6	5	7
Amsterdam-Schiphol	14 800	-3.0	8	8
Singapore-Changi	14 406	11.0	9	9
Zurich-Zuerich	11 585	5.3	10	10
Bangkok-Bangkok Intl.	10 906	10.7	12	11
Toronto-Pearson	10 250	3.5	11	12
Miami-Miami Intl.	10 100	4.1	13	13
Los Angeles-Los Ang. Intl.	10 000	8.2	14	14
Copenhagen-Kastrup	9 268	1.9	16	15
Paris-Orly	9 210	0.6	15	16
Taipei-Chiang Kai-Shek	8 929	15.3	21	17
Dusseldorf-Dussldf. Intl.	8 625	10.8	20	18
Rome-Fiumicino	8 400	4.3	19	19
Manchester-M/Chester Intl.	8 100	-0.5	18	20
Palma De Mallorca-PDM.Int.	7 966	-5.3	17	21
Madrid-Barajas	7 330	11.7	23	22
Brussels-Bruxelles Natl.	7 100	3.4	22	23
Stockholm-Arlanda	6 555	7.7	25	24
Athens-Athinai	6 301	1.1	24	25

Source: Ref.25 (ICAO)

Table 4.4a: Airports Having World's Highest Commercial Traffic Volume In 1990 Ranking By "Total" Aircraft Movements

City-Airport	Number In 000's	% Change From 1989	Rank Order 1989	Rank Order 1990
Chicago-O'Hare	781.3	3.1	1	1
Atlanta-Hartsfield	767.6	20.0	3	2
Dallas-Dallas/Ft.Worth	714.0	2.3	2	3
Los Angeles-Los Ang.Intl.	621.4	6.4	4	4
Denver-Stapleton	444.0	4.9	6	5
Boston-Logan	399.6	10.7	8	6
San Francisco-San Fr.Int.	397.5	-7.1	5	7
St.Louis-Lambert	391.5	3.0	7	8
Phoenix-Sky Harbor	374.0	4.5	9	9
London-Heathrow	367.4	5.9	11	10
Charlotte-Douglas Intl.	365.4	4.6	10	11
Pittsburgh-Pittsbg.Intl.	357.0	3.7	12	12
New York-Newark	356.7	5.1	13	13
Philadelphia-Phila.Intl.	351.9	10.7	17	14
Seattle-Seattle/Tacoma	343.9	6.6	14	15
Miami-Miami Intl.	336.0	12.0	19	16
Detroit-Metropolitan	334.1	3.8	15	17
New York-La Guardia	331.4	3.1	16	18
Minneapolis-Minn./St.Paul	322.2	7.9	20	19
Toronto-Pearson	320.0	3.4	18	20
Frankfurt-Frankfurt/Main	308.5	3.5	21	21
Las Vegas-Maccarran Intl.	284.8	7.8	24	22
New York-JFK	280.6	0.1	22	23
Houston-Intercontinental	271.0	-0.2	23	24
Stockholm-Arlanda	252.7	2.5	26	25

Source: Ref.25 (ICAO)

Table 4.4b: Airports Having World's Highest Commercial Traffic Volume In 1990 Ranking By "International" Aircraft Movements

City-Airport	Number In 000's	% Change From 1989	Rank Order 1989	Rank Order 1990
London-Heathrow	279.0	7.4	1	1
Frankfurt-Frankfurt/Main	223.3	6.9	2	2
Paris-Charles De Gaulle	209.3	14.3	4	3
Amsterdam-Schiphol	188.0	0.6	3	4
Brussels-Bruxelles Intl.	165.0	0.3	9	5
London-Gatwick	160.3	-1.6	5	6
Zurich-Zuerich	153.3	6.3	7	7
Copenhagen-Kastrup	151.6	2.5	6	8
Toronto-Pearson	132.0	9.9	8	9
Miami-Miami Intl.	123.6	14.4	11	10
Tokyo-New Narita Intl.	111.3	5.6	12	11
New York-JFK	108.6	-0.1	10	12
Hong Kong-Hong Kong Intl.	105.8	12.2	13	13
Singapore-Changi	98.1	12.2	14	14
Dusseldorf-Dusseldf. Intl.	89.5	8.2	15	15
Stockholm-Arlanda	87.6	7.1	16	16
Munich-Muenchen	87.0	7.0	17	17
Rome-Fiumicino	84.0	4.6	18	18
Manchester-M/Chester Intl.	81.0	8.9	20	19
Bangkok-Bangkok Intl.	80.8	14.8	21	20
Madrid-Barajas	74.8	6.4	22	21
Vienna-Wien/Schwechat	73.9	9.0	23	22
Paris-Orly	73.6	-2.9	19	23
Geneva-Cointrin	69.4	3.7	24	24
Athens-Athinai	62.5	1.0	25	25

Source: Ref.25 (ICAO)

4.6 Aviation And National Economies:

The importance of aviation in economic growth has already been highlighted. The aviation industry pumps large sums of money into the economy not only by tourism, but through import and export of goods (freight industry) and sales of aircraft and related manufacturing products (e.g. spare parts) particularly in countries where the aircraft manufacturing industry has some economic significance for example in the UK and the USA. Aviation is equally important to the economy of other less developed countries by being the main channel for foreign visitors who bring large sums of foreign exchange into their economy. For the more remote countries of Asia, Africa, and South America, air transport also provides the means for the dominant cultural and political links to the outside world.

For instance, in 1973, a study by the Royal Jordanian Airline (Alia) showing the economic significance of providing air services to a small Middle East state had found that, while 15% of imports were brought into Jordan by air in 1971, 9.3% of all tourists "arrived" by air and made up for 30.7% of the total tourist receipts. It was also estimated that 20.4% of those employed in the manufacturing sector were employed directly or indirectly in civil aviation [17]. In Jordan, where the outcome of the Israeli wars is still evident, air transport has contributed notably to the rebuilding of the economy through 1969-74. There is plenty of evidence that in such countries the flexibility of air services is very important in the rapid development of resources, in the rehabilitation of dislocated regions, and in renewing the links with the outside world particularly when damaged temporarily by war or civil strife [18].

For example, both Iran and Iraq are good examples of such cases where both countries by destroying each other's air fields during the eight year war of the 1980s, have severely weakened each other's economy by cutting aviation links to the outside world. As a result, both countries are now undergoing massive reconstruction projects to re-establish their aviation links in order to prevent further economic losses.

Considering UK's international trade, London Heathrow became the third largest port (seaports included) in the Kingdom in the 1970s where almost 16 million international passengers (82% of the Airport's total) and close to 420,000 tonnes of cargo went through the Airport in 1972-73 making a profit of almost £10m (before tax) in that same year [19]. Today, these figures are much higher since Heathrow and air transport have both grown considerably which makes Heathrow Britain's biggest port and largest in the world outside the USA by covering altogether an area equal to about 12km^2 [Chap.1].

In 1991, Heathrow handled over 41 million passengers and about 672,000 tonnes of cargo bringing immense economic benefit to the Country [20]. As a result, the Airport is considered a good public investment and vital to the UK's economic well-being. Like tourism, cargo too, is very important in the trade and balance of payments. It is therefore appropriate to discuss its recent development and growth.

4.6.1 <u>International Air Freight:</u>

For more than 30 years, air cargo has been growing steadily within the air transport industry. During the late 1960s, the total tonne-kms of freight doubled every four years i.e. an average annual growth rate of 17% [2]. At that time, the aviation world was extremely optimistic about the growth of the air cargo industry. For example, McDonnell Douglas in 1970 projected that growth rates would increase, and that the total market would grow from 10bn tonne-kms in 1970 to approximately 100bn tonne-kms in 1980 [4].

Two factors prevented such growth to continue to the point that, even the growth rates of the 1960s were not maintained. One was the economic recessions of the 1970s, and the other, the increase in the OPEC (Oil Producing Exporting Countries) oil prices which affected the aviation fuel costs. Although the more optimistic forecasts of the early 1970s have not been achieved, air cargo has nevertheless been a strongly growing market in the 1980s. In times of economic buoyancy, air freight grows rapidly, but the recession of the early and late 1970s retarded the growth in the western industrialised nations. To the oil producing countries of the Middle East however, air freight continued to grow rapidly during the above recession periods [4].

Considering UK's international freight traffic, air freight plays an important part in terms of value of goods lifted. For example, it accounted for some 6.1% of exports and 4.6% of imports "by value" in 1960 [22], and, in 1978, the corresponding figures were 19.7% and 17.6% respectively [16]. In 1978, Heathrow had the largest proportion of visible trade by value of all UK Airports and Seaports [16] by handling 14.1% of the visible trade by value of the UK, and some 76% of the visible trade by value through UK Airports [47]. In contrast, other UK Airports played a less important role in the movements of air freight. For example, in 1978, Gatwick and Manchester were the next most important Airports by handling some 4.4% and 3.1% by value of the visible trade through UK Airports [47].

This concentration of air freight at Heathrow restricts expansion of air freight services at other UK Airports. Therefore, haulage of freight by road to and from Heathrow over long distances is common. For example, even British Airways move freight by road between Manchester Airport and London Heathrow [47]. In general, the expansion of air freight services has been constrained by the increased competition for air freight between operators of all-freight services and operators of passenger services with freight capacity in large wide-bodied aircraft. This competition has therefore been reducing the profitability of all-freight air services [23].

The development of air freight has made possible the movement of certain goods and items over long distances in a very short time. Regular commodities with very short commercial life such as newspapers and fresh flowers need fast and reliable delivery. In cases of emergency when speed is vital and lives may depend on rapid delivery of certain goods such as serums; blood supplies; and urgent kidney transplant, a speedy delivery is vital (one advantage of Concorde). Sometimes even urgent food; medical; and other essential necessities are delivered through rapid airlifts such as the recent case of Somalia (drought); Bosnia (civil war); and the 1990 earthquake in Iran.

High value goods such as gemstones and bullion which require special security and handling in terms of both staffing and facilities are normally delivered by air. For example, the diamond which is en route from Johannesburg to Amsterdam or New York, needs speedy, safe, and reliable delivery since high costs are involved. Other items such as dangerous goods, restricted articles, and livestock (animals) are also transported by air but, they need special care, storage and security, and adequately trained personnel is essential for handling them both in the air and on the ground [4].

Dangerous goods normally include hazardous chemicals; radioactive materials; combustible liquids; compressed gases; corrosive materials; explosives; flammable liquids and solids; magnetised materials; noxious and irritating substances; oxidising materials; and poisons. Restricted articles are those such as fire arms and explosives which are normally imported under very strict security conditions. The carriage of dangerous goods by air is nevertheless a great concern to the airlines because of the potential hazards on board [4]. Air mail industry too would grow and thrive through air transport (see Table 4.2). Tables 4.5a and 4.5b show the recent freight traffic at some major airports around the world in a ranking order.

4.6.2 <u>Benefits From Aircraft Manufacturing Industry:</u>

In 1990, Airbus confirmed contracts for 75 A320s for Northwest with options on 30 A321s, it (Airbus) also secured orders from Foshing Airlines of Taiwan for two A320s and six A300-600 with options on four more. In the same year, Boeing announced an order from the Asian Airlines of South Korea for 51 aircraft, worth over $6bn including nine 747-400s (3 in the freighter version), ten 767-300s and eight 737-400s. Also, options for nine 747-400s, eight 767-300s and seven 737-400s were available [13].

Ansett too signed up for ten A321s. McDonnell Douglas also secured orders for 25 MD-11s and bookings were made for

Table 4.5a: Airports Having World's Highest Commercial Traffic Volume In 1990 Ranking By "Total Freight (Tonnes Loaded + Unloaded)"

City-Airport	Number In 000,s	% Change From 1989	Rank Order 1989	Rank Order 1990
Tokyo-New Narita Intl.	1 361.2	2.5	1	1
New York-JFK	1 207.3	-4.1	2	2
Frankfurt-Frankfurt/Main	1 083.5	2.6	3	3
Los Angeles-Los Ang.Intl.	1 025.0	2.8	4	4
Miami-Miami Intl.	907.7	22.2	6	5
Hong Kong-Hong Kong Intl.	801.9	9.8	7	6
Louisville-Standifd. Fld.	754.5	9.8	8	7
Chicago-O'Hare	748.8	-0.2	5	8
London-Heathrow	697.8	1.7	9	9
Seoul-Kimpo	630.5	6.2	10	10
Singapore-Changi	620.7	7.5	13	11
Paris-Charles De Gaulle	617.9	5.7	11	12
Amsterdam-Schiphol	585.0	0.4	12	13
Dayton-Dayton Intl.	542.3	4.4	14	14
Tokyo-Haneda Intl.	484.9	4.9	15	15
New York-Newark Intl.	449.3	12.2	18	16
San Francisco-San Fr.Int.	449.2	-0.2	16	17
Osaka-Osaka-Intl.	445.7	9.7	17	18
Atlanta-Hartsfield	431.9	13.9	21	19
Bangkok-Bangkok Intl.	404.3	16.0	22	20
Dallas-Dallas/Ft.Worth	401.8	2.8	19	21
Taipei-Chiang Kai-Shek	396.3	3.8	20	22
Honolulu-Honolulu Intl.	332.7	1.9	23	23
Toronto-Pearson	320.0	2.5	24	24
Boston-Logan	309.9	8.5	25	25

Source: Ref.25 (ICAO)

Table 4.5b: Airports Having World's Highest Commercial Traffic Volume In 1990 Ranking By "International Freight (Tonnes Loaded + Unloaded)"

City-Airport	Number In 000,s	% Change From 1989	Rank Order 1989	Rank Order 1990
Tokyo-New Narita Intl.	1 350.1	2.4	1	1
Frankfurt-Frankfurt/Main	1 014.3	2.3	3	2
New York-JFK	885.0	-5.9	2	3
Hong Kong-Hong Kong Int.	801.9	9.8	4	4
Miami-Miami Intl.	688.0	16.6	6	5
London-Heathrow	687.0	1.3	5	6
Singapore-Changi	620.7	7.5	8	7
Paris-Charles De Gaulle	599.0	5.4	9	8
Amsterdam-Schiphol	585.0	0.4	7	9
Seoul-Kimpo	576.4	5.2	10	10
Taipei-Chiang Kai-Shek	396.3	3.8	12	11
Los Angeles-Los Ang. Int.	395.0	-2.2	11	12
Bangkok-Bangkok Intl.	392.9	15.5	13	13
Chicago-O'Hare	303.0	0	14	14
Brussels-Bruxelles Natl.	280.0	0.9	16	15
Zurich-Zuerich	246.2	-0.9	15	16
Osaka-Osaka Intl.	230.0	16.2	19	17
San Francisco-San Fr.Int.	217.0	-7.7	17	18
London-Gatwick	214.0	3.8	18	19
Rome-Fiumicino	198.0	1.9	20	20
Paris-Orly	198.0	4.9	22	20
Sydney-Kingsford Smith	195.0	1.4	21	21
Tel Aviv-Ben Gurion	193.0	7.7	23	22
Manila-Manila Intl.	175.0	1.2	24	23
Toronto-Pearson	169.5	5.6	25	24

Source: Ref.25 (ICAO)

MD-11s and MD-90-30s by other firms. British Aerospace too announced firm orders for 25 Bae-146s and options on another eight. These include five 146-300s for Thai Airways with delivery through 1991, four 146-200s plus four options for Sabena, four 146-200s plus four options for Alisarda (the independent Italian carrier), and two each for Air UK and PT National Air Charter of Indonesia [13].

Canadair, a major competitor in the regional jet sector, made agreements in 1990 for 139 orders including 23 firm orders, and 22 options for their first RJ100 50-seater aircraft which entered service in mid 1992. The Brazilian company Embraer, another competitor in this market, in 1990 made some 307 option bookings for the EMB-145 45-seater turbo-prop [13]. Table 4.6 shows the worldwide orders and deliveries of "commercial" aircraft in the year 1990. The sales of military aircraft too injects large amounts of revenue into the aircraft manufacturing industry. British Aerospace for example has recently won a contract to build a number of EFA (European Fighter Aircraft) which is very beneficial considering the present economic recession and job losses in the UK's aircraft industry.

4.7 Financial Benefits To Airports:

Airports in general are centres for generating income and they are "usually" profitable for the operators and the owners. Airports earn large sums of money from duty-free sales; landing charges; rents from airlines; car parking; and airport taxes.

Table 4.6: Aircraft Orders And Deliveries-1990
(Commercial Air Carriers)

Aircraft By Manufacturer And Model (9,000kg MTOW And Over Only) a/	Tot. Delvrd. Before And During 1990 (Total As Of 31.12.1990)	Ordered During 1990 b/	To Be Delivered By 31.12.90 c/
TURBO-JETS			
Airbus Industrie A-300	339	35	80
Airbus Industrie A-310	181	41	70
Airbus Industrie A-320	132	138	526
Airbus Industrie A-321	-	117	137
Airbus Industrie A-330	-	28	138
Airbus Industrie A-340	-	7	89
Boeing 737	1,953	162	920
Boeing 747	812	172	296
Boeing 757	331	97	392
Boeing 767	343	52	183
Boeing 777	-	49	49
British Aerospace-146	159	30	45
Canadair Regional Jet	-	23	23
Fokker 100	66	37	180
McDonn.Douglas MD-80/90	825	116	400
McDonnell-Douglas MD-11	3	52	175
Tot. no. of aircraft d/	5,144	1,156	3,703
TURBO-PROPS			
Aerospatiale/Aeritalia ATR-42/72	202	83	201
British Aerospace ATP	29	-	10
British Aerospace Jetstream 41	-	10	10
CASA/Nurtanio CN-235	14	-	17
DeHavilland Canada DHC-8	226	31	109
Embraer EMB-120 Brasilia	198	41	110
Fokker 50	101	14	29
SAAB SF-340	216	10	94
SAAB 2000	-	6	46
Tot. no. of aircraft d/	986	195	626

MTOW - Maximum Take-Off Weight
a/ Figures do not include the number of aircraft manufactured in 1990 in the former USSR
b/ Reported options are not included in the number of aircraft ordered
c/ Nos. in this column include cancellations during the year
d/ Figures exclude cumulative totals of aircraft models that are no longer in production at 31/12/1989. They also exclude China and USSR.

Source: Ref.24 (ICAO)

Sales from duty-free shops are particularly important. For example, according to a 1990 report, if the duty-free shops for the intra-European Community (EC) flights were abolished at EC Airports, they (EC Airports) would lose about 250m ECU (European Currency Unit) at 1988 levels, and by 1993, this would have risen to 350m ECU [28]. This means that, airlines may have to pay an average of 31% more airport charges, at the same time, landing fees and airport taxes (passenger charges) would also have to rise by an average of 14% to compensate for the loss of sales through duty-free shops which shows how important are duty-free sales at EC Airports [28].

If the charges to the airlines are increased, inevitably there would be a rise in the air fares and consequently a drop in passenger traffic particularly in the intra-European flights. This drop is estimated to be between 0.6-2.1 million passengers per year on both chartered and scheduled flights at 1988 levels of traffic. Consequently, passengers may then switch to the non-European destinations which reduces income at EC Airports, and this figure is likely to grow each year in line with passenger traffic [28].

The same report however, which was based on more than 200 airports, airlines, and other bodies within the community found that, a total of 1.9bn ECU per year at 1988 levels is earned by the EC air transport industry from both duty-free sales and airport taxes together [28]. Of this, 1.6bn ECU is from the sales at EC Airports or on EC charter airlines of which, nearly 1.0bn ECU is to intra-European passengers. Some 27% of EC Airports' 1988 pre-tax profits were from this trade, and 15% of the net profits were from duty and tax-free sales to intra-EC passengers alone [28].

At London Heathrow for example, in 1992, 60% of the Airport's "total income" of £70-80m per year came from the shops and duty-free sales with the Japanese being the biggest spenders. The remaining 40% came from the runways through landing fees paid by the airlines. These fees are set by the Airport authorities but approved by the ICAO. Although the main source of income for airports should be from the runways and not the shops, nowadays the situation is reversed at some of the larger international airports such as Heathrow [1]. In general, as passenger traffic at airports increases, their income from non-aviation activities become more important.

