Airport noise control through land use regulation in the vicinity of airports: the case of Kimpo International Airport

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Airport Noise Control through Land Use Regulation in the Vicinity of Airports: The Case of Kimpo International Airport

by

Hyeog Yun Sim

A Master's Thesis

Submitted in partial fulfilment of the requirements for the award of MPhil. of Loughborough University

October 1997

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Abstract

The effect of airport noise on communities surrounding airports presents a serious problem for airport operations and expansion. In order to resolve this problem, many attempts have been made to control airport noise over recent years all over the world. Of these, land use regulation is an important method for controlling the adverse impacts of airport noise on airport environs. The success of the prevention of noise sensitive development depends on effective land use planning and control.

This study reviews effective noise control through land use regulation at Kimpo International Airport, Korea. For the purpose of a more precise understanding of the noise problem, a review of the various aspects and causes of aircraft noise, the way noise is measured, its effects on people, and the methods to alleviate the adverse impact of airport noise is presented. In addition to these, the characteristics of effective land use planning around an airport, available land use control measures, and the compatible land use planning system practised in the United States, the United Kingdom and Korea are reviewed.

The role of Kimpo International Airport will change to the exclusive use for domestic flights. With the opening of the new international airport in 2001, the noise analysis shows a significant reduction in the noise impacted area at Kimpo Airport following this change in role, due to the decrease of the number of aircraft operations and the elimination of noisier aircraft. However, the pressure for development in less impacted areas may make the airport noise problem worse in the future. In order to prevent encroaching development in the vicinity of Kimpo Airport, the following conclusions are presented:

- More objective and efficient standards for land use regulation are desirable.
- Compatible land use planning through the co-operative efforts of each of the various parties involved is essential for the prevention of noise sensitive development.
- Developing a community relations programme is useful for the resolution of airport noise problems and the restoration of a community's confidence.
- Systematic selection of noise control measures and monitoring programmes are essential for the effective management of the noise environment.

KEY WORDS: Airports, Aircraft Noise, Noise Control, Noise Abatement and Mitigation, Land Use Regulation, Compatible Land Use Planning and Control
Acknowledgement

During the time of my research many people have helped me. Without their help it would not have been possible to write this thesis. First of all, I would like to thank my supervisor Dr. David Gillingwater for important advice and effective suggestions. I would also like to thank my colleague In Kim, the Seoul Regional Aviation Office staff, for providing a number of material relevant to my research. I would further acknowledge my debt to the Korean government, the Ministry of Construction and Transportation, without its financial support this thesis could not have been researched and written.

Last, but not least, I want to thank my sincere wife Yeong Ju who devotedly helped to keep my health.
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Chapter 1
Introduction

Airport noise and its control is currently a major issue in airport operations. The problem of airport noise has developed over a period of years, and has become very important now due to the increased use of air travel and the rapid growth of the community around an airport. The conflict between airport growth and community expansion has manifested itself in the form of noise control and compatibility problems between an airport and its environs (cf. ACI Europe 1995). Numerous measures have been developed and implemented to deal with and resolve the problem of airport noise. Of these, land use regulation around an airport is an important method for controlling the adverse impact of airport noise in airport environs. Effective compatible land use planning and control is a major tool for prevention of encroaching development in the vicinity of an airport.

Kimpo International Airport in Korea has experienced serious conflicts between itself and its surrounding communities due to the negative impact of airport noise. Although the Airport has implemented various noise control measures to resolve the noise problem, it is still felt by local residents that not enough is being done to alleviate the problem. Moreover, it is estimated that there will be a great change in airport noise circumstances at Kimpo Airport in the next century due to the opening of the new international airport. A successful resolution of these problems is essential to the airport's operation in the future. Both the improvement of the community's environment and the best use of the physical capacity of the critical public facility are equally important issues. This study aims to seek practical and balanced solutions for the airport noise and land use problem primarily through compatible land use planning and control around the airport.

This chapter presents the objectives and methodology of this study, and the structure of the thesis.
Objectives of the Study

The prime objectives of this study are to:

- analyse the noise situation at Kimpo Airport based on the evaluation of past noise exposure and prediction of current and future noise exposure in order to identify the impact that will be caused by the airport's operation in the future

- examine the conflict between the airport and its surrounding communities in order to determine what measures should be employed to prevent or remedy the problem

- identify the aspects related to noise metrics, adverse effects of aircraft noise and airport noise control measures so as to understand the main issues associated with the airport noise problem

- examine the main concepts of effective compatible land use planning and control in the airport's surrounding area to discover the potential benefits of airport/environs compatibility

- derive an appropriate strategy for more effective airport noise control at Kimpo Airport, which reflects the changed role of the airport to exclusive use for domestic flights, primarily through compatible land use planning and control around the Airport

Methodology of the Study

With respect to the minimisation or reduction of adverse noise impacts, various measures are available for controlling the use of land in the vicinity of an airport. However, some specific measures can be applied to an airport based on each country's legislative situation, and unique airport and environs
necessities which reflect an airport's own physical environment, social attitudes, political attitudes, economic conditions and regulatory frameworks. The selection of appropriate airport noise control measures, which aim to resolve the particular noise problem of an airport, is thus specific to that airport and the nature of the problem which exists there. In order to be able to discover the nature of the airport noise problem and the corresponding action to deal with it, it is necessary to collect information about the impact of the noise and the nature and extent of the consequences that the impact causes. However, unfortunately there have been no formal surveys and systematic collection of complaints which can show the detailed view of the impact of airport noise on the people of Kimpo Airport's surrounding neighbourhoods. In addition, considering the agitated state of the enraged residents, a personal survey for purposes of this study was not feasible. Thus, the restricted available data made it possible only to suggest desirable basic principles for more effective airport noise control at Kimpo Airport.

The approach followed in this study, benefiting from lessons learned and conclusions drawn after reviewing related literature, puts emphasis on establishing a practical method for assessing the effectiveness of existing airport noise control measures at Kimpo Airport, primarily associated with the land use regulation strategy. This study makes use of a noise impact analysis together with an extensive literature review.

(a) Noise Impact Analysis: The airport noise problem should begin with an evaluation of the existing and future noise situation which can be analysed by a noise impact analysis. Therefore a noise impact analysis forms a major part of this study. A computer based simulation model is capable of analysing and predicting the noise impact associated with the operation of a complex airport and projecting that impact to some future period. The United States's FAA's Integrated Noise Model (INM) is a useful prediction analysis tool which is available and often used for airports. The INM uses the following data to calculate noise exposure levels: (1) airport altitude and ambient air
temperature, (2) runway configuration, (3) fleet size and mix, (4) aircraft operating procedures, and (5) flight tracks and nominal profiles (based on trip length). The data used in the model were the most currently available, and the forecasts used were the most developed to represent future aviation demand.

(b) Literature Review: Since an understanding of the theoretical foundations and determinants of airport noise control is essential to evaluate airport noise control at Kimpo Airport, a literature review gained special importance for this study. Therefore, a large amount of literature was reviewed on the issues of airport noise control, characteristics of aircraft noise, compatible land use planning and control measures, and the Kimpo Airport's noise control system. The data for the study were collected from reports by national and local government agencies, airport authorities and operators, and by private consultants. In addition, consultation with the staff of the airport authority concerned has provided basic and supporting information.

Structure of the Thesis

This thesis is arranged in a sequential order that represents the stages and components of research.

This chapter, Chapter 1, Introduction, explains the aims and methodology of the study.

Chapter 2, Background, presents an introductory discussion of the emergent issues of airport noise at Kimpo Airport. The discussion includes information about facilities and aircraft operation mainly related to airport noise at Kimpo Airport. The noise analysis is the basic tool for studying the airport noise problem and dealing with it. Therefore, the past, current and future airport noise exposure around the airport is analysed to reveal the change of noise circumstances, particularly due to the changed role of the airport to its
exclusive use for domestic flights after the opening of the new international airport. Based on the results of the noise analysis and the potential problems which are anticipated, the need for other effective airport noise control measures - in particular land use regulation around the airport - is reviewed. The anticipated potential problems include the limitation of existing noise control measures, the airport neighbourhood's increasing complaints about noise, and the reduction of the noise impacted area and pressure for development in the area which will be less affected by airport noise.

Chapter 3, Airport Noise Control, is concerned with the effects of aircraft noise on people, and the measures to alleviate the adverse impact of airport noise. Noise, which has often been defined as unwanted sound, is probably the most important issue, especially to those people who are exposed to high levels of aircraft noise. This chapter discusses the adverse effects of aircraft noise. The impact of airport noise on communities surrounding airports presents a serious problem to airport operation and expansion. In order to resolve this problem, many measures to control airport noise have been developed over the years, at many airports. Of these measures, some major airport noise control measures which have been implemented and proposed in the world are reviewed.

Chapter 4, Land Use Regulation around an Airport, presents and discusses effective airport land use planning and control in the area surrounding an airport. Of many airport noise control measures, airport land use regulation is an important method for controlling the adverse impact of airport noise, since incompatible land use would result in constraints on the operation and expansion of an airport. This chapter begins by seeking the characteristics of effective compatible land use planning in airport environs. It defines the term “compatible land use planning” and describes the planning process. Identification and description of the various issues to be considered for successful compatible land use planning around an airport follow. For the purpose of accomplishing the implementation of a compatible land use plan,
the control over the uses of the private properties within noise impacted areas is absolutely necessary. So, this chapter also presents some major compatible land use control measures. Finally, the compatible land use planning system around airports in the United States, the United Kingdom and Korea are reviewed. The bodies responsible for land use planning and control, and the basic national guidelines that exist, are discussed in detail.

Chapter 5, The Case of Kimpo Airport: Analysis and Findings of Its Changed Role, analyses current airport noise control measures, primarily associated with the land use regulation strategy, and suggests the desirable basic principles for more effective airport noise control at Kimpo Airport. This chapter deals with the really important issues and discusses measures for improvement in four different categories:

- standards for land use regulation prescribed in current law
- necessity of compatible land use planning and its appropriate management
- programmes for managing good community relations
- desirable ways to reach effective noise control measures and ways to manage them

Chapter 6, Conclusion, presents a summary of the main findings related to this research. In addition, some recommendations on what needs to be done by the parties involved in the resolution of the airport noise problem in terms of land use planning and control are outlined. Some recommendations for future research are also included.

Appendix A, Airport Noise Metrics and Cumulative Noise Exposure, reviews the various aspects and causes of aircraft noise, the way that the noise is measured.

Appendix B, Planning Process, presents the total planning process for compatible land use plan.
Chapter 2
Background

The purpose of this chapter is to review the emergent aspect of airport noise at Kimpo International Airport. This chapter is in three parts: the first part presents information about airport facilities and aircraft operations of Kimpo Airport. The second part analyses the past, current and future level of airport noise exposure around Kimpo Airport. The third part reviews the need for a further airport noise control measure - land use regulation around the airport - based on the potential problems which are anticipated in the future.

Existing Facilities and Operations at Kimpo International Airport

This inventory documents the information about airport facilities and aircraft operations mainly related to airport noise at Kimpo International Airport. Kimpo International Airport, located about 17 kilometres west of downtown Seoul and in the northwest of the Republic of Korea, is Korea’s gateway to the world and handles the largest volume of international and domestic passengers and cargo in the country. It covers an area of 7.3 square kilometres which accommodates a parallel runway and taxiway system, three passenger terminal complexes of 201,000 square metres of building space and 80 aircraft parking stands, over 51,300 square metres of general aviation transient aircraft parking apron and over 87,000 square metres of air cargo building space.

History of Kimpo International Airport

In 1958, the Ministry of Transportation designated an airfield near Kimpo plain in Kimpo County, Kyonggi Province as an international airport and developed airport facilities for civil commercial aviation. The airfield had been
used as a military airbase since 1939 and its rural setting had little impact on a sparsely settled community.

Kimpo's early scale of operations was very limited. It was not until the advent of the jet age, with its needs for a longer runway and generally enlarged facilities, that national economic growth and the booming airline industry viewed Kimpo Airport in a serious light. In the meantime, the airport's surrounding land character had undergone considerable change. The area's proximity to Seoul, the capital of Korea, was a substantial factor in its rapid growth, which continued through the late 1960s. With land use controls and environmental concerns being less sophisticated than today, the accelerating urbanisation of the area gave rise to land use conflicts, environmental and traffic inadequacies. The concentration of population in the airport's surrounding area tended to contribute to short-sighted community development rather than more reasoned long term considerations. Changes in the area's basic character were sometimes sudden and appeared to threaten the integrity of its residential make-up.

The continuous growth of the economy and introduction of large jets in the 1970s pushed the airport into a whole new threshold of operations. The rapid growth of demand for aviation brought the airport to the limit of its capacity. This became an issue because of the Seoul Olympics which was planned to be held in 1988. The airport authority expanded the airport to a two runway system, and constructed a new runway and international passenger terminal as well as other support facilities. The use of a new runway and an increase in aircraft operations caused the spread of noise impacted areas and intensified the noise effects in the vicinity of the airport. Citizens, both individually and in organised groups, were extremely dissatisfied with the airport's operations and attempted to cope with the worsening environment. There were a number of remedial actions for noise reduction and mitigation, however no overall strategy developed to alleviate growing conflicts between the airport and its anxious neighbours.
According to the trend of growth in aviation demand, it was calculated that Kimpo Airport would reach its full capacity in the late 1990s. However, it was not possible to expand the airport facilities, because of various constraints, such as the airport noise problem, obstructions around the airport, and airspace conditions. In 1990, the Ministry of Transportation decided to develop a new international airport in the Young Jong Do area which was located on the coastal bay of Kyonggi, 52 kilometres west of Seoul. It aimed to meet the aviation demand of a metropolitan area after the year 2000 and provide 24 hour a day operation.

There have been a number of studies about the role of Kimpo Airport after the opening of the new international airport. Although they have suggested more or less differing roles at the initial stage, the final role of Kimpo Airport was the same, that it would be used exclusively for domestic flights. The latest research about it was completed in 1994 by the Korea Transport Institute, the government research institute. The resulting report, "The Optimum Role Assignment System for the New Seoul Metropolitan Airport and Kimpo Airport", recommended that the exclusive use for domestic flights from the beginning is to be the most desirable option.

Runway Systems

The airport’s runway system consists of a northwest/southeast set of parallel runways, 14R/32L and 14U/32R, located west of the main terminals. The parallel runways are 360 metres apart centreline to centreline and the true bearing is 136°/316°. Runway 14R/32L is the westerly of the two runways and is 3,200 metres long and 60 metres wide. It is equipped with High Intensity Runway Lights (HIRL), an Instrument Landing System–Category III on 14R (i.e., the north end of the runway), and Precision Approach Path Indicators (PAPI) on 14R, 32L (i.e., the south end of the runway). Runway 14L/32R is the easterly of the two runways and is 3,600 metres long and 45 metres wide. It is equipped with HIRL, ILS-Category II on 14L, 32R, and PAPI on 14L, 32R.
Kimpo Airport's existing facilities were evaluated in the “Middle and Long Term Airport Development Plan” performed by the Ministry of Transportation in 1993. The practical capacity (called PANCAP) of the runway system is 217,000 aircraft operations with an ultimate capacity of 245,000 aircraft operations on the basis of the aircraft fleet mix at that time. The ultimate capacity means the maximum possible processing capability of the runway system over one year.

The airport's taxiway system consists of a major taxiway thoroughfare and a number of access taxiways which connect the runway with the passenger terminal buildings and cargo areas. Taxiway A is the major thoroughfare. It runs parallel to runways between runway 14L/32R and the terminal areas. All taxiways have centreline lighting. The airport elevation is 17.7 metres above mean sea level (MSL). The airfield layout is illustrated in Figure 2.1.

Airport Boundaries

The Airport is located in Kangseo Ward, about 17 kilometres west of downtown Seoul. The Southern Circular Road runs north and south on the east side of the airport, and the 88 Olympic Highway and Airport Road run east connecting with downtown. To the south, National Road 6 is the approximate boundary of the Airport, and the northern boundary is National Road 39.

Land owned by the airport authority and directly used for the operation of the airport is shown in Figure 2.2. This land is generally accessible from the runways without crossing public right-of-way or private property. This land encompasses the Kimpo Airport facilities, and it includes approximately 7.3 square kilometres. In addition to the land described as within the Kimpo Airport boundary, the airport authority is now in the process of purchasing 1.18 square kilometres of land to the west and south of runway, which was designated as the airport facility district in 1976. Some of this land is to be acquired to remedy serious noise impacts, although the majority is to be acquired to solve the public discontent of limited rights over their property.
Figure 2.1 Layout of Kimpo International Airport
Figure 2.2 Airport Boundaries

Land Under Purchasing
The airport authority has a plan to relocate all of the residents to other areas. This land would then be cleared to be incorporated into the airport boundary.

Aircraft Operations

Kimpo Airport recorded a steady increase of 12.3 per cent over the previous year with 34,442,000 passengers, and 11.8 per cent with 1,357,000 tons of cargo respectively in 1996. The volume of air carrier aircraft operations in 1996 was 214,246 which showed an increase of 8.8 per cent over the previous year. The growth rate of aircraft operations in 1996 was much less than the average annual growth rate of 11.7 per cent for aircraft operation, 12.7 per cent for passengers and 13.0 per cent for cargo tons over the previous five year period, 1990 to 1995. One explanation for this is the increase of large aircraft operation such as the B747, B767 and A300. Table 2.1 shows air traffic at Kimpo Airport between 1990 and 1996.

<table>
<thead>
<tr>
<th>Year</th>
<th>Passenger(1)</th>
<th>Aircraft Operation(2)</th>
<th>Cargo(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>16,903</td>
<td>113</td>
<td>802</td>
</tr>
<tr>
<td>1995</td>
<td>30,684</td>
<td>197</td>
<td>1,480</td>
</tr>
<tr>
<td>1996</td>
<td>34,442</td>
<td>214</td>
<td>1,640</td>
</tr>
</tbody>
</table>

(1) passenger: number of passengers enplaned and deplaned in 1,000's
(2) aircraft operation: number of aircraft landing and takeoff in 1,000's
(3) cargo: tons of cargo including air mail in 1,000's

Table 2.1 Kimpo Airport Traffic (1990, 1995, 1996)

The aircraft operations consist of domestic flights and international flights. Table 2.2 shows the aircraft operation traffic at Kimpo in 1996. The share of domestic flights which were served by Korean Airlines and Asiana Airlines is 58.3 per cent and the share of international flights which were served by 40 airlines on the basis of scheduled flights is 41.7 per cent. Korean and Asiana Airlines account for 60 per cent of all international flights. The scheduled flights account for 95.4 per cent of aircraft operations and the share of charter flights is very slight at Kimpo Airport.
On an average day in 1996, 587 air carrier operations were performed at the Airport. According to data from the airport authority, the typical aircraft in the mix of operations were as Table 2.3.

<table>
<thead>
<tr>
<th>Aircraft Type</th>
<th>Domestic</th>
<th>International</th>
<th>Sub Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>B747</td>
<td>6</td>
<td>102</td>
<td>108</td>
</tr>
<tr>
<td>B737</td>
<td>111</td>
<td>10</td>
<td>121</td>
</tr>
<tr>
<td>B767</td>
<td>20</td>
<td>35</td>
<td>55</td>
</tr>
<tr>
<td>B727</td>
<td>2</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>DC10</td>
<td>-</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>DC8</td>
<td>-</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>MD82</td>
<td>59</td>
<td>9</td>
<td>68</td>
</tr>
<tr>
<td>MD11</td>
<td>1</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>A300</td>
<td>93</td>
<td>46</td>
<td>139</td>
</tr>
<tr>
<td>F100</td>
<td>50</td>
<td>5</td>
<td>55</td>
</tr>
<tr>
<td>IL62</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>TU154</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Others</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>342</td>
<td>245</td>
<td>587</td>
</tr>
</tbody>
</table>

Table 2.3 Aircraft Fleet Mix of Average Daily Operations (1996)

The time of day percentage on an average day in 1996 was 79.1 per cent during the day, 17.7 per cent during the evening, and 3.2 per cent at night. The detailed time of day percentage is as follows,
<table>
<thead>
<tr>
<th></th>
<th>Day (07:00-19:00)</th>
<th>Evening (19:00-22:00)</th>
<th>Night (22:00-07:00)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic Pax.</td>
<td>48.3</td>
<td>9.7</td>
<td>0.3</td>
</tr>
<tr>
<td>International Pax.</td>
<td>26.8</td>
<td>6.4</td>
<td>1.9</td>
</tr>
<tr>
<td>Cargo</td>
<td>4.0</td>
<td>1.6</td>
<td>1.0</td>
</tr>
<tr>
<td>Total</td>
<td>79.1</td>
<td>17.7</td>
<td>3.2</td>
</tr>
</tbody>
</table>

Table 2.4 Time of Day Percentage (1996)

In 1996, general aviation aircraft operations at Kimpo Airport totalled 8,393 on an annual basis. Of the general aviation aircraft operations, helicopter operations accounted for 95 per cent of the total and fixed wing aircraft operations accounted for only 420 of the total annual number of operations. The approach and departure path for helicopters was developed over the farming area to the southwest of the Airport. The fixed wing aircraft use the existing runway and flight track. So, it is expected that the noise exposure levels primarily represent the operations of air carrier aircraft because their noise output is considerably greater than that of general aviation aircraft and fixed wing aircraft operations are much smaller than that of air carrier aircraft. For this study, the number of general aviation aircraft operations are not taken into account.

Flight Tracks

The airspace around Kimpo Airport is restricted within narrow limits due to flight prohibited zones which are located in the northern and eastern area of the Airport. Flight Prohibited Zone 73 is the airspace over a radius of 4.5 nautical miles centred at Seoul where any flight by unauthorised aircraft is prohibited and Flight Prohibited Zone 518 is the airspace near the demilitarised zone. The right downwind airspace centring around Kimpo Airport is not available, therefore all approach and departure paths were developed to the left of Kimpo Airport airspace. All air carrier aircraft operate according to IFR regardless of weather conditions and all flights under IFR are controlled by the ATC system.
The area to the south of the Airport is densely populated and noise sensitive. To minimise the effect of noise on the communities surrounding the Airport, the airport authority has designed and developed a preferential runway system. The preferential runway system has been applied as follows,

(1) In the case of runway 14 use:
   Take-off: Runway 14L
   Landing: Runway 14R

(2) In the case of runway 32 use:
   Take-off: Runway 32R (Runway 32L departure will be ensured by controller's instructions)
   Landing: Runway 32L for domestic flights
            Runway 32R for international flights
   (If meteorological conditions permit and departure traffic is delayed on the ground, international flights landing will be ensured Runway 32L)

Runway utilisation is a function of a combination of factors which include weather conditions, pilot preference, aircraft performance, navigational aids, noise abatement procedures, and aircraft traffic control requirements. The distribution of aircraft arrivals and departures by runway was based on observed frequency of use. A total of 50 percent of movements occurred in each direction of 14/32. The utilisation of runways for the year 1996 is shown in Table 2.5.

<table>
<thead>
<tr>
<th>Runway</th>
<th>Arrivals</th>
<th>Departures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Runway 32R</td>
<td>22.5</td>
<td>50.0</td>
</tr>
<tr>
<td>Runway 32L</td>
<td>27.5</td>
<td>-</td>
</tr>
<tr>
<td>Runway 14R</td>
<td>50.0</td>
<td>-</td>
</tr>
<tr>
<td>Runway 14L</td>
<td>-</td>
<td>50.0</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 2.5 Utilisation of Runway(1996)
Figure 2.3 Flight Tracks

- - - - - Arrivals

- - - - Departures

- - - - Arrivals/Departures (Helicopter)
For noise analysis purposes, the flight track is shown as a single line, representing an average track. The average flight tracks, provided by airport authority, are shown in Figure 2.3. These flight tracks were provided by the airport authority and were derived from radar tracks scope. The tracks indicate the median flight path within specific corridors, but deviation from these tracks does occur because of weather, pilot technique, air traffic control and aircraft weight.

Kimpo International Airport Master Plan

There is a significant interrelationship between the future expansion planned for airport facilities according to the airport master plan and noise exposure. Of particular importance are some of the changes to the airfield in the airport master plan. Several of these changes are also related to the achievement of land use compatibility with the surrounding community.

Most of the existing major airport facilities, including the new runway, had been guided by the previous airport master plan developed in 1980. This plan was prepared before the decision regarding the new international airport development was taken. Kimpo International Airport's existing airport master plan was prepared in 1994. It was basically aiming at meeting the aviation demand until the opening of the new international airport through the rearrangement of some existing facilities in such a way to meet the realistic need at a minimum, instead of undertaking a large scale expansion of airport facilities.

No new runway or extensions of present runways are expected in the future. The master plan therefore shows no new runway configurations. The changes and expansion addressed in the master plan are primarily found in the terminal and supporting facilities. As previously mentioned, currently the land purchasing process is underway; however it is expected that there will be little demand for land within the airport boundary after the opening of the new international airport.
Evaluation of Past Noise Exposure, Predictions for 1996 and Future Exposure

Noise Monitoring Data

The permanent noise monitors were installed and have been operated by the Ministry of Environment around the Airport since 1990. The purpose of these was to measure the actual noise exposure levels and to develop the appropriate noise mitigation measures based on the monitored noise data. The location of the ten permanent remote monitoring stations are shown in Figure 2.4. Noise exposure levels were expressed as the Weighted Equivalent Continuous Perceived Noise Level (WECPNL), which was prescribed in aviation law as the basic metric to be used and adopted for all airport noise analyses in Korea.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>85</td>
<td>86</td>
<td>86</td>
<td>86</td>
<td>87</td>
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<td>86</td>
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<td>86</td>
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<td>80</td>
</tr>
<tr>
<td>3</td>
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<td>71</td>
<td>72</td>
<td>72</td>
<td>74</td>
<td>74</td>
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<td>4</td>
<td>75</td>
<td>76</td>
<td>75</td>
<td>73</td>
<td>75</td>
<td>77</td>
</tr>
<tr>
<td>5</td>
<td>78</td>
<td>78</td>
<td>77</td>
<td>76</td>
<td>78</td>
<td>77</td>
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<td>6</td>
<td>81</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td>82</td>
<td>82</td>
</tr>
<tr>
<td>7</td>
<td>74</td>
<td>75</td>
<td>77</td>
<td>76</td>
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<td>76</td>
</tr>
<tr>
<td>8</td>
<td>89</td>
<td>88</td>
<td>90</td>
<td>89</td>
<td>90</td>
<td>90</td>
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<tr>
<td>9</td>
<td>72</td>
<td>71</td>
<td>75</td>
<td>75</td>
<td>74</td>
<td>74</td>
</tr>
<tr>
<td>10</td>
<td>66</td>
<td>67</td>
<td>70</td>
<td>72</td>
<td>70</td>
<td>69</td>
</tr>
</tbody>
</table>

Table 2.6 Past Noise Monitoring Data

The Table 2.6 shows the average annual noise exposure levels for each station from 1991 to 1996. The average noise exposure level shows a 1 per cent increase from 77.8 WECPNL in 1991 to 78.6 WECPNL in 1996. As
Figure 2.4 Permanent Remote Monitoring Station
compared with the number of aircraft movements of the same period, monitored noise data over the past six years from 1991 to 1996 show very little change in the environment around Kimpo Airport. The number of aircraft movements shows a 75 per cent increase, 122,600 operations in 1991 to 214,246 operations in 1996. The small increase in noise exposure levels at Kimpo might be attributed to the introduction of quieter aircraft and noise mitigation measures, such as flight operational procedure regulations, night curfew, and limitations on aircraft of high noise emission.

