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likely to prevail and the trend toward independent authorities will most likely continue.

Medium and small hub airports will continue their struggle uphill to fiscal independence. More realistic federal airport support policies should help these airports become more independent of the local tax base.

The small general aviation airport appears to be most vulnerable in the temporary economic set back and is likely to suffer most in the cost conscious era to follow. Unless it is located in a hub area which is served by air carrier (not necessarily at the same airport), the airport has little chance of becoming self-supporting and must depend upon continued local tax subsidy. Such airports are becoming less likely candidates for public support as the population perceives a diminished opportunity to use them. Since their revenues are minimal, the possibilities for successful bonding are low. Their continued success will depend on a realistic evaluation of community need and on the use of cost conscious approaches in both capital planning and daily operational policies.

PHYSICAL ENVIRONMENT

Introduction

Noise pollution, air quality, water quality, and land use around general aviation airports are important parts of the physical environment. The planning and construction of public facilities such as general aviation airports should be guided by a desire to achieve the highest possible level of social benefits, with a minimum expenditure of human, physical, economic, and environmental resources. Large scale physical facilities are usually accompanied by undesirable environmental side-effects.

In an attempt to minimize possible environmental damage resulting from major public undertakings, the National Environmental Policy Act of 1969 (Public Law 91 - 190) was enacted to require that for any project which involves major Federal funding, and which significantly affects the quality of the human environment, an environmental impact statement must be filed with the Council on Environmental Quality

(CEQ). This statement must include the following:

- (1) The environmental impact of the proposed action;
- (2) Any adverse environmental effects which cannot be avoided should the proposal be implemented;
- (3) Alternatives to the proposed action;
- (4) The relationship between local short-term uses of man's environment and the maintenance and enhancement, of long-term productivity; and,
- (5) Any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented.²⁵

The environmental impact statement should consider ecological factors including (1) noise pollution; (2) air quality; (3) water quality; (4) fish and wildlife; (5) solid waste; (6) energy supply and natural resources development; and, (7) protection of environmentally critical areas such as floodplains, wetlands, beaches, dunes, unstable soils, steep slopes, and aquifer recharge areas.

This section will discuss environmental legislation affecting airports and the more common environmental effects resulting from airport construction, with special emphasis on general aviation airports. The discussion will focus on the regulation of noise, pollution, and water quality.

Environmental Legislation

Environmental legislation which has emerged within the last five or six years may eventually influence the utilization of general aviation airports. One of the primary objectives of the Noise Control Act of 1972 (Public Law 92-574) is to control noise from aircraft and aircraft operations. The FAA is authorized to develop regulations to control aircraft noise emissions, as well as to impose curfews, flight path modifications, or other procedures deemed necessary to protect the public. Among the states with environmental regulations, the State of California has established state-wide controls for noise around airports.²⁶ Airport authorities may also control noise: the Port of New York Authority imposes noise standards on the airlines and operators who use its airports.²⁷ The right of the operator to control noise through the imposition of a curfew has been upheld in the California courts.²⁸ But at least one decision severely limited the power of

²⁵ P. L. 91 - 190 Title I, Sec 101, pt C.

²⁶ Howard, George P. (Ed) *Airport Economic Planning* (Cambridge The MIT Press, 1974), p. 425

²⁷ *Ibid.*, p. 806

²⁸ *Stagg v Municipal Ct. of Santa Monica*, 82 Cal. Rptr 578 (1969).

a local government to control noise, in cases where it does own or operate the airport.²⁹ This may be an example of the limited control that a community would have over a private airport or possibly an airport just beyond its political boundary.

The 1970 Amendments to the Clean Air Act (Public Law 91-604) include provision for regional transportation controls. Under the supervision of the Environmental Protection Agency, states are to develop a comprehensive air quality policy which includes land use planning and air and surface transportation controls.³⁰ The regional controls will undoubtedly work to reduce automotive traffic—the major source of air pollution—and as such increase the demand for general aviation.

The Federal Aviation Administration affects communities which seek federal funds in acquiring a general aviation airport. Federal airport safety regulations can be fairly costly to the community. If an airport seeks federal funds for expansion under the Airport and Airway Development Act of 1970, it must submit an Environmental Impact Statement.³¹ No project has an adverse effect upon the environment will be authorized if there is a feasible alternative.³² On the other hand, the FAA does not tax general aviation for the total cost of its use of the airway system, and thus cost savings may be passed on to the community using the general aviation services.³³

Aviation Noise

Noise can be defined subjectively as any unwanted or undesirable sound, or a sound which conveys no information or which interferes with information transmission. Response to aircraft noise is dependent upon a number of factors including sound level, weather, time of day, and numerous human factors. The purpose of this section is to evaluate the noise effects of general aviation. To do this, noise and noise response measuring scales and forecasting methods are described and attempts to regulate

noise by different federal agencies are described.