Considering landing fees, they depend on factors such as aircraft weight; type; apron parking and security arrangements; passenger load; noise level created; and peak hour surcharges i.e. time of day [4]. Each airport has its own charging policy, and landing fees vary from one airport to another (see Table 4.7). Airports also make large sums of money through airlines by charges other than landing fees (see Table 4.8). Withdrawal of services, movement of the airline base, or even the collapse of the carrier airline will have a serious financial impact on an airport. A good

Table 4.7: IATA International Airport Charges For Selected Airports (In US Dollars-1983)

Country	Airport	Aircraft Charge		
		DC-9	B707	B747
Argentina	Class 1	252	786	2,137
Australia	All	862	2,732	6,730
Austria	Vienna	703	1,636	3,353
Bahrain	All	186	581	1,419
Brazil	Rio	75	195	447
Canada	Class 1	246	676	1,662
Egypt	All	115	478	1,454
United Kingdom	LHR (peak)	1,659	3,608	9,404
United Kingdom	LGW	807	1,915	5,137
United Kingdom	M/C (ave.)*	740	1,940	3,938
United States	JFK	1,429	1,905	3,650
United States	LAX	74	156	423
Singapore	SIN	166	562	1,509
France	ORY/CDG	464	1,164	3,175
Germany	except FRA	588	1,357	3,338
Netherlands	AMS	621	1,389	3,084

**Note:* Figures for Manchester Airport show "average 1993" charges for peak and off-peak periods.*
Source: Ref.4 & M/C Intl. Airport

Table 4.8: World Scheduled Airlines User Charges And Station Expenses (In Millions Of US Dollars 1986-1990)

Item	1986	1987	1988	1989	1990
Landing and airport charges	4,270	5,010	5,920	6,170	7,000
Other user charges	17,070	19,400	22,520	22,910	26,500
Total	21,340	24,410	28,440	29,080	33,500

Note: Figures "do not include" domestic operations in the former USSR.
Source: Author (Produced from Ref.24 - ICAO)

example is the recent collapse of Pan American Airlines which had an adverse financial impact on many of the world's major airports. A few examples of different airports can demonstrate such economic benefits.

4.7.1 Amsterdam - Schiphol:

Amsterdam Airport Schiphol and its subsidiary made a profit of 52.7m Guilders ($27.7m) in 1989 on a turnover of over 575m Guilders ($301m) [28]. Some $5.1m of the profit is paid to the shareholders of Schiphol (State of Netherlands, Municipalities of Amsterdam and Rotterdam), with the rest being added to the reserves. Revenue from concessions was higher in 1989 than had been expected mainly because more passengers with a higher spending level were spending in the Airport's tax-free shopping centre. Revenue also went up as more passengers were paying airport charges. In 1989, the improvement of the Airport facilities reached a total of $114m the bulk of which was spent on fixed assets under construction, and in the same year, work on the first phase of a major terminal extension had started [28].

In 1989, both passenger traffic and aircraft movements increased by 4.5 and 2.5% respectively while cargo traffic went up by 1.3%. In terms of long-term forecasts, traffic growth at Schiphol is, however, following in line as expected. Based on the traffic figures of the first few months of 1990, Schiphol expected for the whole of 1990 a rise of 4% in both passenger flow and aircraft movements, plus a 4-5% increase in cargo traffic which would boost its economy [28].

4.7.2 London - Heathrow, Gatwick, And Stansted:

The BAA which runs London's Heathrow; Gatwick; and Stansted Airports and the Scottish Airports of Prestwick; Aberdeen; Glasgow; and Edinburgh has announced a 29% increase in profits for the FY 1989-90. Profits rose from £198m to £256m which was well over the expectations. These figures reflect traffic increases of 5% to 71 million for passengers, and 7% for cargo which rose from 918,000 to 985,000 tonnes per year in the same period. Although a 2% drop in duty and tax-free sales were reported, other commercial activities rose by 8.8% to £119.4m, and expenditure on safety and security measures rose by 28% to £96m which included £26.9m for policing, and £10.5m to meet the new government regulations [28].

4.7.3 Helsinki - Vantaa:

Vantaa Airport is growing rapidly although capacity is low. In 1989, passenger throughput reached 7.5 million which means large investment is needed to meet future demand [28]. In 1989, around 40% international, 32% domestic, and 28% charter flights made up the traffic at Vantaa. Charter flights however, are growing rapidly at Vantaa since, in 1986, they were only 25% of the total. Finnair carries about 67% of the total, with SAS (Swedish Airlines) taking another 8.5%. Total aircraft movements reached almost 90,000 in 1980, and then dropped to less than 80,000 in one year in spite of the continuous passenger increase [28].

This drop was mainly due to higher capacity aircraft taking over the traffic, which then went up to 99,400 again in 1987. Since then, aircraft movements have reached 114,000, 122,000, and 132,000 in 1988, 89, and 90 respectively which show a steady growth at Vantaa [25].

The turnover in 1989 was almost double that of 1986, and also 21% up on 1988. The net income for 1989 was nearly four times that of 1986, and some 60% higher than in 1988 which suffered from a heavy interest charge of FIM42.5m ($10.3m) against nothing for the latest year. In 1993, a new domestic terminal opened at Vantaa with more car parking facilities. Some FIM1.5bn ($365m) was needed up to 1995 to adequately fund the vital third runway; to purchase additional equipment; to build the new domestic terminal with parking facilities; and to update the existing terminals. Otherwise, Vantaa may become a feeder airport to other major Scandinavian Airports [28,62]. Table 4.9 shows the financial record of the Airport for 1989.

4.7.4 Miami International:

Miami International Airport has become a main hub between North and Latin America. A "total" of 23.5 million passengers went through the Airport in 1989,

Table 4.9: Helsinki-Vantaa International Airport Financial Report 1989 (Millions Of Finnish Marks)

Revenue	FY Ended 31st Dec. 1988	1989	% Change
International Traffic	171.5	210.2	+ 22.6
Domestic Traffic	41.2	47.1	+ 14.3
General Aviation	1.2	1.3	+ 8.3
Total Traffic Revenue	213.9	258.6	+ 20.9
Rentals	61.7	80.1	+ 29.8
Car Parking	20.8	26.5	+ 27.4
Other	16.7	13.2	- 21.0
Total Revenue	313.1	378.4	+ 20.9
Operating Income	187.0	231.8	+ 24.0
Interest	--	-42.5	--
Net Income	144.5	231.8	+ 60.4

Note: 1 Finnish Mark (FIM) = 0.238 US Dollars in 1989.
Source: Author (Produced and modified from Ref.28)

10 millions of whom were international. Passenger traffic rose to around 25.8 million in the following year indicating a minor change on the previous year. This little increase was due to the soft US economy and the general economic downturn in the Latin America. Cargo has been the fastest growing sector with nearly 15% annual increase from 1985-1990, and was anticipated to reach the million tonnes by 1990 [28]. The total tonnage at Miami for 1990 reached 966,500 tonnes, of which, 58,800 tonnes was mail [25]. In the same year, 107 airlines provided services to the Airport which included 80 scheduled and the rest operated regularly on passenger or cargo charter basis [28].

From 1985-89, total revenue had virtually doubled in four years and was up 14% on the year before i.e. 1988. Of this, commercial operations and concessions accounted for nearly half this figure leaving a quarter each for aviation fees and rentals (see Table 4.10). Improved productivity in 1990 brought a reduction in the landing fees from \$1.38 to \$1.26 per 500kg of the Maximum Gross Landing Weight (MGLW). This reduction was a useful saving to the airlines [28]. By the end of 1989, the Airport's balance sheet showed continuing investment with property and equipment valued at \$1.1bn. As with the capital expenditure, a total of \$535.3m was "foreseen" to be spent at the Airport by 1993. By 1990, the Airport's assets included \$8m in accounts (debts) owed by Eastern Airlines, plus a further \$41.3m in future rentals [28]. Table 4.10 shows the financial record of the Airport for 1988-89.

Table 4.10: Miami International Airport Financial Report 1989

Revenue	FY Ended 31 Sept.		% Change
	1988 (\$m)	1989 (\$m)	
Commercial Operations	90.5	109.9	+ 21.4
Concessions	22.1	21.1	- 4.5
Aviation Fees	60.7	69.0	+ 13.7
Rentals	59.8	64.8	+ 8.4
Other	2.1	2.9	+ 38.1
Total Revenue	235.2	267.7	+ 13.8

Source: Author (Produced and modified from Ref.28)

4.7.5 <u>Liverpool - Speke:</u>

In contrast to the airports discussed earlier, Liverpool Speke Airport has not been profitable for the last few years. For example, in 1987-88, the Airport lost £3.25m on a turnover of £2m, and a year later, it lost another £2m on a turnover of £3.75m [13]. Altogether, from 1989 to the end of 1995, the Airport lost a total of £11.7m most of which was through non-aviation activities [61].

On the other hand, in 1988, British Midland took over the London-Liverpool route from Manx Airlines, and by changing from turbo-prob to jet aircraft "<u>on limited flights only</u>", it increased passenger traffic at Speke "<u>on that route alone</u>" from 53,000 in 1988 to 80,000 per year in 1992, and therefore prevented further losses [13,61]. This increase shows that, the economic growth of an airport is <u>directly influenced</u> by the <u>quality</u> of its services. The highest number of passenger traffic on the <u>London-Liverpool</u> route was in 1990 when 113,000 people travelled on that route alone, and this service (i.e. the jet aircraft operation by British Midland), <u>ceased to operate</u> in 1992 because of small load factors that were approximately around 35% on most flights [61].

In 1990, the total number of passengers (domestic and international) that went through Liverpool Airport was 503,000 per year, and by the end of 1995, this figure increased to 504,000 per year [61]. This small increase shows how little Liverpool has grown as an airport, it also explains why the Airport has been making losses over the last few years. The main reason for Liverpool's lack of growth, may be, in the Author's opinion, that the Airport suffers from close proximity to Manchester International. The recent financial records and the passenger traffic of the Airport are shown in Table 4.11.

Table 4.11: Liverpool Speke International Airport Financial Records And Passenger Traffic

Year	Pass. Traffic (Dom. + Int.)	No. Of Pass. On London - Liverpool Route	Loss Of Revenue (£m)
1989	488,000	105,000	2.4
1990	503,000	113,000	1.3
1991	465,000	82,000	1.2
1992	450,000	80,000	0.8
1993	468,000	-	1.8
1994	442,000	-	2.1
1995	504,000	-	2.1

-No service available
Source: Author (Produced from Ref.61)

Looking at Table 4.11, it can be seen that, the "<u>loss of revenue</u>" has gradually <u>dropped</u> from £2.4m in 1989 to £0.8m in 1992. This shows that, the use of jet aircraft on the London-Liverpool route <u>was improving</u> the Airport's financial situation. The figures also show that, although the London to

Liverpool service stopped operating in 1992, the "overall" passenger traffic at the Airport was not significantly affected. For the time being, there is no service operating from Liverpool to London Heathrow, and the only connection from Liverpool to London is via London Gatwick [61].

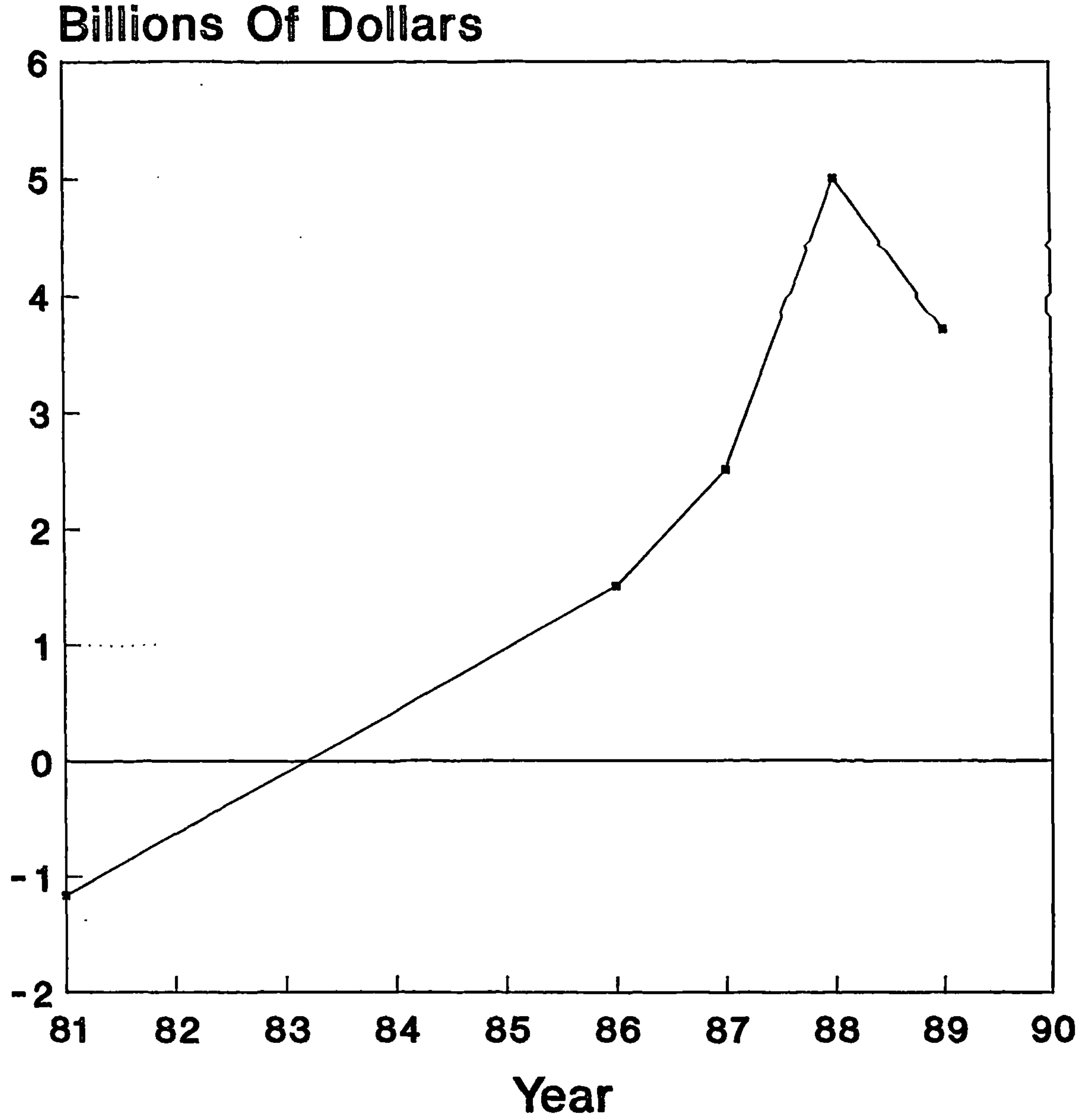
4.8 Financial Benefits To Airlines:

Occasionally airlines do make losses, but mostly they make large profits from their operations. For example, TWA (Trans World Airlines) lost $143m in the first quarter of 1990, and were expecting an annual loss of $350m. In the same year, the airline owed $500m in interest and dividends, but, it had $1.2bn in spare cash gained from profits over the past few years [28].

In the same year, Air Malta had an overall increase of 4% in traffic over the previous year which followed a pattern of higher profits in each year since 1986. 1988, however, showed the highest figure for profits up by 24% over the previous year representing a pre-tax profit of Lm5.25m ($17.85m) [28].

Figure 4.3 shows the financial record of the world airlines in which, values for 1981 and 1989 may indicate recession periods of the late 1970s and early 1990s respectively.

Figure 4.3: Profit And Losses Of The "Scheduled" Airlines Of The World
(After Income Taxes)



Note: Data for 1990 not available
Figures exclude domestic flights in USSR
Source: Author (Produced from Ref.24)

4.9 Economic Impact Of Chicago O'Hare International Airport - A Case Study:

O'Hare's role in the State of Illinois-USA and the regional economy of North America is of vital importance. Acting as the main hub of the national air transportation in the United States, it:-

a) Handles more "passengers" than any other airport in the world, (approximately 170,000 per day, almost 60 million in 1991);

b) Had an average of 110 aircraft movements per hour and over 810,000 per year in 1991;

c) Served nearly 50 commercial, commuter, and cargo airlines on a regular basis in 1991;

d) Created an estimated 186,000 jobs in 1985;

e) Pumped over $9bn per annum into the regional economy in 1985 [42].

Also, it is estimated that, when O'Hare's Development Programme is completed, its economic benefits will reach almost $13bn per annum [42].

4.9.1 Recent And Future Impacts:

In 1985, O'Hare contributed

$9bn/year to the regional economy through employment, payroll, taxes, and expenditures for local goods and services. In addition, business and tourism flourish through O'Hare in the surrounding communities thus boosting their economy. The annual economic impact of O'Hare is expected to grow up to $13bn by the end of this Century mainly because of its Development Programme [42]. By serving nearly 54 million passengers in 1986, and about 60 million in 1992, it ranks as the seventh largest employer in the State of Illinois. Its economic growth came about in 1961 when it overtook Chicago Midway Airport in air traffic volume to become the world's busiest airport. An estimated 186,080 jobs were related to O'Hare in 1985. Direct employment, and the total "aviation related" employment are expected to increase by 45% and 46% to around 60,000 and 272,000 respectively by the year 2000 [42].

O'Hare alone employed 40,800 staff in 1985 ranging from airlines; Government Agencies; and various concessionaires who make extensive purchases of materials; equipment; and local services to conduct their activities. Tourists and business travellers too inject large sums of cash through lodging; food and beverages; local transportation; and entertainment while visiting the area [42]. In 1985, a total of $1.1bn was spent by the "air travellers alone", which is estimated to reach about $2.5bn by the turn of the Century. The figure for 1985 included [42]:-

a) $594m to the hotel/motel, food and beverage industry;

b) $166m to the entertainment industry;

c) $100m to retail stores.

The above three industries alone received about 78% of the total 1985 expenditures from the "air travelling" public. Indirect aviation related impacts for 1985 were $104m, and were estimated to reach $151m by 1995 [42]. These derive from businesses which cater for the passengers and cargo activities, employ local residents, and purchase local goods and services to operate their aviation related business. Approximately 65% of the freight forwarders and cargo handlers in the region use O'Hare for shipping [42].

Induced impacts resulting from direct and indirect benefits of the Airport were, in 1985, $5.1bn/annum. For every job related to aviation, there are 1.9 non-aviation related jobs created in the Chicago Metropolitan area. For every Dollar spent "in relation to O'Hare", an additional $1.25 is spent in the area. For every Dollar spent by the travelling visitor, an estimated $1.5 is spent in induced expenditures [42].

4.9.2 Impact On Industry:

Industries that depend on O'Hare include:- the convention and tourism; hotel/motel; banking; financial institutions; and many others that have immense economic importance to the Chicago Metropolitan area.

a) <u>Convention And Tourism:</u>

Close to 3 million people came to Chicago area for conventions, trade shows, and corporate meetings in 1986 of whom, 70% came by air. In the same year, over 690 conventions, 154 trade shows, and 26,650 corporate meetings were held in Chicago area which is recognised as the largest convention and meeting centre in the United States [42]. Although the figures for the previous years were higher, still they are a significant source of revenue to the region's economy. Chicago's position amongst other convention centres of the USA would be jeopardised without O'Hare which connects Chicago to almost anywhere in the world [42].