Evaluation of Past Noise Exposure

The airport authority officially announced the noise exposure contour and the airport noise impacted area around Kimpo Airport in 1993 in compliance with the aviation law in which the ordinances for airport noise were newly enacted. The airport noise impacted area was classified into three noise bands, that is, 95 WECPNL and higher, 90 to 95 WECPNL, and 80 to 90 WECPNL. Figure 2.5 shows these official noise exposure contours. The total airport noise impacted area over 80 WECPNL is 28.93 square kilometres and the estimated number of residents within that noise contour is 347,434. The noise impacted area and population are shown in Table 2.7.

<table>
<thead>
<tr>
<th>Noise Impacted Area(Km²)</th>
<th>80~90WECPNL</th>
<th>90~95WECPNL</th>
<th>Over 95WECPNL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>322,224</td>
<td>22,600</td>
<td>2,608</td>
</tr>
</tbody>
</table>

Table 2.7 Noise Impacted Area and Population (Officially Announced)

The official noise contours and noise impacted area were based on the result of the noise analysis which was performed by an acoustic consulting firm in 1987. Of the noise contours presented in the analysis report, the airport authority announced only the noise impacted area over 80 WECPNL. Figure 2.6 shows the noise contours presented in the noise analysis report and the noise impacted area corresponding to the noise contour is indicated in Table 2.8.
Figure 2.5 Noise Contours (Officially Announced)
Figure 2.6 Noise Contours (Presented in Noise Analysis Report, 1987)
The noise analysis forecast is based on the aviation demand, the aircraft fleet mix and the time of day percentage on the basis of the actual data in 1987. The number of average daily aircraft operations used in the analysis is 447 which corresponds to the annual service volume of 163.1 thousand aircraft operations. The average daily aircraft operations used in the analysis is almost the same with the actual daily average aircraft operations in 1993. However, there is a wide difference between the noise exposure level presented in the analysis and the monitored noise data in 1993. Table 2.9 shows the difference between these two values as measured at the noise monitor station.

<table>
<thead>
<tr>
<th>Noise Impacted Area (Km²)</th>
<th>70-75 WECPLN</th>
<th>75-80 WECPLN</th>
<th>80-90 WECPLN</th>
<th>90-95 WECPLN</th>
<th>Over 95 WECPLN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>99.13</td>
<td>34.03</td>
<td>22.29</td>
<td>3.11</td>
<td>3.53</td>
</tr>
</tbody>
</table>

Table 2.8 Noise Impacted Area (Noise Analysis Report)

The reasons for the wide difference in noise exposure levels are, firstly, the introduction of quieter aircraft such as the B737, B767, F100, and MD82 which were not expected in 1987. The new quieter aircraft were introduced mainly by national flag carriers, Korean Airlines and Asiana Airlines. Asiana Airlines only became operational in 1988, so as a result they were not taken into account in the noise analysis study. Secondly, the noise impact on the ground was decreased through the airport noise control measures implemented since 1988, such as night curfew and flight operational procedure regulations.
The Table 2.10 and Table 2.11 show the difference in aircraft fleet mix and time of day percentage in detail.

<table>
<thead>
<tr>
<th>Type of Aircraft</th>
<th>Forecast</th>
<th>Actual in 1993</th>
</tr>
</thead>
<tbody>
<tr>
<td>B727</td>
<td>10.9</td>
<td>7.3</td>
</tr>
<tr>
<td>B737</td>
<td>-</td>
<td>21.6</td>
</tr>
<tr>
<td>B747</td>
<td>34.7</td>
<td>17.2</td>
</tr>
<tr>
<td>B757</td>
<td>-</td>
<td>7.8</td>
</tr>
<tr>
<td>F27</td>
<td>4.4</td>
<td>-</td>
</tr>
<tr>
<td>F28</td>
<td>-</td>
<td>1.0</td>
</tr>
<tr>
<td>F100</td>
<td>-</td>
<td>7.8</td>
</tr>
<tr>
<td>DC8</td>
<td>-</td>
<td>0.7</td>
</tr>
<tr>
<td>DC9</td>
<td>17.6</td>
<td>-</td>
</tr>
<tr>
<td>DC10</td>
<td>2.3</td>
<td>2.2</td>
</tr>
<tr>
<td>A300</td>
<td>28.5</td>
<td>22.3</td>
</tr>
<tr>
<td>IL62</td>
<td>-</td>
<td>0.5</td>
</tr>
<tr>
<td>IL76</td>
<td>-</td>
<td>0.2</td>
</tr>
<tr>
<td>L1011</td>
<td>1.6</td>
<td>0.5</td>
</tr>
<tr>
<td>MD11</td>
<td>-</td>
<td>2.0</td>
</tr>
<tr>
<td>MD82</td>
<td>-</td>
<td>8.9</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Table 2.10 Comparison of Aircraft Fleet Mix

<table>
<thead>
<tr>
<th></th>
<th>Day (07:00~19:00)</th>
<th>Evening (19:00~22:00)</th>
<th>Night (22:00~07:00)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forecast</td>
<td>78</td>
<td>18</td>
<td>4</td>
</tr>
<tr>
<td>Actual in 1993</td>
<td>81</td>
<td>17</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 2.11 Comparison of Time of Day Percentage
Prediction of 1996 and Future Noise Exposure

Noise Analysis Methodology

Noise exposure levels were prepared as the Weighted Equivalent Continuous Perceived Noise Level (WECPNL). WECPNL values are expressed in effective perceived noise level (EPNL) and represent the noise level over a 24 hour period. The WECPNL values are then used to estimate the effects of specific noise levels on existing and planned land use. In Korea, as noted earlier, WECPNL was prescribed in aviation law as the basic noise exposure metric in use and to be adopted in usual airport noise analyses.

Version 5.0 of the Integrated Noise Model (INM) was used for the noise analysis. Version 5.0 of the INM was published by the U.S. Department of Transportation, Federal Aviation Administration (FAA) in August 1995 and is a very useful tool for determining the total effect of aircraft noise at and around airports. Noise exposure levels were based on a number of variables which included: runway configuration and utilisation, flight track identification and utilisation, approach and take off profiles, aircraft noise and performance characteristics, and traffic mix (i.e., the number of operations and the distribution of operations by aircraft type, arrival vs. departure, time of day, and trip length of departures). A standard database of individual aircraft noise and performance was used with Version 5.0 of the INM. In the database, each aircraft is associated with an aircraft category. For each category, the following is provided: (1) a set of departure profiles for each applicable trip length; (2) a set of approach parameters; and (3) Effective Perceived Noise Level (EPNL) versus distance curves at several thrust settings.

The 99 per cent maximum take off thrust for the departure of each aircraft was used with INM Version 5.0. It aimed to calibrate the INM Version 5.0, because the predicted noise level for 1996 average daily operations did not sufficiently represent the monitored data of ten stations. The calibration based on the data from a special noise monitoring programme is desirable;
however, it was impracticable for this study. Therefore, the adjustment of maximum take off thrust and climb thrust was used as a calibration tool. This is due to the fact that some pilots use reduced thrust to save fuel during the departure procedure. Of a number of thrust settings, the predicted noise exposure level by 99 per cent maximum take off thrust represented the monitored data. A $\chi^2$ test showed the predicted values satisfied the 95 per cent confidence level. The average flight tracks and runway utilisation used as input to the INM for the future noise analysis are assumed to be the same as in 1996.

**Aircraft Operation Forecast**

The aircraft operation demand forecasts at Kimpo Airport are based on the existing Seoul metropolitan area forecasts which were developed in the "Middle and Long Term Airport Development Plan" performed by the Ministry of Transportation in 1994. Table 2.12 shows the forecast and actual traffic in 1996. The aircraft operations at Kimpo Airport were forecast to increase from 214,246 in 1996 to 245,000 in 1998 or thereabouts and to decrease to 137,700 by 2001 and then increase to 194,800 for 2010.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Annual Volume</strong></td>
<td>214,246</td>
<td>266,200</td>
<td>137,700</td>
<td>160,600</td>
<td>194,800</td>
</tr>
</tbody>
</table>

Table 2.12 Aircraft Operation Demand Forecast

(Source: Ministry of Transportation, Korea 1994)

Kimpo Airport is not able to meet all the demand of the Seoul metropolitan area from 1998 or thereabouts, because it has a capacity limitation which means the ultimate capacity of the existing runway system is 245,000 aircraft operations per year. Also Kimpo Airport is assumed to be for the exclusive use of domestic flights after the opening of the new international airport at Young Jong Do in 2001. Therefore, the aircraft operation forecasts are made considering these conditions. For the future noise analysis, noise exposure
levels attributed to aircraft operations at Kimpo Airport are predicted for ultimate capacity (1998 or thereabouts) and 2001 operations and practical annual capacity (after 2010) which is the practical maximum capacity of the existing runway system. To determine existing and future noise exposure, aircraft traffic levels associated with the average day of the year are used in the calculations. The number of aircraft operations for Kimpo Airport for an average day in 1996, the year of ultimate capacity, 2001, and the year of PAN CAP (Practical Annual Capacity) are shown in Table 2.13.

<table>
<thead>
<tr>
<th></th>
<th>1996</th>
<th>The Year of Ultimate Capacity</th>
<th>2001</th>
<th>The Year of PAN CAP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Daily Operations</td>
<td>587</td>
<td>671</td>
<td>378</td>
<td>595</td>
</tr>
</tbody>
</table>

Table 2.13 Average Daily Aircraft Operation Forecast

Estimates of operations by various aircraft types are made using aircraft fleet data from aviation statistics published by the Korea Airports Authority, sample counts at Kimpo, and the aircraft purchase plans of Korean and Asiana Airlines. The aircraft fleet mix in the year of ultimate capacity, 2001 and the year of PAN CAP aircraft fleet mix are shown in Table 2.14.

Judging from the previous aircraft fleet data at Kimpo Airport, the operations of high noise emission aircraft such as the B727, IL62, IL76 and TU154, have been on the decrease and the operations of quieter aircraft such as the B767, F100, A330 and the late version of the B747 have been on the increase. Korean and Asiana Airlines plan to purchase mainly wide body aircraft such as the B747-400, A330, and B777. These facts and the restriction of slots at Kimpo from 1998 or thereabouts are reflected in the estimates of aircraft operations for the year of ultimate capacity. The estimates of aircraft fleet for 2001 are based on the previous aircraft fleet data of domestic flights at Kimpo and the aircraft purchase plans of airlines. The aircraft mix in the year of PAN CAP is assumed to be the same in 2001 for want of related data.
<table>
<thead>
<tr>
<th>Type of Aircraft</th>
<th>Actual 1995</th>
<th>Actual 1996</th>
<th>Forecast Year of Ultimate Capacity 2001</th>
<th>Forecast PANCAP year of 2001</th>
</tr>
</thead>
<tbody>
<tr>
<td>B727</td>
<td>3.9</td>
<td>1.7</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>B737</td>
<td>21.3</td>
<td>20.8</td>
<td>19.0</td>
<td>32.8</td>
</tr>
<tr>
<td>B747</td>
<td>16.6</td>
<td>17.7</td>
<td>18.5</td>
<td>2.5</td>
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<tr>
<td>B767</td>
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<tr>
<td>B777</td>
<td>-</td>
<td>-</td>
<td>6.4</td>
<td>1.7</td>
</tr>
<tr>
<td>F100</td>
<td>10.0</td>
<td>9.6</td>
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<td>0.1</td>
<td>-</td>
</tr>
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<td>IL62</td>
<td>0.2</td>
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</tr>
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<td>0.05</td>
<td>-</td>
<td>-</td>
</tr>
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<td>MD11</td>
<td>1.9</td>
<td>2.2</td>
<td>2.2</td>
<td>0.3</td>
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<td>1.1</td>
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</tr>
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</tr>
<tr>
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<td>2.4</td>
</tr>
<tr>
<td>TU154</td>
<td>0.05</td>
<td>0.05</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Total</td>
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<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
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</table>

Table 2.14 Aircraft Fleet Mix Forecast
<table>
<thead>
<tr>
<th>Type of Aircraft</th>
<th>Actual 1996</th>
<th>Year of Ultimate Capacity</th>
<th>Forecast 2001</th>
<th>Year of PANCAP</th>
</tr>
</thead>
<tbody>
<tr>
<td>727D17</td>
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<td>727Q15</td>
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<td>-</td>
<td>-</td>
</tr>
<tr>
<td>727Q7</td>
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<td>-</td>
<td>-</td>
</tr>
<tr>
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<td>0.4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
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<td>11.9</td>
<td>23.9</td>
<td>23.9</td>
</tr>
<tr>
<td>737 500</td>
<td>7.1</td>
<td>6.7</td>
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<td>8.9</td>
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<td>747 20A</td>
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<td>0.6</td>
</tr>
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<td>6.3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>747 3G2</td>
<td>0.4</td>
<td>0.2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>747 R21</td>
<td>1.1</td>
<td>0.7</td>
<td>-</td>
<td>-</td>
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<tr>
<td>747 400</td>
<td>5.3</td>
<td>6.5</td>
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<td>100.0</td>
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</tbody>
</table>

Table 2.14(a) Aircraft Fleet Mix Forecast (An Input of Aircraft Type to INM)
Table 2.15 shows the time of day percentage forecast of aircraft operations. The time of day percentage in the year of ultimate capacity is made using the previous data from aviation statistics published by the Korea Airports Authority. The ratio of night operations has been on the increase and it is assumed that it will reach the highest value in the year of ultimate capacity due to the limitation of runway capacity during the day time period. The time of day percentage in 2001 and the year of PANCAP is based on previous data of domestic flights at Kimpo.

<table>
<thead>
<tr>
<th>Year</th>
<th>Day (07:00-19:00)</th>
<th>Evening (19:00-22:00)</th>
<th>Night (22:00-07:00)</th>
</tr>
</thead>
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<tr>
<td>1993</td>
<td>80.7</td>
<td>17.5</td>
<td>1.8</td>
</tr>
<tr>
<td>1994</td>
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<td>79.9</td>
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</tr>
<tr>
<td>1996</td>
<td>79.1</td>
<td>17.7</td>
<td>3.2</td>
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<tr>
<td>Year of Ultimate Capacity</td>
<td>78.5</td>
<td>17.5</td>
<td>4.0</td>
</tr>
<tr>
<td>2001</td>
<td>82.8</td>
<td>16.6</td>
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</tr>
<tr>
<td>Year of PANCAP</td>
<td>82.8</td>
<td>16.6</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Table 2.15 Time of Day Percentage Forecast

1996 and Future Noise Exposure

The results of the noise exposure calculations are expressed as contours. Contours are lines drawn on a map that connect points of equal WECPNL values. The noise exposure map for Kimpo Airport depicts the contours for WECPNL 95, 90, 80, and WECPNL70.

Aircraft noise exposure maps for the year 1996, ultimate capacity, 2001, and PANCAP are displayed over the existing generalised land use map in Figure 2.7, Figure 2.8, Figure 2.9, and Figure 2.10. The noise exposure map for 1996 is provided to confirm the present noise exposure situation. The noise exposure maps for the year of ultimate capacity, 2001, and PANCAP are included here for noise exposure comparison purposes. Table 2.16 shows the area of each noise contour band.
Figure 2.8 Noise Contours (Year of Ultimate Capacity)
Figure 2.9 Noise Contours (2001)
Figure 2.10 Noise Contours (Year of PANCAP)
<table>
<thead>
<tr>
<th>Noise Contour Band</th>
<th>1996</th>
<th>The year of Ultimate Capacity</th>
<th>2001</th>
<th>The year of PANCAP</th>
</tr>
</thead>
<tbody>
<tr>
<td>95WECPNL and Higher</td>
<td>0.77</td>
<td>0.82</td>
<td>0.01</td>
<td>0.07</td>
</tr>
<tr>
<td>90 to 95 WECPNL</td>
<td>1.48</td>
<td>1.62</td>
<td>0.45</td>
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<tr>
<td>80 to 90 WECPNL</td>
<td>9.90</td>
<td>10.66</td>
<td>2.72</td>
<td>3.61</td>
</tr>
<tr>
<td>70 to 80 WECPNL</td>
<td>37.42</td>
<td>39.73</td>
<td>11.74</td>
<td>15.45</td>
</tr>
<tr>
<td>Total</td>
<td>49.57</td>
<td>52.83</td>
<td>15.22</td>
<td>19.83</td>
</tr>
</tbody>
</table>

Table 2.16 Area of Each Noise Contour Band

As shown in the four maps and above table, a very big change in airport noise exposure is expected over the next 15 years or so. The area within the noise contour 70WECPNL is predicted to increase from 49.57 square kilometres in 1996 to 52.83 square kilometres in the year of ultimate capacity (1998 or thereabouts) and then decrease to 15.22 square kilometres and finally increase to 19.83 square kilometres in the year of PANCAP.

The reasons for this dramatic change are (1) the increase in aircraft operations over the next two or four years from 1997, (2) the decrease in aircraft operations and relatively quieter aircraft for domestic flights in 2001, and (3) the increase in aircraft operations of domestic flights from 2002.

The extent of noise impact on residents is largely determined by the number of people residing within the noise contours around the airport. An estimate of the number of people in each contour band around the airport is recorded in Table 2.17. These estimates are based on information from the statistics of population issued by Seoul City in 1996 and the recent urban planning reports issued by local jurisdictions.
The validity and accuracy of airport noise exposure calculations depend on the basic information used in the calculations. For future airport activities, the reliability of airport noise exposure calculations is affected by a number of uncertainties:

- Aviation activity levels - the forecast number of aircraft operations, the types of aircraft serving the airport, the times of operation, and flight tracks - are estimates. The achievement of the estimated levels of activity cannot be assured.
- Aircraft acoustical and performance characteristics are also estimates. When new aircraft designs are involved, aircraft noise data and flight characteristics must be estimated.
- Single flight tracks used in computer modelling represent a wider band of actual flights.

Notwithstanding these uncertainties, noise exposure level mapping was developed as a tool to assist in land use planning around airports. The mapping is best used for comparative purposes, rather than for providing absolute values. That is, noise exposure level calculations provide valid comparisons between different projected conditions, so long as consistent assumptions and basic data are used for all calculations.

Thus noise exposure calculations can show which of the simulated situations is better, from the standpoint of noise effect. However, a line drawn
on a map does not imply that a particular noise condition exists on one side of that line and not on the other. Noise exposure calculations are merely a means for comparing noise effects, not for precisely defining them relative to specific parcels of land (Gillingwater 1996).

Nevertheless, noise exposure contours can be used to: (1) highlight an existing or potential aircraft noise problem that requires attention; (2) assist in the preparation of noise compatibility programmes; and (3) provide guidance in the development of land use controls. Airport noise exposure is the accepted method used for measuring noise, and it is considered to be the best methodology available for depicting noise exposure in general terms.

**Existing and Future Land Use**

Existing and anticipated use of land in the vicinity of an airport is a major determinant of airport noise impact. Obviously, if there were no people or incompatible land uses near an airport or under the flight tracks, there would be little noise impact. But as is the case at Kimpo Airport, there are many land uses impacted by airport noise which make their presence incompatible.

The generalised existing land use is shown in Figure 2.11. The area depicted includes all of the land exposed to significant levels of aircraft noise from operations at the Airport in 1996, plus areas outside the noise exposure range.

The Airport is located in the green belt area and surrounded by green belt on three sides, north, south and west. New development was not permitted in the green belt which was designated in 1971. So there are few residents in the green belt area. However, the other urban area outside the green belt area is densely populated. Nearly all of the land to the southeast of the Airport is within the City of Seoul, and there are few vacant parcels. The predominant land use is residential. The land to the northwest of the Airport, outside the green belt, is mainly an undeveloped rural area, but small scale housing sites have been developed recently.
Figure 2.11 Land Use

- Residential
- Commercial
- Industrial
- Open Space
- Green Belt
- Agriculture and Green Areas
According to recent urban planning reports issued by local jurisdictions and local governments, there is no large scale development planned in the noise impacted area by 2010. However, the construction of houses on prepared housing sites which are located in the rural area to the northwest of the Airport and on the vacant parcel in urban area is expected.

The Need for Land Use Regulation

 Limitation of Existing Noise Control Measures

There are a number of techniques and procedures that can be used to control airport noise in the vicinity of an existing airport. These noise control measures can be grouped as follows;
• Noise reduction at source
• Aircraft operational regulation
• Land use planning and control around an airport.

Of these measures, source noise reduction - in other words, building quieter aircraft - has been the most effective way of reducing the airport noise nuisance. Through the high bypass turbo fan engine technology and through ICAO and each State's action to increase the deployment of this technology, the average noise produced by an individual aircraft movement at an airport has fallen dramatically. The aircraft built today are required to meet the environmental standards set by ICAO, which are contained in Chapter 3 of Annex 16 to the Convention on International Civil Aviation. The ICAO Assembly also passed Resolution A 28-3 in 1991, which mainly addressed the phase out of Chapter 2 aircraft by the year 2002. This should help to reduce noise levels at most airports, but it is no means certain.

However, as M.J.T. Smith of Rolls Royce stated in the ICAO Journal in August 1992, there is no obvious new generation of quieter engines in the pipeline, so we cannot rely only on improved technology to further reduce noise. Hence, average noise per aircraft will not necessarily greatly decrease in the near future. The airport noise level in the vicinity of an airport is determined not only by the fleet mix serving the airport, but also by the
number of aircraft movements. Therefore, in the long term, once the aircraft fleet has become largely Chapter 3, it is expected that noise levels will increase again as traffic continues to grow unless there are Chapter 4 aircraft and/or the noisier Chapter 3 aircraft are phased out.

For many years airport noise was considered to be the most important problem associated with airport operations, particularly the noise exposure levels in the vicinity of Kimpo Airport. Because of the disturbance to the surrounding neighbourhoods, the airport authority has developed and implemented a number of noise control measures for reducing airport noise. The major noise control measures are as follows:

- Cessation of high noise emission aircraft, such as the B707 and DC8
- Preferential runway use
- Preferential approach and departure flight tracks
- Flight operational procedures such as thrust reduction on landing or maximum climb on take off
- Night curfew (23:00 - 06:00)
- Noise related landing fees
- Restriction on maintenance time of day (23:00 - 05:00)
- Installation of soundproofing barrier.

In addition to the above, the installation of soundproofing windows and relocation of seriously noise impacted residents are currently in progress in a limited partial area.

In spite of a big increase in aircraft operations at Kimpo Airport, the noise level around the Airport has increased only slightly considering the monitored noise data from 1991 to 1996. This was basically as a result of quieter aircraft (such as A300, F100, B737 and B767 etc.) and the airport noise control strategies which have been implemented since the late 1980s. The new quieter aircraft were introduced mainly by Korean Airlines and Asiana Airlines. However, with no obvious new generation of quieter engines in the pipeline, the airport environment of Kimpo will become a serious problem in the long term unless it is possible to place restrictions on particular aircraft.
types. It means that the rate of noise level increase in the future will be higher than that of past. There are two reasons for this. Firstly, all the aircraft for domestic flights from the year of 2001 are quieter aircraft such as the later version of the B737 and B747, B767, A300. A320, F100, MD82, and MD83 which meet the standards of Chapter 3. Therefore, it is expected that the noise exposure level will increase continuously with the increase in aircraft operations. Secondly, of the existing noise control measures, the aircraft operational regulations are the only ones which can be applied to the specific situation at Kimpo Airport. Considering the aircraft operational regulations which have been implemented at major airports in the world and recommended by ICAO, there are no other potentially available and innovatory measures at this time. The relocation of noise impacted residents and installation of soundproofing windows being in process are the most expensive ones of the many land use planning and control measures. On the other hand, the economic and more effective land use planning and control measures have not been put into practice. This is because the local governments retain the responsibility for land use planning and control in the vicinity of the airport and they have not played a leading role in that.

Airport Neighbourhood's Increasing Complaints about Airport Noise

Complaining is one of the responses by residents to the noise effects of airport operations. Other responses include organising political opposition to the airport, civil litigation to recover alleged damage, relocation by homeowners and renters, and investing in noise abating renovations (Gillen et al. 1994). Each of the responses to noise is a measure of the demand for relative quiet. Of these responses, political opposition and civil litigation occur less frequently. Complaints about airport noise from surrounding neighbourhoods indicate the extent of the negative impact of airport operations on surrounding neighbourhoods. Complaints are also the easiest of the responses to examine. So they are systematically collected and recorded at many airports.
The U.S. Environmental Protection Agency has shown that the number of complaints in a neighbourhood is directly related to the level of exposure to noise. An increase in complaints can be a sign of the possibility of more intense future responses and the need for strategies to deal with them.

Kimpo Airport has received a large number of complaints every year from enraged residents, either living close to the Airport or under one of the flight paths. These complaints were received by telephone, by letter or by personal visit. The majority of complaints were received by telephone. However, the airport authority has not maintained a full record of noise complaints except complaints received by letter and some reports of meetings with residents and of the assembly. However, it is possible to understand the general view of complaints about airport noise around Kimpo Airport based on the complaints received by letter and consultation with the staff concerned of airport authority.

The major contents of complaints are as follows:
- Heavy damage to human behaviour, health and property value
- Relocation of all the highly noise impacted people
- Compensation with money and grant of tax incentives
- Strengthening of night curfew (after 20:00)
- Extension of existing designated noise impacted area
- Adjustment of existing flight tracks
- Closure of Kimpo Airport after the opening of the new international airport at Young Jong Do
- Downward adjustment of standards for noise impacted area
- Development of a comprehensive airport noise mitigation plan
- Enactment of a special law to prevent airport noise

There had been a limited number of complaints by 1986, but from 1987 there was a dramatic change in the aspect of complaints. Namely, in addition to the increase in the number of complaints, there were a number of group
street demonstrations protesting against airport noise in the new area, which was due to the new runway constructed in 1987. The effect of the use of the new runway was to actually increase the number of people overflown by aircraft who were not previously exposed to serious airport noise. The serious complaints decreased following the subsequent development and implementation of mitigation measures for airport noise; however complaints about airport noise from surrounding neighbourhoods have continued due to the dissatisfaction with the mitigation measures and the worsening of the environment caused by the increase in aircraft operations.

Besides the personal complaints from surrounding neighbourhoods, there were a number of assemblies complaining about airport noise organised by political groups, interested groups and experts on the environment. Also local governments and jurisdictions requested that the airport authority mitigate the airport noise and accept the complaints of the residents. In 1996, some residents instituted a civil litigation against the airport noise, which was the first litigation against airport noise in Korea. Currently it is in the courts.

As stated above, the use of the new runway triggered a significant increase in the airport noise problem at Kimpo Airport and a number of complaints about airport noise have continued since then. Also complaints have shown the intense responses to airport noise and have been made through systematic and reasonable means. These indicate that residents are particularly likely to increase their complaints when a change in aircraft operations exposes them to new sound pressure levels or to new frequencies of noise events. Just after the opening of the new international airport, it is expected that the airport noise exposure level around Kimpo Airport will drop dramatically and the relatively low level of noise exposure will continue for sometime. However, the increase of airport operations will eventually again cause an increase in the airport noise exposure level around Kimpo. Given the breadth and depth of the current responses to the airport noise at Kimpo, it might be expected then that the residents will have an increasing
sensitivity to noise. Moreover, a growing affluence of population in local community area is likely to increase the demand for comfortable living condition, namely quieter environment. This will cause the increase in complaints in the future. Consequently, the combination of higher total noise and increasing resident's sensitivity to noise might lead to sharply increasing resistance to airport operation.

Reduction of Noise Impacted Area and Pressure for Development

The noise impacted land area around Kimpo Airport will substantially decrease in 2001 and then increase over the next ten years or so. Figure 2.12 is a depiction of the anticipated results at Kimpo, which shows a dramatic change. As older and noisier aircraft are withdrawn from service, the 80 WECPNL contour area at Kimpo Airport is expected to decline by about 85 per cent. The area within the 80 WECPNL contour will fall from 28.93 square kilometres, which was officially announced by the airport authority in 1993, to 4.38 square kilometres in the year of PANCAP. Also the area within the 70 WECPNL contour in the year of PANCAP is less than the area within the 80 WECPNL contour announced in 1993. This means there will be an increase of land which can be exempted from the current land use and development limitation. There will, therefore, be strong pressure on local governments to allow houses to be built nearer the airport in the area which has become less affected by airport noise.