Noise Scales

The basic measure of sound level is the decibel (dB) which is defined as a sound-pressure level equal to $20 \log_{10} (P/P_0)$ where P is the level of a given sound and P_0 is an arbitrary sound-pressure level usually taken to be 0.0002 dynes/cm.³⁴ The decibel is generally considered to be a poor measure of annoyance and reaction to noise because the human ear perceives higher frequency sounds as being louder than lower frequency. For this reason, three other scales have been developed. These can be summarized as follows:

(1) **Measurement by meter:** utilizing the A-Scale sound level, [dB(A)], (a measurement that reflects loudness by filtering lower frequencies and weighting higher ones), more closely approximates the response of the human ear, or "loudness." The dB(a) scale has the advantage of being objective, but does not take into account the duration of the sound as some of the other scales described below. The dB(A) scale is used in FAR Part 36F which regulates the noise level of small propeller-driven aircraft.

(2) **Computation of response to a single exposure:** Scales in this category are among the most important because they are the ones used to measure and compute noise levels generated by jet aircraft for the purpose of regulation and certification. They include the Perceived Noise Level (PNdB), which is a measurement of the noise level of maximum intensity during a flyover of an aircraft at specified altitude and engine power, and accounts for the amplitude, frequency, and direction of the sound. Another measure in the category is the Effective Perceived Noise Level (EPNdB), which is subjectively adjusted for perceived noise. It accounts for absolute noise level, noise spectrum, maximum tone, and noise duration. Basically it is intended to reflect perceived noise as determined by human reaction, and is used in FAR Part 36 which regulates the noise level of jet aircraft.

(3) **Computation of response to multiple exposure:** The measurement and prediction of public response to aircraft noise involves more complex factors than those considered in the scales discussed. Operational procedures, aircraft types, environmental conditions, and people are highly variable. This makes the prediction of annoyance and complaint levels a complex matter. The following facets of an-

²⁹ *Lockheed Air Terminal v. City of Burbank*, 411 U.S. 624, 12 Av. 17,889 (May 14, 1973).

³⁰ Staff of the House Committee on Interstate and Foreign Commerce, 93rd Cong., 1st Sess., *Transportation Controls Under the Clean Air Act* (Comm. Print No. 10, 1973), p. 52.

³¹ Little, Arthur D., Inc. et al., *Civil Aviation Development: A Policy and Operations Analysis* (New York: Praeger Publishers, 1972), p. 188.

³² *Ibid.*, p. 188.

³³ Warford, Jeremy J., *Public Policy Toward General Aviation* (Washington, D.C.: Brookings Institute, 1971), p. 66.

³⁴ Dickerson, D. O., et al., eds., *Transportation Noise Pollution: Control and Abatement* (NASA-ASEE Summer Faculty Fellowship Program in Engineering Systems Design, 1970), p. 14.

TABLE II-II
CHART FOR ESTIMATING RESPONSE OF RESIDENTIAL
COMMUNITIES FROM COMPOSITE
NOISE RATING

Composite Noise Rating (CNR): Takeoffs and Landings	Zone	Description of Expected Response
Less than 100	1	Essentially no complaints would be expected. The noise may, however, interfere occasionally with certain activities of the residents.
100 to 115	2	Individuals may complain, perhaps vigorously. Concerted group action is possible.
Greater than 115	3	Individual reactions would likely include repeated, vigorous complaints. Concerned group action might be expected.

Source: CLM/Systems, Inc., *Airports and Their Environment: A Guide to Environmental Planning*. (U.S. Dept. of Transportation, Washington, D.C., 1972), p.97.

noyance and complaint have been determined:

- (1) Estimation of annoyance using noise exposure as the sole predictor is rather poor.
- (2) The inclusion with noise exposure of certain attitudinal or psychological variables affords good prediction of individual annoyance.
- (3) An equation can be written for predicting individual annoyance with good accuracy.
- (4) Within certain limits the number of highly annoyed households in a community may be estimated from the number of complaints.
- (5) An equation for predicting complaints among a random sample, similar to the predictive equation for annoyance, can be written, but its accuracy is questionable.
- (6) There is a substantial difference between predictors of annoyance and predictors of complaint: predictors of annoyance are primarily physical/attitudinal; predictors of

complaint are primarily physical/sociological.³⁵

Techniques in common use for predicting public response to the impact of noise exposure and for use in land-planning are the Composite Noise Rating (CNR) and Noise Exposure Forecast (NEF). Recently, the Federal Aviation Administration has developed the Aircraft Sound Description System (ASDS).

The CNR method, which was developed in 1952, is based on PNdB or EPNdB and the following factors:

- (1) The average noise level spectrum;
- (2) Discrete frequency components—presence or absence;
- (3) Nature of sounds—impulse or non-impulse;
- (4) Sound repetition;
- (5) Ambient noise level;
- (6) Time of day of the noise; and,
- (7) Adjustment for previous exposure of the community to the noise.³⁵

Expected response zones have been suggested as shown in Table II-II.