In 1987, 56 airlines were served by O'Hare (18 domestic; 16 foreign; 7 commuter; and 15 all-cargo carriers), and later in 1991, the numbers dropped to 50. Non-stop services in the same year were provided to 165 airports (142 domestic and 23 foreign). Altogether, they enhance Chicago's position as the convention centre of the USA and to gain a commercial and financial entry into the world. IVI Travel, the largest single travel agency in Chicago noted that, "their gross volume exceeded $100m, and over 0.5 million of their passengers per year used O'Hare" in 1987 [42].

b) <u>Hotel And Motel:</u>

These are very important to the local service industries and their livelihood depends upon O'Hare particularly the ones close to its vicinity. A 1987 survey of the hotel/motel in the region showed that, on average, half of their guests arrived by air, and the ones around O'Hare had the highest rate of occupancy in the region. In addition, there are 8,900 hotel/motel rooms available in the area, and the numbers are increasing annually with the building of new hotels [42].

c) <u>Banking, Finance, And Postal Services:</u>

The banking industry also depends on O'Hare to the extent that their executives protested against night-time flight restrictions and curfews which slow down the transfer of mail. Flight restrictions and night-time curfews do not favour the banking industry as their ability to transfer and clear bank cheques would be restricted. Also, interference with financial institutions on both regional and national scales would become inevitable through such restrictions [42].

Over 870,000 tonnes of freight and mail went through O'Hare in 1986, with nearly 250,000 tonnes of it in mail. The Airport claims to have the largest "<u>on-airport</u>" air mail facility in the world. In 1990, the total figure for freight and mail reached to 986,700 tonnes (Table 4.2), and by the year 2000, this figure is estimated to reach over 1.2 million tonnes. Local businesses depend heavily on these shipments when they have to air freight their finished products to their customers. One firm for example, Extel, that are based in Chicago and operate in more than 100 countries, ship approximately $30m of equipment per annum (1987) through O'Hare to their overseas distributors [42].

d) Development In The Airport Area:

Chicago is the third largest metropolitan area in the United States and is growing too. O'Hare attracts secondary types of development many of which provide its supporting services while others seek the convenience of close proximity to the Airport. The location of many economic activities are directly linked to the presence of another complementary activity such as community growth to the Airport growth [42].

The O'Hare Exhibition Centre, located near O'Hare in Rosemont is the 11th largest convention centre in the Country with a large hotel/motel base, and its prime purpose is to attract visitors using O'Hare. The office market around O'Hare has boomed too over the past few years. In 1985, there were over 50 buildings available with over 63,000m^2 of space around O'Hare, and there will be over 153,000m^2 by the end of 1996 to accommodate for the businesses and employees attracted to the area. Developers in the surrounding Cook and DuPage County continue to benefit from development interests attracted to O'Hare area [42].

4.9.3 Benefits From The O'Hare Development Programme:

The Development Programme (DP) at O'Hare has brought additional benefits to the Chicago region through jobs both during construction phase, and permanent ones due to the improved facilities. From 1984-85, over 7,700 construction related jobs with an average duration of two and a half years were created. These included 3,100 on-site, 420 off-site, and 4,410 in the related manufacturing industries. The payroll from these jobs was about $700m which would generate an unquantified amount of induced employment, payroll, and expenditures in the local service economy [42].

By the year 2000, O'Hare Airport is expected to contribute more than $10bn/annum to the region's economy. More economic benefits will rise from the Development Programme, since it would enable O'Hare to operate more efficiently, and on a much larger capacity. The Development Programme, once completed, will bring an extra $2bn/annum with 46,000 new jobs into the region. But, if the Development Programme does not take place, the annual regional economic contribution would then reduce to $11bn from $13bn with the loss of 46,000 new jobs [42].

4.9.4 <u>Regional Development And Growth:</u>

O'Hare is a major factor in the rapid economic development of its surrounding communities. The following examples show how communities have prospered because of their close proximity to O'Hare. As the Airport grew, so did suburban communities and industries thus, more jobs became available. Des Plaines, which is in the northern border of O'Hare has grown rapidly in business ever since O'Hare began commercial operations in the early 1960s. Estimates show that, at that time, the number of businesses in Des Plaines had quadrupled, and city planners and businessmen confirm the importance of O'Hare to the vitality of the business community [42].

Elk Grove Village incorporated in 1956, has also been growing in-line with O'Hare. According to Crain's Chicago Business Magazine, in 1982, the Village gained Chicago more major manufacturing plants than any other Cook County Suburb because of its proximity to O'Hare which offers major transportation facilities, and has caused such a growth in a short time. As a result, a 1967 plan for the Village had noted the importance of O'Hare, and suggested the reservation of land adjacent to it for industrial uses [42].

This land, in 1987, contained the world's largest industrial park taking advantage of O'Hare's air services. The Village was planned specifically with O'Hare in mind by dividing it into two sections. One industrial bordering the Airport, and the other residential away from the Airport. The Village is a member of the Greater O'Hare Association of Commerce and Industry (i.e. a suburban cooperative active towards the growth of industry and commerce), and was established in 1956 by businessmen who recognized the growth potential of O'Hare. Other members of the Association are Wood Dale; Elmhurst; Bensenville; and Itasca [42].

Rosemont, a small village of only $8km^2$, most of which is devoted to industrial and commercial use, has become a major exposition and trade show centre with the development of the Rosemont Horizon in 1979, and the O'Hare Exposition Centre. The development of major hotels with plans to construct more, followed by a large dinner theatre, and a shopping complex have also been encouraged by Rosemont [42].

4.9.5 O'Hare's Employment Distribution:

When assessing the economic impact of an airport, it is important to know where the direct on-site employees live. In 1987, nearly 40% of the employees lived within the City of Chicago, and the rest in the suburban Cook and Du Page Counties. Over 10% of the on-Airport employees lived in Du Page, and the other 90% in Cook County. Of the non-Chicago employees, the greatest distribution resided in the West and Northwest of the Airport in the following communities [42]:-

Community	O'Hare Employees (1987)
Des Plaines	2.6%
Mt. Prospect	2.3%
Schaumburg	2.2%
Elk Grove Village	1.8%
Arlington Heights	1.8%
Hoffman Estates	1.7%
Palatine	1.6%
Roselle	1.2%

4.9.6 Summary:

The economic impact of an airport can be direct; indirect; or induced (see 4.2.1 before).

a) Direct Impacts:

Those pounds and jobs directly raising from activities occurring on the airport.

b) Indirect Impacts:

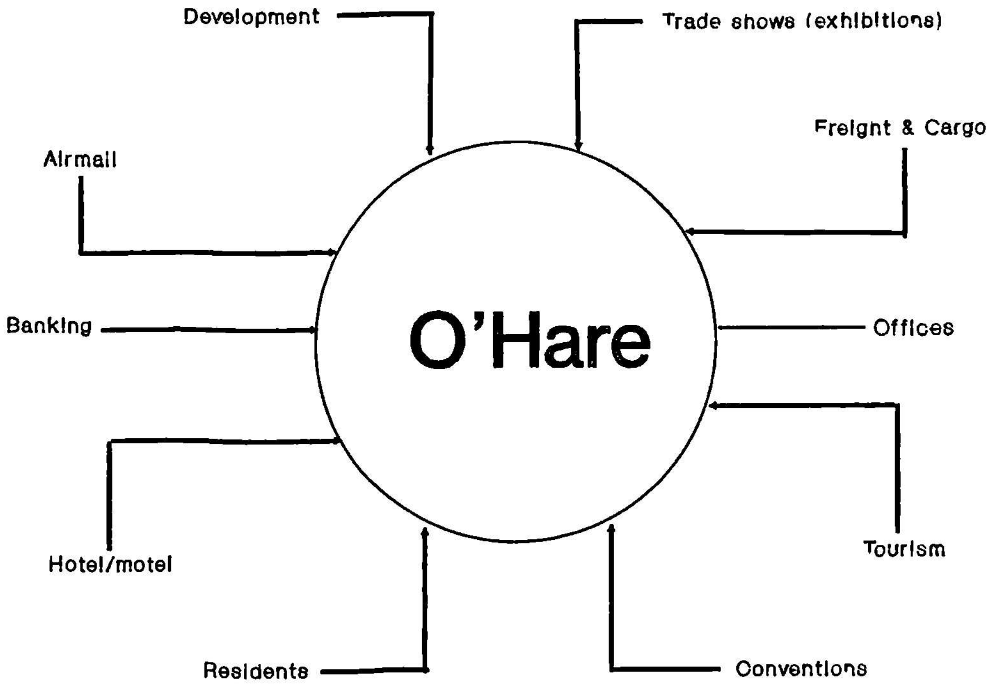
Those pounds and jobs created by businesses occurring off the airport but rely mainly on aviation for a substantial portion of their economic existence e.g. hotel/ motel; cargo handlers; and freight forwarders.

c) Induced Impacts:

A by-product of both direct and indirect aviation activities e.g. green grocers; doctors; lawyers; fuel station attendants; small retailers; and other local employers.

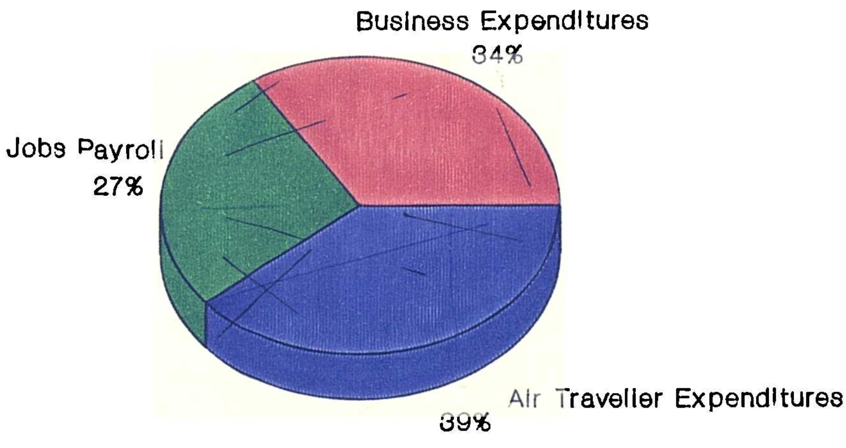
Figures 4.4 to 4.10 and Table 4.12 illustrate the economic impact of O'Hare International Airport up to 1995.

Figure 4.4: Chicago O'Hare Economic Impact



Source: Ref.42

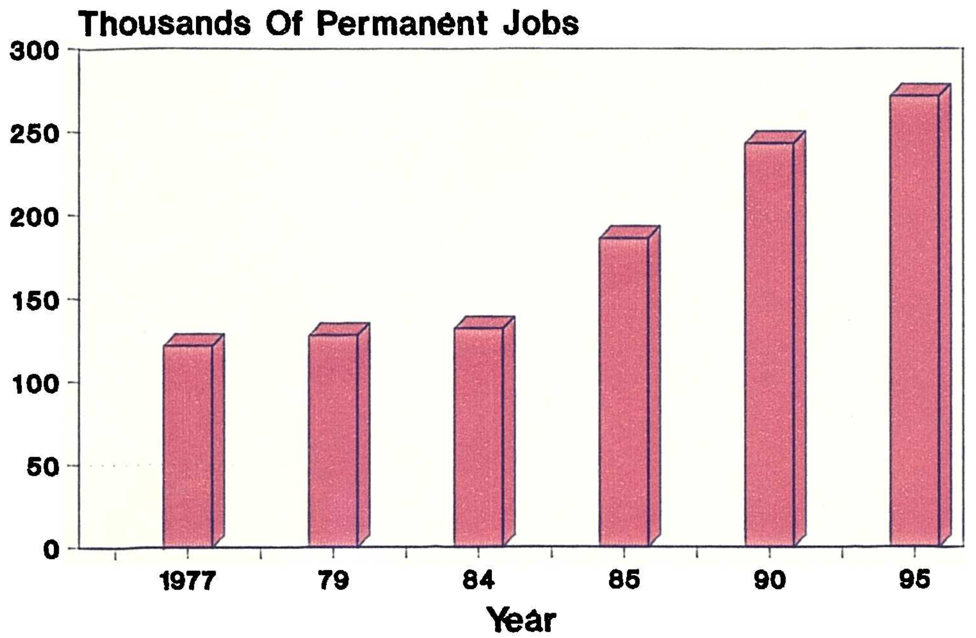
Figure 4.5: Chicago O'Hare Economic Impact



(Total Of $12.8bn By 1995)

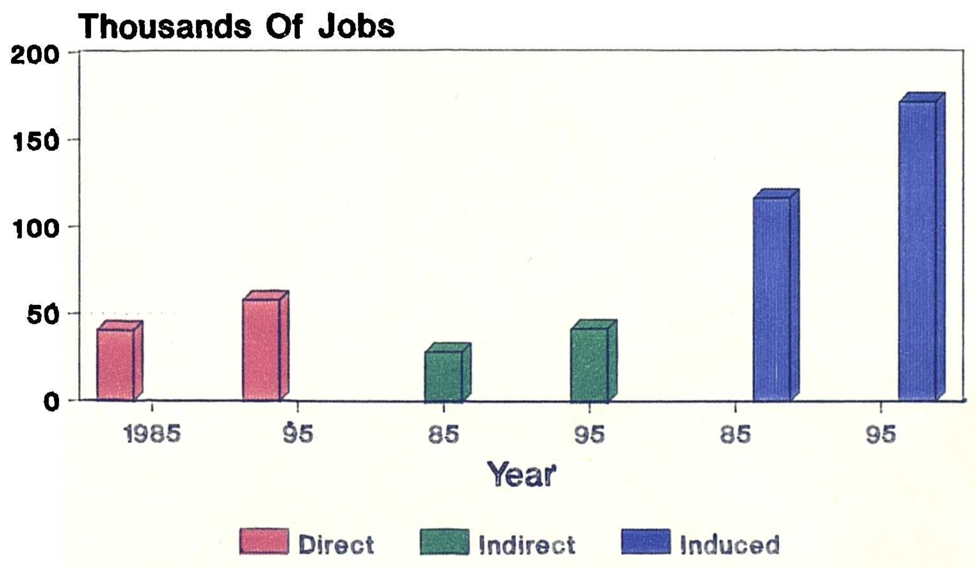
Source: Ref.42 (Chicago O'Hare)

Figure 4.6: Number Of Permanent Jobs



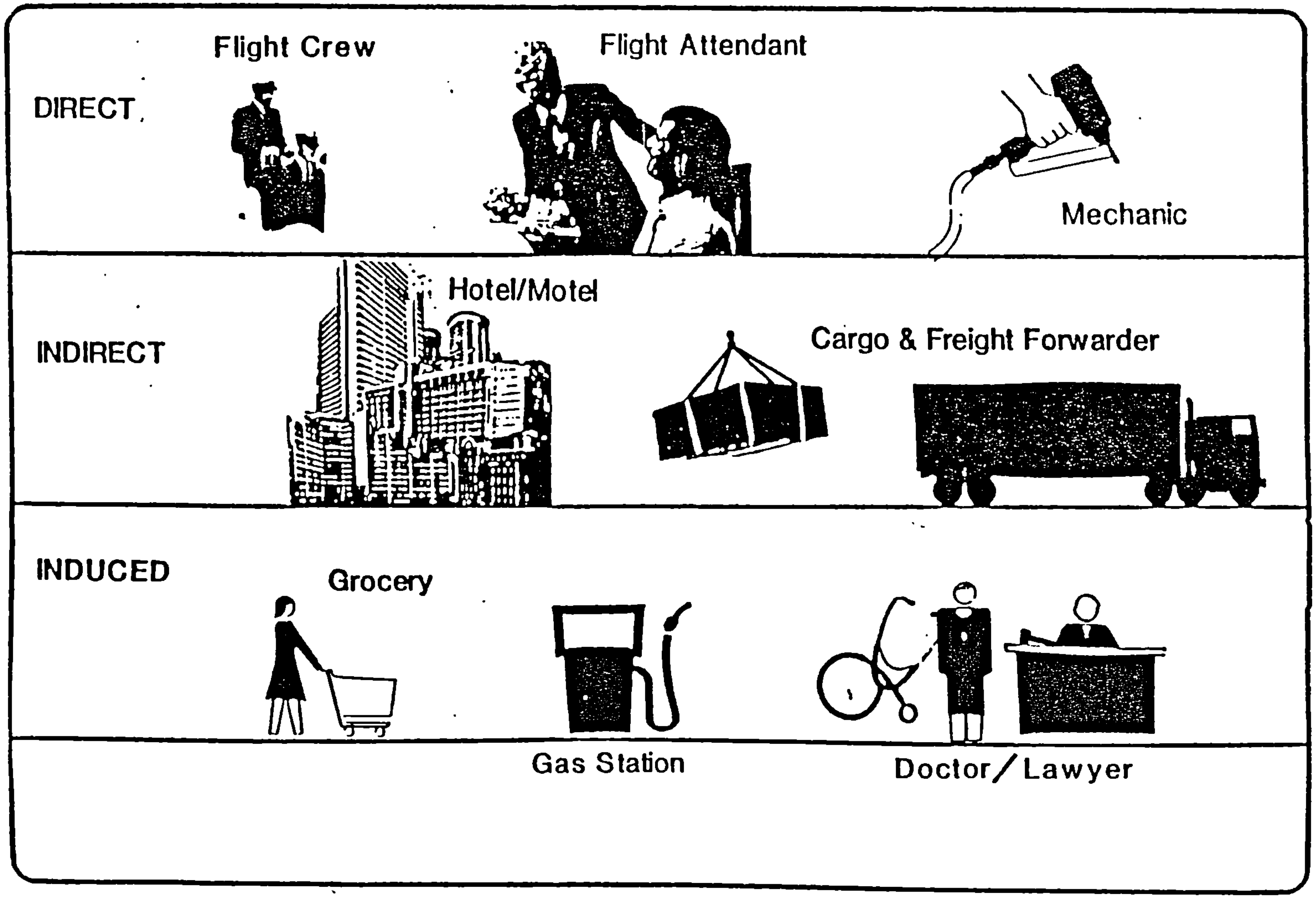
Note: 1995 data is a forecast
Source: Ref.42 (Chicago O'Hare)

Figure 4.7: Aviation Related Employment (Direct, Indirect, And Induced)



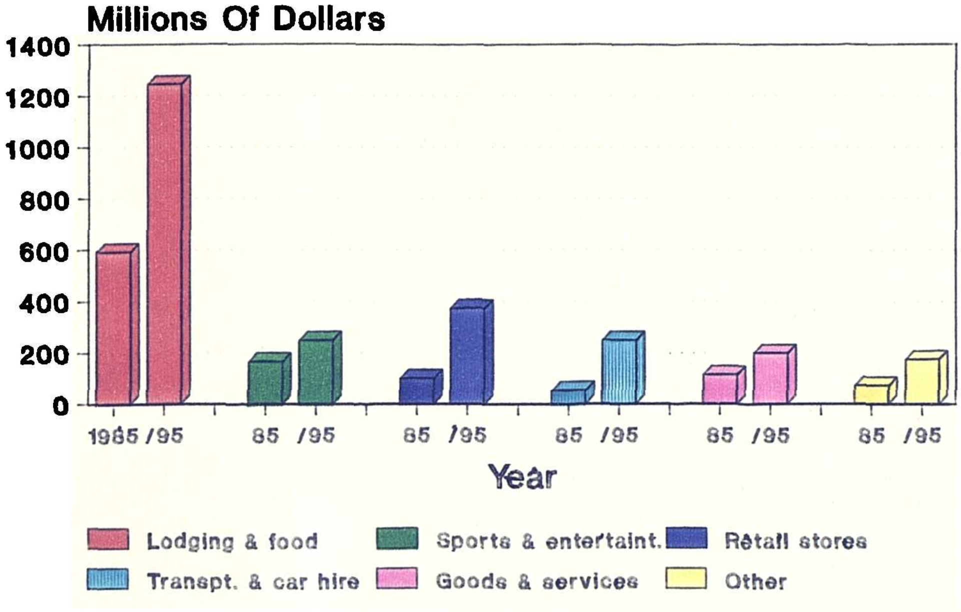
Source: Author (Produced from Ref.42)
(Chicago O'Hare)