The reasons for this are as follows. The benefits and economic importance of the airport have attracted people, and it is currently very difficult to prevent new houses being built close to the airport. However, for the purpose of minimising the airport noise impact on residents around the airport, keeping houses and noise sensitive buildings far enough from the airport is essential. The land use and development control over the land areas affected by airport noise may be a major tool for that. The local government, in general, retains the responsibility for land use and development control around the airport. Also the local government is interested in increasing the tax base and the
Noise Contours (Officially Announced)

Noise Contours (Year of PANCAP)

Figure 2.12 Noise Contours (Comparison)
owners of property are keen to improve the values of their property. So local land development decisions are often made on the basis of considerations which may ignore the need to minimise the impact of airport noise on the community, as well as the importance of protecting the airport from encroachment by incompatible development. The housing site prepared to the southeast of Kimpo Airport in the 1970s was an example of this decision. Although the surrounding area of Kimpo Airport is located at the outskirts of Seoul, the accessibility from this area to the downtown area is very good. In addition, the potential development area for housing is currently in short supply in and around Seoul. At this time, new residential development is taking place in Kimpo County which is an undeveloped area to the northwest of Kimpo Airport. The urban planning report of Kimpo County indicates that there will be a continuous increase in population and development of the residential area.

In 1993, the Ministry of Transportation enacted the ordinances for airport noise, which included completely prohibiting the new development of houses in noise impacted areas within the 80WECPNL contour. Just after the announcement of this, there were a number of strong complaints against it from the surrounding neighbourhoods. One year later, the government yielded to the pressure and revised the provision to conditionally permit the development of new houses in noise impacted areas.

Considering these conditions, there will be a strong demand and pressure for housing development on the land less affected by airport noise.

Conclusion

The size of the area affected by airport noise will be reduced at Kimpo Airport as a result of the opening of the new international airport and the introduction of newer, quieter aircraft. However, there are limits to the reduction in noise nuisance that can be achieved from the use of quieter aircraft, since there is currently limited technological scope for reductions in
aircraft noise levels beyond those specified in Chapter 3, and there are no other more effective countermeasures to reduce airport noise levels through the aircraft operational regulations at this time. In addition, air traffic continues to grow at Kimpo Airport. Further, it is expected that the residents will be increasingly sensitive to airport noise in the future.

Moreover, there will be strong pressure on local governments to allow houses to be built nearer to the airport in the area which has become less affected by airport noise. This may eventually cause the airport environs to deteriorate and restrict the airport operations in the future. So it is inevitable that a proper measure to make best use of Kimpo Airport’s physical capacity should be developed. For this, the first priority is to minimise the number of residential dwellings in the noise affected area and to prevent new inappropriate use of land near the airport, whether the land is a piece of developed or undeveloped land. So even though land use and development control may seem to be very difficult to achieve, it is the only means of ameliorating the airport noise impact in the long term.

For all these reasons, effective and regulatory land use planning including land use and development control is essential to minimise noise disturbance around the Airport. At the second meeting of the ICAO Committee on Aviation Environmental Protection (CAEP) in December 1991, the urgent need for appropriate and effective control of building on land near airports was emphasised. The CAEP confirmed that one of its basic objectives was to minimise the noise impact of air transport, and that land use control is one of the best means of achieving this objective.
Chapter 3
Airport Noise Control

Today, of all the environmental issues, noise has often been considered as the most undesirable feature of life, and this is probably the single most important issue to those people who are exposed to high levels of aircraft noise, such as those people living near an airport. The public reaction to aircraft noise has become vigorous and research has made it clear that aircraft noise causes a great deal of annoyance to those people who are exposed to high levels of it. The effects of airport noise on communities surrounding airports present a serious problem to aviation. In order to resolve this problem, there has been a great deal of work attempting to quantify and control the airport noise over recent years. The purpose of this chapter is to review the effects of aircraft noise on people and, the measures to alleviate the adverse impact of airport noise. This chapter is intended to briefly cover these matters. (The various aspects and causes of aircraft noise, the way that the noise measured are reviewed in Appendix A.)

Adverse Effect of Aircraft Noise

Annoyance

People who are exposed to aircraft noise may be annoyed by the disturbance of rest or relaxation, interference with sleep and conversation, disturbance of reception of television and radio, surprise and vibration or shaking of houses caused by the aircraft noise. In general, the typical response of people to aircraft noise is annoyance.

Annoyance due to aircraft noise is a result of an interplay between the physical attributes of the sound and the psychological or subjective attributes of the human mind (Newman et al. 1985). Therefore, an annoyance response is remarkably complex and, considered on an individual basis, shows wide variability for any given noise level. This variability makes it impossible to
predict accurately how any one individual will respond to a given noise. However, when one considers the community as a whole, trends emerge which relate noise to annoyance. In any community there will be a given percentage of the population 'highly annoyed', a given percentage who are simply 'annoyed' and others who are 'not annoyed' at all. The changing percentage of population within a given response category is the best indicator of noise annoyance impact. In this way it is possible to correlate noise exposure with community annoyance. This measure will represent the average annoyance response for the community. However, it is obvious that there are large gaps in current knowledge, and yet there is no satisfactory theory on how different factors contribute to the adverse effects of noise. Figure 3.1 shows the relationship between equivalent continuous sound level and the percentage of the population that is highly annoyed.

![Figure 3.1 Percentage of U.K Aircraft Noise Index Study (ANIS) Respondents "Very Much Annoyed"](adapted from Ollerhead 1996)

Many researchers suggest that loudness related to the noise level is the major factor in producing annoyance. The most widely used dose-response relationship relates a relatively high degree of annoyance to noise level
(Schultz 1978). Namely, there is a steady increase in annoyance with noise level. Also, annoyance is affected by the number of noise events which occur. Finally, acoustically similar noise environments are often assumed to cause more annoyance in residential areas during the evening or night hours than they would during the daytime. A nighttime weighting is therefore included in some noise metrics.

The response of communities to exposure to aircraft noise is a function of the land and building use, type of building construction, distance from the airport, ambient noise level, and community attitudes (ICAO 1985). Therefore, based on the relationship between noise and the collective response of people to their environment, many countries have established standards for evaluating noise exposure and a decision making aid regarding the compatibility of alternative land uses.

Speech Disturbance Effect

The sound level of speech decreases as distance between talker and listener increase. As the sound level of speech decreases in the presence of background noise, it becomes harder and harder to hear. Figure 3.2 presents typical distances between talker and listener for satisfactory outdoor conversation in the presence of different steady A-weighted background sound levels for three degrees of vocal effort, namely, raised, normal, and relaxed. As the background level increases, the individuals either must talk louder or must get closer together to continue the conversation.

One of the most common and, therefore, most undesirable effects of noise is its interference with communications based on sound, with all that this implies in the disturbance of domestic life and business efficiency. Noise may disturb either communication by direct speech or telephone, and the enjoyment of radio and television programmes. It may also drown out alarms and other audible signals. This may not only cause inconvenience, but for example in the workplace, misheard directions may cause inefficiency and
even accidents (Kerse 1975). The necessity to talk more loudly to overcome noise and misunderstanding may cause fatigue. However, individuals react differently to noise and it is difficult to prove, for example, that the employees become more tired working in a noisy environment than in a quiet one (Kerse 1975).

One of the most important forms of communication is teaching, and it is clear from the evidence given that in those schools which are close to aircraft flight paths the normal process of education is being seriously handicapped by noise.

Figure 3.2 Communicating Distance and in a Noise Environment
(adapted from Environmental Protection Agency)

Sleep Disturbance Effect

Exposure to noise can induce disturbance of sleep in terms of difficulty to fall asleep, alterations of sleep pattern or depth, and awakenings. These effects are referred to as primary sleep disturbance effects. In 1991, there was a field study of aircraft noise and sleep disturbance in the United
Kingdom. The purpose of this study was to determine the relationship between outdoor aircraft noise levels and the probability of sleep disturbance, and the variation of these relationships with time of night. Subjects were recruited from homes in eight study areas near four major U.K airports - Heathrow, Gatwick, Stansted and Manchester. The main results of this study were as follows (DOT 1992):

- Once asleep, very few people living in proximity to airports are at risk of any substantial sleep disturbance due to aircraft noise, even at highest event noise levels.

- Below outdoor event levels of 90 dB(A) on the SEL scale (80 dB(A) Lmax), aircraft noise events are more unlikely to cause any measurable increase in the overall rates of sleep disturbance experienced during normal sleep. For outdoor event levels of 90 - 100 dB(A) on the SEL (80 - 95 dB(A) Lmax), the chance of the average person being wakened is about 1 in 75. Based on expert opinion on the consequences of sleep disturbance, the results of the study provide no tangible evidence to suggest that aircraft noise is likely to cause harmful after-effects.

- There may be particular times of night, perhaps when sleep is not so deep, when individuals could be more sensitive to noise. People appear more resistant to disturbance after first falling asleep and less resistant at the end of the night.

- The data indicates that aircraft events with noise levels greater than 100 dB(A) on the SEL scale (95 dB(A) Lmax) outdoors, will have a greater chance of disturbing sleep.

Increased noise exposure levels result in higher probabilities of sleep disturbance is the general finding in related research. The threshold level of noise which will cause awakening from sleep depends on sleep stage and the age of the subject (Newman et al. 1985). However, there is little agreement on the extent of awakening for different maximum noise levels.

Vegetative reactions, such as effects on heart rate, finger pulse and respiration have been observed during exposure to noise, while sleeping.
However, the increase in heart rate after high level noise events is generally small and well within the normal variations in heart frequency during the day (Wilkinson 1984). Thus, there seems to be no reason to believe that this small extra load on the cardiovascular system from a limited number of aircraft overflights/night is of significance for health.

Auditory Effect

After exposure to high noise levels for a short time, or moderate noise levels over a long time, the minimum level that the person can perceive may shift to a higher level. Temporary threshold shift is a common effect of noise on hearing. When this shift is only temporary, the recovery of the pre-noise exposure hearing acuteness usually occurs within several hours. However, excessive exposure to loud noise can lead to noise induced permanent reduction in hearing acuteness. Therefore, many countries have issued regulations that identify maximum noise exposure which do not produce noise induced hearing loss in any segment of population exposed to industrial noise. The Occupational Safety and Health Administration (OSHA) regulation in the United States, for example, cites a maximum permissible sound exposure of 90 dB(A) for eight hours.

However, relatively little is known of the auditory effects of aircraft noise. This is partly due to the specific exposure conditions of aircraft noise, consisting of short exposure duration, but occurring frequently during the entire 24 hours, thus making it difficult to compare it to occupational and community noise exposure (Newman et al. 1985). It is also partly based on the small number of field studies performed on auditory effects of aircraft noise which makes it difficult to draw definite conclusions on its possible adverse effects.

Non Auditory Health Effect

Many airport neighbours have claimed a direct health impact from aircraft noise. According to the various reports, the self-reporting of general health status due to noise itself are as follows:
- Cardiovascular effects including elevation of heart rate and blood pressure.
- Mental and emotional effects ranging from anxiety, emotional stress, nervous complaints, nausea, headaches, instability, argumentativeness, sexual impotency, changes in general mood and anxiety, and social conflicts to more general psychiatric categories like neurosis, psychosis and hysteria.

The overall evidence for the effects of noise on cardiovascular functioning is suggestive of moderate effects of aircraft noise on blood pressure. However, the clinical significance of these elevations is not clear. In 1986 Cohen et al. reported that "although there were several traffic noise and cardiovascular studies, the findings from these studies indicated that no conclusions can be drawn from the existing database". Also, there have been a number of studies to find a relationship between noise exposure and mental illness. These studies used some different indicators, such as the General Health Questionnaire (GHQ) as a screening instrument for psychiatric disorders, the use of medicines, and admission to mental hospitals. In some studies, reviewed by McLean and Tarnopolsky (1977), a correlation is shown with indicators of mental health. In contrast, Gattoni (1973) could not find significant relationships when controlling for demographic factors and Grandjean (1974) found no correlation between symptoms and exposure. Taylor et al. (1980), after a critical review of noise and mental health studies, conclude: "the examination of mental health effects indicated that no clear effect on mental hospital admissions could be attributed to noise".

As previously mentioned, the fact that aircraft noise above a certain level annoys local inhabitants is generally accepted. However, the effects of aircraft noise on the physical, mental and emotional health of airport neighbours are far less established. Most survey reports on this subject find that there is little reliable evidence on the relationship between noise exposure and mental or physical health (Berglund et al. 1990).
Property Value Effect

Studies have shown that aircraft noise may be a factor which decreases the value of residential property around airports. If people view noise as a source of annoyance, noise affected properties should have a lower value, all else being equal, and this lower value will be reflected in the level of rental income and house prices (Uyeno et al. 1995). Statistical techniques, primarily multiple regression, can be employed to estimate just how much positive or negative effect each characteristic of a property, such as the noise level, has on the value. Since there are many characteristics which can affect property value, a thorough study is required if one is to confidently show the share of the effects attributable to one specific characteristic, such as airport noise.

Nelson (1978) reports a mean of 0.8 percent decrease in value per decibel change in Ldn, based on the estimates of seven major airports in the United States and Canada covering the period from 1967 to 1970. However, studies of the property values have given results varying not only from one airport to another but from one place to another in the neighbourhood of the same airport.

In addition to the property value, the monetary effects of aircraft noise can be assessed by comparing the cost of escaping from it with the cost of putting up with it. Among possible indicators of such costs are falls in the cost of moving house in order to get away from noise impacted areas; and the difference in the market values of houses and the subjective value which owners attach to them due to their surroundings, familiarity, proximity to friends and so on (Gratjios 1990).

Noise Abatement and Mitigation Measures

Noise Certification and Phase-out Program

Today, all new civil aircraft must meet noise requirements, not only in all industrialised countries but also in those countries that are members of ICAO.
In addition to this, individual countries can prohibit the purchase and operation of certain noisier aircraft types. ICAO Annex 16 (Environmental Protection) sets noise standards that aircraft must meet to obtain airworthiness for operation. It was first promulgated in 1971 and then amended for application to civil subsonic aircraft, propeller driven aircraft, supersonic aircraft and helicopters. Annex 16 also prescribes the procedures for aircraft manufacturers and others to use in measuring aircraft noise for certification purposes. The subsonic jet aircraft are classified into two groups known as chapters. Chapter 2 aircraft were old types (e.g., B707, DC8) accepted before 6 October 1977, and Chapter 3 aircraft are those newer, quieter types accepted on or after 6 October 1977 (ICAO 1993).

Some member states adopted Annex 16 and required it as part of the aircraft certification process. They have also added legislation requiring the phasing out of noisier aircraft. So, non-Annex 16 aircraft could not be registered or imported and could not be flown in those states. Eventually noise certification is the process which requires an aircraft manufacturer to demonstrate that his aircraft is able to meet certain noise standards. This is similar to the way a new aircraft must be able to meet safety standards before it is able to enter service. After the introduction of noise certification, the major airframe manufacturers and their engine suppliers all had the benefit of advance warning of the new rules and invested heavily in noise research and development. As a result manufacturers have made significant advances in recent years in the design of quieter aircraft, primarily through the design of quieter engines and improved aerodynamic design, which permits steeper and quicker ascents and descents (Smith 1989).

To reduce noise, efforts for the development of quiet engines have proceeded in two directions: change in the design of aircraft engines and retrofitting of older aircraft. This would mean with respect to aircraft still to be built that they would be equipped with quieter engines and with respect to aircraft already in use would mean that they would be retrofitted by acoustic treatment of engine nacelles, by nacelle redesign, by engine modification, or
they would be reengined with quieter engines (Lyle 1990). However, retrofitting or replacing old aircraft with new ones is a process which requires substantive financial input. Therefore, before such measures are adopted, a cost/effectiveness analysis has to be carried out covering all existing aircraft to see whether the costs of general retrofitting could be compensated by substantially decreased annoyance both in terms of time and space (Gratjios 1990).

**Operating Restriction of Aircraft**

Aircraft can be prevented from operating to or from an airport, unless they meet certain standards. The benchmark may be certification status, contour area or a locally imposed noise level. However, such restrictions often have uneven economic consequences and are employed only after careful consideration of other alternatives and after thorough consultation with affected parties. Some of the forms that such restrictions take are listed below.

**Limit the number of operations**

This strategy, although not a pure noise abatement rule, affects the overall noise generated by limiting the number of aircraft in a given time interval. The primary reason for establishing this is often capacity supply at an airport. However, restricting the number of aircraft operations also limits the quantity of noise.

**Restriction based on cumulative impact**

Under this strategy, a maximum cumulative impact is established and then the airport's operations are adjusted or limited so as to not exceed that maximum. This is done through “capacity limitations” e.g. limiting either the aircraft types based upon their noisiness, or the number and mix of aircraft so as to observe the established cumulative noise exposure restriction.

**Restriction based on estimated single event noise levels**

Since aircraft noise levels vary widely with changes in operational procedures, it may be possible to set limits on estimated single event noise
levels. In order to do this a target noise level limit or threshold should be discussed in advance and an appropriate level selected, balancing the needs of aviation with the noise impacts on the community.

**Restriction based on certificated noise level**

As previously stated, most aircraft types in general service today have been certificated for noise. Therefore it is possible to set limitations based upon those certificated data. Such limitations might take the form of threshold noise levels for the airport of different levels for day and night at the airport. For the purpose of noise control, many countries have found it necessary to impose operating restrictions on noisier aircraft which meet the standards in Chapter 2, but which exceed the noise levels of the more stringent standards in Chapter 3 (e.g. B-727, early version of B-737 and DC9). In the case of Chapter 2 aircraft, the extraordinary session of the ICAO Assembly in 1990, unanimously adopted a resolution on a worldwide policy towards operating restrictions that represents a careful balance between the interests of developing and developed member states and take into account the concerns of the airline industry, airports and environmental interests. This compromise allows states that have noise problems at airports to start phasing out operations by Chapter 2 aircraft from 1995 and to have all of them withdrawn by the year 2002, with certain exceptions. A number of states have now started to take action on the phasing out of the compromise reached in ICAO. Over the next few years, this should help to reduce noise levels at most airports. Although the effect of an operating restriction of Chapter 2 aircraft is to accelerate the ongoing fleet modernisation process, it would somewhat reduce the value of the assets of the operators concerned and require them to make capital commitments earlier than planned from purely economic and commercial considerations (Wickrama 1990).

**Restriction based on operation time**

A partial use or closure of an airport's facilities at a specified time (usually night hours) can reduce aircraft noise exposure. A curfew prohibits aircraft operations at times when the surrounding communities are more sensitive to
noise intrusion, especially early morning and late evening. A night curfew should be reserved as a strategy of last resort, especially for major airports, because of the negative impacts to commerce, scheduling and capacity (DWG Research Associates 1990). Cooperation from airport users, airport authorities and the community must be established so that a balance of noise reduction and airline service is maintained.

An alternative to an airport curfew is a runway curfew. The result of this action would be to close the runways that cause the noise intrusion to the most impacted area. With this system the noise exposure is eliminated from the area of concern yet all night time operations are not stopped.

**Noise related fees based on aircraft noise characteristics or time of day**

Noise fees are special charges which an airline operator or aircraft owner pays to an airport in order to operate an aircraft which generates noise above the standard set by that airport. Another application of the charge could be to an aircraft operator who operates the aircraft during a noise sensitive period. This particular user surcharge is basically directed at those operators who choose to operate noisier aircraft which do not meet the noise level qualifications of some airports. However, this strategy would allow the airline to continue operating the present aircraft fleet until replacement is financially possible, but at an additional operating cost.

In defining the fee, it is important that the value of the charge should be high enough to encourage purchase of quieter aircraft but not so inflated that service is discontinued or disrupted (Horonjeff et al. 1994). The standard noise level and resultant noise fee are based on a standard single event noise rating for the aircraft or a specific, measured noise level as indicated by noise monitoring equipment. For maximum benefit, the resulting income to the airport should be spent on the noise control programme of that airport. This would aid in reducing the noise exposure level. The reverse strategy can be applied. Instead of imposing a fee, an airport authority can reward aircraft
operators who try to reduce noise generated by their aircraft by providing a discount in landing fees.

Flight Procedure and Operation Regulation

Arrival and departure flight paths and procedures can reduce noise exposure if aircraft can be guided away from the noise sensitive areas. For this objective, higher altitude, lower power and shorter duration of time between the aircraft and the impacted community is required. Aircraft with different operating characteristics, weather conditions and airport facility situations all influence decisions of runway use and flight procedure. However, safety has to be considered as a major factor in determining these measures. The major measures of this regulation are set out below.

Minimum noise routings

Minimum noise routings are designed to direct approaching and departing aircraft to follow over routes predetermined to take aircraft away from built-up areas wherever possible. The routes are selected generally on the basis of population density with the purpose of minimising the number of people disturbed by aircraft noise. In addition to this, air traffic considerations, safety requirements, and the actual airspace available for traffic are considered in designing these routes. The design is also politically controversial, especially in areas where the over flying of towns is unavoidable (Smith 1989). Once these routes are set then it is best not to move them, as moving the routes will produce a whole set of new complaints from newly affected people.

There have in the past been arguments that it is preferable to have a large number of flight routes in order to spread the noise exposure around more evenly rather than to concentrate it over very few routes, but such arguments now have very little support (DWG Research Associates 1990). It is obvious that nobody wants to live underneath a flight path. In light of this the airport authorities try to keep as many people happy as possible by keeping minimum noise routes to a minimum. An ideal minimum noise route structure
is to have as few routes as possible and to keep these routes as narrow as possible.

**Use of preferential runway**

A preferential runway system directs airline traffic from a specific runway or runways for arrivals and departures with the purpose of minimising aircraft noise over noise sensitive areas. The main constraints that influence the runway selection are the weather patterns and the prevailing wind conditions: direction, velocity, tailwind and crosswind. In addition to weather, the use of runways is based on the number of available runways, the handling capacity of each runway, land use around the airport, the goal of the noise abatement programme, the desired level of noise reduction and times of aircraft operations. Deciding runway preferences is a compromise of the economic, environmental and safety aspects of an airport and its environs. A designation of runways can be used as a tool to restrict specific types or classes of aircraft from overflying noise impacted areas at specific times in order to reduce aircraft noise exposure, but it also reduces the operational capacity of an airport.

**Reduction of power on takeoff**

To reduce noise impact over a community under the takeoff flight path, engine power can be cut back once the aircraft has attained a safe operating altitude. Operation continues at reduced power until a depopulated area is reached, when the full power climb is resumed. Several airports have allowed or even demanded noise control via a reduction in engine power over populated areas, and the technique has long been permitted in the compliance - demonstration procedures of noise certification. Heavy power reduction close to the airport will alleviate the highest levels, but it will restrict the aircraft climb gradient. Moreover, noise will increase downstream of the airport, when high power is reselected for the climb to cruise altitude (FAA 1986). However, by careful planning the power cut back on takeoff, the level of noise on the total community can be reduced. Safety is a major factor in determining whether a noise reduction measure will be employed.
Maximum safe climb procedure on takeoff

This aircraft operating procedure requires a rapid safe climb on takeoff to a desired altitude to minimise the length of time overflying the community. The maximum safe climb technique has been possible because of the significant improvements in aircraft wing and flap design and available engine thrust (Smith 1989). This strategy is designed to aid the reduction of takeoff noise for communities further removed from the airport site (9 - 18 kilometres and beyond). However, it will increase the noise exposure for any area bordering the airport, so it is necessary to identify the segment of the population which will be most impacted (FAA 1986).

Increased altitude on approach

This noise abatement procedure requires the aircraft to be kept at an increased height above the ground. Control on approach is rather more difficult than takeoff, since aircraft are generally tightly controlled by both air traffic procedure and the pilot, who is looking for a safe and stable aircraft configuration in the delicate manoeuvre prior to touchdown. Several procedures can be used to increase the height of approach operations (Smith 1989):

- Interception of angle slope at higher altitudes when interception is from below the slope
- Performing the final descent at a steeper than normal angle
- Two segmented approaches with the initial descent at 5 or 6° flaring to 3° for final approach and touchdown.
- Low drag approaches with reduced flap settings and lower engine power settings demonstrates some reduction of noise
- Use of continuous descent approaches, utilising secondary surveillance radar for height information. This prevents the use of power in a stepped descent and consequently reduces noise under some parts of the descent path.

The primary benefit is achieved for those residential communities that are located 4 to 7 kilometres from the airport. The greater the distance from the
source (the aircraft) to the receiver, the greater the reduction of noise impact. However, pilots, in general, recommend that flying an approach steeper than 3° is unsafe due to the increased sink rate (DWG Research Associates 1990).

Another procedure, practised at airports where the runways are long enough, is to displace the landing threshold so as to allow aircraft to overfly communities close to the end of the runway at a higher altitude. This measure results in the reduction of landing noise for those residential areas located directly under the approach path.

**Limited use of reverse thrust during landing**

This procedure requires aircraft to reduce the use of high power settings during the landing roll. By extending the landing roll, the noise level can be reduced. Limited reverse thrust is employed only after a safe speed for taxiing is attained and when sufficient runway length is available. This measure, combined with noise barriers and a high speed taxiway, provides more of a noise benefit to very close residences. The high speed exit taxiway provides the physical space to slow the aircraft thereby reducing the need to employ reverse thrust to the extent that is otherwise necessary.

**Ground Noise Control**

Ground level noise sources at an airport include run ups, engine maintenance, taxiways and apron areas. Because the noise is generated on the ground, the impact is usually confined to those areas immediately adjacent to the sources. The use of physical barriers, berms, trees, walls, specially built hush houses or noise suppressors which absorb a part of the noise generated is beneficial. Strategic placement of new hanger or terminal structures may also shield adjacent neighbourhoods by absorbing noise. However the benefit is directly related to how well designed the structure is and its proximity to either the source or receiver of the noise.
In relation to ground run ups and engine maintenance, a limitation can be placed on the time of day and/or airport location. From an environmental point of view, the maintenance run up area should be located as far from any noise sensitive area as possible. However, the run up pad should be situated where it causes no interference with movements on the active runways and taxiways. Eliminating night maintenance provides the most benefit since it removes a noise source at a time when residents are most irritated by noise. The direction of the aircraft during the run up procedure should also be limited based on the aircraft types.

Land Use Regulation around Airports

Airport land use regulation, including land use planning and control, is intended to establish a clear demarcation between the airport and the people living and working near it by identifying the sort of uses to which the land close to airports, and elsewhere, can be put (Walder 1993). Essentially this means keeping houses and other noise sensitive buildings, such as schools, far enough away from the airport so that aircraft noise is not unduly intrusive. However, the very success and economic importance of airports has attracted people, and it is very difficult to prevent new houses being built close to the airport. Several countries around the world have developed land use planning controls that apply to airports to minimise the degree of incompatibility with their surrounding land use. In applying land use compatibility in the vicinity of airports, the noise exposure level is combined with a noise contour.

Airport compatible land use planning achieves four basic aims (DWG Research Associates 1990):
- Reinforcing existing compatible land use and promoting the location of future compatible uses in vacant areas or redeveloped land
- Converting existing incompatible land uses to compatible ones over time (this is more complicated and costly but is usually the process taken by airports threatened by urban sprawl)
- Guarding against the introduction of any new incompatible land uses (this requires constant attention especially from individuals who desire urban expansion and possible profit)

- Committed zoning requirements (these safeguard the airport and its environs from the construction of structures which do not comply to height, bulk and content restrictions required within the vicinity of an airport environment).

Various measures are available for controlling the use of land around airports. However, the selection of a particular measure or measures for existing or new airports depends to a certain extent on specific national and local circumstances. The major measures of land use control are as follows:

- Comprehensive planning
- Zoning and subdivision regulations
- Acquisition of rights on land
  - Land purchase
  - Easement acquisition
  - Transfer of development rights
- Building design and sound proofing
- Financial assistance
  - Tax incentives
  - Relocation assistance
- Implementation of public capital improvement projects
- Real estate disclosure statement.

In most cases the measures are used as an aid to planning, but in many cases noise policy makers and land use controllers are different groups who represent different interests. Therefore the problem with land use control is enforceability. Also the benefits to be derived from land use planning and control may necessarily be long term. However, it may be a fruitful measure for the minimisation of exposure to noise around airports through the cooperative efforts of all those involved.
Aircraft Noise and Operation Monitoring

A current complete monitoring system such as FANOMOS is capable of providing information on both aircraft sound levels and aircraft operations based on the data drawn from the noise monitoring system, the flight tracking system, the aircraft identification system and the central computer. The monitoring facilities consist of five basic components: ① a remote sensor system which collects all the data, ② a central processing station which integrates, collates and stores the data, ③ computer hardware and software dependent on the specific noise abatement strategy at the individual airport, ④ facility accessories which include monthly reports, public display boards and newsletters, and ⑤ trained staff to interpret the results (Penn 1995).

The primary uses of aircraft noise and operations monitoring systems are to help establish and monitor compliance with noise abatement procedures, verify trends in overall fleet noise, and provide input and validation data for computer based airport noise simulation models (Horonjeff et al. 1994). Monitoring systems are established as a control mechanism to measure the degree of success of a noise abatement strategy on an hourly, daily and monthly basis. The secondary benefits include pilot education and cooperation, purchase of new aircraft, reduction in noise exposure and a public relations tool for communication with the impacted community. Noise measuring equipment enables the airport operator to demonstrate levels of aircraft noise to the airline operator, aircraft owner and concerned residents. Advanced systems are capable of separating the airport's contribution to the total noise level from the background noise. The data collected and analysed can be checked with noise contours to determine the accuracy of the noise levels and limits for land use. The monitoring strategy is costly because of the equipment required. However, where the data are used in a more aggressive manner, in the development of strategy, these systems are deemed appropriate.
Developing Community Relation Programmes

In an attempt to resolve the noise problem faced by communities, airports have developed various community relation programmes. The contents of this strategy are presented below.

**Establishing formal noise complaint procedures**

A noise complaint procedure includes responding to all complaints and correlating complaints to noise data, aircraft type and flight tracks (Gillen 1994). Its purpose is to aid both the public and the airport operator in understanding the nature of the noise problem. Airports generally utilise a systematic method of recording noise complaints and staff. Airports with radar tracking are more successful in correlating noise complaints to flights.

**Developing a community information programme**

The purpose of this strategy is to keep the airport community (residents, operators, public officials, and airport related personnel) informed of airport related issues, primarily concerning noise, but also including other areas of interest. Airports have typically undertaken community information campaigns on a need basis, i.e. prior to major construction and rerouting of traffic. This approach is attractive because of the relatively low cost of implementing it, and its effectiveness in turning aside complaints from residents who do not understand the nature of the noise annoyance (FAA 1986). The media generally employed to distribute information include newspaper articles, press conferences, newsletters, special reports, public relation campaigns, and appearances at interest group gatherings.

**Establishing noise related meeting**

The purpose of this strategy is to maintain open lines of communication with the airport's neighbours in the process of development and implementation of noise abatement strategies. In order to elicit the community input, airports have established workshops, panels, groups and committees with the public participation. The meeting provides a continued interchange of information.
between the airport community and airport staff who are in charge of noise abatement strategy, enabling the airport staff to address a number of issues of concern to the community. The meeting may also assist parties with differing interests in reaching an acceptable agreement.

Conclusion

Aircraft noise pollution is unlike most other forms of pollution. Rather than being an ecological problem, it is primarily a sociological and psychological problem. In order to be able to discover the nature of the problem, and the corresponding action to deal with it, it is necessary to collect information about the impact of the noise and the nature and extent of the consequences that the impact causes.

Noise abatement and mitigation strategies are a result of the concerns expressed by members of the aviation field, airport operators, airlines and their customers, and impacted community residents. Therefore, the success of those strategies is linked to the view that full participation of all involved parties is fundamental.

It is now generally accepted that the future growth of the aviation industry will largely be dependent upon the way in which the problem of aircraft noise is handled. Given the breadth and depth of the environmental movement worldwide, it might be expected that the public will have increasing resistance to airport noise. Therefore the airport authority or operator should maintain a balance between the needs of the air industry and those of the airport’s neighbours. For the purpose of this, the most beneficial and effective method of dealing with the airport noise problem is establishing good community relations in addition to applying mitigation measures, positive land use planning and operation of quieter aircraft. The following are desirable ways of creating this. The first is the creation of an open planning process where those who may be opposed to development and operation of airport can participate. Recent experience has shown that a thorough attempt to provide
information and to cooperate with the neighbouring communities results in changed perception on both sides and leads to very satisfactory relationships. Transparency and advance information on airport and flight operations might help explain their value and their environmental implications to the communities served by these airports. The second way of creating good community relations is to use available scientific evidence to establish the facts of the effects of proximity to the airport on people. Environmental monitoring, whether using noise monitoring or tracking computers, and/or research and/or consultation, is a necessary foundation to the development of an effective noise control policy.
Chapter 4
Land Use Regulation Around An Airport

Airport land use regulation is an important technique for controlling the adverse impact of airport noise in airport environs. A number of commercial airports have been the focus of compatible land use planning and control, since incompatible land use may result in public pressure which would threaten the operation and expansion of airports. In order to prevent encroaching development in the vicinity of airports, systematic, short and long term control measures are necessary. The success of the prevention of incompatibility depends on effective planning and control of land use. This chapter deals with this matter. The first part seeks to list the characteristics of effective land use planning. The second part reviews the available land use control measures that are implemented at existing airports in the world. The third part analyses the compatible land use planning system in the United States, United Kingdom and Korea.

Principle of Compatible Land Use Planning

Airports and airlines have applied many different ideas to minimise noise impact which has been one of the greatest threats to aviation operation. The successful development of aviation requires that airports become as compatible as possible with their environs. To achieve and maintain the compatibility of an airport with its environs, assurances are needed that an airport can maintain and expand its size and level of operations to satisfy existing and future aviation demands whilst persons who live, work or own property near the airport may enjoy a maximum amount of freedom from noise or other adverse impacts of the airport (Koppert 1996). Compatibility of an airport with its environs is an ideal which can be pursued by proper planning of the airport, control of pollution-generating sources and land use planning of the area surrounding the airport (ICAO 1987).
Compatible land use planning - first initiated in the United States in the 1960s (FAA 1967) - is a formal joint planning effort which considers and evaluates both aviation and urban planning strategies in searching for long-term solutions to existing and future noise problems around an airport. The planning effort should be adequate to find the most practical alternative for those which might be proposed, to demonstrate that it is proper to those affected, and that is fully implementable. This planning should be incorporated into the existing or ongoing comprehensive planning for the region involved and should be practical in respect of costs and its ability to generate the local planning and land use control measures necessary for its implementation.

The purpose of compatible land use planning is to seek optimal accommodation of both airport operations and community activities within acceptable safety, economic and environmental parameters (FAA 1977). That may be achieved by reducing existing incompatible land uses in the vicinity of the airport and preventing the introduction of new incompatible land uses in the future. For this purpose, the airport authority and other responsible bodies should consider a variety of practicable alternatives of noise control measures and land use patterns. So, compatible land use planning should be formulated as a balanced and effective programme to minimise or reduce the airport noise impact on local communities. The following sections describe the desirable approaches to be followed for successful compatible land use planning around an airport. (Compatible land use planning process is reviewed in Appendix B.)

Comprehensive Planning

Compatible land use planning takes into account a number of general goals and specific objectives of the several functional elements comprising the plan, and development proposals for the community and airport needs. Therefore, if it is to be successful, a comprehensive planning approach should be taken in the planning process. Comprehensive planning for an
airport environs is a co-ordinated effort to ensure the compatibility of airport operations with the needs of the airport environs and the region (FAA 1985). Such planning can also protect the general public interest by suggesting that adverse socio-economic impacts should be minimised and unavoidable impacts reduced to the highest degree. The purpose of comprehensive planning is to seek practical and balanced solutions and to formulate and implement compatible land use measures that are consistent with airport operation and development (FAA 1985). A properly established comprehensive plan which is useful guidance to local land use decisions and development controls and airport operation and development may be the most effective compatibility strategy.

In respect of comprehensive planning, it is desirable that compatible land use planning is developed within the framework of a community or regional plan. In other words, the compatible land use planning should be considered as part of the overall comprehensive planning for the community. So, both aviation and urban planning solutions to the problems must be reviewed equally in the planning study, and then practical solutions evaluated against the realities of the social, economic, and environmental needs of the community involved. The following are major items to be considered in the compatible land use planning study.

Airport and community: The airport and the community exert a number of important influences upon each other. Those influences may be generally classified as economic, social, and environmental; and they must be taken into consideration during the process of developing a compatible plan (FAA 1985). The plan must also be incorporated into the appropriate comprehensive plans of the community, metropolitan area or region.

Airport master plan: A compatible land use planning study should be developed in conjunction with preparing a complete airport master plan since future airport requirements may change the land use pattern around an
airport. The airport master plan may provide the basic data for the compatible land use planning study and this approach also permits changes in airport development proposals to achieve greater airport environs compatibility. If a current airport master plan is available, a compatible land use planning study may be developed as a supplement to the master plan.

**Airport noise control:** The compatible land use plan is an important part of a noise impact analysis study which should take into account several noise control measures, including preferential noise routes. The selection of a certain airport noise control measures may result in corresponding off-airport noise impacts. The trade-off between airport noise impacts and land use requires precise evaluation during the overall compatible land use planning process.

**Cooperative Effort**

The airport authority and the local authority exercising land use and development control over the land areas affected by airport noise are fundamentally responsible for the compatible land use planning. These two groups have the planning and implementation authority to conduct the study and to execute the plan through the implementation programme. However, there are usually a number of land use control authorities within the noise impacted area. All the land use control authorities with noise impacted land within their jurisdictions have a land use plan, zoning codes, and building codes, etc. So, effective compatible land use planning requires co-operative efforts by local land use authorities, airport authorities and planners.

An appropriate control measure for compatible land use around airport is taken to restrict the use of land adjacent to or in the immediate vicinity of the airport to activities and purposes compatible with normal airport operations, including landing and take-off of aircraft. Therefore, cooperative efforts are also required between airport users and interested or affected citizens.
The cooperative efforts can be accomplished through consultations and interactions between the airport authority, airport users, airport neighbours and local land use control authorities. These consultations should place as early as possible in the planning process in order that the view and perspectives obtained may be fully integrated into the study effort. However, sufficient consultations should be conducted throughout the progress of the study.

Through cooperative efforts the planners may proceed in reasonable confidence that their actions are in accord with airport, community and citizens’ needs and desires. When related authorities, parties and citizens become fully involved before major decisions or commitments are made, the planners can better deal with issues and improve the chances of reaching a solution on controversial matters. The chances that planning decisions may be overturned by adverse reactions at the final stage of planning can then be greatly reduced.

Monitoring

Land usage is a continuously changing issue, particularly in urban environments, and community growth creates pressures for changes to land use plan and control actions established to achieve and protect compatibility between airport and environs. The airport noise impact can be seriously changed by aircraft operations due to the diverse and changing conditions which may affect the compatible land use plan. For this reason, a monitoring plan is necessary for successful land use control. An appropriate plan for monitoring should be established and contained in the planning process. Also, responsibility for the activity should be identified in order to ensure that all the parties involved are aware of their roles. Monitoring includes surveillance of aircraft operations, land use actions and changes in community attitudes.
Monitoring land use change forms an important part of the process by which the plan is continuously reviewed and up-dated. Careful monitoring of land use change enables planners to modify strategies accordingly. Moreover, monitoring may identify areas within which particular types of change should be encouraged (or discouraged) by future plans (Dikinson et al. 1977). This is needed to identify proposed land use changes which would not be consistent with the adopted compatible land use plan. Consequently all requests for changes in the land use plan and control actions within the authority area should be monitored.

Aircraft operational procedures adopted as part of noise control measures must be monitored to ensure that they are being complied with. A complete noise monitoring system provides information on both aircraft noise levels and aircraft operations. So it helps to establish and monitor compliance with noise abatement procedures, and verify trends in overall aircraft noise. Detailed presentations of actual aircraft flight tracks are extremely helpful for examining noise abatement alternatives. Effective compatible land use planning may be based on specific noise control measures which can result in a specific off-airport noise impact situation.

Changes in community attitudes toward airport impacts or changes in local growth objectives may affect the plan. A periodic social survey and a formal noise complaint procedure are useful means for collecting this information. As previously stated, complaining is one of the means of response by residents to the noise effects of airport operations and residents are likely to increase their complaints when a change in operations exposes them to new noise levels or to new frequencies of noise events. Consequently, complaints should be monitored for use in subsequent formalised reviews of the compatible land use plan.

Noise Exposure and Land Use Category Guidelines

Different uses of land have different sensitivities to noise. Schools, residences, churches and concert halls are very sensitive to noise. By
contrast, factories, warehouses, storage yards and open farm land are relatively insensitive to noise. Other uses, such as offices, shopping centres, recreation areas or hotels have intermediate levels of noise sensitivity (FAA 1975). The response of communities to aircraft noise exposure is dependent upon such factors as: land use; building use; type of building construction; distance from airport; ambient noise in the absence of aircraft; diffraction, refraction and reflection of sound due to buildings and topographical and meteorological conditions; and factors of a sociological nature (ICAO 1985). All of these factors contribute to the sensitivity of the communities to the airport environment. Therefore, for planning and regulatory purposes, the application of objective criteria based on the relationship between noise exposure and the collective response of people to their environment is required.

Noise exposure and land use category guidelines act as an objective criterion which directly relates to compatible land use planning and establishes a single system for determining the impact of noise upon people resulting from the operations of an airport. In other words, noise exposure and land use category guidelines show the relationships of airport noise to categories of land use and identifies land uses that are normally compatible or incompatible with various levels of noise exposure. So, it is a basic planning tool in a compatible land use planning process. It serves as a guide for airport and community planners in planning land use and building construction in the vicinity of airports. It can also provide general indications as to whether particular land uses are appropriate for certain measured or predicted noise exposure levels.

Forecasting aircraft noise exposure and predicting community response are necessary for the development of guidelines which makes airport operations and the community life mutually compatible. The noise exposure and land use category guideline system employs common noise estimating procedures as inputs and connects these with categories of land use compatible to the
existing and forecast noise impacts of the airport. However, it should not be forgotten that vegetation, configuration of the ground, and the position of buildings or walls may often affect the impact of noise on the human users at a specific site.

The land use categories are based primarily upon studies of noise-induced annoyance and interference with critical activity associated with use. However, it should be kept in mind that no two communities are likely to have identical goals, values and needs. The noise exposure criterion that is considered appropriate by one community may not be considered so by another. Thus, adjustments to the noise exposure and land use categories may be necessary when considering specific local conditions. These decisions should be made early in the planning process.

According to specific local conditions, noise level reduction through blocking of noise paths or soundproofing measures may be taken into account in determining the compatibility of indoor uses or activities, since users located within soundproofed structures may normally be placed in a more noisy zone. This implies that windows and doors must be closed and that air-conditioning or artificial ventilation must be used. However, most careful attention should be given to the noise level reduction to put individual residences or schools into a compatible category.

Citizen Involvement

Compatible land use planning may have a potential impact upon a related community or region and a direct impact on citizens who live and work around an airport. Whether this impact is acceptable to the citizens will depend to a large degree upon the effectiveness of the citizen involvement programme. An effective citizen involvement effort should ensure that the citizen has an opportunity to be heard early, before major project decisions are made, provide adequate notice of opportunities for involvement to interested or potentially affected parties, and provide for frequent forums throughout all stages of the planning process (FAA 1975).
The basic objectives of citizen involvement in the compatible land use planning process are improved planning, minimisation of controversy, and citizen support of the final plan. The planning can often be improved through the meeting of citizens and planners throughout the planning process and through clear identification of citizen views on all planning contents. Citizen input is also invaluable in identifying the specific goals, values and needs of the affected communities. Controversy can be minimised by identifying and resolving sensitive issues through citizen involvement before they become controversial. The citizen's involvement with the planning study and resulting understanding of its benefits, the problems encountered, and the trade-offs necessary for their resolution can induce citizen support for the plan. Citizen involvement is also an educational activity which informs the general public of conflicts between airport use and other adjacent land use as well as the justification for using community resources.

Public hearings, citizen planning group workshops, public information programmes, publications necessary or desirable for the planning and coordination activities are elements that may be included in the planning process. Above all, the early involvement of citizens in the process and the early identification of potentially controversial issues or choices are important. This is particularly important for sensitive issues.

Compatible Land Use Control Measures

It is indeed not practical for an airport authority or local authority to own all of the airport noise impacted areas to prevent conflict between the airport and the environs. Thus there has been and will be a continuous need for development related to the utilisation of the benefits of the airport and the growth of the community. Consequently, for the purpose of accomplishing the implementation of a compatible land use plan, control over the uses of private properties within noise impacted areas is absolutely necessary.
The desired goal of effective compatible land use control is to minimise the amount of noise sensitive use and development close to the airport, while allowing other productive uses of the land (FAA 1977). Development control relates to the land use controls which can protect the noise impacted areas from encroachment by noise sensitive uses.

There are two general approaches to dealing with land use controls; these are preventive measures and remedial measures. These are often used in combination. Preventive measures are normally employed to avoid the future problems that can be anticipated. To effectively control the problems of airport noise and incompatible land uses, there must some sort of long term planning. Preventive actions take many different forms, i.e., adoption of land use regulations, the practice of comprehensive planning such as comprehensive community development planning and compatible land use planning in the vicinity of the airport. Each of these forms of preventive action requires the involvement of communities surrounding the airport, national government, and interested citizens. An essential part of correcting the already existing incompatible uses is through the use of remedial measures and strategies. These are often more expensive than taking preventive measures, but as airport traffic intensifies and the community continues to grow, noise problems may become so severe that drastic measures, such as removal of entire neighbourhoods, may be implemented.

Various measures are available for controlling the use of land around an airport. However, some specific measures can be applied to an airport based on each country's legislative situation and unique airport and environs necessities. Also, the applicability of these measures for existing and new airports should be considered for each particular situation. Some major compatible land use control measures are presented in the following sections.
Zoning and Subdivision Regulation

Zoning

In many countries, but especially North America, the basic measures of land use control are zoning and subdivision regulation with zoning being the most pervasive and relatively inexpensive. Zoning is used as a land use compatibility implementation tool which regulates land use and development in the vicinity of an airport in relation to noise exposure. It can be applied to existing airports and projected future airport development so that future airport expansion would not be obstructed by incompatible land use.

Zoning is the division of a jurisdiction into districts ("zones") within which permissible uses are prescribed and restrictions on building height, bulk, layout, and other requirements are defined (Delafons 1969). The zoning regulations should be uniform in all districts zoned for the same use. Zoning is an exercise of policing powers of a national or local government and is essentially a legal means. Zoning should be based on a comprehensive plan that takes into account the total needs of the community, airport need and airport noise controls. In order to effectively protect the airport and the residents, zoning should be applied fairly in noise impacted areas and have a reasonable necessity for its usage.

When well applied and coordinated with airport information, zoning can play a vital part in securing long term land use compatibility. However, the following limitations must be considered when using it. Zoning is not retroactive. In developing and applying zoning regulations, attention must be given to the existing and potential use of land in the vicinity of the airport. This is necessary in view of the difficulty there would be in changing zoning in order to prohibit a use which is already in existence. For this reason, most zoning regulations have an exclusion clause which permits the continuance of existing uses that do not conform either as to use or detailed requirements. Zoning is subject to continual change. The power to amend zoning regulations or district boundaries resides with the land use control authority.
Consequently, amendments to them are more liable to take into account the community growth and the pressure from developers or citizens rather than airport needs. Zoning is jurisdiction limited. Airport noise impact often affects several jurisdictions which might have different zoning regulations. This makes it difficult to apply fair zoning regulation over noise impacted areas, and prevents effective zoning.

Height/Noise/Safety Zoning Overlay

These types of overlay are intended to (1) ensure aircraft safety by specifying maximum height limits on structures, (2) restrict noise sensitive land use in areas with high levels of noise exposure, and (3) provide safety areas under the approaches to each runway. The primary purpose of a height restriction is to ensure aircraft safety by controlling the location and height of trees, towers, poles, buildings, and smokestacks in the vicinity of the airport. The objective is to ensure that entire runway lengths are not restricted.

Noise compatible zones can be determined from aircraft noise exposure maps that are based on existing and future levels of aircraft operations. Such information can be displayed on a map with noise contours to form noise zones. By overlaying the map with height restriction zones, a combined height/noise overlay is created. Safety areas off the ends of all runways in which all forms of development are severely restricted are then added to the overlay. The height/noise/safety overlay is a useful tool for determining conforming and non conforming land use, and it can be used in conjunction with the zoning described previously.

Subdivision Regulations

Subdivision regulations are the controls governing the preliminary stage of development. They can cover many aspects of development, such as the layout, density and open space requirement, and noise insulation requirement. Accordingly, subdivision regulations can be useful in preventing problems with new development, since the developers should meet the required regulations in design and construction of buildings. It normally consists of subdivision ordinance.
Acquisition of Rights in Land

Land Purchase

The acquisition of critical land through purchase is the surest way to ensure that incompatible land uses are not introduced in noise sensitive areas. Land acquisition of noise impacted areas by an airport authority can eliminate long term incompatibility problems.

This land may then be (1) used for airport uses, (2) leased for airport compatible uses, (3) resold with avigation easements and deed restrictions that would permit only specific compatible uses, (4) retained by the airport and maintained as permanent open space, and/or (5) used by other governmental agencies for public purposes, such as storage yards and parks, or for other noise tolerant uses.

For any acquisition programme that includes development of residential land, relocation programmes and assistance (both with costs and social aspects) must be considered. Since acquisition programmes involving noise sensitive housing can result in severe disruption to residential neighbourhoods, such programmes should be used in critical locations where other solutions are not practicable. Land can be acquired through negotiation with the property owner, dedication or through compulsory purchase.

Easement Acquisition

For the purpose of achieving land use compatibility, an airport authority can acquire a specific part of the total rights of the property which is located in the noise impacted area. The transferred right from the property owner is the easement. When an airport authority acquires an easement, the property owner concedes his claim to that portion of his property and yields to the airport authority limited rights to the property. In relation to effective airport operation, the easements of avigation to make noise over the property are required. Avigation easement secures the right to fly over affected properties. Noise easement may also prevent the establishment or maintenance of noise sensitive uses on the designated property.
Acquisition of avigation and noise easements offers a means of protecting, to a limited degree, the airport authority against future claims from property owners in noise impacted areas. It also means that property owners cannot sue the airport authority or airlines for nuisance caused by normal operations of aircraft at the airport. Easements may be acquired through purchase, condemnation, and dedication. Normally, property owners are compensated for the loss in value of their property attributable to the easement. Easement is less expensive than land purchase and a permanent method of land use control. When used with sound insulation, the easement can be a highly effective land use control measure.

Transfer of Development Rights (TDR)

Another form of right acquisition of land use control involves the transfer of development rights, a legal system which separates certain development rights associated with a parcel of land and allows their transfer to property in another location where they may be used to intensify allowable development. In the context of compatibility associated with an airport, land development rights from noise sensitive tracts may be transferred to another lot in a more appropriate location within the same jurisdiction.

The transfer of development rights must be fully coordinated with a community's planning and zoning. The noise impacted land may then be used for a compatible purpose such as open space or agricultural uses, thus preserving some development potential on the original site. Landowners could be compensated for the transferred rights by their sale at the new locations or the rights could be purchased by the airport authority.

Building Design and Soundproofing

Buildings likely to be exposed to external noise should be expertly designed and constructed to ensure that they provide good sound attenuation, since once buildings have been constructed and occupied, it is difficult to introduce acceptable control measures for the transmission of external noise.
As far as possible, external noise should be controlled by site and building planning, so that building design can be primarily concentrated on reducing sound transmission. Architects should take into account the following (Penn 1995):
- the avoidance of incompatible uses
- the proper design and layout of buildings
- the proper internal design of dwellings.

Good sound insulation as one of the construction requirements for new buildings is extremely important, as is the design and layout of buildings. Structural construction methods and material can increase the interior noise reduction levels of typical residential or commercial structures in noise impacted areas. The sound insulation requirements for new buildings and the material changes of use are introduced to building codes. Building codes are essentially legal means of requiring adequate sound insulation to be incorporated in new construction.

Where there are many people who are seriously affected by airport noise who are likely to remain, such as in urban areas and for many existing airports, soundproofing can be taken to solve the problems of existing unprotected noise sensitive uses within the noise impacted areas. Soundproofing aims to reduce the noise transmission through sound sealing the building structure itself. Suitable agreements in the context of noise sensitive land use control should be secured in any contractual arrangements.

Achieving noise reduction through soundproofing applications includes the minimal efforts of sealing and weather-stripping of windows, doors, vents and external openings. For more noise reduction, it is necessary to take into account the treatment of exterior walls, ceilings and attic. To be effective in warm weather, air conditioning must also be part of a basic soundproofing programme, so proper ventilation can be achieved with the windows closed.
The effect of soundproofing application depends upon the degree of noise insulation and the condition of the building, and is directly related to the cost. The airport authority or local land use control authority which is responsible for the implementation of the soundproofing programme should conduct a structural and acoustical analysis of the building for the appropriate soundproofing applications.

Financial Assistance

Tax Incentives

Tax incentives, such as the reduction or elimination of property taxes and differential tax assessment, are a means of allocating the noise reduction cost equitably. Such incentives can be used to induce future as well as present property owners to comply with performance standards for noise insulation contained in the building codes. Reduced property taxes can provide a form of compensation to owners of property subjected to airport noise. Tax policy can also discourage the conversion of facilities such as golf courses or agriculture to more profitable uses by offering preferential tax treatment for compatible land uses. Tax incentive programmes require drastic cooperation of local government in terms of designation of areas, and planning and zoning with regard to compatibility issues.

Relocation Assistance

This programme can assist residents in the noise impacted areas who wish to voluntarily relocate outside the noise impacted areas. The assistance includes grants or low interest loans to cover the actual costs of relocation. These costs could include loss in property value between comparable old and new residences, any mortgage penalties incurred, realty fees, and actual moving costs. In order to be made compatible with noise levels, the properties are noise insulated prior to sale to future owners and usually sold with easement. This strategy can be useful in lightly noise impacted areas where it has been decided that existing residential neighbourhoods will be maintained.
Implementation of Public Capital Improvement Projects

As an implementation method for achieving land use compatibility, the thoughtful use of capital improvements related to public works can greatly assist changes in land use or reduce the demand for growth in an area. The timing, as well as location and programming of capital improvements and public works projects can strongly influence land use trends and demands. Such projects may include road construction or widening, the development of schools and parks and recreation facilities, the building of water and sewerage treatment plants and flood control facilities.

The timing of these projects is related to urban growth in that denial or delay of projects serves to discourage development. In contrast, early completion of such projects encourages development. Accordingly, sequencing the implementation of capital improvements and public works projects to be consistent with land use compatibility objectives is very important in the planning of capital improvements.