Figure 4.8: Category Definitions Of Aviation Related Employment



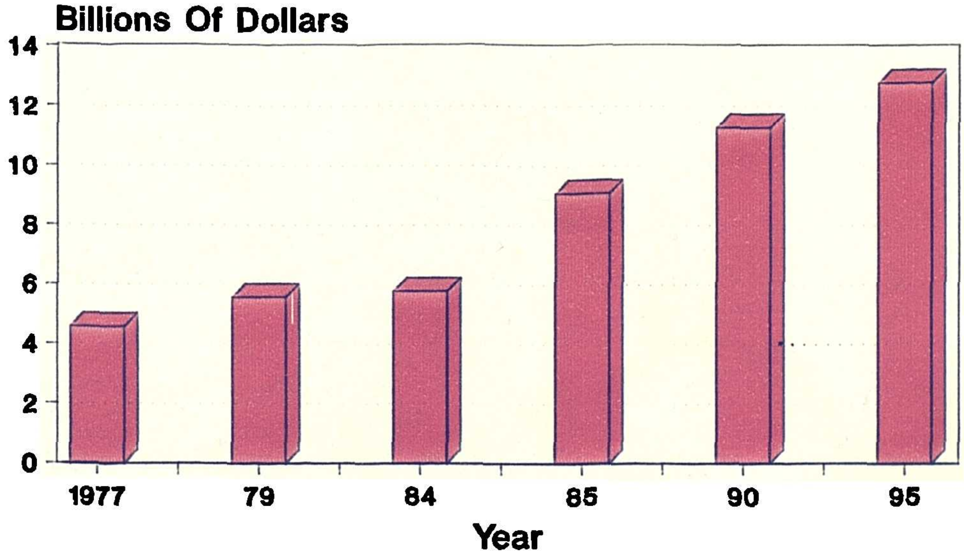
Source: Ref. 42

Figure 4.9: Air Travellers Expenditure



Source: Author (Produced from Ref.42)
(Chicago O'Hare)

Figure 4.10: Total Regional Economic Impact Of Chicago O'Hare Int. Airport



Note: Data for 1990 & 1995 are forecasts
Source: Author (Produced from Ref.42)
(Chicago O'Hare)

Table 4.12: O'Hare's Economic Impact On The Region In Millions Of Dollars

				Forecast	
	1979	1984	1985	1990	1995
No.Employed					
dir.on/off	28,413	28,636	40,800	53,750	58,310
indirect	21,819	23,816	28,830	36,530	41,910
induced	77,725	79,516	116,450	153,000	171,530
Total	**127,957**	**131,968**	**186,080**	**243,270**	**271,750**
Payroll					
direct	576.1	568.7	1,156.1	1,515.7	1,636.0
indirect	174.8	201.9	63.8	80.2	92.2
induced	804.2	812.5	1,246.2	1,647.5	1,826.8
Total	**1,555.1**	**1,583.1**	**2,466.1**	**3,243.4**	**3,555.0**
Expenditures					
direct	469.6	476.6	1,050.6	1,152.6	1,239.3
indirect	428.4	450.1	40.1	51.1	58.5
induced	1,097.0	1,113.3	1,313.3	1,562.0	1,741.4
Total	**1,995.0**	**2,040.0**	**2,404.0**	**2,765.7**	**3,039.2**
Air Traveller					
direct	848.3	877.0	1,694.0	2,170.6	2,493.4
induced	1,272.4	1,315.5	2,541.0	3,255.8	3,740.3
Total	**2,120.7**	**2,192.5**	**4,235.0**	**5,426.4**	**6,233.7**
Total					
direct	1,894.0	1,922.3	3,900.7	4,838.9	5,368.7
indirect	603.2	652.0	103.9	131.3	150.7
induced	3,173.6	3,241.3	5,100.5	6,421.9	7,308.5
Total	**5,670.8**	**5,815.6**	**9,105.1**	**11,312.1**	**12,827.9**

Source: Ref.42 (Chicago O'Hare International Airport)

4.10 Economic Impact Of Manchester International Airport - A Case Study:

Manchester Airport is said to be Europe's fastest growing International Airport, and it is hoping to take off into the next century as one of the world's ten busiest airports. It is also Britain's third largest and busiest Airport coming after Heathrow and Gatwick, with a considerable economic potential in the North West of England which shall be discussed here in the following sections [12,30,44].

4.10.1 Employment Potential:

As with employment, research has shown a clear relationship between passenger throughput and job creation which is in the order of 1,000 new jobs on site for every additional million passengers [44]. In 1990, nearly 10,000 people were employed at the Airport directly on site, with another 15,000 jobs dependent on the Airport in the region. By the year 2000, the direct on-site jobs are expected to reach over 15,000, and up to 30,000 by 2005 with more than 45,000 other jobs in the region depending on the Airport's further expansion and development [44].

The Airport Company alone is the largest employer with nearly 2,000 employees in 1990, and there are over 150 other companies based at the Airport ranging from the very large to companies employing only one or two people [44]. For example, in 1991, about 260-280 people were directly employed in the

ATC section of the Airport [43]. These jobs are skilled, and they are provided by the CAA involving landing; takeoff; taxiing; and other ground operations of aircraft. Therefore, an increase in the passenger traffic will increase the number of aircraft movements (i.e. landings and take offs) thus, increasing employment in this section. In 1991, there were approximately 45 movements per hour at Manchester Airport during peak periods [43].

The recent expansion of Manchester Airport by building a new terminal has had a significant importance in terms of employment. For instance, during the 50 month construction period of phase 1 (1989-93), it was estimated that some 3,000 temporary jobs were created on site [44]. Also, research has shown that, for every job created on site, there were 1.5 jobs created outside the Airport. In other words, the Airport has a multiplier effect of 1.5. The research also highlighted the Airport as the most important factor in attracting inward commercial and industrial investments [44].

For example, between 1983 to 1988, nearly 150 inward investments were made in the North West of England providing more than 13,000 jobs. And by 1990, another 15,000 jobs within the region were dependent on the Airport [44]. Also, according to a research by Cheshire County Council in 1990, it was shown that many of these investments were the Airport service firms, and that they were located in the surrounding area within a 20 minute drive time of the Airport [44].

In 1991, research by the Henley Centre clearly concluded that the Airport has now become the largest single generator of economic activity within the North West of England, and that its influence spreads far beyond the direct job creation. It further concluded that the economic good of the region was best served by further expansion of Manchester Airport through building a second runway [44]. This is because, by the end of 1991, the Airport had handled 11 million passengers, and was responsible for 25,000 jobs. At the same time, passenger numbers on the increase have had a direct effect on jobs, and in a much wider area than that which the planners had initially forecasted between Macclesfield, Warrington, and Manchester City Centre [35,41]. As a result, having built a new international terminal, the Airport is now planning to build a second runway, should permission be granted.

The Airport's 1992 <u>terminal capacity</u> was 12 million, which increased to 18 million when the first phase of the new 2nd terminal opened in 1993 [12,60]. With 30 million passengers forecasted for the year 2005, the Airport believes that by building a second runway, a further 50,000 <u>new</u> jobs will be created (see 4.2.2 before) in the North West of England most of which will be at the Airport or in the service industries [41]. The new runway is said to increase Manchester's <u>runway capacity</u> from 42 in 1991 to 70 movements per hour at peak periods (i.e. 1 every 50 seconds), and to double the capacity to 30 million passengers per year by 1998. The estimated cost of the new runway is about £36-40m, and it could be ready by 1998 [12,33]. Table 4.13 shows the employment potential of Manchester Airport in the region.

Table 4.13: Employment Potential Of Manchester Airport

Jobs - Aviation Related	1990	2001	2005
On-Site	10,000	15-20,000	25-30,000
Off-Site Direct	5,000	8-10,000	10-12,000
Off-Site Indirect	5,000	8-10,000	10-12,000
Off-Site Induced	3,000	5-8,000	8-10,000
Total	**23,000**	**36-48,000**	**53-64,000**

Source: Based on York Consulting Limited (Ref.44)

4.10.2 <u>Other Benefits:</u>

In 1982, IATA forecasted that 6.6 and 8.3 million passengers would go through Manchester Airport in 1990 and 1995 respectively [37]. In 1985, another forecast showed that, by 1995, a total of 10-13 million passengers (domestic plus international) would go through Manchester Airport [37]. The latter estimates, however, are much closer to the actual figures than those forecasted earlier by IATA since, the number of passengers that went through Manchester Airport (domestic and international) in 1991 was 11 million, and in 1995, it was 15 million [31,60]. These figures clearly show the growth potential of Manchester Airport which is mainly caused by the fact that, every day passengers arrive at the Airport from all over the world as new routes open every year and more carriers arrive [31].

This arrival of new airlines makes Manchester more important as a connecting point in the global network of aviation. For instance, in its first summer season of 1990, there were almost 140 "connecting flights" through the Manchester hub including Dusseldorf to Edinburgh; Newcastle to New York; Exeter to Hong Kong; Belfast to Copenhagen; Isle of Man to Frankfurt; Glasgow to Paris; and Bristol to Chicago. By mid 1996, these connections reached almost 200 [31,60].

In 1991, the CAA was investing more than £750m in the new air traffic control equipment and procedures, part of which included substantial investment to raise capacity at Manchester Airport. More controllers and engineers were therefore being recruited and trained. All this investment should provide a better service for air travellers at the Airport [31]. Work on the second runway which "was projected" to start in 1996 and finish by 1998 but has not yet received government approval, will run parallel to the existing runway, and once completed, millions of extra passengers will be able to come into the UK from the North and South Americas and other long distance departure points, and then en route to other destinations in Europe. This would not only boost the economy of the North West of England, it would also help reduce the load at both Heathrow and Gatwick Airports

[33,36,60].

This expansion at Manchester may place the Airport amongst the top ten airports in the world, and at the same time, it would ensure Britain's leading position in dominating the multi-billion pound European market against competition by other European countries namely France and Germany. The new proposed relaxation in <u>EC</u> air regulations which allows airlines to fly freely to any destination within the fifteen Common Market Countries is also advantageous to the Airport and its regional economy [33]. In addition, other <u>Continental</u> airlines such as Singapore; Cathay Pacific of Hong Kong; and Quantas of Australia are nowadays becoming regular visitors at UK's third largest Airport (Manchester) which means more economic benefits [34].

For instance, when American Airlines came to Manchester from Chicago, they brought £30m worth of investment into the North West [34] plus an <u>extra</u> 750 jobs resulting from the one flight per day operation assuming a multiplier effect of 1.5 [30]. They (American Airlines) have now requested a second service since their Manchester-Chicago service is now their most successful route with a load factor of over 90% on every flight, and further flights from Washington or Pittsburg may triplicate that investment. If, however, the new scheduled services to Japan; Vienna; Turkey; Finland; and other destinations are to be successful, then a second runway is important in the smooth operation of the Airport [34].

In 1991, Manchester Airport ranked 17th in the world in terms of "international passenger traffic" by handling 11 million passengers (see 4.10.1 earlier), and a "total" of 80,000 tonnes of freight (embarked + disembarked) with Dublin and Belfast as its busiest routes for freight traffic [34]. See Table 4.14 for recent traffic figures at Manchester Airport.

Table 4.14: Traffic (Dom. + Int.) At Manchester International Airport (1988-1990)

	1988-89	1989-90	% Change
Aircraft Movements	149,287	155,305	+ 4.0
Freight And Mail (tons)	76,556	74,906	- 2.2
Passengers Flown (millions)	9.7	10.2	+ 5.2

Source: Author (Produced from Ref.38 - M/C Int. Airport)

Looking at Table 4.14, it can be seen that, although passenger traffic for 1990 has increased, cargo traffic has dropped. This drop in cargo traffic at Manchester may have been caused by the current economic recession, or it could have resulted from the diversion of freight to London Heathrow. This diversion however, is mainly due to the fact that most wide-bodied aircraft with excess bellyhold capacity have replaced the all freighter aircraft and use Heathrow more than Manchester [4.6.1]. Future changes in the aircraft mix at Manchester could, however, alter the existing pattern.

According to a 1990 report by the Centre for Local Economic Strategies, Manchester Airport is an essential economic generator in the North of England [38]. For instance, in 1991, the Airport made more profit from its shops and concessions than from landing and takeoff fees. It also allocated £500m to be invested in the Airport's future development programme, part of which is the second terminal which opened in 1993 (see 4.10.1 earlier), and is said to be the largest "single" civil engineering project in the UK [34,60]. As with safety, the Airport has recently increased its standards by employing extra security personnel [38].

Manchester Airport brings economic benefit not only through jobs, but by paying dividends to the share holders i.e. the ten Northern Borough Councils of Greater Manchester with Manchester City Council having the largest share of 55%, and the rest i.e. Bolton; Bury; Oldham; Rochdale; Salford; Stockport; Tame side; Trafford; and Wigan Borough Councils each having a 5% share of the total. Out of the £29.8m profit made in 1990, more than £8.5m was paid in dividends to the share holders and the remainder retained in the Company i.e. Manchester Airport PLC [38]. See Table 4.15 and Figures 4.11 and 4.12 for the financial statements of Manchester Airport for 1989-90.

From Table 4.15, it is interesting to note that, although the trading profit increased by only 0.16% (very little), at the same time, the shareholder's and the Company's profits went

Table 4.15: Profit And Loss Account At Manchester Airport In £m (1989-90)

	Year Ended 31.3.90	Year Ended 31.3.89	% Change
Turnover	118.308	107.650	+ 9.9
Expenditure	81.263	70.665	+ 15.0
Trading Profit	37.045	36.985	+ 0.16
Shareholder's Profit	29.821	25.190	+ 18.4
Dividends	8.50	8.50	-
Retained Profit	21.321	16.690	+ 27.7

Source: Author (Produced from Ref.38 - M/C Int. Airport)

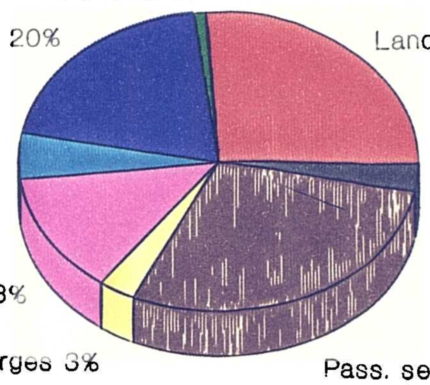
up by 18.4 and 27.7% respectively. These figures clearly demonstrate the economic benefit of the Airport to the area.

Also, looking at Figures 4.11 and 4.12, the "trading profit" for FY 1989-90 is:-

118.308 - 81.263 = £37.045m (see Table 4.15 above).

Since Manchester Airport is owned by the County's ten Town Halls, therefore, the more profitable it is, the lower is the new council or community tax [35]. This reduction of the new council tax will be financially very beneficial for the population of the area. The Airport also funds local charities; arts; operas; and theatres which boosts cultural activities in the area. For example, during 1989-1990, the Company contributed a total of £51,000 to UK charities, and £150,000 to support the Manchester Olympic Bid [38].

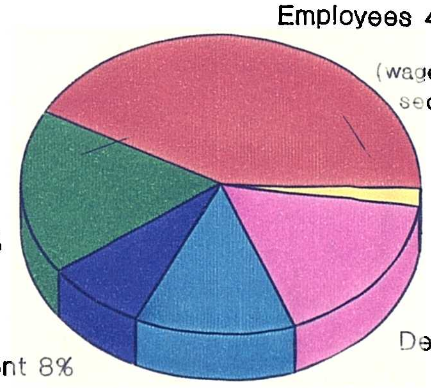
Figure 4.11: Analysis Of Income At Manchester Int. Airport 1989-90



(Total Revenue £118.308m)

Source: Author (Produced from Ref.38)

Figure 4.12: Analysis Of Expenditure At Manchester Int. Airport 1989-90



(Total Expenditure £81.263m)

Source: Author (Produced from Ref.38)

Finally, although a second runway, and the new international terminal at Manchester will have indisputable economic benefit to the Airport and to the region, at the same time, the problem of aircraft noise will be greater in certain areas such as in the West of Stockport [36], plus additional air pollution that will be added to the existing local levels.

4.11 Conclusions:

Airports in general are large commercial and economic centres with big turnovers. Large sums of money are normally invested in providing the airport facilities and infrastructure. This makes it important to plan airports well in advance, and with good anticipation in both traffic and economic growth coupled with "sensible timing". Such strategy helps avoiding any unforeseen future losses that may occur from inadequate planning. It is, therefore, unwise to build new airports at times of economic recession as in the case of Denver Airport.

The role of an airport is very important in the economic prosperity of a community. Given the necessity to move people and goods, it is difficult for a major metropolitan area to function efficiently without an airport. The greatest economic benefit of an airport is the providing of air transportation services through which other beneficial activities develop. Airports usually have immense economic impact the size of which depends directly on passenger and cargo traffic i.e. the busier an airport, the larger the impact. It is, therefore, very important as to where to locate and site an airport.

Most airports are normally profitable, but occasionally some make losses as in the case of Liverpool Speke which was discussed earlier (see 4.7.5 before). As stated earlier, the economic growth of an airport is directly influenced by the quality of its services and by its annual passenger traffic (see 4.7.5 earlier). Passenger traffic, and to a lesser extent cargo and mail traffic, are still the most beneficial activities of an airport. These activities themselves are influenced by the socio-economic characteristics of the region; by accessibility to the airport; by the value of time; by population density; by the size and type of an airport; by the quality of services in terms of flight frequencies; number of connections available particularly to medium and long distance destinations; and by the efficiency of its services.

Large international airports tend to be centres of industry and commerce. Their economic impact is much greater on the local scale than on regional or national scale. Depending on their size and their level of activities, they can penetrate deep into the heart of their national economy in the same way as London Heathrow does. Also, in a country which is densely populated and where receipts from transport play an important part in the balance of payments, the building of an airport can have a major economic impact. Furthermore, since airports are growth centres for employment; commercial activities; passenger and freight traffic; and other related industries, they can therefore be used by governments and planners as the means for redistributing wealth and prosperity from one region to another.

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Chapter 5

The Use Of Energy And Materials, And The Environmental Contamination Impact (Water Pollution)

5.1 Introduction:

Other important environmental issues related to airports are the use of energy and materials and the contamination of the local environments. Depending on the size of the airports, they usually consume considerable amounts of energy and materials e.g. electricity; gas; fuel; and chemicals some of which may be environmentally harmful. The releasing of waste energy and other contaminants to the general environment is therefore inevitable. For instance, the contamination of the waterways, rivers, and canals is a common problem with airports. In addition to sewage, aircraft painting and chemicals such as solvents; runway and aircraft de-icers; fire-fighting and anti-freeze agents; fuel; oil; and other fluids spillage are all added to the water effluent which may contaminate the waterways.

Furthermore, millions of people may use airports every day producing large amounts of liquid and solid waste (rubbish; leaves; worn tyres; empty cans and bottles; food products and sanitation) which when burnt or disposed of otherwise, may all contaminate the environment. This chapter however, will attempt to demonstrate the environmental importance of both energy and materials consumed by airports and airlines by showing examples related to British Airways (BA), it will also discuss the importance of environmental contamination particularly, water contamination.

5.2 Waste From Airports:

Airport related wastes are mainly:-

A) Water and related effluent;

B) Energy;

C) Materials.

The main areas normally generating waste are:- Engineering; aircraft catering; offices; cargo; motor transport; canteen catering; and properties. With a few exceptions, all waste is defined as controlled waste and is subject to the Environmental Protection Act, 1990 [1]. Controlled waste divides into household; industrial; and commercial waste, with the waste from airports being either commercial or industrial. In general, there are three ways to reduce waste effectively [1]:-

a) Reduce it at source (most favoured way);

b) Reuse it (second best option) e.g. envelopes for internal use;

c) Recycle it (which can be costly and inconvenient).

For example, the following materials are being recycled by BA:- Aluminium cans; blankets; cardboard; hydraulic fluid; laser printer cartridges; linen; magazines; metals and metal trays; oils; pallets; paper; polythene; save-a-cup; tyres-both aircraft and car [1]. A good waste management scheme helps reduce the amount of waste generated by an airport. It can also prove very cost effective, and at the same time be environmentally friendly.

5.3 Energy Consumption:

The consumption of energy at airports is mainly from two areas:-

a) Consumption in the air;
b) Consumption on the ground.

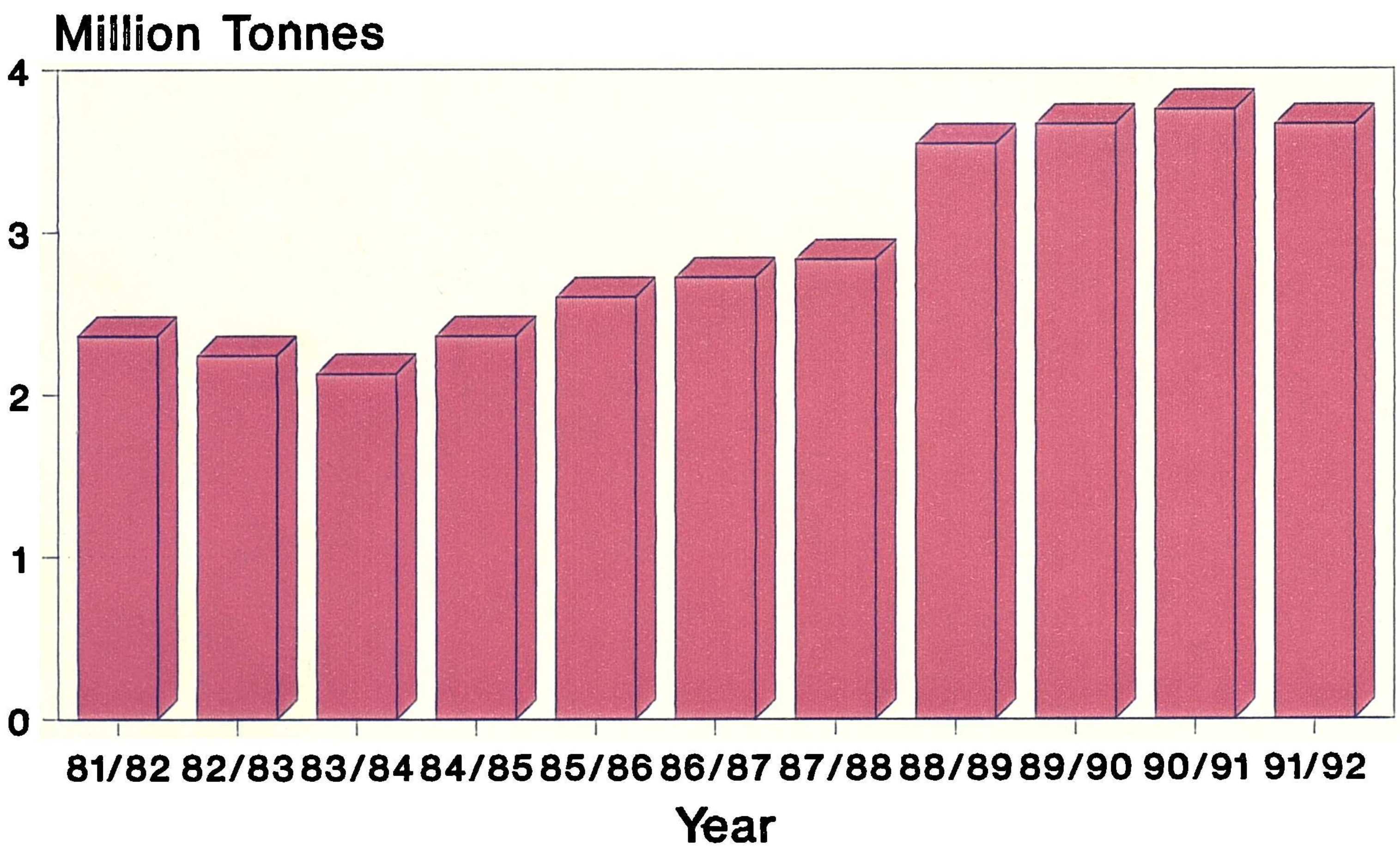
5.3.1 Consumption In The Air:

In 1991-92, BA's scheduled services used 3.66 million tonnes of fuel i.e. a 2.4% decrease on the previous year. In terms of passenger capacity, this represents 39gms per *ASK (Available Seat-km) i.e. a 4.1% decrease on 1990-91. In terms of overall tonnage, it represents 274gms per **ATK (Available Tonne-km) i.e. a 5.8% decrease on the previous year [1]. See Figure 5.1 for the total energy (fuel) consumed by BA over the past few years.

**ASKs - The No. of seats made available for sale multiplied by the distance flown.*

***ATKs - The No. of tonnes of capacity available for the carriage of revenue load (passengers and cargo) multiplied by the distance flown.*

Figure 5.1: British Airways Total Fleet Fuel Consumption



Source: Author (Produced from Ref.1)
(British Airways)

5.3.2 Consumption On The Ground:

Ground transport operations also use large amounts of energy some of which is inevitably released to the atmosphere. For instance, studies made at large airports show that ground service vehicles consume approximately 32 litres of gasoline (diesel)/vehicle/day [2]. In addition to fuel cost, the main sources of ground energy are electricity; gas; oil; and "High Temperature Hot Water" (HTHW) which is normally supplied by airports for heating purposes [1].

BA for example, in 1991-92, consumed a total of 222.4m kwhrs of electricity; 124.6m kwhrs of gas; and more than 2m litres of oil at Heathrow and Gatwick Airports. It (BA) also used a total of 175.3m kwhrs of HTHW at Heathrow alone at a cost of £2.95m, which is an increase in consumption of 1.33% on the previous year (see Tables 5.1 and 5.2). See also Figures 5.2; 5.3; 5.4; and 5.5 for energy use by BA over the recent years [1].

Figure 5.5 shows a downward trend in the energy consumption levels from 1989 onwards which could have resulted from factors such as:- a reduction in the number of employees; energy saving policies in general; fewer activities at the airports; better use of resources and equipment; and above all, the general economic recession of the 1990s.

Table 5.1: British Airways Ground "Gas And Electricity" Consumption At Heathrow And Gatwick

	Gas (millions of kwhrs)			Electricity (millions of kwhrs)		
	1990-91	91-92	% Change	1990-91	91-92	% Change
Heathrow	85.0	90.85	6.9+	204.5	206.1	0.78+
Gatwick	29.6	33.7	13.9+	16.2	16.31	0.68+
Total	114.6	124.6	8.7+	220.7	222.4	0.77+

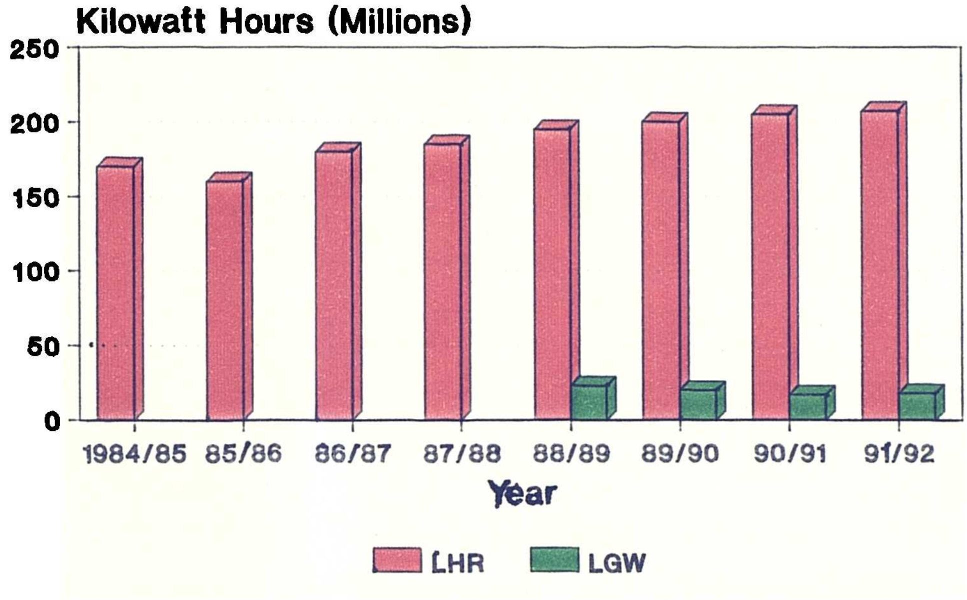
Source: Author (Produced and modified from Ref.1 - British Airways)

Table 5.2: British Airways Ground "Oil And HTHW" Consumption At Heathrow And Gatwick

	Oil (millions of litres)			HTHW (millions of kwhrs)		
	1990-91	91-92	% Change	1990-91	91-92	% Change
Heathrow	1.70	1.81	6.5+	173.0	175.3	1.33+
Gatwick	0.23	0.25	8.7+	n/a	n/a	-
Total	1.93	2.06	6.7+	173.0	175.3	1.33+

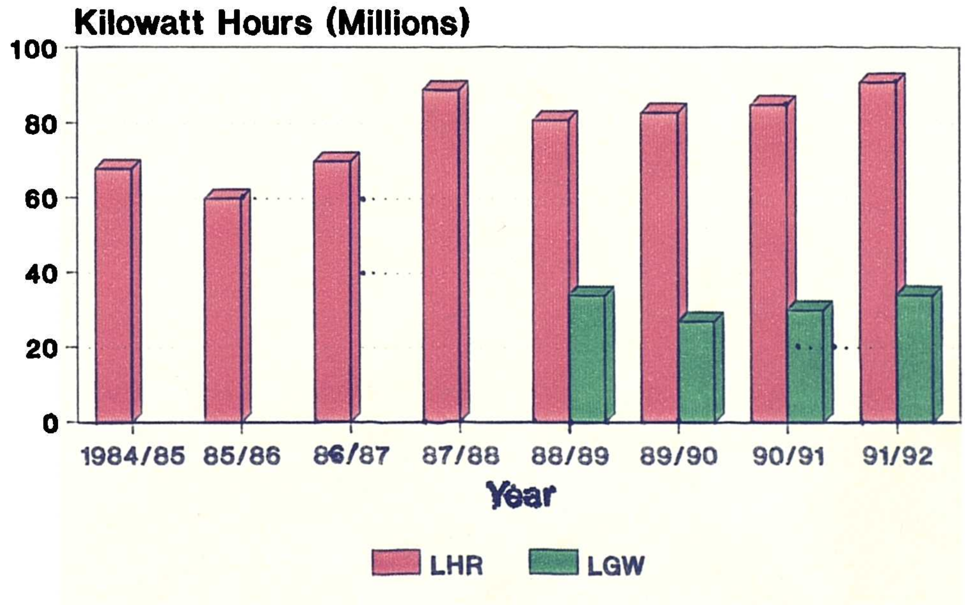
Source: Author (Produced and modified from Ref.1 - British Airways)

Figure 5.2: British Airways Electricity Consumption At Heathrow And Gatwick



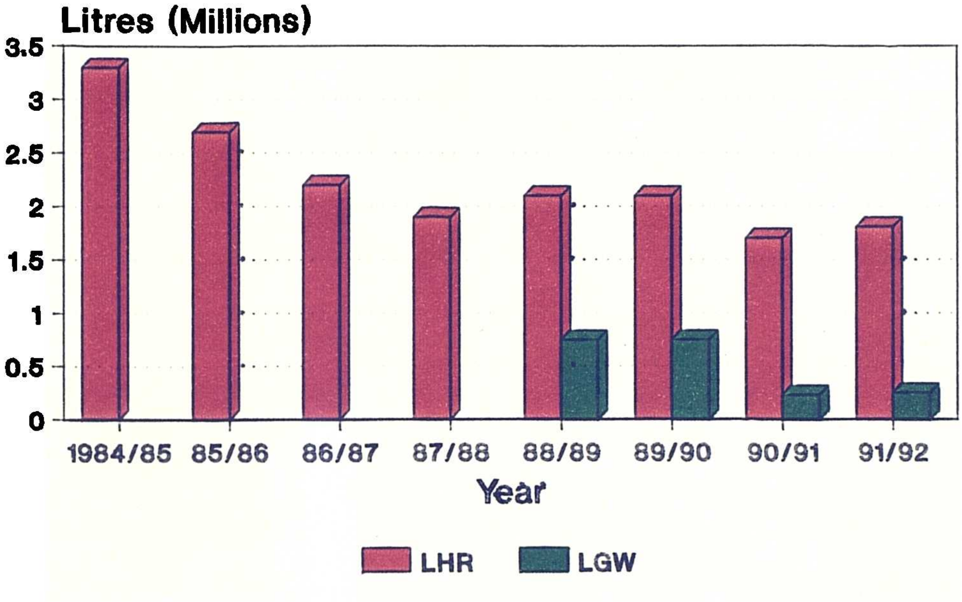
Source: Ref.1 (British Airways)

Figure 5.3: British Airways Gas Consumption At Heathrow And Gatwick



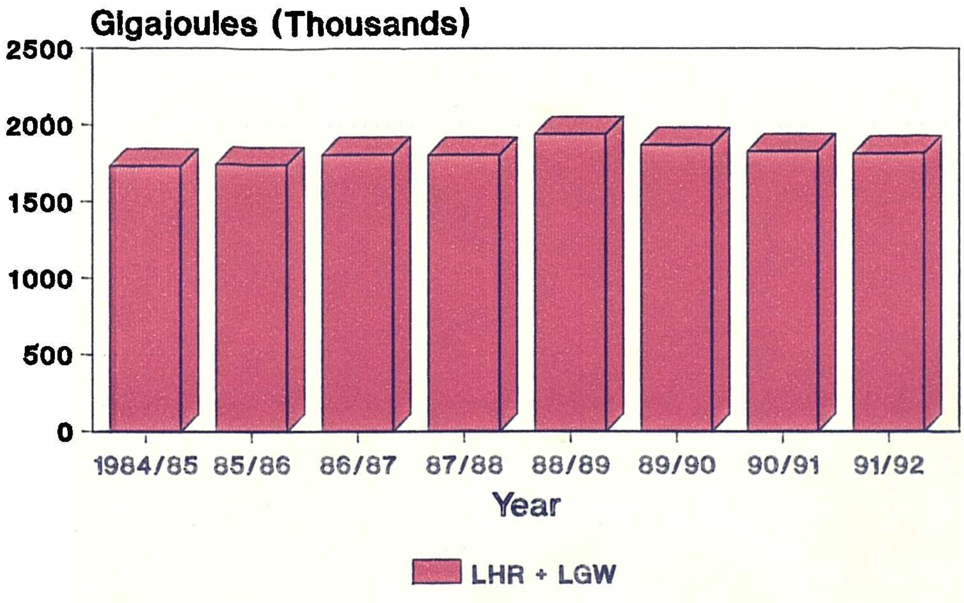
Source: Ref.1 (British Airways)

Figure 5.4: British Airways Oil Consumption At Heathrow And Gatwick



Source: Ref.1 (British Airways)

Figure 5.5: British Airways Total Ground Energy Consumed At Heathrow And Gatwick



Source: Ref.1 (British Airways)

5.4 The Use Of Materials:

Many environmentally sensitive materials and substances are used at airports the most common of which are Chlorofluorocarbons (CFCs); Chlorocarbon (CC); halons (fire protection); and other harmful materials e.g. Urea and Glycol which are used for aircraft de-icing [1,3].

5.4.1 CFCs:

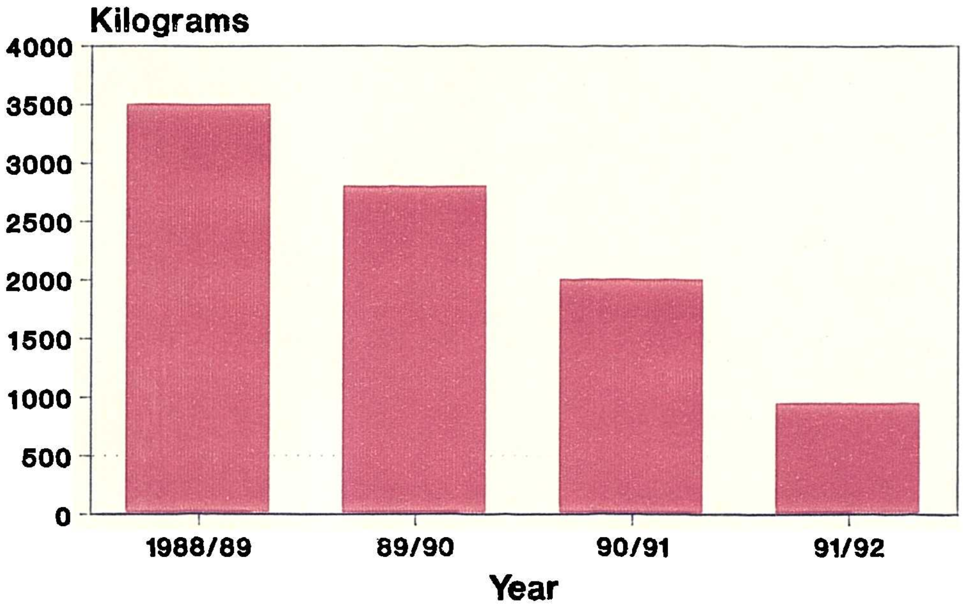
CFCs are man-made chemicals used in aerosols, cleaning solvents, as refrigerants and as foam blowing agents. Once released, they will stay in the atmosphere for a long time and destroy the ozone layer the importance of which (ozone layer) was discussed earlier in Chapter Three. The Montreal Protocol, limits the overall release of CFCs and other controlled substances that destroy the ozone layer. The Protocol came into force on January 1st 1989 and was strengthened in June 1990. Its revised version has been implemented in the EEC since March 1991. The controls vary depending on the substance, and in 1992, there were altogether 70 countries including the UK and other EEC members that were bound by the Montreal Protocol [1].

CFCs and other harmful materials are mainly used in the engineering and property sections of airports and airlines. The Montreal Protocol and its EEC version call for a freeze on production of CFC 11, 12, and 113 at 1986 levels by July 1st 1991, a cut of 50% by the end of 1992, and a complete ban by July 1st 1997. CFCs 11 and 12 better known as "Arcton" are used extensively as refrigerants in the air conditioning chillers and units. Since 1988, BA has reduced the use of Arcton by as much as 73% (see Figure 5.6) [1].

CFC containing solvents are to a large extent used for the cleaning of metals and plastics in engineering operations. The main ingredient is CFC 113 (trichlorotrifluoroethane) which is used under the trade names "Arklone and Prochemcgr". A replacement for Prochemcgr which contains no CFC, and is based on citric acid was being evaluated in 1992. BA however, has gradually reduced the use of these products (CFC 113) in their operations since 1989 (see Figure 5.7) [1].

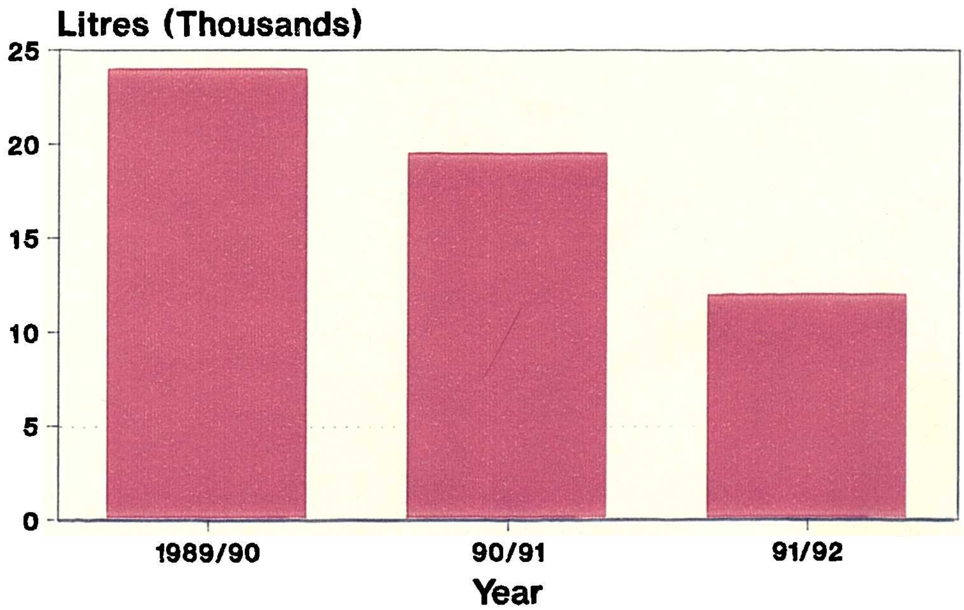
Some CCs too, destroy the ozone layer particularly trichloroethane 1,1,1 (methyl chloroform). The Montreal Protocol calls for a freeze on its production at 1989 levels by January 1st 1992, a 30% reduction by January 1st 1995, and a complete ban by the year 2005. Trichloroethane 1,1,1 (Genclene and Amberklene), is a cold solvent cleaner used for metals in workshops and hangars. See Figure 5.8 for the use of these products within British Airways [1]. BA also uses several other CCs which do not harm the ozone layer such as trichlorethylene (Triklone), perchlorethylene (Perklone), methylene chloride (Applied 8-02) and chloroform. Methylene chloride is used as the bases for all aircraft paint stripping. Since 1988, BA has cut the use of these materials by 32.5%, and Figure 5.9 shows the total use of these CC based materials by BA over the recent years [1].