Real Estate Disclosure Statement

Many homeowners buy property in noise impacted areas without accurate information about airport noise and then they become a noise complainant or noise litigant. Accordingly, the future buyer of residential property which is located in a noise impacted area should be made fully aware of the noise levels expected at the location and of any locally adopted requirements for sound insulation. The effectiveness of such a strategy normally depends on the willingness of the community to enforce it. In addition, the seller must be willing to bear some financial cost, and penalties should be attached for non-compliance.
Review of Land Use Planning Systems around Airports in Various States: United States, United Kingdom and Korea

Compatible Land Use Planning System around Airports in the United States

In 1976, the Department of Transportation delineated the responsibility of each party under the noise compliance rule. Accordingly, airport proprietors (or operators) are responsible for planning and implementing action to reduce the effect of noise on residents. Such actions include site location, improvements in airport design, noise abatement ground procedures, land acquisition, and restrictions on airport use. State and local government and planning agencies must provide for land use planning and development, zoning, and housing regulation that will limit the uses of land near airports to purposes compatible with airport operations.

Airport Noise Compatibility Planning Regulation (FAR Part 150)

The Federal Aviation Administration (FAA) established the Federal Aviation Regulation Part 150 in 1983, that sets out national standards for identifying airport noise and land use incompatibilities and to develop programmes to eliminate them.

The overall goal of FAR Part 150 is to develop a programme for airport proprietors to use in conjunction with state and local planners, aviation organisations, and concerned citizens, to minimise and mitigate airport noise levels (FAR Part 150 1983). FAR Part 150 provides for the preparation and submission of Noise Compatibility Programmes and Noise Exposure Maps. Its purpose is to seek optimal accommodation of both airport operations and community activities within acceptable safety, economic and environmental parameters. Specifically, it establishes a single system for measuring airport noise and determining the effects upon individuals exposed to airport noise. The programme provides technical guidance to the airport operator and a list of federally identified land uses that are considered to be compatible with airports under most circumstances. It is a voluntary programme and
encourages airport operators to develop their plans with affected
communities, airport users, neighbours, and the FAA.

As of December 1995, a total of 232 airports were participating in the FAR
Part 150 Airport Noise Compatibility Planning Programme (Airport Noise
Report 1995). These are widely recognised in the airport/land use
communities for setting reasonable standards for planning to avoid airport
and related land use conflicts.

Compatible Land Use Planning

Land use planning and control authority in the United States is vested in
both state and local governmental bodies. FAR Part 150 provides land use
guidelines and a comprehensive airport noise planning process which
involves the active participation of those land use authorities which are
needed to actually plan and control the land around airports. An airport
operator may voluntarily prepare a noise exposure map and a noise
compatibility programme. A noise exposure map describes the airport layout
and operation, aircraft-related noise exposure, land use in the airport
environs and the resulting noise related land use compatibility situation.
Eventually, the basic output of the map development is an identification of
existing and potential future noise and land use incompatibilities.

Noise compatibility programme is a list of the actions the airport operator
proposes to take to minimise existing and future noise and land use
incompatibilities. In order to establish this programme, the airport operator
must consider all potential compatibility measures, including the airport
layout, operational and use alternatives, and land use alternatives. The
above map and programme must be developed and prepared in balanced
consultation with states, FAA officials, aeronautical users, public agencies
and planning agencies whose area of jurisdiction is within the Ldn 65 contour
area. The main purpose of this is to select the best combination of land use
control strategies to fit the specific airport and community situation.
<table>
<thead>
<tr>
<th>Land Use and Related Structures</th>
<th>Yearly day-night average sound level Ldn in dB</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Residential Use</strong></td>
<td><strong>Below 65</strong></td>
</tr>
<tr>
<td>Residential, other than mobile homes and transient lodgings</td>
<td>Y</td>
</tr>
<tr>
<td>Mobile home park</td>
<td>Y</td>
</tr>
<tr>
<td>Transient lodgings</td>
<td>Y</td>
</tr>
<tr>
<td><strong>Public Use</strong></td>
<td></td>
</tr>
<tr>
<td>School</td>
<td>Y</td>
</tr>
<tr>
<td>Hospitals and nursing homes</td>
<td>Y</td>
</tr>
<tr>
<td>Churches, auditoriums, and concert halls</td>
<td>Y</td>
</tr>
<tr>
<td>Government services</td>
<td>Y</td>
</tr>
<tr>
<td>Transportation</td>
<td>Y</td>
</tr>
<tr>
<td><strong>Commercial Use</strong></td>
<td></td>
</tr>
<tr>
<td>Offices, business and professional</td>
<td>Y</td>
</tr>
<tr>
<td>Wholesale and retail-building materials, hardware, and farm equipment</td>
<td>Y</td>
</tr>
<tr>
<td>Retail trade-general</td>
<td>Y</td>
</tr>
<tr>
<td>Utilities</td>
<td>Y</td>
</tr>
<tr>
<td>Communication</td>
<td>Y</td>
</tr>
<tr>
<td><strong>Manufacturing and production</strong></td>
<td></td>
</tr>
<tr>
<td>Manufacturing, general</td>
<td>Y</td>
</tr>
<tr>
<td>Photographic and optional</td>
<td>Y</td>
</tr>
<tr>
<td>Agriculture (except livestock) and forestry</td>
<td>Y</td>
</tr>
<tr>
<td>Livestock farming and breeding</td>
<td>Y</td>
</tr>
<tr>
<td>Mining and fishing, resource production and extraction</td>
<td>Y</td>
</tr>
<tr>
<td><strong>Recreational</strong></td>
<td></td>
</tr>
<tr>
<td>Outdoor sports arenas and spectator sports</td>
<td>Y</td>
</tr>
<tr>
<td>Outdoor music shells, amphitheatres</td>
<td>Y</td>
</tr>
<tr>
<td>Nature exhibits and zoos</td>
<td>Y</td>
</tr>
<tr>
<td>Amusements, parks, resorts, and camps</td>
<td>Y</td>
</tr>
<tr>
<td>Golf courses, riding stables, and water recreation</td>
<td>Y</td>
</tr>
</tbody>
</table>

*Note*

Y (yes)  Land use and related structures are compatible without restrictions.

N (no)  Land use and related structures are not compatible and should be prohibited.

25, 30, or 35  Land use and related structures generally compatible; measures to achieve outdoor-to-indoor noise level reduction of 25, 30, or 35 dB must be incorporated into design and construction of structure.

There are special provisions pertaining to many of the compatibility designations that are not included here; refer to FAR part 150 for details.

Table 4.1 FAA Noise and Land Use Compatibility Guideline
(Source: Federal Aviation Administration)
Land Use Guideline

FAR Part 150 establishes Ldn (day-night average sound level) as the official cumulative noise exposure metric for use in airport noise analysis, and provides guidelines for noise and land use compatibility evaluation. Table 4.1 shows these guidelines. The land use guidelines indicate which land uses are and are not compatible with various Ldn noise levels.

Compatible Land Use Planning System around Airports in the United Kingdom

The Civil Aviation Act 1982 enables the government to specify noise control and amelioration measures in respect of aircraft noise at designated airports such as London/Heathrow, Gatwick and Stansted Airports. At other airports, responsibility for noise control and amelioration measures rests directly with the airport operator through its owner. However, the local planning authorities are responsible for the land use planning and development control around the airports. The government has published guidance to local planning authorities on the various matters to be taken into account when formulating land use development plans for determining applications for specific development.

Planning Policy Guidance 24: Planning and Noise

The present guidance on planning and noise, which has been applied since 1973 and revised in 1994, suggests various types of development and use which are susceptible to exposure by noise from transport (road, railway and aircraft) and other sources (industrial and commercial developments). The aim of this guidance is to provide advice on how the planning system can be used to minimise the adverse impact of noise without placing unreasonable restrictions on development or adding unduly to the costs and administrative burdens of business (PPG24 1994).

It outlines some of the main considerations which local authorities should take into account in drawing up development plan policies and when
determining planning applications for development which will either generate noise or be exposed to existing noise sources. Some general principles in respect to the development are as follows:

- wherever practicable, noise sensitive developments should be separated from major sources of noise
- new development involving noisy activities should, if possible, be sited away from noise sensitive land uses
- where such separation is not possible, local planning authorities should consider the use of planning conditions or planning obligations
- consideration should be given to the possible intrusion that may be caused by an intensification or change of use
- proposals for noise sensitive development should not normally be permitted in areas which are - or are expected to become - subject to unacceptably high noise levels, especially where high noise levels will continue throughout the night (Penn 1995).

PPG24 provides a recommended range of noise levels for each “Noise Exposure Category”. Recommended criteria are set out for control of new residential development in areas affected by aircraft noise using Leq dB(A).

Compatible Land Use Planning

The local planning authorities are responsible for not only land use planning and assessment of the proposals for new noise sensitive development around the airports but also dealing with strategic issues such as development and intensification of use of airports. Local planning authorities should consider carefully whether proposals for development may be incompatible with existing activities. The basic national guidance to the planning and control is PPG24 on planning and noise. Local planning authorities should determine which areas are likely to fall within the different noise exposure categories. For this, they seek the cooperation of the airport operator to arrive at the most appropriate long term forecasts of air traffic and its affect on the noise contours.
Any application for planning permission must be accompanied by a plan of the land and other plans, drawings and information necessary to describe the development including the noise impact of a development or the assessed effect of an existing noise source on a proposed development, and may require a formal environmental impact statement. In advance of submitting a planning application, it is necessary that developers consult with local planning officers. This consultation will enable an applicant to take account of requirements in formulating the development proposal. Airports are encouraged, in consultation with local authorities and consultative committees, to introduce noise amelioration schemes. They can also review existing noise control measures and the operation of those measures. Consultation is not limited to environmental matters, but may cover any matter concerning the management or administration of the airport affecting user or local interests.

The local planning authorities, in granting planning permission, can impose such conditions as they think desirable to control noise. Conditions should be enforceable and usually be consistent with national planning policies. This could include the noise attenuation standards for a building or limiting the hours of aircraft operation and the number and type of aircraft.

**Recommended Noise Exposure Categories for New Dwellings Near Existing Noise Sources**

PPG24 sets a range of noise levels which would provide guidelines for authorities responsible for assessing development proposals. These are based on four Noise Exposure Categories. Rather than the use of traditional indices to describe noise from aircraft, all noise levels are expressed in terms of LAeq,T over the periods 07:00 - 23:00 or 23:00 - 07:00. Tables 4.2 and 4.3 show these guidelines.
A Noise need not be considered as a determining factor in granting planning permission, although the noise level at the high end of the category should not be regarded as a desirable level.

B Noise should be taken into account when determining planning applications and, where appropriate, conditions imposed to ensure an adequate level of protection against noise.

C Planning permission should not normally be granted. Where it is considered that permission should be given, for example because there are no alternative quieter sites available, conditions should be imposed to ensure a commensurate level of protection against noise.

D Planning permission should normally be refused.

Table 4.2 Noise Exposure Categories (Source: Department of Environment)

<table>
<thead>
<tr>
<th>Noise Source</th>
<th>Noise Exposure Category</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>air traffic</td>
<td>&lt;57</td>
</tr>
<tr>
<td>07:00-23:00</td>
<td>&lt;48</td>
</tr>
<tr>
<td>23:00-07:00</td>
<td></td>
</tr>
</tbody>
</table>

1 Night-time noise levels (23:00-07:00): sites where individual noise events regularly exceed 82 dB LAmax (S time weighting) several times in any hour should be treated as being in N.E.C.C, regardless of the LAeq.8h (except where the LAeq.8h already puts the site in N.E.C.D).

Table 4.3 Noise Levels corresponding to the Noise Exposure Categories for New Dwelling LAeq,T dB (Source: Department of Environment)

Compatible Land Use Planning System around Airports in Korea

In Korea the government has the authority to control airport noise by the regulation of source emissions and by flight operational procedures in ways that minimises noise impact on residential areas. The Civil Aviation Act 1991 enables the airport operator to establish noise mitigation measures in respect of airport noise at designated airports, which are currently Kimpo and Cheju International Airports. Noise mitigation measures refer to off-airport measures.
that lessen the intensity or severity of airport noise for people living in the noise impacted areas, such as soundproofing and air-conditioning for schools. Land use planning and control authority rests almost exclusively with local governmental bodies. Civil Aviation Regulation 1993 sets the guideline for local authorities to take into account in the planning and assessment of the development proposals in noise impacted areas.

Compatible Land Use Planning

The airport authority should determine the noise impacted area at a designated airport and give a public notice of it. The noise impacted area at a designated airport is classified into three categories. The local governments are responsible for land use planning and approval of development proposals in this noise impacted area. The basic national guidance to local government for planning and development control is Article 274 of Civil Aviation Regulation 1993. Its purpose is to restrict the noise sensitive development in the noise impacted area to prevent and lessen the aircraft noise impact.

The local government should consult with central and local planning agencies and concerned citizens in the process of planning of land use. In assessing the development proposal, the local government should consider whether it may be compatible or not with a classified range of noise levels. When it is not compatible, any proposal can be restricted.

Land Use and Facility Restriction Guidelines

Civil Aviation Regulation 1993 provides guidelines for land use and development compatibility evaluation. Tables 4.4 and 4.5 show these guidelines. These indicate which land uses and facilities are and which are not compatible with various WECPNL noise levels.
### Table 4.4 Restriction of land use in noise impacted area
(Source: Ministry of Construction and Transportation)

<table>
<thead>
<tr>
<th>Noise Level</th>
<th>Zone 1</th>
<th>Zone 2</th>
<th>Zone 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facilities</td>
<td>Over WECPNL 95</td>
<td>WECPNL 90-95</td>
<td>WECPNL 80-90</td>
</tr>
</tbody>
</table>

**Dwellings**
- Prohibition of new and rebuilding
- 1. Prohibition of new building
- 2. Permission of extension / rebuilding with soundproofing
- Permission of new, extension and rebuilding with soundproofing

**Schools and hospitals**
- Prohibition of new and rebuilding
- 1. Prohibition of new building
- 2. Permission of extension / rebuilding with soundproofing
- Permission of new, extension and rebuilding with soundproofing

**Public office**
- Prohibition of new and rebuilding
- 1. Prohibition of new building
- 2. Permission of extension / rebuilding with soundproofing
- Permission of new, extension and rebuilding with soundproofing

**Warehouses, factories and transportation facilities etc.**
- Permission of airport related facilities
- Permission of new, extension and rebuilding irrelevant to the aircraft noise

### Table 4.5 Restriction of facilities in noise impacted area
(Source: Ministry of Construction and Transportation)
Conclusion

The United States, the United Kingdom and Korea have their own specific systems for dealing with the airport noise and land use problem around airports. In order to minimise the adverse impact of airport noise on a local community, both the United States and the United Kingdom emphasise the active role of local authority and community involvement. However, there have been no appropriate efforts for these at Kimpo Airport and the Civil Aviation Regulation does not enact any related provision which can induce the active participation of a local authority and the community involvement for effective airport noise control. Considering the importance of these issues as previously stated, the introduction of related provision to Civil Aviation Regulation is desirable for ensuring them.

In respect of the airport noise problem, the negative aspects of airports are often rather emphasised. The residents generally desire the airport to be closed and even local jurisdictions which are concerned with the noise impacted area do not necessarily view the airport as 'their' facility. This is not surprising since the recipients of the noise tend to be concentrated while the beneficiaries of the airport are widely dispersed in the community and region. However, an airport is a major component in any national transportation infrastructure since airports generate and sustain economic activity, although to differing degrees. An airport functions as a facility which is vital to local economies and to the nation as a whole. Thus, an airport should be recognised as a community asset. For this objective to be achieved, it is desirable that the airport authority or the airport operator develop a programme to educate affected citizens as well as local authorities which are need to actually plan and control the land around an airport. Accordingly, the airport noise problem which threatens the efficient and vital operation of the airport would be considered as a community problem. Compatible land use planning can therefore be seen as a means of achieving the desirable and managing the undesirable aspects of an airport's operations.
Compatible land use planning is primarily a local function. Furthermore, as the noise impacted areas often do not fall in one jurisdiction but are spread over various jurisdictions, it would be difficult to control generally from one central body. Consequently, for successful compatible land use planning and development control, the following may be seen as minimum requirements:

- It is essential that compatible land use planning is developed within the framework of a wider community or regional plan. So a comprehensive planning approach through a coordinated effort of the various parties concerned should be undertaken in the planning process.

- It is desirable that the responsibilities for planning and implementing action to reduce the effect of noise on residents are clarified between the parties concerned.

- It is desirable that the compatible land use planning and implementing authority rests directly with local land use control authorities. In this case, the precise guidance on land use planning and development control should be provided by the central government. However, in the case when airport operators are responsible for compatible land use planning, the active participation of those local planning authorities is necessary to ensure a comprehensive planning process.
Chapter 5
The Case of Kimpo Airport:
Analysis and Findings of Its Changed Role

The purpose of this chapter is to analyse the current airport noise control measures, primarily those associated with the land use regulation strategy, and to suggest the desirable basic principles for more effective airport noise control at Kimpo Airport. This chapter is in four parts: the first part reviews the standards for land use regulation which are prescribed in current law. The second part reviews the necessity for compatible land use planning and its appropriate management. The third part discusses the programmes for managing good community relations, including a complaints handling system, community consultation, and community information. The fourth part presents the desirable ways to reach effective noise control measures and the ways to manage them.

Standards for Land Use Regulation

Civil Aviation Regulation 1993 lays out the guidelines for an airport authority to observe in designating the noise impacted area and the guidelines for a local land use control authority to take into account in planning and assessing the development proposals in a noise impacted area. It also prescribes the noise mitigation measures which an airport operator should or could implement in a noise impacted area.

In 1993, in compliance with the new Civil Aviation Regulation, the Seoul Regional Aviation Office designated and officially announced what the noise impacted area was in the vicinity of Kimpo Airport and classified it into three noise zones. The noise impacted area was based on the result of the noise analysis which had been performed by an acoustic consulting firm. Since then, the Seoul Regional Aviation Office and Korea Airports Authority have been implementing the noise mitigation measures prescribed in the Civil
Aviation Regulation. The local land use control authorities which are concerned with the noise impacted area have also been applying the standards of land use and facility restriction to assess the development proposals in their jurisdictions. However, those people who are exposed to airport noise in the vicinity of Kimpo Airport have continuously requested an extension of the existing designated noise impacted area, and the establishment and implementation of various noise mitigation measures in addition to the measures currently in place. Local governments and land use authorities have also requested the same thing. Furthermore, a number of houses on prepared housing sites are expected to be built in the noise impacted area to the northwest of the Kimpo Airport. Consequently, these situations indicate that the current standards related to airport noise are insufficient to resolve the adverse effects of airport noise and prevent incompatible land use in a noise impacted area.

This part aims to review the suitability of current standards prescribed in the Civil Aviation Regulation 1993 and suggest desirable basic principles for more effective airport noise control at Kimpo Airport. The preparation of those detailed standards is beyond the scope of this study since they should ideally be provided through the intensive research and consultation with governmental bodies, and all parties and citizens involved.

Establishment of Noise Zone

Article 271 of Civil Aviation Regulation sets the standard for the classification of a noise impacted area. Noise impacted areas are classified into three zones based on the noise exposure levels. That is, zone 1 is the area of 95 WECPNL and higher, zone 2 is the area of 90 to 95 WECPNL and zone 3 is the area of 80 to 90 WECPNL. Table 5.1 shows the establishment of these noise zones. The standards for the restriction of land use and facilities in each noise zone are shown in Tables 4.4 and 4.5 of the previous chapter, and Figure 2.5 in chapter 2.
An established noise zone is the basic guideline for land use and facility restriction and implementation of noise mitigation measures. The approved land use and facility restriction are different in each noise zone. The content of noise mitigation measures and their relative priorities are also determined by the noise zone category. The noise zone is directly connected with the interests of those people who are exposed to airport noise, and as such is a very important standard. The matter of primary concern in the standard of noise zone classification is the noise exposure level related to the each noise zone, not the number of the noise zone. In the light of the noise exposure level, the key issue is whether people who live and work in the area of below 80 WECPNL are or are not affected by airport noise. Unfortunately, there has been no relevant research about this matter in Korea. Also, the ICAO which suggests the WECPNL as the international version have not provided a precise degree of annoyance based on the noise exposure levels. This may be because people’s response to airport noise varies between state to state, airport to airport and community to community, and so it is difficult to provide uniform annoyance levels to airport noise.

A number of countries which have an airport noise problem have implemented land use regulation strategies as a major airport noise control measure. The direct conversion of a noise exposure criterion corresponding to a specific land use category is not practical since the noise exposure criterion that is considered appropriate by one community may not be considered appropriate by another. Also, because of the difference in

<table>
<thead>
<tr>
<th>Zone</th>
<th>Noise Exposure Level (Unit: WECPNL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone 1</td>
<td>95 WECPNL and Higher</td>
</tr>
<tr>
<td>Zone 2</td>
<td>90 to 95 WECPNL</td>
</tr>
<tr>
<td>Zone 3</td>
<td>80 to 90 WECPNL</td>
</tr>
</tbody>
</table>

Table 5.1 Establishment of Noise Zone
frequency weightings, differences in accounting for the duration of individual events, and differences in the time of day weightings, there is no exact functional relationship among noise metrics (Horonjeff et al. 1994). However, the rough comparison with land use regulation standards of those countries may be an alternative means of reviewing the suitability of the Korean standard.

In respect of the noise zones and associated noise exposure levels, the ICAO provides the broad comparison table which shows a rough comparison between the values of different methods used by countries, as shown in Table 5.2. This table also shows the types of noise sensitive land uses to be permitted in each noise zone. According to this table, the Netherlands, Germany, the United Kingdom and France use different noise metrics, noise zones and associated noise exposure levels. For the purpose of comparison between the four countries' standards, the table provides the LDN value as a basic noise exposure index.

Each country does not restrict the noise sensitive land uses and developments below a specific noise exposure level. This indicates that the noise effect is acceptable in such an area. According to Table 5.2, this specific noise exposure level is approximately 53 LDN in the Netherlands, 58 LDN in Germany and the United Kingdom, and 60 LDN in France. In the United States, Federal Aviation Regulation Part 150 of 1983 prescribes no restriction on noise sensitive developments within the noise zone of below 65 LDN.

As previously stated, the Civil Aviation Regulation of Korea does not restrict the land uses and developments in the area of below 80 WECPNL and does not prescribe any noise mitigation measures in this area. So, it is feasible to compare this value with those of other countries. The value of 80 WECPNL may be related roughly to 69 LDN using the table of approximate relationships between noise indices presented by the ICAO in 1985. Japan, which uses the same noise metric as Korea, has been operating a noise insulation
<table>
<thead>
<tr>
<th>Ratio</th>
<th>Netherlands</th>
<th>Germany</th>
<th>United Kingdom</th>
<th>France</th>
</tr>
</thead>
<tbody>
<tr>
<td>LDN Ke Measurements</td>
<td>Leg(1) Measures</td>
<td>Day/Night Measures</td>
<td>IP Measures</td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>70</td>
<td>No new housing allowed</td>
<td>76</td>
<td>72</td>
</tr>
<tr>
<td>65</td>
<td>Limited new housing allowed when insulated.</td>
<td>65-70</td>
<td>Noise should be taken into account when determining planning applications and, where appropriate, conditions imposed to ensure adequate protection.</td>
<td></td>
</tr>
<tr>
<td>65</td>
<td>Limited new housing allowed when insulated.</td>
<td>67</td>
<td>Noise need not be considered as a determining factor in granting planning permission.</td>
<td></td>
</tr>
<tr>
<td>55</td>
<td>Limited new housing allowed; some exemptions</td>
<td>62</td>
<td>57</td>
<td>free</td>
</tr>
<tr>
<td>40</td>
<td>In principle no new housing allowed; some exemptions</td>
<td>free</td>
<td>48</td>
<td>free</td>
</tr>
<tr>
<td>free; Additional measures for night operations; max. noise limits specific night index = 26 dB(A)Leq.</td>
<td>Additional planning zone used by some Federal Länder</td>
<td>(legal standard for measures according to the Air Traffic Noise Act = 67 dB)</td>
<td>(legal standard = 84/78 IP since 1/1/93 compensation or Paris airports and Lyon, Marseille, Nice, Toulouse)</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>In principle no new housing allowed; some exemptions</td>
<td>(legal standard for measures = 35 Ke and 26 dB(A)Leq with structural night operations)</td>
<td>(no legal standard, only guidance to local authorities)</td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>In principle no new housing allowed; some exemptions</td>
<td>(legal standard for measures = 35 Ke and 26 dB(A)Leq with structural night operations)</td>
<td>(legal standard = 84/78 IP since 1/1/93 compensation or Paris airports and Lyon, Marseille, Nice, Toulouse)</td>
<td></td>
</tr>
</tbody>
</table>

Table 5.2 Broad Comparison of Airport Noise Indices and Adjacent Measures (adapted from ICAO 1995)
programme for public use buildings, such as schools, hospitals and government services, in the noise zone of over 70 WECPNL, which may be related roughly to 58 LDN.

Summing up these various values, the outer boundary noise exposure level for restriction of land uses and developments, and noise mitigation measures of other countries is lower than that of Korea by 4 to 16 LDN, as shown in Table 5.3. Consequently, most states have also recognised the area of noise exposure level below 80 WECPNL as an airport noise impacted area.

<table>
<thead>
<tr>
<th></th>
<th>Korea</th>
<th>Netherlands</th>
<th>Germany</th>
<th>United Kingdom</th>
<th>France</th>
<th>United States</th>
<th>Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>69</td>
<td>53</td>
<td>58</td>
<td>58</td>
<td>60</td>
<td>65</td>
<td>58</td>
</tr>
</tbody>
</table>

Table 5.3 Outer Boundary Noise Exposure Level of Various Countries

Considering the fact that many countries have been operating the low boundary noise exposure level for airport noise control (and particularly Japan, using the same noise metric as Korea, which has the low values), it can be expected that the airport neighbours' complaints against existing noise zones will continue in the future.

The changed role of Kimpo Airport to the exclusive use for domestic flights after the opening of the new international airport will give rise to a substantial decrease in the size of the airport noise impacted area around the airport. The area within the 80 WECPNL contour is estimated to fall from 28.93 square kilometres, which was the area officially announced by the Seoul Regional Aviation Office in 1993, to approximately 4.38 square kilometres in the year of practical annual capacity (PANCAP). This means there will be an increase in land which should be exempted from the current land use and facility restriction. Consequently, noise sensitive land uses and developments will encroach on areas surrounding the airport more and more and this will only make the airport noise problem at Kimpo Airport worse. Keeping houses and other noise sensitive buildings far enough from the airport is essential for
the purpose of minimising the airport noise impact on airport surrounding
neighbourhoods. So, it is desirable that the size of the future noise impacted
area around the Airport which is subject to the land use and facility restriction
is maintained at the current size. For these reasons, a downward adjustment
in the current outer boundary noise exposure level for land use and facility
restriction is necessary. However, a downward adjustment of noise zone
standards may impose a somewhat heavy burden on airport authorities and
airport operators in respect of the implementation of the noise control
measures at Kimpo Airport as a whole and influence the noise problems of
other airports in Korea. Also, for effective planning and regulatory purposes,
the application of objective criteria based on the relationship between noise
exposure and the collective real response of people to their environment is
required. Therefore, this matter should be considered based on the result of
further intensive research.

Limitation of Noise Mitigation Measures

Article 272 of the Civil Aviation Regulation prescribes the specific noise
mitigation measures which an airport operator should or could implement in
the established noise zones. These measures are as follows,
- Relocation of residents (restricted to noise zone 1)
- Soundproofing of existing houses
- Countermeasures for bad reception of television
- Financial support for the establishment of convenient facilities for common
  uses
- Financial support for air-conditioning of schools.

The Civil Aviation Act 1991 enables the airport operator to establish noise
mitigation measures for people living and working in the noise impacted area.
However, the noise mitigation measures which the airport operator can
actually implement are limited to the above five measures by the Civil
Aviation Regulation. There are a number of off-airport noise control measures
which minimise the noise impact and induce the noise compatible land use
and development. The above five measures are only a part of those various
measures. Thus it can be seen that article 272 of the Civil Aviation Regulation seems to prevent the introduction of other practical measures.

Noise mitigation measures refer to off-airport measures that lessen the airport noise impact for people living or working in the airport neighbourhood. These measures also help to limit the conversion of existing compatible land uses into potentially incompatible ones and reduce existing incompatible land uses. Eventually, the present and future vital operation of an airport can be assured through the implementation of practical and effective noise mitigation measures. These measures depend upon the current legal framework of a country, the airport's specific condition and specific local condition.

Noise mitigation measures, as part of comprehensive airport noise control measures, and strategies are also the product of negotiation among concerned parties, such as the airport authority, airport operator, airlines, local authorities and affected citizens. So, effective measures require the cooperative efforts of these parties. Considering these facts, suggesting the basic principles for the effective establishment and implementation of noise mitigation measures is desirable as opposed to specifying the specific noise mitigation measures in respect of airport noise control action through the Civil Aviation Regulation.

Facility Restriction in Noise Impacted Area

Article 274 of the Civil Aviation Regulation prescribes the prohibition of new noise sensitive developments and permission for extension and rebuilding with soundproofing of existing buildings in noise zone 2. It also prescribes the permission of new noise sensitive developments and extension and rebuilding with soundproofing of existing building in noise zone 3.

The above article 274 was amended by adding a new exceptional provision in 1994. In the established noise zone 2, the exceptional provision permits new housing development on land which had already been granted permission for the land owner to build a house under the application of other
laws before the official announcement of the noise impacted area in 1993. Also in the established noise zones 2 and 3, this permits extension and rebuilding without soundproofing of existing houses which had already been built before 1993. This conditional permission was attributed to the strong complaints of property owners in the established noise zones. However, the new housing developments and intensification of use in the noise impacted area may result in making the airport noise problem of Kimpo Airport worse rather than resolving the complaints of citizens involved, since this strategy will give rise to an increase in the number of people who are exposed to noise impact. The prevention of the incompatible land use and development to minimise the noise impact around an airport is one of the objectives of airport noise control. So, in order to resolve the complaints of citizens involved, the basic policy of exceptional provision should be changed to, for example, the purchase of interested land and compensation for the loss and/or inconvenience due to the prevention of intensification of use, instead of permitting the land use and development.

Under article 274 of the Civil Aviation Regulation, new development and intensification of use in the established noise zone 3 are permitted with the condition of soundproofing. However, the soundproofing requirements for various facilities in each established noise zone are not specified. Without appropriate requirements, the soundproofing application may fail to realise the anticipated result, since the effect of soundproofing application fully depends upon the degree of noise insulation. Soundproofing aims to reduce the noise transmission through sound sealing application to the building structure itself. So, the provision of appropriate target noise level reduction in each case should be introduced. For more noise reduction, it is necessary to introduce building design requirements for new buildings, such as the design and layout of the building, construction material, and construction method. In this case, building codes rather than the civil aviation regulation are desirable legal means of enforcing adequate sound insulation.
Compatible Land Use Planning

Kimpo Airport has been recognised for decades as a critical public facility vital to both local and national economies. However, during the past ten years, there have been serious conflicts between the airport and its surrounding community due to the adverse environmental effects of airport operation, particularly as shown in Figure 2.11, in airport noise impact. The typical pattern of development around the airport includes, primarily, residential land uses geared to housing developments paying no regard to the airport's operation and development. The planned housing developments around the airport by national and local governments are shown in Figure 5.1. The incompatible land use and developments in the vicinity of the airport have resulted in constraints on the operation and expansion of Kimpo Airport. These problems will also remain as a major issue in the future, after the opening of the new international airport. In order to make the best use of the existing facilities of Kimpo Airport, the incompatible land use problem must be treated effectively through more specialised planning, in which the compatible land use plan is reviewed in relation to airport operations, airport noise control and urban planning. This part reviews the necessity of compatible land use planning and appropriate planning at Kimpo Airport.

The Need for Compatible Land Use Planning

Kimpo International Airport was inaugurated in 1958 and the airport noise problem around it was not taken into account at that time because it was located in a rural setting. The distance from city congestion and the little impact it would have on a sparsely settled community would be sufficient to sustain good growth and ensure compatibility with its environs. Only ten years later, airport/community compatibility became an issue due to the rapid growth of nearby neighbourhoods. Furthermore, there had been remarkable town expansion through the large scale housing developments in the 1970s to the southeast of Kimpo Airport. These were planned land uses responding to the rapid influx of migrants into the city (Seoul Metropolitan Government
Figure 5.1 Planned Housing Developments around Kimpo Airport

- Designated Noise Impacted Area (1993)
- Planned Housing Development Area
Incompatible land use in the area surrounding Kimpo Airport was fostered by legal urban planning decisions. Thereafter, the urbanisation of the surrounding area gave rise to serious land use conflicts and produced an obstacle to the expansion of Kimpo Airport. The concentration of population in the airport's surrounding area tended to contribute to short-sighted community development rather than more reasoned long term considerations. Consequently the lack of adequate land use planning around Kimpo Airport probably contributed to the current serious airport noise problem in the area surrounding it.

In respect of airport noise impact, there are three kinds of legal planning programmes which can deal with the airport noise and land use problem in the area surrounding Kimpo Airport. One is the urban planning of each jurisdiction including the noise impacted area around Kimpo Airport. Another is the middle and long term airport development planning which includes Kimpo Airport. The last is the noise mitigation measures planning for Kimpo Airport. The following paragraphs review the consideration given to the airport noise and land use problem at Kimpo Airport during this planning.

The local government system in Korea is composed of metropolitan city government and provincial government. There are five metropolitan city governments and nine provincial governments. The metropolitan cities, such as Seoul City and Incheon City, have a number of wards as local authorities and the provinces, such as Kyonggi Province, have a number of small cities and counties as local authorities. Although Kimpo Airport is located in the Kangseo Ward of Seoul City, the noise impacted area which was designated by Seoul Regional Aviation Office in 1993 is widely distributed over many jurisdictions. There are seven local authorities within the designated noise impacted area. These include three wards in Seoul City, one ward in Incheon City, and two cities and one county in Kyonggi Province. Figure 5.2 portrays the jurisdictional boundaries in the designated noise impacted area around Kimpo Airport.
Figure 5.2 Jurisdictional Boundaries in the Designated Noise Impacted Area around Kimpo Airport
All the local authorities with designated noise impacted land within their boundaries have established respectively an urban master plan or urban rearrangement plan in compliance with the Urban Planning Act. The details of latest plans are as follows,

- Urban Master Plan of Kangseo (Kangseo Ward, Seoul City 1995)
- Urban Master Plan of Yangcheon (Yangcheon Ward, Seoul City 1995)
- Urban Master Plan of Guro (Guro Ward, Seoul City 1995)
- Urban Master Plan of Incheon (Incheon City 1996)
- Urban Master Plan of Bucheon (Bucheon City, Kyonggi Province 1994)
- Urban Rearrangement Plan of Kimpo (Kimpo County, Kyonggi Province 1992)
- Urban Master Plan of Gwangmyong (Gwangmyong City, Kyonggi Province 1994)

The above listed plans dealt with the various urban planning matters including appropriate land use planning and improvement of the environment. These plans, except the Urban Rearrangement Plan of Kimpo, were established after the official announcement of the noise impacted area around Kimpo Airport in 1993. However, none of these plans reflected the existence of the noise impacted area and the efforts to reduce the noise impact. This indicates that during urban planning the airport problem in effect was only considered as an afterthought.

The Ministry of Transportation established the “Middle and Long Term Airport Development Plan” in 1994. This was prepared as the national airport system plan. The development of Kimpo Airport was reviewed in this plan. The Kimpo Airport development plan aims to expand its capacity to meet the aviation demand until the opening of the new international airport. This will be done through the rearrangement of some existing facilities and the expansion of some facilities but only at a minimal level. The changes and expansion addressed in this plan are restricted to the terminal and supporting facilities. A very general environmental impact assessment was also carried out in this plan, in which airport noise was reviewed as a part of it. The airport noise
study reviewed in general the future airport noise situation according to the increase in aviation demand and suggested only the basic measures for airport noise control, without having carried out a precise analysis. Compatible land use planning and airport noise were treated as relatively insignificant issues in this plan. Consequently, the expansion of airport facilities was the first consideration in the Kimpo Airport development plan. The middle and long term airport development plan deals primarily with the development of airports of the whole nation, so it is difficult to expect an intensive review of the airport noise problem including compatible land use planning for a specific airport.

The Civil Aviation Act 1991 enables the airport operator, Korea Airports Authority in the case of Kimpo Airport, to establish a plan for preventing airport noise impact in areas designated as being noise impacted by the airport authority. This plan must include the programme of noise mitigation measures and the plan of land use in the designated noise impacted area. However, since then there has been no plan established by the Korea Airports Authority. The Korea Airports Authority has only been implementing some noise mitigation measures which are prescribed in the Civil Aviation Regulation. In its passive attitude toward the airport noise problem, the Korea Airports Authority provides little help in the quest for compatible land use planning in the area surrounding Kimpo Airport.

Summing up the above situation, up to now there has been no compatible land use plan worthy of special mention as well as the comprehensive airport noise control plan for reducing the airport noise impact at Kimpo Airport.

It is estimated that there will be a great change in airport noise circumstances at Kimpo Airport in the next century. The changed role of Kimpo Airport to its exclusive use for domestic flights will bring about the elimination of noisier aircraft and a decrease in the number of aircraft flights. This will considerably reduce the noise impacted area near the airport.
Under the Civil Aviation Regulation, the noise impacted area should be reviewed every five years and can be adjusted according to the results of the noise analysis. As discussed in Chapter 2, the current noise impacted area was designated in 1993. Considering the aviation demand and the changed role of Kimpo Airport, the designated noise impacted area will be at its minimum in 2003 and it will increase after that time. This indicates that the subject of land use regulation should be changed every five years. This may result in making the airport noise problem worse in the area surrounding Kimpo Airport. In order to prevent this, it is essential that a preventive and long term strategy for land use and development control around Kimpo Airport should be developed. This strategy should take into account the future airport plans, airport noise control measures, and land use plans of the jurisdictions involved. This strategy may be developed through more specialised planning rather than the current planning framework, such as airport development planning, urban planning and environmental impact assessment. Compatible land use planning is suitable for this purpose. Furthermore, the less impacted area must be retained by preventing new noise sensitive building nearer the airport, since this area is needed to minimise the noise impact in the future. This can only be done by ensuring that strict and appropriate land use planning and control is in place and enforced around the airport.

Incompatible land use in the area surrounding the airport may be traced almost totally to a lack of adequate planning and land use control by local authorities. This has been aggravated by a lack of coordination between local community plans and airport development plans. Inadequate land use planning in the area surrounding the airport has resulted from a lack of basic available information needed by local planners to develop appropriate land use proposals for communities near the airport. Thus, it can be seen that the adequate land use planning through cooperative efforts of related parties is a major tool for managing the area surrounding an airport. In the absence of effective compatible land use plans, significant progress toward the resolution of conflicts between Kimpo Airport and its surrounding area seems unlikely.
Appropriate Management of the Compatible Land Use Planning Study

Compatible land use planning aims primarily at formulating a balanced and effective programme to minimise or reduce the airport noise impact on local communities in the area surrounding the airport. Essentially both aviation and urban planning solutions to the problems must be reviewed equally in the planning study, and then practical solutions are evaluated against the realities of the social, economic and environmental needs of the community involved. The major items to be considered in the compatible land use planning are the urban plans of the local community, the airport operation and development plan, airport noise analysis and noise control. So, compatible land use planning should take into account a number of general goals and specific objectives of the functional elements comprising the plan, and development proposals for the community and airport needs. The planning process requires the involvement of various concerned and affected groups, such as governmental bodies, the airport authority, airport operator, airlines, local authorities, citizens, interested parties and planning organisations. With many different groups and views, the managing body of compatible land use planning should lead the planning study to a successful outcome.

Under the Civil Aviation Act, the airport operator is charged with developing a land use plan within the noise impacted area as part of the plan for preventing the airport noise impact. So, the Korea Airports Authority, the operator of Kimpo Airport, is responsible for compatible land use planning. However, until now there has been no formal compatible land use plan. Presumably Korea Airports Authority has had some difficulties managing the compatible land use planning study, since it is a collaborative effort. The following paragraphs discuss this matter, that is, which body involved is suitable for managing the compatible land use planning study.

Korea Airports Authority: Korea Airports Authority is the government contribution agency which is now in charge of managing and operating airport
facilities and as such the operator of Kimpo Airport. As previously stated, the airport operator is charged with developing the plan for preventing airport noise impact including the land use plan. In addition, in general, responsibility for ensuring that an airport is compatible with its environs lies with the airport operator. However, most of the methods for airport noise control are not under the control of the Korea Airports Authority, i.e., source noise reduction, aircraft operational regulation, and land use planning and control around the airport. Furthermore, there are no strong guidelines in terms of the compatible land use planning process, which prescribes the active participation of those local authorities who are needed to actually plan and control the land around the airport according to the result of the later planning study. This may give rise to difficulties for the Korea Airports Authority in consulting with various authorities. Under these conditions, a successful planning study seems unlikely.

**Seoul Regional Aviation Office:** Seoul Regional Aviation Office is the local office of the Ministry of Construction and Transportation and is the proprietor of Kimpo Airport. It is in charge of exercising control over airport operations and large scale development of airport facilities. In respect of airport noise control, it has the authority in terms of noise source reduction and aircraft operational regulation, which are major parts of airport noise control measures. These measures may result in the corresponding off-airport noise impacts. This 'airport noise to land use' tradeoff requires precise evaluation during the overall compatible land use planning process. So Seoul Regional Aviation Office may play the leading role in the planning process and the implementation of the proposed noise control measures which are related to aircraft operational regulation. Seoul Regional Aviation Office is in a favourable position with regard to consultation with local government and the local land use authority, since it is a governmental body.

**Local Authority:** The local authority is responsible not only for land use planning and control but also for assessing the proposals for new noise
sensitive development around Kimpo Airport. Thus, compatible land use planning and implementing authority is vested directly with the local authority. However, the latest urban plans related to the noise impacted area have not reflected any effort to resolve the airport noise and land use problem. The reason for this may be that the local authorities have traditionally recognised that they are not responsible for dealing with the airport noise problem caused by the airport operation but the airport authority is wholly responsible for the resolution of it. Without adequate legal provision, a dramatic change in this tendency cannot be expected in the near future. There are seven different local authority areas within the noise impacted area around Kimpo Airport. These local authorities also have different community goals and needs of their own. So, it would be difficult to generally control the compatible land use planning study from one local authority.

**Ministry of Construction and Transportation:** The Ministry of Construction and Transportation is the national government body, and prescribes and amends such rules and regulations as it may find necessary to provide for the operation and development of the airport and the control of airport noise. The Ministry of Construction and Transportation also establishes the middle and long term airport development plan as part of the national airport system plan. In respect of compatible land use planning process, the national government body can exert a powerful influence on the consultation process between various local governments and local authorities to achieve a successful outcome. However, the authority of managing and operating Kimpo Airport was delegated to Seoul Regional Aviation Office and Korea Airports Authority by law. Also, the compatible land use planning at Kimpo Airport is primarily a local function. So, it is not practical to expect that the Ministry of Construction and Transportation would manage the planning study.

Considering all of these conditions, such as the aim of compatible land use planning, legal regulations, and efficient consultation, it seems desirable that the management of the planning study should be a joint organisation of the Korea Airports Authority and Seoul Regional Aviation Office. For a successful
planning study, Korea Airports Authority should take charge of the overall planning process and Seoul Regional Aviation Office should take charge of the consultation with other authorities, citizens, etc.. Figure 5.3 shows the participants in the development of a compatible land use plan at Kimpo Airport. As previously stated, compatible land use planning considers the urban plan of the local community, the airport operation and development plan, and airport noise analysis and noise control. Thus the participation of the related consultants is essential to the planning process. These include urban planning consultants, airport planning consultants, and noise analysis and control consultants. Korea Airports Authority should control these planners and lead the planning process to a successful outcome. Also the planning process requires consultation with the various concerned and affected groups, such as the Ministry of Construction and Transportation, local governments and authorities, airlines, interested parties, and citizens. Seoul Regional Aviation Office should consult the proposals prepared by Korea Airports Authority and the consultations with the above groups and ensure that the compatible planning is balanced. Throughout the planning process, the full cooperation of both bodies is required.

Figure 5.3 Participants in Development of Compatible Land Use Planning
Community Relations

Airports will no longer be able to resolve airport noise issues themselves. In recognition of the damage that opposition and distrust can cause, many airports have community relation programmes in order to keep the community informed of issues of concern to them and to minimise the annoyance suffered by the airport's neighbours. Maintaining good community relations through advance information, effort and cooperation with the neighbouring communities is vital to successful airport operation.

Manchester Airport is worthy of noting in terms of its attempts to maintain good community relations through a long-standing "good neighbour" policy. The airport realises that if it were to pay little or no attention to the views and feelings of its neighbours then it is likely that the progress and growth of the Airport would be slowed down considerably by objections from local pressure groups, and the resultant need for time consuming and expensive inquires, possible alterations to plans and possibly even having planning permission refused. In recognition of these, the Airport has programmes of consultation and public relations work in order to keep the community informed of airport related issues and to reassure them that as much as possible is being done to safeguard the environment and to minimise the annoyance suffered by the airport's neighbours. These programmes included the operation of a Noise Office for handling complaints with the comprehensive monitoring system FANOMOS, the publication of a bulletin for public information, and a formal consultation process and frequent meetings with concerned groups including local residents. Additionally, the Airport committed itself to many wide ranging environmental measures under the motto of 'Towards a Better Environment'.

Kimpo Airport has received a number of complaints from nearby communities including residents, local governments and jurisdictions by telephone, letter and personal visit. Besides these, there have been several meetings complaining about airport noise and some residents instituted a civil litigation against the airport noise. Strenuous opposition to adverse airport
noise impact from local communities has resulted in constraints on airport expansion and operation, and distrust between the airport and its neighbours has built up. Although the Airport has done a great amount of work to reduce the noise created by aircraft, it is still felt by local residents that not enough is being done to alleviate the problem. Poor community relations is not helpful for airport operation. There is an understanding that the Airport needs to have the support, or at least the cooperation, of its neighbours in order for it to be able to sustain the mobility of the airport and thus needs to maintain a good neighbour policy. Among noise control measures, land use regulation of noise impacted areas is one that is often closely related to a citizen's life, property and vested interests. For successful management of this problem, it is necessary for the airport to provide opportunities for citizen participation in the airport's actions, and to monitor the needs of the local community.

This part reviews the complaints handling system, and community consultation and information programmes at Kimpo Airport.

Complaints Handling System

Obviously an airport such as Kimpo has received a large number of complaints from enraged residents, either living close to the airport or under one of the aircraft flight paths. Complaints about airport noise from Kimpo Airport's surrounding neighbourhoods are handled by Seoul Regional Aviation Office and Korea Airports Authority. These complaints are received by telephone, by letter or by personal visit. The majority of complaints are received by telephone.

Both the Airport Operator and the Airport Authority do not have dedicated staff, so complaints are distributed to the relevant division according to the contents of the complaints. They also do not have dedicated telephone lines. Thus when the complaint is by telephone, the complainant can only be connected to the appropriate member of staff after at least two telephone calls. Complaints by telephone are handled only during the working hours of both bodies. The consultation with the staff of both bodies indicate that
complainants are not satisfied with their attitude in the handling of complaints, since they cannot get a swift and proper reply.

It is well known that there has been a rapid increase in the number of complaints and a dramatic change in the nature of complaints since the use of the new runway constructed in 1987. However, both bodies have not maintained a full record of noise complaints except those received by letter and some reports of the meetings with residents and of the assembly. So it is not possible to analyse the annual trend of complaints and to recognise the exact concerns of the community. Consequently, the current complaints handling system at Kimpo Airport is not adequate for the maintenance of good community relations and may be an obstacle to building trust between the airport and its neighbours.

It is estimated that there will be a great change in airport noise circumstances at Kimpo Airport in the next century. Accordingly, there will be a change in the number and contents of complaints. Complaints about airport noise from surrounding neighbourhoods indicate the extent of the negative impact of airport operations on surrounding neighbourhoods (Gillen et al. 1994). Complaints are also the easiest of the responses to examine and can be readily linked to the characteristics of the area from which they arise. They should be systematically collected and analysed to develop proper strategies to deal with them. For the purpose of accomplishing this objective, a new complaints handling system should be introduced. The following paragraphs review the major parts of the complaints handling system required.

Firstly, every effort should be made to respond to all community inquiries in a helpful and timely manner. For this, the operation of a dedicated airport noise office is necessary, which should work directly with the air control tower. In addition, a noise hotline should be installed, i.e. a dedicated community telephone line that is staffed 24 hours/day. This hotline would be for the use of local residents who wish to complain about airport noise and other airport related problems. The public should be welcome to address their
opinions to this office by telephone, letter or in person. Noise office staff should analyse the complaints and opinions, and report them to senior staff within the two bodies. This approach guarantees that senior staff are aware of the concerns of the community. The effective response to complaints may be an important part of building trust between the airport and its neighbours.

Secondly, a systematic method of recording noise complaints should be introduced to correlate complaints to noise data, aircraft type and flight tracks. Its purpose is to aid both the neighbourhood and the airport management in understanding the nature of the noise problem. Under a proper noise complaints recording system, complaints may be handled according to the following procedure. When a complaint is made it is referred to the noise office where the complaint is stored on file along with information about the person making the complaint, the location, the time of day and the nature of the complaint. (A copy of the form used for recording an aircraft complaint at Manchester Airport is shown in Figure 5.4.) Depending on the complaint, it is acknowledged and replied, where possible, by a telephone call or a letter, or even a personal visit. The noise office may investigate as those many complaints as responsible for causing the complaint.

Community Consultation

As stated in Chapter 2, the use of the new runway triggered the airport noise problem at Kimpo Airport and since then there have been a number of street demonstrations protesting against airport noise. There have also been a number of meetings complaining about airport noise organised by political groups, interested groups and experts on the environment. Those people who were exposed to airport noise at Kimpo Airport tend to express their concerns mainly through group demonstration rather than dialogue with the airport authority.

Although the airport authority set up a consultation subcommittee with local groups and attended meetings at the request of the local community
RECORD OF AIRCRAFT COMPLAINT

MEANS OF COMMUNICATION: Telephone/Answerphone Received By ...................

DATE AND TIME OF COMPLAINT .............................................................................

COMPLAINANT'S NAME .................................................................................. ADDRESS ................................................................
................................................................................................................ TEL NO ..........................................................

AIRCRAFT TYPE ........................................... FLIGHT NO ................................................
LANDING/TAKEOFF/GROUNDRUN ...................................................
DESTINATION ..................................................................................
RUNWAY IN USE ..........................................................................
SID .................... ON TRACK/OFF TRACK
NOISE LEVEL ............................................. MICROPHONE NO ..........................

BRIEF DESCRIPTION OF COMPLAINT ...........................................................
..........................................................................................................................
..........................................................................................................................
..........................................................................................................................
..........................................................................................................................
..........................................................................................................................

ACTION REQUIRED FILE/ACKNOWLEDGE RECEIPT/RETURN CALL/LETTER OF EXPLANATION

ANY OTHER COMMENTS ....................................................................................
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Figure 5.4 The Recording Form of An Aircraft Complaint (Manchester Airport)
for communication with the Airport's neighbours, they were not successful (Seoul Regional Aviation Office 1992). Whenever the Airport staff talked to the community, it turned into a confrontation rather than a dialogue. Neither side made a conscious effort to understand each other or to find common ground. These all affected the Airport's neighbours, some of whom were either opposed to, or deeply suspicious of, any noise control activity. Consequently, this indicates that there was no proper open lines of communication about the airport noise problem between the Airport and its neighbours. In order to be able to discover the nature of the problem and the corresponding action to deal with it, it was necessary to collect information about the impact of the airport noise and the nature and the extent of the consequences that the impact caused. However, the Airport's community relations programme was minimal and consequently the distrust of the airport authority continued to build up.

The Korea Airports Authority, the operator of Kimpo Airport, established the Kimpo Airport Noise Committee in 1995, which was a consultation framework to discuss specific airport noise issues with representatives from the districts most affected by the airport's operation. This committee is made up of local politicians, officers from local authority areas, schoolmaster, citizens, and senior staff from the Korea Airports Authority and Seoul Regional Aviation Office. The main function of this committee, which meets on a quarterly basis, is to consult and adjust the method of implementation of noise mitigation measures prescribed in the Civil Aviation Regulation.

Considering the previous antagonistic aspect of both sides in terms of the airport noise problem, the formal establishment and operation of this committee is a sign of a great change in communication between the airport and its neighbours. The improvement in community relations seems to be attributed to the several noise control measures which have been implemented by the airport authority since 1987. However, this committee is not sufficient to deal with the whole airport noise issue, since it is restricted by the participants and its function. Furthermore, a great change in airport
noise circumstances at Kimpo Airport in the next century will need a new proper noise control policy reflecting the changed situation. So, for better community consultation in the future, improved and various community consultation programmes are necessary.

The noise control policy to be implemented by the airport cannot be developed purely by the airport, but should be aided by a process of consultation with the affected community, since the development and implementation of airport noise control policy has a potential impact on that community. So extensive consultation with, and an understanding of, the concerns of the airport’s neighbouring community is of great importance. These can be attained through effective community consultation programmes which ensure the involvement of interested citizens and parties in noise issues. Citizen involvement or participation is a process in which the airport opens itself up to its neighbours with regular dialogue. Public support can be generated by citizen participation in the noise control policy and consequent understanding of its benefits, the constraints encountered and the tradeoffs necessary for their resolution. Citizen participation is defined as an open process in which the rights of the citizen to be informed, to influence, and to receive an adequate response from decision makers are reflected, and in which a representative cross section of affected citizens interact with appointed and elected staffs on all issues concerned (FAA 1975). The participants in the process identify and examine all reasonable alternatives and their consequences to assist the appropriate decision makers in choosing the course of action that they believe to be needed and that they feel will best serve the needs and objectives of the community. Accordingly, citizen participation may be used mainly as an appropriate decision making and solving device for dealing with an issue of concern and interest for the citizens. For this purpose, a great variety of citizen participation techniques have been suggested (cf. Wilson et al. 1983). These include paired-comparison choice making, getting some groups of people together and asking them to rank order four or five alternatives, having a multi-disciplinary team of planners with a strong team leader, establishing a technical team to
assist the community to determine what is best for itself, survey research, interviews, establishing a drop-in centre in an impacted area, sending a multidisciplinary team of planners into the community to talk to people, the provision of a reference book, a grand town hall meeting, small group meetings, a hearing, citizens’ planning council, and community interaction in preplanning phases, etc.. Larrabee (1970) has classified citizen participation techniques into four categories: educational; advisory; partnership; and delegated power. The educational approach is really often little more than a promotional sales technique. The basic goal is to ‘sell’ what has already been planned. The advisory approach provides information about plans plus a request for citizens to advise the planner with regard to proposed alternatives. The partnership approach tries to have planners and citizens work on a plan together, but leaves the final decision with the politicians. The goal is for planners and citizens to become familiar with each others values, constraints and points of view. The delegated power approach allows the citizen to control decision making as well as planning. The effectiveness of a citizen participation technique, however, often depends to a large extent on the adequacy of the information inputs to citizens which educate and motivate them to provide the desired social information (Wilson et al. 1983).