Figure 5.6: British Airways CFC 11, 12 Use - Arcton



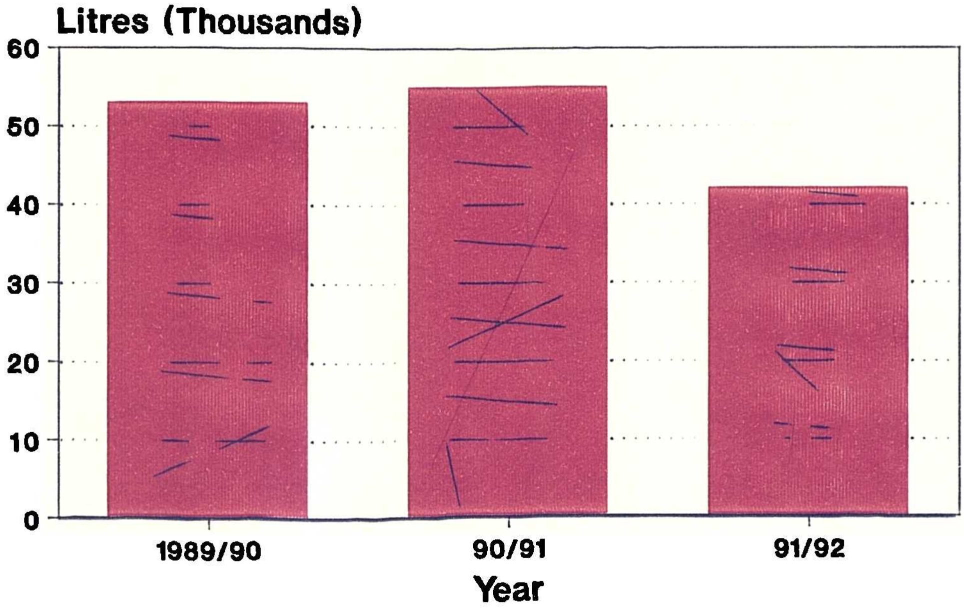
Source Ref.1 (British Airways)

Figure 5.7: British Airways CFC 113 Use As Solvent



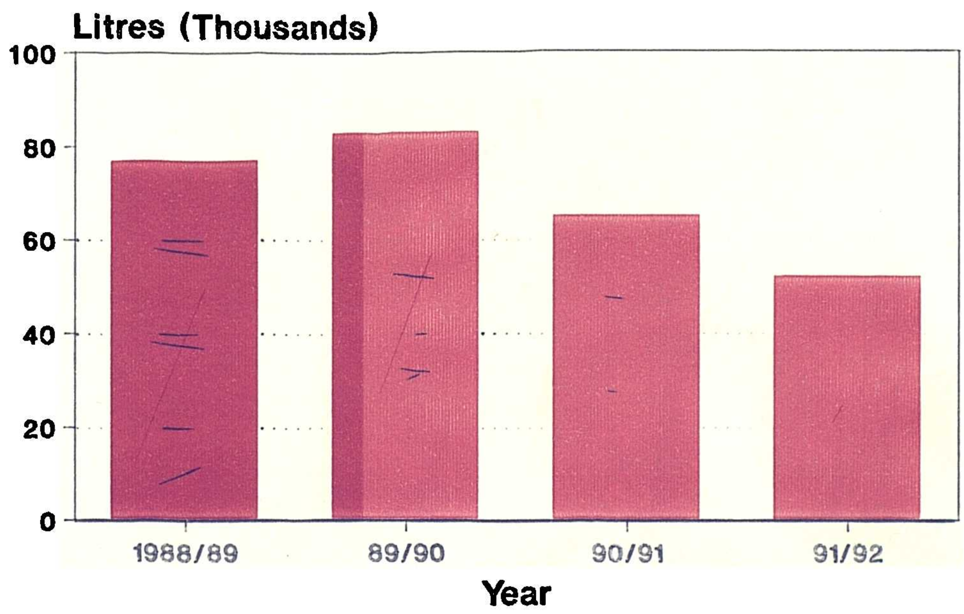
Source Ref.1 (British Airways)

Figure 5.8: British Airways Trichloroethane 1,1,1 Use



Source· Ref.1 (British Airways)

Figure 5.9: British Airways Other Chlorocarbon Use



Source. Ref.1 (British Airways)

Many of the CFC and CC based materials are used in aerosol form. Where possible, aerosols are being replaced by trigger sprays. Since 1989, the number of actual products supplied in aerosol form has been cut from 111 to 82 i.e. a reduction of 26%. Until 1992, there was no record of the quantity of CFCs used by BA in refrigeration and in insulation, but, a data base of all refrigeration equipment containing CFC-based refrigerants has now been produced by the BA's Properties Maintenance Department. Also, contractual changes which require the reporting of all CFC usage came into force from July 1992 [1].

5.4.2 Halons:

One particular group of CFC compounds is collectively known as halons. Worldwide consumption of halons was, in 1992, equivalent to only some 3% of the total worldwide CFC consumption, but, the high potential of halons for destroying ozone has led the UK government to propose that the production of "virgin" halons should be stopped in the EEC by 1995 unless, its use is absolutely essential. One area where halons may still be allowed is on board aircraft for fire protection as there is not yet an acceptable alternative and, its application is of "high social benefit compared to the environmental damages that may result from halons" [1].

The Montreal Protocol has led to a freezing of production of Halons 1211 and 1301 at 1986 levels in 1992, and in June 1990 the Protocol was amended to cut the production of Halons 1211 and 1301 by 50% by 1995, and to stop their production completely by the year 2000. Also, according to a report by the UK's DOE, the use of halons has fallen by 25% between 1987-1992, and in a survey of industrial and commercial halon users, 71% believed that CO_2 extinguishers are a suitable substitute for halons for certain applications [1].

Within BA, halons are mainly used for fire protection. BA uses Halon 1211 and Halon 1301, and the releases of Halon 1301 in 1990 and 1991 both resulted from failures in the fire protection systems of BA's computer installations. These halons are effective fire extinguishing agents, and they are electrically non-conductive. They dissipate quickly and leave little if any solid residue. Halon 1211 is held in portable fire extinguishers which are placed in buildings to protect key electrical installations, on aircraft ramp areas for ground servicing operations, and in fixed systems on aircraft [1].

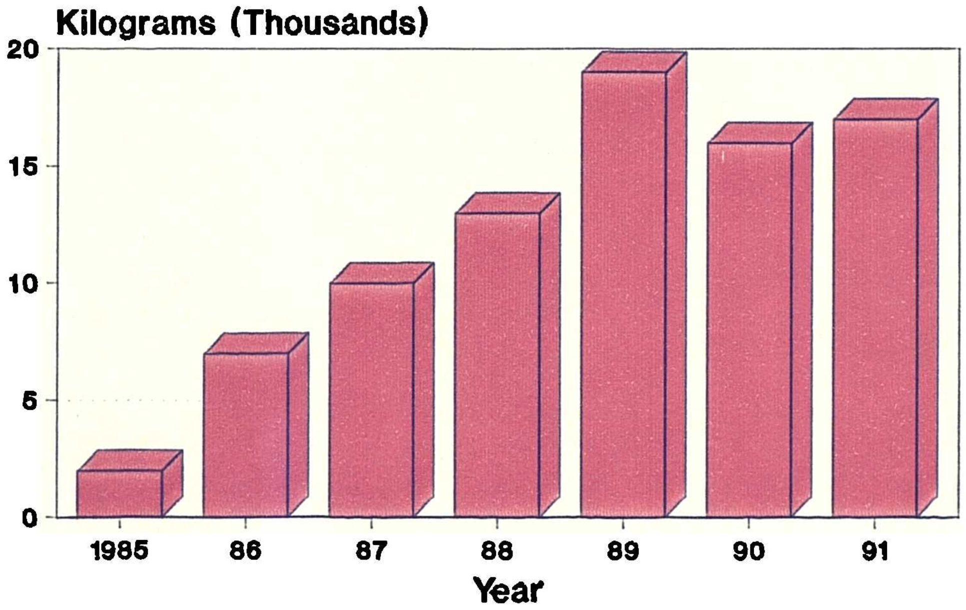
By 1992, BA had approximately 14,000 portable fire extinguishers in stock which contained Halon 1211 (BCF), and they varied in size from 1.5-50kg. The majority of this equipment must meet statutory requirements. Halon 1301 (BTM) is installed in computer rooms; flight simulators; aircraft; and other key technological centres. BA has taken measures to reduce the use of Halon 1301 and 1211. For instance, in 1990, BA ceased to use Halon 1301 in its new installations, and when the old systems are taken out of service, the contractor removes and recycles the material [1]. Also, since August 1st 1992, BA has not been installing any new fire fighting installation systems containing Halon 1301 as the main extinguishing agent except, on the aircraft [1].

In many cases however, Halon 1211 is being replaced with water and Aqueous Foam Forming Film (AFFF) or being returned for recycling. Furthermore, in agreement with the Civil Aviation Authority (CAA) the amount used in staff training is being reduced. Additional measures are planned for the future including:- investigating alternatives; more use of sprinklers and pressurised water systems; and an improved staff awareness fire training scheme. Figures 5.10 and 5.11 show the purchase and use of Halons 1211 and 1301 by BA [1].

5.4.3 <u>De-icing Fluids And Chemicals:</u>

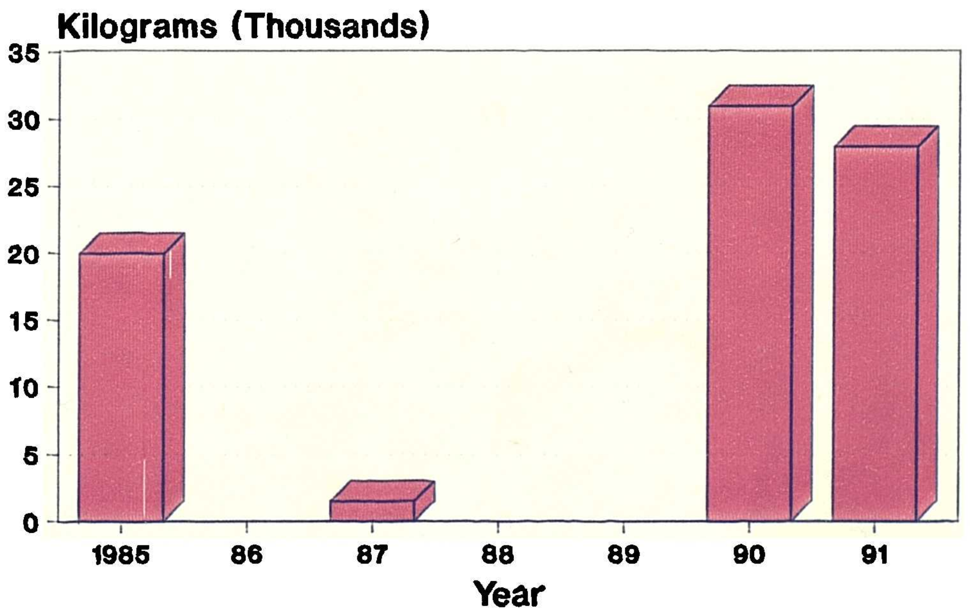
As the temperature drops below freezing, each year, up to 50 million litres of chemicals (1993 figures) are sprayed onto aircraft and runways in Europe to prevent them from freezing during cold winter months, and particularly in the countries of Northern Europe and Scandinavia where winter is severe [3]. In a bad winter for example, up to 1.5 million litres (1993 figures) of de-icing fluids are used at Copenhagen Airport [3]. This is essential for safety as iced-up wings and fuselages may not produce sufficient lift for the planes to take off, and also, icy runways; taxi ways; and aprons may cause aircraft

Figure 5.10: British Airways Halon 1211 Use And Purchase



Source· Ref.1 (British Airways)

Figure 5.11: British Airways Halon 1301 Use



Source: Ref.1 (British Airways)

skidding.

These chemicals cause environmental harm by contaminating the waterways and ground water often killing fish and sometimes creating toxic blooms of algae. The use of such chemicals is considered a serious threat to the rivers and ground water by all major European Airports. Two types of chemicals are commonly used [3]:-

a) Urea;

b) Glycol.

Both urea and glycol work by lowering the freezing point of water. A solution of urea sprayed onto runways will effectively lower the freezing point of ice to -10^0C. Solutions of ethylene glycol and propylene glycol, which are used on runways and aircraft lower the freezing point of ice to -13^0C and -59^0C respectively [3]. Iced-up planes must be treated before takeoff, and glycol is the only chemical that meets the stringent safety specifications for this treatment. Heated hangars can be one solution to keep the aircraft free from ice, but are expensive and energy consuming. For runways, sand and salt are not alternatives, since sand blows away in jet blasts and salt corrodes the aircraft. A new runway de-icer based on potassium acetate is much less damaging to the environment, but is about 6 times more expensive than urea [3].

Environmental problems start once the de-icing of a runway is completed. Urea breaks down into ammonia and then into nitrates, killing fish and encouraging the growth of algal blooms which may greatly reduce the amount of oxygen in water. Up to 80% of the glycol solution sprayed onto aircraft runs straight off and onto the tarmac where it will eventually reach water-courses and combine with the oxygen thereby reducing the amount available to aquatic life. Stockholm's Arlanda Airport is a classic example where large amounts of glycol from Arlanda have dissolved the oxygen in the nearby waters [3].

In principle, the best alternative to glycol is to use chemicals that are harmless to the environment. In practice, with no alternative "aircraft de-icer" available, the trend is towards a more polluting solution of glycol known as "Type 2". While "Type 1" contains only glycol and water, a Type 2 is a mixture which includes chemicals that help it stick to the aircraft. Following several accidents in the USA thought to have resulted from icing-up after treatment with Type 1, the use of Type 2 which has been used for more than a decade has increased recently, particularly in Europe which has higher safety standards [3].

A non-polluting alternative for "runways" is "Clearway 1" which has been developed by BP Chemicals in Britain and it primarily consists of potassium acetate solution. It was launched in Scandinavia in 1988 following two years of tests on its effectiveness; corrosive qualities; and environmental impact to ensure that it met the European safety standards. This product (Clearway 1) is now used at about 55 airports and air bases around the world. It is believed that 50-60% of airports worldwide will be using Clearway 1 in cold climates within the next few years [3].

Arlanda started using Clearway 1 in Winter 1993 and is now monitoring its impact in waterways and soil. So far, no damage has been attributed to the acetate, and it breaks down easily to CO_2 and water using little oxygen from the waterways. Heathrow and Gatwick are also using the product. In Britain, the NRA (National Rivers Authority) prefers the use of Clearway 1 by the airports but accepts that its cost may be a deterrent. Clearway 1 is expensive, but because of its high ice-melting capability and effectiveness down to -60^0C, it is very cost effective when compared with the loss of revenue to the airports resulting from closure in winter months [3].

As for the aircraft, the problem of glycol still remains and up to date there is not yet a solution but, the large market is a good incentive for manufacturers to produce an environmentally acceptable replacement. As for BA, aircraft de-icing is a vital part of its operations during the winter months in which "Kilfrost ABC-3" containing propylene glycol is used to de-ice aircraft. Propylene glycol is a biodegradable material and its effect on the environment is said to reduce when it is adequately biodegraded. Figures 5.12 and 5.13 show the amounts of de-icing fluid purchased by BA in recent years [1].

5.4.4 Other Environmentally Sensitive Materials:

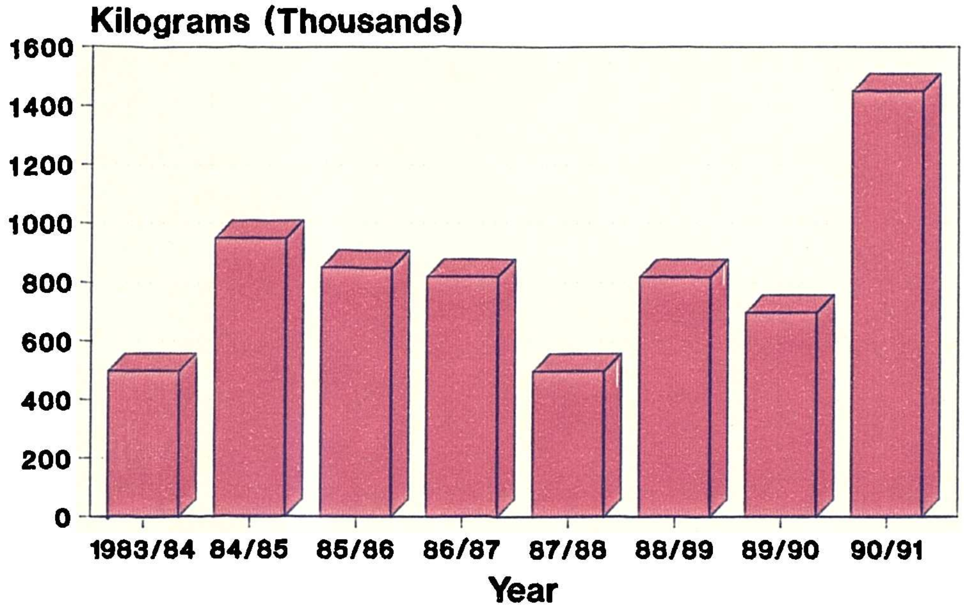
In addition to CFCs; halons; and de-icing fluids, other environmentally sensitive materials such as solvents (not containing CCs); metals; fluids; and chemicals that are highly toxic and are used to remove paint and clean and rechrome aircraft engine parts are also used by airports. For instance, when painting an aircraft a large quantity of paint is used which will then emit evaporative solvents. An electrostatic nozzle fitted to the spray gun will help reducing the amount of paint required thus less solvents are emitted. This process of nozzle fitting is called "Electrostatic Painting" which came into use by BA in 1988. Tables 5.3; 5.4; and 5.5 show the use of those environmentally sensitive materials within BA's engineering operations [1].

Table 5.3: British Airways Non-CFC Solvent Use At Heathrow, Gatwick, And Other Maintenance Bases

Solvents	1990 (lit)	1991 (lit)
Acetone	1,368	1,028
Odourless kerosene	14,200	19,800
Methyl ethyl ketone	8,775	8,213
Industrial methylated spirit	1,145	909
Petroleum distillate	1,800	1,000
Toluene	85	63
White spirit	25,071	22,244
Xylene	30	40
Undifferentiated	3,250	2,670
Paint solvents	n/a	25,075
Isopropyl alcohol	315	420

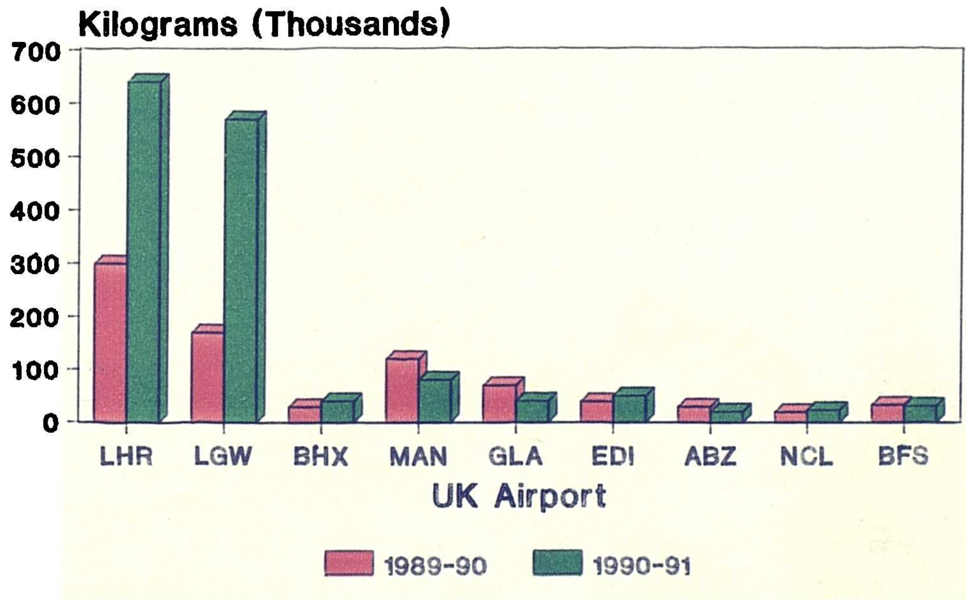
Source: Ref.1 (British Airways)

Figure 5.12: British Airways De-icing Fluid Purchased



Source· Ref.1 (British Airways)

Figure 5.13: British Airways De-icing Fluid Purchased For Use At UK Airports



Source: Ref.1 (British Airways)

Table 5.4: British Airways Engineering Materials Used At Heathrow, Gatwick, And Other Maintenance Bases

Chemicals And Metals	1990	1991
Acids	1,339 lit	6,320 lit
Cadmium metal	631 kg	180 kg
Sodium hypochlorite	11,272 lit	6,210 lit
Caustic soda	8,675 kg	6,500 kg
Sodium bisulphite	3,700 kg	6,050 kg
Lead (plating)	approx. 417 ft	158 ft
Nickel metal (plating)	50.5" x 5 ft	various
Nickel compounds	266 lit	60,040 lit
Chromic acid compounds	950 kg	2,300 kg
Cyanide	150 kg	300 kg
Plating strippers	1,050 lit	2,500 lit
Chemical deoxidisers	2,525 lit	n/a
Blasting grit-organic	14,265 kg	11,206 kg
Blasting grit-inorganic	14,280 kg	10,940 kg

Source: Ref.1 (British Airways)

Table 5.5: British Airways Other Environmentally Sensitive Materials Used At Heathrow, Gatwick, And Other Maintenance Bases

Material	1990 (lit)	1991 (lit)
Hydraulic fluid, mineral based	5,719	6,971
Hydraulic fluid, phosphate ester based	88,453	88,211
Hydraulic fluid, silicate ester based	11,604	8,576
Corrosion inhibitor	6,203	6,834
Non-destructive testing of fluorescent inks	1,350	1,915
Aircraft exterior cleaners-solvent based	252,595	154,970
Aircraft exterior cleaners-water based	0	126,865
Paint strippers-phenolic	59,405	83,325
Paint strippers-non-phenolic	3,385	3,440
Solvent additives	4,320	1,095
Paint thinners	15,926	12,660
Solvents for washing out spray guns	29,360	25,125
Adhesive thinners	973	867
Aircraft paint (50% solvent based)	0	12,368
Non aircraft paint (50% solvent based)	3,846	556

Source: Ref.1 (British Airways)

5.5 Environmental Contamination (Water Pollution):

In addition to noise and atmospheric pollution, water pollution is probably the next most concerning environmental issue related to airports. It may result directly from the construction and operation of an airport, or indirectly from other developments whose presence are because of the airport e.g. hotels; motels; fuel stations; shops and restaurants. The removal of natural cover (top soil) and other airport construction activities (e.g. earth moving and excavation) may result in soil erosion and sedimentation. Increased sedimentation may block drainage structures such as pipes; manholes; or gullies and cause flooding, it may also destroy biological activities by covering the bottom of lakes and streams [Ch.1]. Additional waste materials such as fuels; lubricants; construction debris and sanitary wastes from the construction personnel are also produced during construction.

In general, water pollution from an airport may be the result of [2]:-

a) Sanitary wastes;
b) Storm water and related effluent;
c) Wastes related to fuelling, operation, and cleaning of aircraft;
d) Wastes related to major aircraft overhaul and maintenance;
e) Industrial wastes.

5.5.1 <u>Sanitary Wastes:</u>

Sanitary wastes are those wastes generated by the people using the airport and they (wastes) are produced from activities such as food and meal preparation; washing; showers; and toilet use. For example, BA has two main catering centres at Heathrow. One is located in the South and the other in the West. The one in the West, in 1992, produced more than 29,000 meals per day and used some 189,000m^3 of water per annum. The corresponding figure for the South centre was 258,000m^3 per annum [1]. Both these centres are equipped with a trade effluent treatment plant which assists in reducing the sewage costs [1].

In general, it is estimated that, as much as 90 litres of water per passenger per day is used at a typical airport e.g. Manchester International, and that 90% of this water returns to the collection system [4]. This water must be treated to remove inorganic solids and dissolved impurities and to destroy disease-causing organisms.

5.5.2 <u>Storm Water And Related Effluent:</u>

Storm water (rain water) runoff may be polluted by chemicals used for insect control; for snow and ice removal; by fuel and oil spills on the runways; taxi ways; and apron areas; by effluents from aircraft washing and de-icing which are common at most airports (see 5.4.3 earlier); and by fire-fighting foams used for aircraft emergencies [2]. Waste "<u>liquids</u>" at airports are normally produced from [1]:-

a) The washing; steam cleaning; de-icing; and degreasing of the ground vehicles and equipment such as the ground power units;

b) The washing and the steam or chemical cleaning of aircraft and their component parts e.g. seats and wheels;

c) The charging of vehicle and aircraft batteries using diluted acid, and from the battery washing facilities;

d) The paint stripping of aircraft; vehicles; and equipment;

e) The preparation of meals and from the washing of cooking and eating utensils containing fats and detergents;

f) The cleaning of metals and the electro deposition of Cadmium; Chromium; Copper; Lead; Nickel; Zinc; and Silver; and from crack detection; heat treatment; test tanks; and the crushing of sodium and fluorescent lamps;

g) The emergency pumping facilities from underground collecting sumps;

h) The non-destructive testing of aircraft components and radiographic film processing;

i) The compressor cooling;

j) Sanitation.

5.5.3 <u>Aircraft Cleaning; Fuelling; And Operation Wastes:</u>

These wastes may also be carried to nearby lakes and streams through the rain water drainage system. Fuel spills and leaks, oil and grease deposits and harmful cleaning detergents may seriously pollute the water unless such wastes are collected and treated. For instance, wastes from paint stripping consist largely of wash water which is contaminated with paint stripping chemicals. Within BA, this contaminated wash water is collected and stored as hazardous waste before being removed by contractors [1,2].

5.5.4 <u>Aircraft Overhaul; Maintenance; And Industrial Wastes:</u>

Major aircraft overhaul and maintenance activities may cause even more serious water pollution by involving highly toxic chemicals that are used to remove paint and clean and rechrome engine parts (see 5.4.4 earlier). Similar pollutants may also be added by other light industries and developments that are located on or near the airport and use the airport's sewage disposal system. They (other industries and developments) too may have a serious impact on the problem of water pollution unless suitable countermeasures are undertaken [2].

5.5.5 Water Pollution Reduction:

In general, it is necessary to collect; separate; and treat all waterborne wastes irrespective of the geographic location. Although it is outside the scope of this thesis to discuss in detail the specific procedures for the treatment of wastes, the following steps may, however, be taken to reduce and prevent water pollution from airports [2]:-

a) By having a well coordinated and cooperative regional plan which ensures that the capacity of the streams to absorb waste is NOT exceeded, nor is their usefulness to the downstream communities affected;

b) By imposing tight controls on the pollution of lakes and waterways whereby, airport operators must consult with the appropriate water authorities about the treatment and discharge of wastes (solids and liquids) into the waterways particularly those suitable for navigation. Also, where applicable the discharge of wastes into such waters (navigable) with regards to "type and quantity" must be licensed by the relevant water authorities;

c) By using shallow gradients wherever possible for backslopes; channels; or canals to avoid and minimise erosion;

d) By protecting the slopes from erosion with suitable ground cover both during and after construction;

e) By taking measures so that fuel spills do NOT enter into the rain water pipes. For instance, the use of centralised chemical collection systems [5];

f) By prohibiting the dumping of oil and grease wastes into the rain water pipes;

g) By avoiding flushing fire-fighting foams down the rain water pipes;

h) By using low-phosphate detergents for aircraft washing;

i) By limiting the amount and type of chemicals used for insect and vegetation control.

In addition to the above measures, it is worth mentioning that, there are ways of treating most forms of water pollution, and, where possible, much of the waste water from hygiene and food preparation should be discharged into the normal sewers in order to be treated with other domestic and commercial effluent. In this way, further reduction in water pollution can be achieved.

5.6 Conclusions:

Like noise and air pollution, the consumption (waste) of energy and materials, and the contamination of the environment particularly the waterways are as important as any other environmental impact related to airports. Also, large quantities of waste materials are inevitably generated by airports as it is impossible to run a waste-free airport. The amount and type of waste generated depend directly on the size and scale of operations of the airport. The dumping of waste material into the water-courses mostly contaminates rivers and waterways which then affects the soil; the fish; and other aquatic life. Waste from airports (energy or materials) may be controlled in several ways [1]:-

a) By having a general policy on fuel and energy saving. For example, better use of equipment; updating and modernising the equipment to increase their efficiency and reduce their fuel consumption levels; or by reducing the number of employees wherever possible;

b) By fuel replacement particularly for the ground transport. Fuel replacement is very effective in reducing waste energy which in turn increases energy savings;

c) By having a good and effective Cost Control Policy which helps reduce the costs thereby leading to more energy savings;

d) By waste minimisation i.e. reduction at source, or by the recycling and reusing of goods; materials; and chemicals e.g. paper; plastics; tyres; de-icing fluids and other substances. For instance, waste heat from the power plant could be used for runway de-icing thus avoiding the need to use harmful chemicals [5];

e) By more use of environmentally friendly materials, and at the same time less use of environmentally harmful substances;

f) By imposing controls and regulations by the concerning bodies over the limits and release of certain materials in order to prevent the excessive use of those materials. For example, the Montreal Protocol which limits the overall release of CFCs and other controlled substances;

g) By having a good waste management and water and effluent treatment scheme which controls the amount of discharge, and by having an effective sewage system;

h) By appointing bodies to control the amount of waste entering the rivers and waterways in order to keep them free from excessive pollution, and to maintain an acceptable level of Solids and Chemical Oxygen Demand (COD). In the UK for example, the NRA is responsible for controlling such matters;

i) Finally, by increasing air fares which results in less number of people travelling thus reducing the overall activities of the airport. In this way, less waste is generated, more energy is saved, therefore less damage is inflicted on the environment. On the other hand, discouraging air travel by increasing air fares may help reduce the amount of airport waste, but it will most certainly have an adverse economic impact.

References:

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Chapter 6

Environmental Impact Assessment Of Airports

6.1 Introduction:

Throughout this thesis, the major and most important positive and negative environmental impacts of an airport have been identified and discussed. Also, problems raising and associated with each impact have been identified and discussed together with the ways and methods that reduce and minimise these impacts. It is, however, appropriate in this final chapter to finalise and complete this research by bringing together a general assessment of the major impacts of an airport.

The most common technique available for evaluating the impacts of any project is the "EIA" (Environmental Impact Assessment) technique. Although it is outside the scope of this thesis to make a "detailed assessment" of the environmental impacts of an airport, but, in order to give some general idea as to the magnitude and importance of the impacts, it is necessary to make an overall assessment of each impact. It is, therefore, useful to make a brief discussion of the EIA and its application in general.

6.2 What Is EIA:

There are many definitions of EIA by various authors all of which are almost similar to each other. For instance, according to Goode and Johnstone, EIA is an instrument which provides the opportunity to identify, mitigate or enhance the potential environmental, health and social consequences of a proposed project activity, and to create alternatives or additional options to that activity [1]. Furthermore, it can present information in such a way which allows logical and rational decisions to be made, and at the same time, providing the basis for planning the continuous use of resources. Goode and Johnstone also stated that there is not a clear, precise, or widely accepted definition for EIA [1].

According to Wathern, EIA is simply a special type of analysis which involves a careful, thorough, and detailed study of the most likely impacts of a development or scheme [2]. Many countries have developed lists of projects which are subject to EIA (see below). The main considerations in such lists are the project type; size; and the consequence of the likely impacts. So far as building; civil; and transportation engineering are concerned, the following projects are those subject to a mandatory EIA:-

a) Construction of motorways;
b) Intercity railways, including high-speed tracks;
c) Airports;
d) Commercial harbours;
e) Construction of waterways for inland navigation;
f) Permanent motor and motorcycle racing tracks;
g) Installation of surface pipelines for long-distance transport.

Source: Commission of the European Communities

The <u>location</u> of the project is also a determinant of the impact since, a development (in this case an airport) in one area may have a more severe impact than if it were located somewhere else. Also, it is the combination of the project and the location which determines the magnitude and significance of the impacts [2].

Before any assessment, the most important and significant likely impacts whether positive or negative, direct or indirect, short term or long term must be <u>identified</u>. Long term impacts are usually considered more adequately than the temporary ones, and, it is useful to distinguish between direct (primary) and indirect (secondary, tertiary or higher order) impacts. Some impacts are a direct consequence of a particular activity, whereas others may occur as a result of changes in a chain of environmental parameters. There may also be many impacts of little or no significance, but, it is the most significant ones over which decisions are usually made. Scoping is the process for determining which issues are likely to be important [2].

Having identified the major issues, then the impacts can be assessed and decisions made with remedial measures recommended. In general, EIA methods are mainly used for:-

a) Impact identification;
b) Prediction;
c) Interpretation and communication; and;

d) Devising monitoring schemes.

A particular method however, may not be equally useful for each activity [2]. There are several techniques of EIA available with each one having its own strengths and weaknesses. The most widely used techniques of assessment are mentioned in the following section.

6.3 The EIA Techniques:

The most common methods of assessing the environmental impacts of a development are [3]:-

A) Checklists (simple, descriptive and scaling, weighting and scaling);
B) Matrices (simple, scaling, stepped matrix);
C) Networks;
D) Modelling;
E) Adhoc;
F) Overlays;
G) Adaptive methods;
H) Evaluation techniques.

As previously stated, each method has advantages and disadvantages. According to Mitchell and Wathern, checklists and matrices are the simplest and most suitable methods of EIA [2,4]. A brief discussion of these two methods is useful at this stage.

6.3.1 <u>The Checklist Method:</u>

A checklist includes all the potential impacts that <u>should be</u> considered, and it is the simplest approach to an EIA [2,4]. The main advantage of this method is the fact that it ensures all the possible and important environmental consequences of a proposed development are considered, and also, it aids the gathering of data as well as their presentation [2,3,4]. The main disadvantage of checklists is that they must be complete and thorough in order to avoid a major and serious impact being overlooked. Also, a complete and thorough checklist can be awkward and complicated thus, it may restrain initiative during assessment [2].

Checklists provide the basis for many of the cause-effect matrices and they vary from a simple listing of the environmental features and anticipated impacts, to a more comprehensive approach which involves the scaling and weighting of the impacts of each alternative. In a <u>simple checklist</u>, a specific list of environmental aspects are investigated for possible impacts. They do <u>NOT</u> need to establish a cause-effect link to each project activity, and they may or may not include guide-lines about how parameter data are to be measured and interpreted [5].

A <u>Descriptive and Scaling Checklist</u> however, identifies all the environmental parameters as well as providing guidelines on how the data for the parameters are to be measured. In a descriptive and scaling checklist, more basic information to subjective scaling or parameter values are provided [5]. The Scaling and Weighting Checklist is the scaling checklist with additional information provided for the subjective evaluation of each parameter with respect to every other parameter [5].

According to Ahmad and Sammy, the best way to prepare a checklist of impacts is by looking at other EIAs on similar actions [6]. They are useful for structuring the initial steps of the assessment. They mainly consider the direct impacts, and do not specifically concentrate on the interaction, magnitude, or importance of the impacts. At the most, the checklist concentrates on the most significant impacts, and in the least, it brings together a large amount of information which does not integrate into the overall plan of the analysis [5]. See Table 6.1 for a typical checklist of impacts used for a land development project.

6.3.2 The Matrix Method:

This method is "probably" the most suitable method of EIA [5]. According to Mitchell and Wathern, matrices identify the first-order interactions and are a step ahead of checklists [4,2]. Leopold et al., were the first to suggest the use of the matrix method for an EIA. This method is especially useful for EIA since it shows that the impacts result from the interaction between the development activities and the environment [2].

Table 6.1: Checklist Of Impact Categories For Land Development Projects (Summarized From Schaenam 1976)

1 Local Economy
- Public fiscal balance
- Employment
- Wealth

2 Natural Environment
- Air quality
- Water quality
- Noise
- Wildlife and vegetation
- Natural disasters

3 Aesthetics And Cultural Values
- Attractiveness
- View opportunities
- Landmarks

4 Public And Private Services
- Drinking water
- Hospital care
- Crime control
- Feeling of security
- Fire protection
- Recreation - public facilities
- Recreation - informal settings
- Education
- Transportation - mass transit
- Transportation - pedestrian
- Transportation - private vehicles
- Shopping
- Energy services
- Housing

5 Other Social Impacts
- People displacement
- Special hazards
- Sociability/friendliness
- Privacy
- Overall contentment with neighbourhood

Source: Ref.2

The matrix method is ideal for identifying impacts and it can also be used to show the results of an appraisal. The Leopold matrix is complex, and its weakness (disadvantage) is its inability to identify the indirect impacts. The matrix identifies each impact and checks each development activity against each environmental parameter to show where and to what extent an impact is likely to occur. Numbers showing magnitude and significance of each activity on a scale of 1 to 10 are used in the matrix to show the EIA of a proposed development [2]. Other disadvantages of this technique are [5]:-

a) It shows a direct cause-effect relationship which sometimes may not occur;

b) It does not differentiate between immediate and long-term impacts therefore, separate matrices may be needed for different time periods e.g. present and future, and;

c) The extent of its subjectiveness i.e. the scoring of magnitude and significance of any impact is the judgement of one assessor, whereas different assessors may have different judgement on each impact.

6.4 Assessment Of The Main Impacts:

At this stage, it is useful to take an existing airport as an example for the assessment purposes in order to make the task simpler and more realistic. Manchester International Airport is a good example of a "typical" airport. Typical in the sense that:-

a) It has a reasonable level of activities i.e. traffic volume and aircraft movements (up to 45 movements per hour at peak hours);

b) It has a reasonable number of passenger and cargo traffic, (about 15 million passengers per year);

c) It serves a large enough area within the region (up to 150kms radius);

d) It is located in a region with a population of more than 2.5 million people, (i.e. Greater Manchester);

e) It has a reasonable number of employment (over 10,000 employees);

f) It has a considerable economic influence in the local and regional areas;

g) It serves as a main hub airport in the region and has a good European connection with few continental links;

h) It is the UK's third largest and busiest Airport.