The purpose of community consultation programmes is to maintain open lines of communication with the airport’s neighbours in the process of development and implementation of noise control measures. They can be established and operated differently in the organisational structure and activities according to the purpose of the programme, and the airport’s specific situation, in which the level of community involvement may be different. In addition to the current noise committee, for the development of a noise control policy including compatible land use planning, a comprehensive community consultation programme is necessary. This programme maximises opportunities for citizens to participate in the noise control policy developing process. Citizens can evaluate and discuss the issues and alternatives as well as express their opinions. The membership includes citizens, local politicians, representatives of local communities, airport users, officers from
local authority areas, interested environmental groups, planning organisations, and airport authority and operator staff. To be effective, smaller consultation subgroups may be introduced to this programme. Besides consultative meetings, it is necessary to provide regular information to the airport's neighbours in order to sustain their interest and to provide accurate information.

In addition to the current noise committee, for the purpose of collecting the general information of community concerns, a community consultation programme which is open to all interested citizens is necessary. The membership of this consultation programme is all interested citizens, local politicians, and airport authority and operator staff. The concerns of citizens with respect to the airport noise control policy may vary from neighbourhood to neighbourhood, the meetings should be held at a variety of locations within the noise impacted area and scheduled on several consecutive days. This would allow the maximum opportunity for attendance by community members and consequently the most efficient interchange of information between the airport staff and interested citizens. The airport authority and operator cannot satisfy everyone all the time in terms of the airport noise issue, and there will be a number of confrontations in the process of community consultation. Seattle-Tacoma Airport is worthy of note in terms of its specific community consultation programme. In an attempt to resolve the noise problem faced by communities, Seattle-Tacoma Airport has established the Port of Seattle Commission. This commission has introduced an innovative method of dealing with the issue of aircraft noise called "environmental mediation". The process, which is voluntary, involves negotiations between interested parties with the assistance of a neutral third party whose responsibility is to assist the differing interests in reaching an acceptable agreement. The interested parties include representatives from the community, airline pilots, FAA personnel, members of the Port Commission, airport users and air industry officials. The process of environmental mediation supports the basic goals that:

- the present situation must warrant a change by all concerned parties
- the problem must be identified, evaluated and alternatives considered
- "real" needs and issues are defined by the involved interests
- the premise to "seek to agree" must be accepted by all
- the solution must not exclude any interested participants (DWG Research Associates 1990).

Community Information

The purpose of a community information programme is to keep the airport community (citizens, operator, public officials, and airport related personnel) informed on airport related issues, primarily concerning noise, but also including other areas of interest. It is useful for keeping the affected citizen aware and informed about the activities of the airport authority and operator and in generating citizen support in the process of development and implementation of airport noise control policy.

Up to now there have been scarcely any formal programmes fitting in with the above purpose at Kimpo Airport. Kimpo Airport is a major source of the disturbance in its neighbour's daily life. The impact of the airport's operation and activities to deal with it are issues concerning the airport's neighbouring community. So, the airport which is closed to the local community and regarded as unapproachable and secretive, is not helpful in maintaining good community relations. The operation of Kimpo Airport can be constrained if local opposition is sufficiently great. One of the programmes for good community relations is a positive and effective community information programme. In addition to the information concerning noise, it is desirable to provide information on airport operations and develop an awareness within the community of the benefits which the airport brings to the local community.

There are various kinds of media for disseminating information, such as the use of existing public media, the production of specific publications, the opening of a visitor centre, the organisation of public relation campaigns and open days, and the appearance at interest group gatherings. Among these,
the production of a specific publication like a regular newsletter or bulletin and the opening of a visitor centre may be suitable for Kimpo Airport. A newsletter or bulletin can be intended to concentrate on areas more heavily affected by airport noise, and the existing observatory which was opened in 1994 at Kimpo Airport could be remodelled easily to become a visitor centre. However, a different programme may be introduced as occasion demands.

Heathrow Airport is worthy of note in terms of the operation of a visitor centre. The visitor centre at Heathrow Airport was opened both in response to local demand and to provide BAA Heathrow with a platform to demonstrate all the different aspects concerning life at Heathrow. The centre is free, open to all and in its first 12 months received visits from more than 90,000 local people and around 200 schools (Thompson 1996). It contains features such as a Boeing 777 simulator and a number of interactive displays showing how the airport works. These include demonstrations of environmental activities, the work of HM Customs and a display of airport and airline memorabilia. It also houses the Heathrow Job Centre, which has successfully placed over 2,500 people in jobs in the previous 12 months (Thompson 1996).

Managing Effective Airport Noise Control

Numerous noise control measures have been developed to handle the noise problem with some measures being more successful than others. This success, however, depends on a number of factors including the nature of the noise problem and the demand and capacity characteristics of the airport. It is estimated that there will be a great change in airport noise circumstances at Kimpo Airport in the next century due to the decrease of aircraft operations and the introduction of newer, quieter aircraft. In order to meet this changed noise circumstance, new effective airport noise control measures will be required. The selection of measures is specific to an airport since there is no general standard on airport noise control. The problem of selecting the most effective set of measures is very complex. There are a number of factors and alternatives to be considered during the process of selection, particularly with
respect to land use regulation measures around the airport. Therefore, the process of selection ought to be systematic.

Improvement of the airport noise problem in the vicinity of an airport demands constant monitoring of the changing noise environment. As a result, many airports have established monitoring programmes which include noise monitoring, flight track monitoring, monitoring of the needs of the community, and land use monitoring. Although each monitoring programme has its specific functions, they have the common purpose of minimising or reducing the adverse noise impact in the vicinity of the airport.

This part reviews the systematic selection of noise control measures and monitoring at Kimpo Airport.

Systematic Selection of Noise Control Measures

Many noise control measures, as stated in Chapter 2, have been developed and implemented at Kimpo Airport since the use of the new runway in 1987. According to the data on noise control measures, existing measures have been developed mainly through the simple choice of a useful measure rather than through a systematic selection process, and these have evolved through time from the short term measure which is easy to implement to meet the immediate concerns of residents, such as the cessation of high noise emission aircraft, to long term measures, such as sound insulation programme without any comprehensive strategy. Although these noise control measures have been effective in decreasing the serious complaints from surrounding neighbourhoods, there are still a large number of complaints about airport noise impact and existing measures from the Airport's environs. In order to address the problem of the change in the noise environment at Kimpo Airport in the next century, the improvement of existing noise control measures or the development of new ones is essential. If it is to be effective, the introduction of a specific noise control measure, whether improved or new, should be the result of a systematic selection process, because there are many factors and alternatives to be considered.
Meeting the problem of airport noise requires local airport compatibility programmes, aircraft operational procedures, and innovative noise management strategies. As stated in Chapter 3, there are a number of airport noise control measures which are operative and proposed at many airports to reduce adverse noise impact in the vicinity of airports. Existing noise control measures are a result of the concerns expressed by members of the aviation field, national legislators, the aircraft industry, airport authority or operator, and impacted community residents.

Every airport is unique, and the noise control measures must reflect this uniqueness. The uniqueness of an airport situation is reflected by its physical environment, social attitudes, political attitudes, economic conditions, and legislative and regulatory frameworks (Varma 1987). So, the selected noise control measures will vary from country to country, within a country and from airport to airport. If it is to be effective, a mix of measures which includes at least the following elements is essential to reduce airport noise impact at an airport:
- noise reduction at source
- operational procedures designed for maximum reduction of aircraft noise
- compatible land use planning and control.

The selection of measures for noise control purposes is not a straightforward process and cannot be done solely based on the noise reduction it achieves and the cost that is required to apply the measures. The measures affect the other sectors of the air transport industry. There are a variety of factors and alternatives to be considered in selecting a noise control measure. The problem of selecting the most effective set of measures is very complex. Therefore, it is essential that the process of selection of measures is systematic and should usually contain the following four distinct phases:
- Identification of problem areas or causes
- Exploration of a set of available alternative options
- Evaluation of each option
- Selection of appropriate measure.
The process of selection of noise control measures should start with the evaluation of the existing and future noise situation. The noise situation has to be analysed to find out what the problem areas or the causes of the problems are. Problem areas would refer to the causes of the noise problem. The causes of the noise problem are:

- type and magnitude of activity at the airport
- growth in the fleet size and increase in the number of operations at the airport
- movement of the aircraft on the ground and in the air
- maintenance operation (Varma 1987).

This phase is very important because it would make the exploration of options much easier and is a logical basis for their exploration.

The measures can be explored based on the problem area analysed. In this phase all of the available measures should be explored. It is very important to realise whether a measure is feasible or not during the process of exploring the alternatives. The feasibility of a measure would depend on the physical constraints, safety requirements, economic constraints and technological limitations. Conceptualisation is more important than minute details at this phase (DWG Research Associates 1990). The FAA Advisory Circular gives an illustration of the basic nature of measures for the particular problem area. This shows a matrix of noise control actions which would be useful in selecting the available actions. They are segregated into six broad categories (airport layout and design, airport use, airspace use, corrective land use measures, preventive land use measures, and noise programme management).

The evaluation of each measure would help in justifying the selection or rejection of measures. If a measure is feasible it is evaluated in detail against the following criteria: cost, effectiveness, legal authority, political acceptability, and ease of implementation (FAA 1983). A brief explanation of each factor is presented as follows:
- The cost involved in applying a measure is an important consideration and comprises the cost of implementation, operation and maintenance of the measure.

- The effectiveness is determined by the results of the application of the measure. The reduction in the noise level and the reduction in the number of people impacted are both important for determining the effectiveness. The reduction in the area impacted could also be an indicator.

- Any measure considered should conform to the regulations and the legislation existing. These regulations and legislation could be national or local. The restrictions should be constitutional.

- The goals and various programmes of the community are the outcome of the local, political decision making process and the programmes reflect the political realities of the community. Thus the measures should be politically acceptable.

- Ease of implementation refers to the ease with which the measures considered would integrate with the system where it will be applied. The involvement of too many authorities and systems will definitely affect the ease of implementation. Technical difficulties can also make implementation difficult.

The selection of an appropriate measure should thus be based on the results of previous phases and is specific to an airport. The appropriateness of a noise control measure will depend upon the objectives of the airport management and the particular characteristic or set of characteristics of the noise which has generated the need to implement a noise control measure (DWG Research Associates 1990).

Monitoring

The Ministry of Environment installed an aircraft noise monitoring system around Kimpo Airport in 1990. The purpose of this monitoring system is to measure the actual noise exposure level and to develop appropriate noise control measures based on the monitored noise data. The noise monitoring
system - previously illustrated in Figure 2.4 - consists of ten remote microphones including noise monitoring equipment located in the community surrounding the airport and a central processing unit located at an off airport office. Data processed at the microphone sites are transmitted digitally to the central station via a modem and voice grade telephone line. Each aircraft’s noise level and daily average noise exposure level can be obtained from a noise monitoring system. This system has been managed by the Seoul Regional Environment Office which is the local office of the Ministry of the Environment. Although the Seoul Regional Environment Office has furnished the results of its noise monitoring to the airport authority every three months, it has not permitted other users to have access to its noise monitoring system. The results of its noise monitoring programme have usually been utilised as internal operations data in the Ministry of the Environment. Differing from the original intention with respect to the installation of noise monitoring system, the Ministry of Environment has not yet established any effective noise control measures based on the monitored noise data.

Because of an unapproachable and secretive management attitude, the residents of the airport’s surrounding area distrust the results of the noise monitoring programme. The following account shows an example of this distrust. In 1994, local residents claimed that the actual noise exposure level might be higher than the result furnished by the Seoul Regional Environment Office to the airport authority, and demanded the airport authority measure the actual noise level. Responding to the demand, the Korea Airports Authority measured the noise exposure level at one site for one month with mobile noise monitoring equipment. However, the measured noise exposure level was the same as the result of noise monitoring system of the Seoul Regional Environment Office.

Many airports install noise monitoring systems for a variety of reasons. Prominent among these are the needs to measure local noise levels, enforce noise limits, measure the noise climate and provide information to the airport,
airlines, local community and national governments (ACI Europe 1995). The noise monitoring system process is very effective in assisting the management of airport community relations. Considering these situations, the introduction of new and efficient ways to make the best use of this system at Kimpo Airport for the improvement of noise environment is necessary.

Among the complaints received from the airport’s surrounding areas, a number are related to some operational characteristics of the aircraft which differed from the usual situation. For example, “they never used to fly directly over my house,” “an aircraft flew too low,” etc. This problem is usually caused by the deviation from the designated routes and procedures of aircraft during take-off and landing. However, the airport authority does not know exactly which aircraft caused this problem and the reason for it since the airport’s equipment is not sophisticated enough to deal with this problem. So the airport authority is not able to respond satisfactorily to complainants and reduce this problem to a minimum. Ensuring aircraft comply with designated routes and procedures during take off and landing which is designed to minimise the impact of aircraft operations on the surrounding population and to direct aircraft away from the most densely populated areas is extremely helpful in improving the noise environment in the vicinity of an airport. So it is important for an airport authority to monitor compliance with these routes and procedures.

Air traffic control systems are not normally set up to detect deviations from track which, while not compromising flight safety, cause noise problem. Consequently in most cases a separate system is required. Many airports install flight track monitoring systems. The flight track monitoring system is used primarily to improve departure and arrival procedures and to monitor, and in some cases, enforce adherence to the track. Other uses include assisting the investigation of complaints, assisting air traffic control to achieve separation, and assisting in the generation of noise contours (ACI Europe 1995).
Considering a variety of functions of noise and flight track monitoring systems, the positive and effective utilisation of these monitoring systems would be helpful in reducing the airport noise impact in the vicinity of Kimpo Airport. The noise monitoring system and flight track monitoring system are directly related to controlling the aircraft operations and dealing with the complaints from noise impacted areas. So, if it is to be effective, these two systems must be managed by one body, that is, the airport authority which is responsible for aircraft operations in the airspace near to the airport. The airport noise should be controlled according to law. For this reason, it is desirable that the noise monitoring system, which is currently managed by the Seoul Regional Environment Office, should be transferred to the airport authority.

Manchester Airport is worthy of note in terms of flight track monitoring. In order to minimise the frequency with which aircraft deviate from designated routes, Manchester was the first airport in the UK to install a computer based tracking system known as FANOMOS, a revolutionary new system which recorded not only the noise an aircraft made, but its flight path as it left or arrived at the airport. This equipment was utilised by the airport company, the airlines and the CAA in order to identify the action which needs to be taken by each part of the aviation industry to reduce the incidence of disturbance associated with poor track keeping. In addition to the standard departure routes, designated to take aircraft away from built-up areas, the Airport recommended that pilots adopt noise abatement procedures during take-off. FANOMOS stores a digital record of the movements of aircraft landing and take-off from the airport. It links this to data on the type of aircraft, the flight number, the standard instrument departure route it should be flying, the destination, and so on. The computer can be called upon to produce a print-out showing firstly a map of the area surrounding the airport onto which is plotted the route taken by the aircraft, secondly, a plot on the same map of the route the aircraft should have taken, and thirdly, a graph showing aircraft height and speed from the airport. Print-outs can be selected according to any criteria. However, they are normally produced for aircraft which deviate
from expected departure routes. The staff then listen to the radio exchanges between the pilot and air traffic control to determine the source of the error. Briefly FANOMOS enables research into why aircraft go off track, and provides information to pilots and air traffic controllers to ensure good operations, to aid investigating complaints, to impose tracking fines on deviant aircraft, and to allow the community to assess whether the airport has tracking under control.

Land usage is a continuously changing process, and community growth creates pressures for changes to land use plan and control actions which were established to achieve and protect compatibility between airport and environs. Furthermore the noise impacted land area around Kimpo Airport will substantially decrease in the next century, as stated in Chapter 2. Therefore, there will be strong pressure on local governments to allow houses to be built nearer the airport in the area which has become less affected by airport noise. The increase of noise sensitive land use and development in the vicinity of the airport will result in the aggravation of the airport noise problem at Kimpo Airport. For this reason, land use monitoring is necessary for successful land use control in the noise impacted area. All requests for changes in the land use plan and control actions within the area concerned should be monitored. Land use monitoring is a kind of surveillance over the local land use planning and control authority. So, it is desirable that the airport operator is responsible for it. The airport operator should cooperate with local authorities for this purpose.

Conclusion

Some of the current airport noise control measures, primarily associated with the land use regulation strategy, are considered to be insufficient to effectively deal with the airport noise problem at Kimpo Airport. The really important issues are as follows;
- The current standards related to airport noise, which are prescribed in the Civil Aviation Regulation, are not appropriate to resolve the adverse effect of airport noise.
- There has been no adequate planning and control to deal with the airport noise and land use problem in Kimpo Airport's surrounding area.
- Kimpo Airport has made minimal efforts to maintain good community relations with its neighbours.
- The selection of measures for Kimpo Airport's noise control purposes has not been systematic and Kimpo Airport has no monitoring programme of the noise environment.

In order to meet the change of noise circumstances and reduce the noise impact at Kimpo Airport in the future, the issues discussed above should be tackled properly. For this, the following need to be addressed:

- Adequate standards for land use regulation should be provided based on the results of intensive research and consultation for the practical resolution of the airport noise problem. The standards associated with the establishment of noise zones, the limitation of noise mitigation measures, and facility restriction in the noise impacted area could all be adjusted. For regulatory purposes, the application of objective criteria is essential.

- The effective compatible land use planning through cooperative efforts of related parties should be prepared for significant progress toward the solution of conflicts between Kimpo Airport and its surrounding area. For a successful planning study, the management of the planning study should be through a joint organisation of the current airport operator and authority.

- Good community relation programmes should be introduced to prevent the community's opposition and distrust, since these can constrain the operation of the Airport in the future. Effective community relations programmes will require adequate responses to complaints, periodic provision of opportunity for citizen participation in the airport's actions that are of interest, and an advance information initiative.
- Improving the existing noise control measures and developing new noise control measures for the change of the noise environment at the Airport should, in the future, be conducted through the systematic selection process of appropriate measures. Also a complete monitoring system should be established for information on both noise levels and aircraft operations.
Chapter 6
Conclusions

Today, of all the environmental issues, noise has been often considered as the most undesirable feature of life, and this is probably the single most important issue, especially to those people who are exposed to high levels of aircraft noise, such as those people living near an airport. The adverse effects of aircraft noise on the human environment are well documented: it is a problem that can no longer be ignored. Although the effects of aircraft noise on the physical, mental and emotional health of an airport's neighbours are far less established, the fact that aircraft noise above a certain level annoys those neighbours is generally accepted. People who are exposed to aircraft noise may be annoyed for a wide variety of reasons, including the disturbance of their rest or relaxation, and interference with sleep and conversation. In general, the typical response of people to aircraft noise is annoyance. Studies have also shown that aircraft noise is a factor which may decrease the value of residential property around an airport.

Airport noise is generated as a result of the number of vehicles and aircraft required to service the facilities of an airport operation. Various sources contribute to an airport's total noise level. However, aircraft influence the noise climate during runups, taxiing, approach, arrival, departure, flight and maintenance. In practice, the effects of ground activities of aircraft are unlikely to affect the noise contours in regions beyond the airport boundary (ICAO 1988).

Noise can be quantified in terms of its physical variables, although this is not an accurate way of measuring the annoyance caused by aircraft noise. In order to quantify the annoyance, experts and authorities have suggested many different methods. These methods take into account a number of other factors in addition to the absolute noise level. Several metrics of airport noise
have been developed over the years, because people’s reactions to aircraft noise differ (Smith 1989). The noise metrics have been used for measuring and evaluating noise for airport noise control and abatement including land use planning and environmental impact assessment. Noise is a very subjective experience, thus many different conclusions have been reached with regard to a suitable measure of disturbance caused by aircraft noise. There are, therefore, many different metrics which have been developed by different countries with airport noise problems.

There are a number of techniques and procedures that can be used to minimise or reduce the adverse impact of airport noise in the vicinity of airports. Source noise reduction through noise certification procedures and the phasing out programme is the major noise control measure commonly used all over the world. Today, all civil aircraft must meet noise requirements, not only in all industrialised countries but also in those countries that are members of ICAO. Individual states can prohibit the purchase and operation of certain noisier aircraft types. A number of controls on aircraft operations can be imposed to minimise noise exposure. Aircraft can be prevented from operating, unless they meet certain standards. Arrival and departure flight paths and procedures can also reduce noise exposure if aircraft can be guided away from the noise sensitive areas. For this objective, higher altitude, lower power and shorter duration of time between the aircraft and the impacted community is required. Land use planning and control around an airport utilises available land use control techniques to ensure that the land surrounding the airport is used in a manner compatible with the airport noise environment. This measure may be the most fruitful one to minimise the exposure to noise through the cooperative efforts of all those involved parties. In addition to the above measures, many airports have established monitoring and community relation programmes to improve the airport noise environment.

Of the many airport noise control measures, airport land use regulation is an important method for controlling the adverse impact of airport noise in an
airport's environs. A number of commercial airports have generally been the focus of compatible land use planning and control, since incompatible land use results in public pressure which could threaten the operation and expansion of airports. In order to prevent the encroaching development in the vicinity of airports, systematic, short and long term control measures are necessary. The success of the prevention of incompatibility depends on effective land use planning and control.

It is desirable for compatible land use planning to be developed within the framework of a community or regional plan. In other words, compatible land use planning should be considered as part of the overall comprehensive planning for the community. So, both aviation and urban planning solutions to the problem must be reviewed equally in the planning study, and then practical solutions evaluated against the realities of the social, economic and environmental needs of the community involved. Effective compatible airport land use planning also requires cooperative efforts by the airport authority, local land use planning authorities, airport users, planners, and interested or affected citizens. Through cooperative efforts, planning may proceed with reasonable confidence that its actions are in accord with airport, community and citizen needs and desires, and planners can better deal with issues and improve the chances of reaching a solution on controversial matters. Environmental noise is the primary problem addressed in compatible airport land use planning. The preparation of a compatible land use plan should also include the study of safety issues, airport development, social effects, economic impacts and costs, emerging technology, and environmental impacts. The information developed through such studies provides a vital base of information for immediate and future problem formulation and decision making. An essential aspect of compatible airport land use planning is citizen involvement. The inclusion of concerned and interested citizens in the planning process inevitably raises the level of public understanding of the local issues in a perspective that includes the needs of their communities for air travel.
For the purpose of accomplishing the implementation of a compatible land use plan, control over uses of private properties within noise impacted areas is absolutely essential. The desired goal of effective compatible land use control is to minimise the amount of noise sensitive use and development close to airport, while allowing other productive uses of the land (FAA 1977). Various measures are available for controlling the use of land around an airport. However, some specific measures can be applied to an airport based on each state's legislative situation and unique airport and environs necessities. To effectively control the problem of airport noise and incompatible land uses, compatible land use control measures should be the combination of preventive measures and remedial measures.

In the United States, airport operators are responsible for planning and implementing action to reduce the effect of noise on residents, and land use planning and control authority rests with state and local governmental bodies. The Federal Aviation Administration established the Airport Noise Compatibility Planning Regulation (Federal Aviation Parts 150) that set forth national standards for identifying airport noise and land use incompatibilities and for the development of programmes to eliminate them. FAR Part 150 provides land use guidelines and a comprehensive airport noise planning process which involves the active participation of those land use authorities which are needed to actually plan and control the land around airports. Airport operators may voluntarily prepare a noise exposure map and noise compatibility programme. This is a list of the actions an airport operator proposes to take to reduce noise and incompatible land uses.

In the United Kingdom the government is able to specify noise control and amelioration measures in respect of aircraft noise at designated airports and the airport operators are responsible for them at other airports. However, in respect of the land use planning and development control around the airports, the local planning authorities are responsible for them. The government has published guidance to local planning authorities on various
matters to be taken into account when formulating land use development plans determining applications for specific development. The aim of this guidance is to provide advice on how the planning system can be used to minimise the adverse impact of noise without placing unreasonable restrictions on development or adding unduly to the costs and administrative burdens of business.

In Korea the government has the authority to control airport noise by the regulation of source emissions and by flight operational procedures in ways that minimum noise impact on residential areas, and the airport operator is responsible for establishing noise mitigation measures at designated airports. Land use planning and control authority rests almost exclusively with local governmental bodies. The government sets the guidelines for local authorities to take into account in planning and assessing the development proposals in noise impacted areas under Article 274 of the Civil Aviation Regulation. Its purpose is to restrict the noise sensitive development in the noise impacted area to prevent and lessen the adverse airport noise impact.

Kimpo International Airport has been expanded to meet the rapid growth of aviation demand due to the continuous national economic growth and booming air travel. At the same time, there has been an increased concentration of population in the airport's surrounding area. The typical pattern of development around the airport includes, primarily, residential land uses geared to planned housing development. The use of the new runway constructed in 1987 and the increase of aircraft operations caused the spread of noise impacted areas. During the past ten years, there have been serious conflicts between the airport and its surrounding community due to the adverse environmental effects of airport operation, particularly airport noise impact. Although the airport authority has developed and implemented various noise control measures to resolve the noise problem, they were not sufficient to alleviate growing conflicts between the airport and its anxious neighbours. Consequently the incompatible land uses and developments
around the airport have resulted in the constraints on the operation and expansion of Kimpo Airport. In 1990, the government decided to develop a new international airport to meet the aviation demand of the Seoul metropolitan area after the year 2000 and secure an airport operating 24 hours a day. Kimpo Airport, it is assumed, will serve as an exclusive domestic airport after the opening of the new international airport in 2001.

The results of the noise analysis, for which the INM was used, shows that the noise impacted area around Kimpo Airport will substantially decrease in the next century due to the decrease in the total number of aircraft operations and the elimination of noisier aircraft. However, there are limits to the reduction in noise that can be achieved from the use of quieter aircraft, since there is limited technological scope for reductions in aircraft noise levels beyond those specified in chapter 3, and there are no other more effective measures to reduce airport noise level through aircraft operational regulations at this time. In addition, domestic air traffic will grow at Kimpo Airport after 2001. So it is expected that the residents will have increasing resistance to airport noise in the future. Moreover, there will be a strong demand and pressure for housing development on the land less affected by airport noise. These situations may eventually make the airport noise problem worse and restrict airport operations in the future. In order to prevent the deterioration of the noise environment around the airport, the minimisation of the number of residential dwellings in the noise affected area and the prevention of new noise sensitive use of land near the airport is essential. Effective and regulatory land use planning and control in the vicinity of Kimpo Airport is one of the best means of achieving this objective. Even though land use and development control may seem to be very difficult to achieve, it should be implemented for ameliorating the airport noise impact in the long term at Kimpo Airport.

However, the current airport noise control measures, primarily associated with the land use regulation strategy, are considered to be insufficient to deal effectively with the airport noise problem at Kimpo Airport. This study has
analysed the really important issues in respect of effective airport noise controls mainly through land use regulation in the vicinity of the Airport. As a result, it is possible to identify four critically important conclusions from the Korean experiences.

Firstly, the current standards related to airport noise, which are prescribed in the Civil Aviation Regulation, are not appropriate to resolve the adverse effects of airport noise.

Each country which has implemented a land use regulation strategy as a major airport noise control measure does not restrict the noise sensitive land uses and developments below a specific noise exposure level. This indicates that the noise effect is acceptable in such an area. Article 271 of Civil Aviation Regulation of Korea also sets this noise exposure level as 80 WECPNL which may be related roughly to 69 LDN. This value is by 4 to 16 LDN higher than those of other countries. The lower boundary noise exposure level is a very important guideline which decides whether the noise effect is acceptable or not. Therefore, the appropriate standard for this noise exposure level and the classification of a noise impacted area should be reviewed based on the real annoyance level of airport noise at Kimpo Airport.