Prior to any assessment, the following points should be remembered:-

A) The scoring of the magnitude and importance of each impact is:-

a) Based entirely on the earlier discussions made throughout this thesis, and;

b) Entirely reflecting the Author's personal views and opinion;

B) Assessment will be mainly on the "operation phase", and it will concentrate more on the impacts raising from an airport "after construction" i.e. an airport in existence and running. Nevertheless, problems caused by the construction of an airport have been discussed throughout this thesis, but emphasis will be put more on the operation side since, most of the long-term and major impacts of an airport result from its operation rather than its construction;

C) Since the main aim of this thesis is to look into the environmental impacts of an airport "in general", therefore, a "general assessment" of the main impacts shall be made here instead of a detailed one;

D) The checklist (weighting and scaling) method shall be used for simplicity and clarity, showing the magnitude and significance of each impact on a scale of 1-10;

E) The assessment shall be based on a "typical" airport, in this case Manchester International;

F) The values in Tables 6.2-6.7 have been chosen in comparison to London Heathrow. This means to say that, if we use London Heathrow which is a large; busy; and fully operational international airport as a "reference point", and assume that on a scale of 0-10 it has a magnitude and significance of 10 (considering its size and level of activities) for each environmental impact, then the corresponding values for the same impacts from Manchester Airport would be as shown in Tables 6.2-6.7.

For instance, if the magnitude and significance of the economic impact of London Heathrow are both 10, then the same values for Manchester Airport considering "all aspects" such as passenger traffic; size; aircraft movements and employment structure would be 7 and 8 respectively (see Table 6.7 later). Similarly, if the magnitude and significance of the problem of aircraft noise from London Heathrow are 10 again, then the same values for the same impact from Manchester Airport would again be 7 and 8 respectively (see Table 6.7 later).

The same assumption (i.e. using Heathrow as a reference point) has been used to assess the magnitude and significance of other environmental impacts from Manchester Airport. It should, however, be noted that, although there is "NOT" a "direct" relationship between the magnitude and significance of the impacts from both Heathrow and Manchester Airports, nevertheless, to use Heathrow as a "reference point" will help us make a near enough assessment for Manchester Airport;

G) An assessment will be made for <u>each</u> major impact i.e. for each chapter heading, followed by an <u>overall assessment</u> of the <u>major</u> impacts (see Tables 6.2 to 6.7).

Table 6.2: EIA Of The Most Likely Environmental Impacts

Impact	Magnitude	Significance			
		Local	Regional	Short term	Long term
Increased urbanisation	6	7	2	4	6
Changes in the patterns of development	4	5	2	4	5
Increased accessibility	4	7	5	4	6
Increased demand for housing and public services	3	5	2	4	2
Demographic changes	3	5	4	4	3
Supply of air transportation and increased mobility	7	7	8	5	7
Prestige and convenience to the area	5	7	5	4	5
Reducing congestion at larger airports	4	8	4	4	6
Supply of public services	5	6	1	3	6
Improved aesthetics	5	5	-	3	1
Increased road traffic	7	6	2	3	6

- Negligible or insignificant *(Continued Overleaf)*

Table 6.2: EIA Of The Most Likely Environmental Impacts

Impact	Magnitude	Significance			
		Local	Regional	Short term	Long term
Additional delays and congestion	5	6	1	3	5
General deterioration of the area	3	6	1	3	5
Affecting sites of special interest	2	4	1	2	4
Loss of natural environment	4	6	1	5	6
Loss of natural resources	2	5	2	4	3
Competition between modes of transport	5	-	4	3	5
Community severance	4	6	2	3	5
Land take	2	6	-	1	2
Visual intrusion	1	2	-	1	2
Vibration	1	1	-	1	2
Construction nuisance	5	5	1	6	-
Noise pollution	*	*	*	*	*
Atmospheric pollution	*	*	*	*	*
Economic worth	*	*	*	*	*
The use of energy and materials and environmental contamination	*	*	*	*	*

- Negligible or insignificant
** See separate table*

(Continued Overleaf)

Table 6.2: EIA Of The Most Likely Environmental Impacts

Impact	Magnitude	Significance			
		Local	Regional	Short term	Long term
Aircraft development	1	1	4	1	3
Time savings	5	-	6	2	4
Accidents	1	2	-	-	-
Changes in the natural landscape	4	6	1	2	3
Ecological changes (e.g. plants, animals, fish, soil, birds and insects)	3	4	2	2	4
Hydrological changes (the re-routing of canals and waterways and changes in the water movements)	2	4	3	3	4
Reduced water table	1	2	-	1	2
The recharging of the groundwater	1	2	-	1	3
Salinity intrusion	-	-	-	-	-
Soil erosion and siltation	1	3	-	1	3
Possible flooding and sedimentation	1	3	1	2	3

Note: Figures are derived from discussions in Chapter 1.
- Negligible or insignificant

Table 6.3: EIA Of The Noise Impact

Impact	Magnitude	Significance			
		Local	Regional	Short term	Long term
Construction noise	2	7	-	7	1
Aircraft noise (takeoff)	8	9	-	7	8
Aircraft noise (landing)	2	7	2	5	6
Aircraft noise (ground operations)	4	6	-	3	4
Aircraft noise (cruising)	1	-	1	1	-
Road traffic noise	5	7	2	6	7
Night-time disturbance	2	3	-	2	3
Loss of value in recreational areas	3	4	1	2	4
Disturbance to normal activities	4	5	1	3	4
Vibration	3	5	-	2	3
Physical damage to the ear	3	5	-	2	5
Loss of hearing	3	5	-	2	5

- Negligible or insignificant

(Continued Overleaf)

Table 6.3: EIA Of The Noise Impact

Impact	Magnitude	Significance			
		Local	Regional	Short term	Long term
Occupational deafness	3	3	-	3	6
Cardiovascular effects	1	4	-	3	4
Neurophysiological effects	1	3	-	3	4
Psychological effects	4	7	-	3	6
Sleep annoyance	6	6	-	5	7
Difficulty in speech and communication	5	6	-	7	-
Degradation of task and work performance	2	4	-	5	1
The masking of useful sounds	4	5	-	5	-
Stress and annoyance	5	7	1	6	7
Social effects	6	8	4	5	7
Loss of house values	3	4	-	3	4

<u>Note</u>: Figures are derived from discussions in Chapter 2.
- Negligible or insignificant

Table 6.4: EIA Of The Atmospheric Pollution Impact (Aircraft Mainly)

Impact	Magnitude	Significance			
		Local	Regional	Short term	Long term
Pollution from construction activities	4	6	1	7	1
Pollution from the ground vehicles and equipment	4	5	1	3	5
Pollution from power plants and heating plants	4	5	2	3	4
Pollution from the road traffic	8	8	3	6	8
Pollution from aircraft	1	2	1	2	5
Reductions in air quality	1	3	-	2	3
Reductions in other organic gases and aerosols	1	2	1	1	2
Damage to the natural environment (e.g. forests, wildlife, soil, water)	1	2	1	1	2
Damage to crops and plants	1	1	-	1	2
Deterioration of buildings and structures by dust, dirt, and smoke	1	2	-	2	3

- Negligible or insignificant

(Continued Overleaf)

Table 6.4: EIA Of The Atmospheric Pollution Impact (Aircraft Mainly)

Impact	Magnitude	Significance			
		Local	Regional	Short term	Long term
Excessive CO_2 increasing the effects of poisonous gases	1	1	-	-	1
Excessive CO_2 and respiratory problems	1	-	-	-	1
Increased photosynthesis	1	2	-	1	2
Formation of ozone at low altitudes	2	1	2	1	2
Destruction of ozone at high altitudes	2	-	1	1	2
Formation of smog and other toxic oxidants	2	2	1	1	2
Effects on human health	2	2	1	2	4
Health hazards by HCs	2	3	2	2	3
CO poisoning	1	2	1	3	3
Respiratory effects of SO_2	1	1	-	1	2
Possible lung damage by smoke	1	1	-	1	2
Lead poisoning by motor vehicles	4	3	1	2	3
Exposure to asbestos dust and risk of asbestosis	1	1	-	-	1

- Negligible or insignificant

(Continued Overleaf)

Table 6.4: EIA Of The Atmospheric Pollution Impact (Aircraft Mainly)

Impact	Magnitude	Significance			
		Local	Regional	Short term	Long term
Possible risk of skin cancer and related diseases from UV radiation	3	1	5	2	6
Changes in the atmospheric processes	3	-	2	2	4
Formation of acid rain	1	-	1	1	2
Cloud formation	3	-	4	2	4
Removal of methane	1	-	1	1	-
Removal of chlorine	1	-	1	1	-
Damage to the biosphere by ozone	2	-	1	1	2
Greenhouse effect and global warming	3	-	2	1	3
Climatic changes	1	1	-	1	2
Formation of haze and smoke	1	1	-	1	-
Fog formation	1	1	-	1	-
Reduced visibility	1	1	-	1	-
Reduced sunshine hours	1	1	-	1	2
Increased humidity	4	-	4	1	4
Economic losses	1	2	2	1	2

Note: Figures are derived from discussions in Chapter 3.
- Negligible or insignificant

Table 6.5: EIA Of The Economic Impact

Impact	Magnitude	Significance			
		Local	Regional	Short term	Long term
Increased commercial activities (e.g. banking and insurance, entertainment, shops and restaurants, retail stores)	6	6	4	5	7
Increased industrial activities (e.g. freight forwarding and cargo handling, food and beverage, transportation, hotel/motel)	7	8	6	6	8
Increased employment (direct)	6	5	7	6	7
Increased employment (indirect)	6	7	5	6	8
Increased employment (induced)	3	9	2	6	9
Increased exports and imports	3	5	7	5	7
Aircraft manufacturing	3	2	7	5	7
Increased air travel and tourism	6	5	7	5	7
Increased revenue from air travel and tourism	6	6	7	5	6

- *Negligible or insignificant*

(Continued Overleaf)

Table 6.5: EIA Of The Economic Impact

Impact	Magnitude	Significance			
		Local	Regional	Short term	Long term
Reductions in house prices	1	-	2	1	2
Reductions in the labour market	2	1	3	3	5
Increased cargo traffic	2	3	5	4	6
Generation of income (wages and salaries)	6	7	5	6	7
Increased revenue from taxes	5	4	6	5	7
Purchase of local goods and services	6	7	6	6	7
Increased economic activities in the area	7	7	5	6	7
Rise in house values	3	5	1	4	4
Rise in land values	5	7	4	5	7
Benefits to Manchester Airport and shareholders	5	6	5	5	7
Benefits to airlines	7	7	5	5	7
Overall economic contributions	7	8	5	5	7

<u>Note</u>: *Figures are derived from discussions in Chapter 4.*
- Negligible or insignificant

Table 6.6: EIA Of The "Use Of Energy And Materials", And The Environmental Contamination Impact (Water Polltn.)

Impact	Magnitude	Significance			
		Local	Regional	Short term	Long term
Fuel consumption by aircraft	4	2	5	4	6
Fuel consumption by ground vehicles and equipment	4	3	1	2	4
Gas and electricity consumption	2	6	2	3	5
Oil and HTHW consumption	1	4	1	2	3
The use of CFCs	2	4	1	1	5
The use of CCs	4	4	1	1	5
The use of Halons	1	3	-	1	7
The use of de-icing fluids and chemicals	2	6	1	4	5
The use of other environmentally harmful materials (e.g. paints and paint strippers, sprays, fire fighting agents and chemicals)	3	5	-	3	5

- Negligible or insignificant

(Continued Overleaf)

Table 6.6: EIA Of The "<u>Use Of Energy And Materials</u>", And The Environmental Contamination Impact (Water Polltn.)

Impact	Magnitude	Significance			
		Local	Regional	Short term	Long term
Solid wastes (e.g. empty cans and bottles, plastic cups, paper, tyres)	4	6	-	3	5
Liquid wastes (e.g. oils and fluids, acids, solvents and detergents)	3	5	-	2	4
Sanitary wastes (food preparation, washing, showers and toilets)	3	5	-	2	4
Rain water wastes and effluent (e.g. fuel and oil spills, diluted acids and cleaning agents)	4	6	-	3	5

- *Negligible or insignificant*

(Continued Overleaf)

Table 6.6: EIA Of The "Use Of Energy And Materials", And The Environmental Contamination Impact (Water Polltn.)

Impact	Magnitude	Significance			
		Local	Regional	Short term	Long term
Aircraft cleaning, fuelling, and operation wastes (e.g. fuel spills, oil and grease deposits, harsh detergents)	2	5	-	2	4
Aircraft overhaul, maintenance, and industrial wastes (toxic chemicals and acids)	3	6	-	3	5
Contamination of rivers and waterways	3	4	1	3	5
Reductions in water quality	3	4	1	4	6
Soil contamination	3	4	1	3	5
Damage to fish and other aquatic life	2	3	1	3	5

Note: Figures are derived from discussions in Chapter 5.
- Negligible or insignificant

Table 6.7: An "Overall" EIA Of The Major Impacts

Impact	Magnitude	Significance			
		Local	Regional	Short term	Long term
Increased air travel demand	6	7	8	5	6
Increased urbanisation	6	7	2	4	6
Supply of air transportation	7	7	8	5	7
Changes in the natural environment	4	6	1	5	6
The problem of aircraft noise	7	8	3	6	7
The problem of road traffic noise	5	7	2	6	7
Atmospheric pollution from aircraft	1	2	1	2	5
Atmospheric pollution from the road traffic	8	8	3	6	8
Economic benefits from the Airport	7	8	5	5	7
The use of energy and resources	3	4	3	3	5
Environmental contamination and water pollution	5	5	2	4	6

Note: Figures are derived from Tables 6.2 to 6.6 inclusive.
- Negligible or insignificant

6.5 Conclusions:

Based on the above assessments, the larger and busier an airport, the greater are its environmental impacts. The degree and magnitude of these impacts vary from one airport to another depending on the size and population of the region served by the airport; the socio-economic characteristics of that region; the geography and the whole nature of that region. The environmental impacts of an airport can be short-term e.g. construction nuisance; long-term e.g. economic benefits; and in some cases continuous e.g. the problem of aircraft noise. Since airports provide the means for linking places far apart, their environmental impacts are therefore not only local or national, but they are worldwide and international.

In general, the need to build new airports rises from the growing demand for air travel which itself is produced from a healthy economy; from the value of time for each individual; from the economic and cultural links of a nation with the outside world; and from cheaper air fares and other incentives. Cheaper air fares and holidays for example encourage tourism and air travel which may spoil a country's cultural and natural environment by too many people travelling and overdevelopment such as that in Spain; Greece; or Cyprus. Venice for example is overpopulated during the holiday season and excessive tourism is causing overweighing and settlement problems [7].

In addition, according to some sources, cheap air travel may also loosen community bonds by creating disoriented groups of people without the locational centres essential for maintaining their cultural and social values [8], at the same time, it is widely known that holiday travel particularly "long distance" tends to relieve people from boredom and tiredness through their jobs and everyday life and that they will perform much better on their return. This improved performance is especially true for the industrial and factory workers.

Looking at airports economically, they are in many cases a large and very expensive and an indispensable part of the infrastructure involving huge amounts of sunk costs. For these reasons, the proper planning; siting; and location of airports are very important for their future economic growth. For instance, in countries such as Russia; China; Brazil; Canada; and the United States where distances are great, it is perhaps more economical to build airports rather than investing in land transportation, whereas in countries such as Luxembourg; Switzerland; Holland; or Austria it may be cheaper to do the opposite.

In today's fast world however, airports have become almost a necessity as many economies particularly those of the developed countries depend on airports for the safe and rapid delivery of goods; commodities; and people. At the same time, it is impossible to build and run an airport without an impact on the environment. Therefore, based on earlier discussions made throughout this thesis, the following points can be concluded:-

a) The environmental impacts of an airport are either direct or indirect; local or regional; and sometimes global e.g. atmospheric pollution. The local and the direct effects are usually noticed much sooner than the indirect and regional or global effects which normally take longer to be noticed. The significance and magnitude of each impact tend to decrease with the distance from the airport i.e. the further away from the airport the smaller the impact and vice-versa;

b) The construction or major expansion of an airport may alter the patterns of local and regional development through urbanisation effects, and activities such as hotels; restaurants; warehousing; conventions; freight forwarders; and particularly cargo centres are likely to expand much faster than before in the airport region. Changes in the local and regional landscapes are also inevitable;

c) Lack of fuel resources and the cost of environmental protection may affect the economics of air transport industry and reduce air travel;

d) Land acquired because of aircraft noise can be developed to increase the economic potential of the airport;

e) Airports are usually built on the urban periphery and their routes often pass through relatively undeveloped areas. It is therefore essential to improve the road and rail links;

f) They (airports) need extensive road networks since their traffic flows are often much higher than those generated by any other single land-use development;

g) The road and rail links built for air travellers will also serve the residents of the airport district thereby increasing its accessibility and causing more urbanisation;

h) Other services such as sewerage; water; gas; electricity; and telephone lines serving the airport can be used for other developments thus reducing the cost of re-laying such services;

i) Airports usually have large work forces and other significant economic impacts, but their economic importance to the overall life of a nation is very rarely considered;

j) Airport employees and their dependents living in the airport district will have to be served by commercial and other activities which will have a multiplying effect on the local economy, and possible increases in the house and land values are likely to occur;

k) Competition between air and land transportation (rail in particular) for both passengers and cargo over "short" distances such as London-Manchester or London-Glasgow will become inevitable which may reduce rail's revenue from such routes. For instance, BA is competing with BR for passengers over the above routes which reduces BR's overall revenue and profitability;

l) Airports greatly increase personal mobility especially to long distance and intercontinental destinations with resulting effects on people's cultural; educational; life styles; and living standards.

6.6 Recommendations:

With the growing world population and economy, and the increasing desire for personal mobility, together with the current consumption levels of materials; resources; and energy for economic activities all of which (i.e. materials; resources; and energy) will end up in some form on waste dumps or will be dissipated into the atmosphere or disposed of into the oceans, the question is should we build more airports or not, and if so, how can we minimise their environmental impacts. This is because the future of the environment is vitally important. Therefore, based on the assessments made earlier in this chapter, to complete and finalise this study, the following points are recommended in order to reduce and minimise the environmental impacts of an airport:-

a) The development of high-speed surface transport particularly rail effectively reduces short-haul air travel between metropolitan areas. A good example is the French high-speed trains (TGV) which are being used in France between major cities, and the new Channel Tunnel which links the UK to nearer European centres;

b) The expansion and the more intensive use (i.e. increasing the capacity and improving the efficiency) of an existing airport generally have less regional impacts than building a new airport particularly with regards to the urbanisation impacts and the demand for public services such as water and sewage disposal; additional road and rail links;

c) The use of new techniques and modern facilities in the power and heating supplies; in passenger and cargo handling; and in the whole operations of an airport helps reduce environmental problems;

d) The use of larger and more advanced aircraft with a higher load factor and lower fuel consumption reduces the amount of energy waste; noise; and air pollution;

e) The development of STOL and VTOL aircraft reduces the problem of aircraft noise, and this makes it possible to site airports nearer to urban centres and shorten the access time which is a critical factor in <u>domestic</u> air travel;

f) More use of new communication techniques such as fax machines; telephone conferencing systems; electronic mail; and videophones may replace unnecessary <u>business</u> trips thus reducing aircraft noise; air pollution; and other impacts;

g) An efficient rail link similar to those serving Frankfurt and Zurich Airports is very effective in reducing the airport road traffic and its related noise and air pollution;

h) More control of tourism by higher air fares and more expensive holidays or other restrictions help protect those environmentally sensitive parts of the world, and nature appreciation holidays may be effective in the long term.

Finally, how the environment is handled is very important and raises a number of wider issues. Although promoting the aviation industry may be economically beneficial, but paramount consideration must be given to the environmental factors in such a way that does <u>NOT</u> sacrifice the needs of air transportation to those of the environment and vice-versa. There has to be a balance between the two but inevitably there will be conflicts in this controversial area. It should, however, be noted that, whatever action is taken today whether right or wrong, it will reflect onto the future, and a wrong decision made today may become much larger tomorrow. We should, therefore, NOT neglect the future in our present actions by concentrating only on our immediate problems in the environment, some of which may only add to those of the future.

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