Practical and effective noise mitigation measures depend upon the legal framework of the country, the airport's and local community's specific condition and needs. They are also the product of negotiation among concerned parties. However, Article 272 of the Civil Aviation Regulation specifies a small number of restricted measures which an airport operator can implement in the noise impacted areas. This seems to prevent the introduction of other practical measures.

Article 274 of the Civil Aviation Regulation, amended due to citizen's strong complaints, permits new housing development on land which has already been given permission for the land owner to build a house under the application of other laws before the official announcement of the noise
impacted area in 1993, and permits extension and rebuilding without soundproofing of houses which had already been built before 1993. This strategy will give rise to increase the number of people who are exposed to noise impact. The prevention of incompatible land use and development to minimise the noise impact around an airport is one of the objectives of airport noise control. Thus this standard operates against the objectives of effective airport noise control.

The effect of soundproofing application fully depends upon the degree of noise insulation. However, there is no related standard of soundproofing requirements for various facilities in a noise impacted area. Without appropriate requirements, the soundproofing application may fail to realise the anticipated result.

Secondly, there has been no adequate planning and control to deal with the airport noise and land use problem at Kimpo Airport.

For the purpose of minimising the airport noise impact on residents, keeping houses and noise sensitive buildings far enough away from the airport is essential. The land use and development control over the land areas affected by airport noise may be the major tool for that. This strategy should take into account the airport plan for the future, airport noise control measures, and the land use plan of the local communities involved. This strategy may be developed through more specialised planning rather than the current planning framework such as airport development planning, urban planning and environmental impact assessment. Compatible land use planning is suitable for this purpose.

The urbanisation of Kimpo Airport's surrounding area, which was fostered by the statutory urban planning process, has brought about serious conflicts between the airport and its neighbourhoods, and resulted in an obstacle to the operation and expansion of the airport. Incompatible land use in the area surrounding the airport may be traced almost totally to a lack of adequate
planning and land use control by local authorities. This has been aggravated by a lack of coordination between local community plans and the airport development plan. It is estimated that there will be a great change in airport noise circumstances at Kimpo Airport in the next century. However, in the absence of an effective compatible land use plan, significant progress toward the resolution of conflicts between Kimpo Airport and its surrounding area seems unlikely. The major items to be considered in the compatible land use planning are the urban plan of the local community, the airport operation and development plan, airport noise analysis and noise control. Thus, with many different groups and views, the managing body of compatible land use planning programme should lead the planning study to a successful outcome. However, Korea Airports Authority which is responsible for compatible land use planning has some difficulties in managing this planning study.

Thirdly, Kimpo Airport has made minimal efforts to maintain a good community relation with its neighbours.

The airport is a major source of disturbance in its neighbour's daily life. The impact of the airport's operation and activities are issues of concern to the airport's neighbouring community. The airport is closed to the local community, and regarded as unapproachable and secretive. This has caused opposition to adverse airport noise impact from the local community and distrust between the airport and its neighbours. Many airports have community relation programmes including advance information efforts and cooperation with the neighbouring communities. Maintaining good community relations is vital to long term successful airport operations. However, up to now there have been scarcely any formal programmes fitting in with the above purpose at Kimpo Airport. The three important issues which follow from this are as follows:

- Kimpo Airport has no proper complaints handling system to respond to community inquiries in a prompt and helpful manner, or to systematically record noise complaints.
- The Kimpo Airport Noise Committee, established in 1995, is not a sufficient community consultation programme to maintain open lines of communication with the airport's neighbours in the process of the development and implementation of noise control measures.
- Kimpo Airport has no useful community information programme to keep the airport community informed on airport related issues, primarily concerning noise, but also including other areas of interest.

The operation of Kimpo Airport in the future could be constrained even further if local community's opposition is sufficiently great.

**Fourthly, the selection of measures for Kimpo Airport's noise control purposes has not been systematic and Kimpo Airport has no monitoring programme of the noise environment.**

The selection of airport noise control measures is specific to an airport since every airport is unique and the noise control measures must reflect this uniqueness. There are a variety of factors and alternatives to be considered during the process of selection of effective measures, particularly in respect of land use regulation measures around an airport. The problem of selecting the most effective set of measures is very complex. Therefore the process of selection of appropriate noise control measure ought to be systematic. However, the existing noise control measures at Kimpo Airport have been developed mainly through the simple choice of useful measures rather than through a systematic selecting process, and these have evolved through time from the short term measure which is easy to implement to meet the immediate concerns of residents to long term measures without any comprehensive strategy. This approach is not helpful in improving the existing noise control measures and developing new noise control measures for changing the noise environment at Kimpo Airport in the next century.

Improvement of an airport noise problem in the vicinity of an airport demands constant monitoring of the changing noise environment. As a result,
many airports have established monitoring programmes which include noise monitoring, flight track monitoring, monitoring of the needs of the community, and land use monitoring. However, Kimpo Airport has not established any effective monitoring programme. Without such a programme, meeting the problem of airport noise effectively cannot be expected.

Recommendations

In order to tackle these four critically important issues, it is recommended that each party related to the airport noise and land use problem should do the following:

- For practical resolution of the airport noise problem, the Ministry of Construction and Transportation should provide adequate standards for land use regulation through intensive research and consultation with governmental bodies, parties and citizens involved. In this case, the application of objective criteria based on the relationship between noise exposure and the collective real response of people to airport noise is required.

- National government bodies such as the Ministry of Construction and Transportation, the Ministry of Environment, and the Ministry of Home Affairs should be required to assess the combined effects of their separate programmes on airport related communities and demonstrate the compatibility of their proposed projects with local community development plans as well as the general public interest.

- Local authorities should be required to operate the "precautionary principles" to provide for land use planning and development, zoning and housing regulation that will limit the uses of land near the airport to purposes compatible with airport operations. In connection with these matters, the airport should be promoted as a community asset, and airport noise and land use problems should be considered as a community problem.

- The Korea Airports Authority and the Seoul Regional Aviation Office should work together on the preparation of a compatible airport land use plan aiming
primarily at formulating a balanced and effective programme to minimise or reduce the airport noise impact on local communities. In addition, local authorities should be required to participate in compatible land use planning as a continuing activity underpinning the operation of the airport. Compatible airport land use planning should be integrated effectively with traditional airport and urban development planning. The Korea Airports Authority should cooperate with local authorities on land use monitoring.

- In an active attempt to resolve the airport noise problem, the Korea Airports Authority should establish and operate effective community relation programmes in which the airport opens itself to its surrounding community. This would generate citizen support response to the development and implementation of airport noise control measures and build up trust between the airport and its neighbours. Good community relation programmes will require adequate response to complaints, periodic provision of an opportunity for citizen participation in relevant airport's actions, continuous monitoring of the needs of the local community and advance information provision.

- The Seoul Regional Aviation Office together with the Korea Airports Authority should be required to develop a comprehensive airport noise control plan or strategy reflecting the change in the noise circumstances in the next century. This should be done through the systematic selection of effective noise measures, and the installation of a compatible monitoring system for the improvement of the noise environment. A complete monitoring system should provide information on both noise levels and aircraft operations.

- In order to implement successfully the established noise compatible land use planning proposals, the Seoul Regional Aviation Office and the Korea Airports Authority need to concentrate their activities on three inter-related actions: first, they should set a target which specifies a proper cumulative noise exposure level at Kimpo Airport which should be not permitted to increase; second, they should monitor associated activities including noise
emissions, aircraft operations and land usage; and finally, they should report the results of this monitoring to related parties for further consultation.

Suggestions for Future Research

In this study, airport noise control has been researched in terms of compatible land use planning and control in the vicinity of Kimpo Airport. In other words, it has only focused on the land use regulation side of various airport noise control measures. However, it would also have been interesting to investigate the other side of the measures such as source noise reduction and aircraft operational regulations.

Another limitation is that there have been no formal social surveys and systematic collection of complaints which can show the detailed view of the impact of airport noise on people who live in the area surrounding Kimpo Airport. In order to be able to discover the nature of the airport noise problem more precisely and the corresponding action to deal with it, it would be necessary to collect information about the impact of the noise and the nature and extent of the consequences of the noise. However, considering the general level of agitation of the residents, a personal survey for the purpose of this study was not desirable. Thus this study was restricted to suggesting the basic principles for effective airport noise control at Kimpo Airport.

To develop the study further, the limitations of the study should be taken into account. Therefore, further studies should consider other aspects of airport noise control measures and the suggestion of detailed standards for effective noise control. For these, the Airport should commission intensive research through social surveys amongst the people living in the neighbouring area. In addition, the systematic collection of complaints and continuous monitoring of community concerns are necessary. These would provide a comprehensive picture of the feelings of local noise impacted residents.
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Appendix A

Airport Noise Metrics and Cumulative Noise Exposure

Source of Noise

Airport noise is generated as a result of the number of vehicles and aircraft required to service the facilities of an airport operation. Various sources contribute to an airport's total noise level: roadside vehicles, cars, vans, taxis, buses, and trucks required for passenger and cargo ground transportation; and on-site vehicles including fuel trucks, baggage carts, emergency vehicles, auxiliary power units and maintenance trucks necessary for airport ground support. However, aircraft are recognised as being the largest contributors to the noise level. Aircraft influence the noise climate during run-ups, taxiing, approach, arrival, departure, flight and maintenance. In practice, the effects of ground activities of aircraft are unlikely to affect the noise contours in regions beyond the airport boundary (ICAO 1988).

Aircraft noise is generated whenever the passage of air over the aircraft structure or through its engines causes fluctuating pressure disturbances. The former is airframe noise and the latter is engine noise. There are a number of sources of airframe noise, including the wings, tailplane, fuselage, engine nacelles, leading slats, trailing edge flaps and landing gear and wheelbays. When making the initial climb out and on final approach to landing there is a significant increase in airframe noise due to the reaction of the airframe to the turbulence induced by the retracted landing gear and flaps (Smith 1989). Under normal flight conditions, the noise is dominated by that generated by the wings.

The main source of jet aircraft engine noise is the roar of the jet exhaust and the whine of the compressor and the fan. This engine-generated noise causes a high level of annoyance and widespread environmental disturbance, the origins and effects of which are complex and hard to treat. The jet noise is the result of the interaction of the main exhaust flow from the
engine with the surrounding air and is a stream of noise stretching out behind the engine, diminishing in intensity as the exhaust flow mixes with the surrounding air. Fan noise originates basically from the tips of the fan blades and it is easier to identify. All sources of aerodynamic noise are a function of velocity, so as the bypass ratio increases and the jet velocity falls there is a reduction in the extreme jet mixing noise.

In the past, the major source of noise has been the jet exhaust and rotating machinery which were mainly in the early turbofan or fanjet engines. In recent years, as higher and higher by-pass ratio turbofan engines have been introduced, the fan has started to become the major source of noise. The roar of the jet exhaust is of concern primarily during the takeoff procedure, and the whine of the compressor and fan is of concern primarily during the landing approach, particularly from a point some five miles from touchdown (Harper 1988).

Noise Measurement

Noise has often been defined as “unwanted sound” or as “sound which is undesired by the recipient” (Taylor 1970). Two important features of this definition are that noise is sound and noise is subjective. So noise metrics incorporate both objective and subjective information about the impact of acoustic events (Bugliarello et al. 1976). In dealing with airport noise, there are two main approaches to the measurement of that noise. The first measures the actual physical sound; the second includes adjustments to the sound level, based on an estimate of annoyance, in order to predict noise exposure.

Noise can be quantified in terms of its physical variables, although this is not an accurate way of measuring the annoyance caused by aircraft noise. In order to quantify the annoyance, experts and authorities have suggested many different methods. These methods take into account a number of other factors in addition to the absolute noise level which is measured by sound
level meters located around the airport. Several metrics of airport noise have been developed over the years, because people's reactions to aircraft noise relate to the sound level, the varying sensitivity of the human ear to different frequencies or pitches of sound, the duration of the exposure to the sound, the frequency of aircraft noise intrusions, the time of day of these intrusions, and the number of intrusions over a period within a day (Smith 1989).

The noise metrics have been used for measuring and evaluating noise for airport noise control and abatement including land use planning and environmental impact assessment. As previously stated, noise is a very subjective experience, so many different conclusions have been reached with regard to a suitable measure of disturbance caused by aircraft noise. Table A.1 shows the many different metrics which have been developed by different countries with airport noise problems. Some of the more common ones are presented in the following sections.

Sound Pressure and Frequency

Sound is created by any vibrating body which sets the air near it into vibration. It causes small fluctuations in air pressure which are detected by the ear. A complete physical description of a sound must account for the overall sound pressure level, the frequency spectrum and the variation of both of these quantities with time.

Sound can be measured in a number of ways; sound power (flow of energy), sound intensity (energy flow per unit area), or sound pressure (fluctuations in air pressure). The metric generally used quantifies the pressure of the sound wave, ignoring the frequency and temporal characteristics. As a metric of sound pressure, the most common and internationally accepted scale is the Sound Pressure Level (SPL), a scale of reference based on logarithmic ratios termed "bels" and having the relationship:

\[ SPL = 20 \log_{10}(\frac{p}{p_{ref}}) \]
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<td>PNL: Perceived Noise Level</td>
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<tr>
<td>PNL'T: Tone Correction PNL</td>
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<tr>
<td>SEL: Sound Exposure Level</td>
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<td>•</td>
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<tr>
<td>SENEL: Single Event Noise Exposure Level</td>
<td>•</td>
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<tr>
<td>EPNL: Effective Perceived Noise Level</td>
<td>•</td>
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<tr>
<td>WECPNL: Weighted Equivalent Perceived Noise Level (ICAO)</td>
<td>•</td>
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<tr>
<td>Leq: Equivalent Continuous Sound Level</td>
<td>•</td>
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<tr>
<td>NNI: Noise and Number Index (UK)</td>
<td>•</td>
<td>•</td>
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<tr>
<td>NEF: Noise Exposure Forecast (US)</td>
<td>•</td>
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<tr>
<td>DNL: Day-Night Equivalent Sound</td>
<td>•</td>
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<tr>
<td>HNL: Hourly Noise Level (California, US)</td>
<td>•</td>
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<tr>
<td>CNR: Composite Noise Rating</td>
<td>•</td>
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<tr>
<td>DEN: Day Evening Night Level (Danish)</td>
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</tr>
<tr>
<td>B: Kostan Unit (Dutch)</td>
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</tr>
<tr>
<td>I: Isopsonic Index (French)</td>
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<tr>
<td>Q: Storindex (German)</td>
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Table A.1 Various Noise Measurement Methodologies and Metrics  
(Source: Rolls Royce Plc)
where $P_e$ is the measured effective pressure of the particular sound wave in units of force per unit area, and $P_{ref}$ is the reference effective pressure. For sound pressure levels in air, the reference effective pressure is approximately equal to $2 \times 10^{-5}$ Newton/M$^2$, the level of the quietest audible sound. The decibel (dB), the most common unit for measuring the amplitude of sound, relates to the manner in which sound is perceived by individuals. A 10dB increase in a sound is perceived to be twice as loud to the receiver. The decibel scale has the range between 20 and 120 which is a manageable set of values to which an individual can relate.

The sensitivity of human hearing varies with the frequency of sound, that is the number of sound pressure oscillations per second. The units of frequency are hertz (Hz). The audible range of frequencies extends from a low of 20 Hz to a high of about 20,000 Hz. However, the human hearing system is not equally sensitive across this entire range. Frequencies in the range of 2000 to 4000 Hz sound louder than lower or higher frequencies heard at the same sound pressure level. Thus, it is possible for two different sounds with the same sound pressure level to sound different in loudness. For this reason, any metric used to express human response to either loudness or annoyance has to include a weighting element that varies both with pressure level and frequency. Accordingly, the A-weighted sound level (dB(A)) was developed for rating noise on the basis of human reaction to loudness. The dB(A) scale is conveniently available for direct reading on commercial sound level meters through an electronic weighting network.

In addition to sound level and frequency, another important factor to environmental sound is its variation over time, because an aircraft pass-by produces a distinct and transient noise event. Thus aircraft noise measurement and quantification is concerned with the effect of noise which varies significantly with time. Some of the metrics are discussed in the following sections.
Metrics for the Noise of Single Event

Aircraft sounds can be easily described as single events because their sound levels tend to exceed existing background sounds. There are two ways commonly used to quantify the noise of the single event: either the maximum or peak level is adopted, or the sound pressure levels from instant to instant during the course of the event are combined, with time, to give a metric of the total sound energy. Some major metrics of this category are presented in the following paragraphs.

**Maximum A-Weighted Sound Level, L\text{Amax};**

That is the maximum instantaneous value of dB(A) recorded during an aircraft flyover. This value is easy to measure and to describe since most people can relate to the loudest part of a noise event. However, it does not include the time element or duration of the event.

**Sound Exposure Level, SEL;**

The sound exposure level is a metric of the level of sound in dB(A) of a one-second burst of steady noise which contains the same total A-weighted sound energy as the whole aircraft flyover noise. Mathematically, it is given by,

\[ SEL = 10 \log_{10} \int_{0}^{\infty} L(t) \, dt \]

where \( L(t) \) is the instantaneous sound level in dB(A) at time \( t \) and the time integration includes a sufficiently long sample of the flyover. This metric accounts for the duration of the sound as well as its maximum level. Annoyance reactions increase with duration and an appropriate trade-off between sound level and duration is 3 dB per doubling of duration. SEL is measured using an integrating sound level meter.

**Perceived Noise Level, PNL;**

The perceived noise level is a rating of the level of noise generated by an aircraft which has been calculated from the frequency spectrum of that aircraft noise. The PNL was established to emphasise the frequency spectrum to which the human ear is most sensitive. Unlike the frequency
weighted noise levels, which can be measured using electronic devices, the
PNL must be calculated by applying a subjective weighting factor to each
frequency component. In general, it adjusts sounds to make them equally
annoying rather than equally loud. As a general rule, the PNL is
approximately 13 dB greater than the A-weighted sound level.

**Effective Perceived Noise Level, EPNL**;

The PNL and EPNL were developed specifically to correlate with subjective
response to aircraft noise. The effective perceived noise level, sums the PNL
in a manner similar to the way SEL sums the dB(A) level. However, EPNL
also incorporates a tone correction adjustment to account for the increased
subjective noisiness of sounds containing discrete frequency tones. Both the
PNL and the tone correction are computed from sound pressure levels
measured in individual one-third octave bands from 50 to 10,000 Hz. The
effective perceived noise level in units of EPNdB takes account of pure tones
and the duration of sound to reflect the true noisiness of a flyover sound. It is
used for the noise certification of jet aircraft and is not directly measurable.
As a general rule, the EPNL is about 3 dB greater than SEL, but it can be
more if very noticeable pure tones are present or less at very large distances.

**Metrics for the Noise of Cumulative Event**

Noise measurements derived from single event metrics correlate with the
cumulative community annoyance response. Cumulative metrics are derived
from single event metrics or computed from continuous noise measurement
data. The cumulative noise metrics, however, do not relate accurately to the
specific areas of sleep or speech interference.

A number of metrics of noise exposure have been developed which attempt
to incorporate subjective metrics of annoyance. The methods differ in: noise
index, index for the duration of a single sound event, weighting factors
allocated to certain periods of the day, the mathematical relation between the
acoustic variable and noise index, the level increment which is equivalent to
doubling the duration of exposure and the reference period on which the noise rating is based (Matschat & Mueller 1981). Some major metrics of this category are presented in the following paragraphs.

**Day-Night Sound Level, Ldn;**

The day-night sound level (Ldn) value in dBA is developed as an index of the effects of cumulative aircraft noise to the airport environs. In the Ldn process of measuring, the noise generated from each aircraft takeoff or landing at ground level is calculated and accumulated for a 24 hour period. Due to increased sensitivity to noise during nighttime hours, daytime and nighttime exposures are treated separately with nighttime allocated a 10 dB penalty. It can be written,

\[
L_{dn} = SEL + 10 \log_{10} \left( 10^{Nd} + 10^Nn \right) - 49.4
\]

where Nd and Nn are the daytime and nighttime numbers, Ldn is usually based on annual average values of SEL, Nd and Nn. This metric is widely used in the U.S. as the workable tool for community noise measurement.

**Equivalent Continuous Sound Level, Leq;**

The equivalent continuous sound level is the sound level of a hypothetical steady sound which, over the measurement period, contains the same sound energy as the actual variable sound. Essentially, the Leq is based upon the total energy concept, in which case it integrates the instantaneous noise signals at 1 second rates of integration, that are contained in each event during the period in question. It can be written:

\[
Leq = SEL + 10 \log_{10} N - \text{con.}
\]

where N is the number of single events during the measurement period. SEL is the average sound exposure level of these N sounds, and the constant depends upon the measurement period as follows,
Weighted Equivalent Continuous Perceived Noise Level, WECPNL;

The WECPNL may be considered to be an international version of the weighted noise exposure level which has been suggested to member states by the ICAO in Annex 16. It is based on the EPNL and divides the 24 hour day into three periods, daytime (07:00 - 19:00), evening (19:00 - 22:00), and night (22:00 - 07:00). It can be written:

\[
WECPNL = 10 \log \left[ \frac{1}{2} \text{antilog} \frac{ECPNLD}{10} + \frac{1}{8} \text{antilog} \frac{(ECPNLE + 5)}{8} + \frac{3}{8} \text{antilog} \frac{(ECPNLN + 10)}{10} \right] + S
\]

where ECPNLD, ECPNLE and ECPNLN are ECPNL during daytime, evening and nighttime and S is a seasonal adjustment. In practice, it is used in a modified form in some states and expressed as follows:

\[
WECPNL = 10 \log \left( \frac{1}{n} \sum_{i} \frac{L_i}{10^{10}} \right) + 10 \log N - 27
\]

where \( L_i \) is the maximum A-weighted sound pressure level of an aircraft flyover \( i \), \( n \) is the number of operations within a 24 hour period, and \( N \) is based upon the number of single events with weightings for the numbers during the day, evening and night.

Noise and Number Index, NNI;

The Noise and Number Index was developed in the U.K. on the basis of social survey results, but has now been largely replaced in the U.K. by Leq.
It was aimed at direct measurement of the relationship between annoyance and various explanatory variables including aircraft noise levels in PNL. Only the daytime period (07:00 - 19:00) is considered and the number coefficient $K$ is 15. NNI can be written:

$$NNI = PNL + 15 \log 10^N - 80$$

where $PNL$ and $N$ are average daily values for the period mid-June to mid-September. Only sounds which exceed 80 PNdB are included in the calculation.

**Noise Exposure Forecast, NEF;**

The noise exposure forecast is a metric which is expressed in EPNL over a 24 hour period weighted for the time of day. It is very similar to Ldn except that noise levels are defined in EPNL and the constant takes a finite value to ensure that zero NEF corresponds to a level of no concern to the community. NEF can be written:

$$NEF = EPNL + 10 \log 10^{(Nd+16.7Nn)} - 88$$

where $Nd$ is the number of operations during the 15 hour day (07:00 - 22:00) and $Nn$ is the number during the 9 hour night (22:00 - 07:00). The constant of 16.7 applied to nighttime operations means that for the same average number of operations per hour, the NEF correction will be 10 dB higher for nighttime operations. The NEF has now been replaced by the Ldn in the United States.

**Calculation of Aircraft Noise Contours**

The presentation of noise impact by the use of contours of constant noise level plotted on a local map is a visual way of expressing either the general situation or a change in aircraft noise around an airport. Noise contours are computed rather than measured because of the large areas of ground covered and the length of time over which noise data have to be averaged.
The noise level heard beneath a passing aircraft depends upon a number of factors and the following information is required to allow the contour calculation process to be undertaken (ICAO 1988):
- Aircraft types that use the airport
- Noise - power - distance relationships for each type
- Aircraft performance data for each type
- Routes used in departure and arrival
- Number of movements on each route within the period chosen
- Operational data typical to each route, including aircraft mass, power setting, speed and configuration through the different flight segments, and
- Airport related data, including meteorological conditions and physical alignment of runways.

The accurate calculation of an aircraft noise contour requires very complex mathematical models. The ICAO has published a recommended method for computing noise contours around airports (Recommended Method for Computing Noise Contours around Airports, ICAO Circular 205 - AN/1/25 1988), in which the noise level at any point J arising from an individual aircraft movement is expressed by the following formula:

\[ L_J = L(X, d) + \Delta(\beta, I) + \Delta_0(Q) + \Delta_s(V) + \Delta_T(T) \]

where
- \( L(X, d) \) = noise level interpolated from the noise -thrust - distance data
- \( \Delta(\beta, I) \) = extra ground attenuation (a function of the elevation angle \( \beta \) and distance to the ground track \( I \))
- \( \Delta_0(Q) \) = correction for directivity behind the start of roll (a function of the angle \( Q \) subtended to the rear of the aircraft)
- \( \Delta_s(V) \) = correction for aircraft speed \( V \), and
- \( \Delta_T(T) \) = correction for changes in duration during turns, a function of time \( T \)

The whole process is repeated at a sufficient number of other points on the ground to permit contours to be plotted.
Because of the large quantity of data required to compute the noise of each individual operation, it is usual to make certain simplifications to reflect average noise exposure over long time periods. The simplifying assumptions that are most frequently made include the noise levels of groups of similar aircraft types, average climatic conditions and the average operational pattern over the time period in question. Although average contour areas can be predicted in the long term, errors can arise because of the uncertainty of future traffic levels and other simplifying assumptions. So noise contours are usually recommended as a planning guide only, to explore 'what-if?' type questions, and to be used to estimate appropriate changes to the annoyance level likely at a particular point in the community, and not to indicate the absolute level of noise at any given point.
Appendix B

Planning Process

Compatible land use planning employs the basic urban planning process with the inclusion of noise exposure and land use category guidelines and airport safety as additional inputs or criteria. Planning in the sense implied here is the process of identifying and analysing problems and exploring and assessing options open to an urban community in the pursuit of general goals and specific land development objectives (Chapin et al. 1979).

Figure B.1 shows the total planning process. The principal steps are as follows. Problem definition is the first step in the rational planning process. It includes formulating brief, clear statements of problems, describing associated conditions, and analysing and describing the problem structure (i.e., cause-effect relationships). Identification of goals and objectives, the second step, is so closely associated with problem definition that some include it as an integral aspect. Objectives are intermediate ends instrumental to the achievement of a goal; they are statements of consequences which solutions are intended to achieve. Based on objectives and an understanding of the problem situation obtained from the first two steps, the rational planning process next attempts to formulate guidelines for solution searching. These guidelines go further than objectives in delineating a solution searching suggestions for subsequent planning decisions and action decisions. Given a set of objectives and derived solutions - searching guidelines, alternative means of realising objectives, within the reality of the problem structure, must be identified. This is the fourth step. Developing the alternative schemes is the nucleus of the planning process. The objective is to explore a wide range of feasible options and alternative compositions of land use patterns, noise control actions, and noise impact patterns, seeking optimum accommodation of both airport users and airport neighbours within acceptable safety, economic, and environmental parameters. The alternatives should address both the physical planning and the implementation aspects of
the proposed solutions. The fifth step of the progression is the development of a systematic method for evaluating alternatives. Evaluation includes both the projection of consequences related to objectives and the assessment of those consequences with respect to evaluative criteria derived from them.

These steps are not always taken in this order. Sometimes alternatives are proposed by others before problems are analysed, objectives identified, and solution principles formulated. More often, solutions are identified together with objectives, problems, structures, and solution-searching principles, and there is considerable interaction and feedback among these tasks.

![Planning Activity Diagram]

Figure B.1 Land Use Planning Process (Source: Chapin et al. 1979)