The NEF method involves the use of EPNdB, and attempts to forecast community response by incorporating such factors as absolute noise levels, noise spectrum, noise duration, maximum tone, aircraft type, mix of aircraft, number of operations, runway utilization, flight pattern, operating procedures, and

³⁵ Tracor, Inc., *Community Reaction to Airport Noise, Vol. II* (NASA CR-1761, Washington, 1971), p. 223

³⁶ Bolt, Beranck, and Newman, Inc., *Noise Exposure Forecasts: Evaluation, Extensions and Land Use Interpretations* (FAA, Washington, 1970).

TABLE II-III
COMPARISON BETWEEN CNR AND NEF VALUES

CNR	Runups	NEF
Takeoffs and Landings		
Less than 100	Less than 80	Less than 30
100 - 115	80 -95	30 - 40
More than 115	More than 95	More than 40

Source: CLM/Systems, Inc., *Airports and Their Environment: A Guide to Environmental Planning*. (U.S.Dept. of Transportation, Washington, 1972), p. 99.

TABLE II-IV
ASDS 85dB(A) CONTOUR TABLES FOR SELECTED AIRCRAFT*

Airplane Model	Down Range Distance (Feet)	Aircraft Altitude (Feet)	Cumulative Contour Area (Acres)
C-340	2400	0	34
C-340	4418	426	70
C-340	7899	434	134
B-707	7497	0	420
B-707	8702	134	495
B-707	6473	134	369
B-747	4733	0	256
B-747	5598	134	309
Learjet	5000	0	209
Learjet	6146	188	265
Jet Commander	4500	0	176
Jet Commander	5217	116	207
Jet Commander	5585	176	224
Gulf Stream II	5500	0	278
Gulf Stream II	5665	26	286
Gulf Stream II	6217	116	318
Gulf Stream II	6585	176	340
Jet Star	5500	0	215
Jet Star	5665	26	221
Jet Star	6585	176	263

*Data from: Donald Goldman and Francis X. Maginnis, *Aircraft Sound Description System (ASDS) Application Procedures, Vol. III, Data Tables* (Department of Transportation, FAA-EA-74-2, III, Washington, D.C. 1972).

time of day. Table II-III provides a comparison between the CNR and NEF Scales.

The Aircraft Sound Description System (ASDS) is based on the amount of time that noise levels exceed 85dB(A). It has the advantage of having no subjective correction factors which reflect community response to aircraft noise.³⁷ This method is applied by using one or more scenarios which reflect variation in runway length, air traffic, time of day, or operational procedures.³⁸ ASDS values are easier to calculate than those of the previous two methods.

General Aviation Noise

There are ample data available on the noise effects of air carrier aircraft at airports, but much less information is available on general aviation vehicles and facilities. There are several reports which give the noise levels of general aviation aircraft, but no studies have been completed which illustrate CNR, NEF, or ASDS contours for a general aviation airport.

Noise levels of propeller driven and jet propelled general aviation aircraft are presented in Figure 2-3. This figure shows a line designating noise levels allowable in accordance with FAR Part 36. As can be seen, a number of presently available aircraft are not in compliance with these regulations. Not enough data are available to compile such a figure for business jets. Although business jets are generally noisier, the FAR Part 36 allows them a higher noise level.

Table II-IV shows the area contained within the 85dB(A) contour for several aircraft at various stages of takeoff. Landing figures are not given, because they are smaller than takeoff figures. As one might expect, propeller driven planes do have the least effect, followed by business jets and the commercial carriers, in that order.

Prediction of annoyance and complaint from aviation noise, and specifically general aviation noise, is difficult because of the subjective factors which must be considered. Mathematical models for the prediction of annoyance and complaint levels are available, but their predictive accuracy is questionable.

³⁷ Goldman D and F X Marinis *Aircraft Sound Description System (ASDS) Application Procedures, Vol I-IV* (FAA-EA-74-2, Washington, 1974)

³⁸ *Ibid*

³⁹ Tracor, Inc. *Community Reaction to Airport Noise, Vol I* (NASA CR-1761, Washington D C 1970) Chapter 6

⁴⁰ Platt, M and E K Bastress *The Impact of Aircraft Emissions Upon Air Quality* (S A E, New York, 1972), pp 42-55

Several variables have been identified and appear to be correlated with annoyance and complaint. In one study the annoyance variables were: fear of crash, noise susceptibility, distance from airport, adaptability, air traffic volume, belief in misfeasance, importance of airport, and CNR. The predictive variables for complaint were: CNR, pollution annoyance, disturbance of weekday hours, discussion of noise, disturbance of weekend hours, mobility, ethnicity, size of household, occupation, organizational involvement, misfeasance, fear of crash, age, visitation, rent/house cost, and distance from the airport.³⁹

With the possible exception of business jets, general aviation activity around airports causes few noise problems; especially if such movements are mixed with commercial activity. At an exclusively general aviation airport, there may be noise annoyance, but usually the problem is much less than at air carrier facilities.

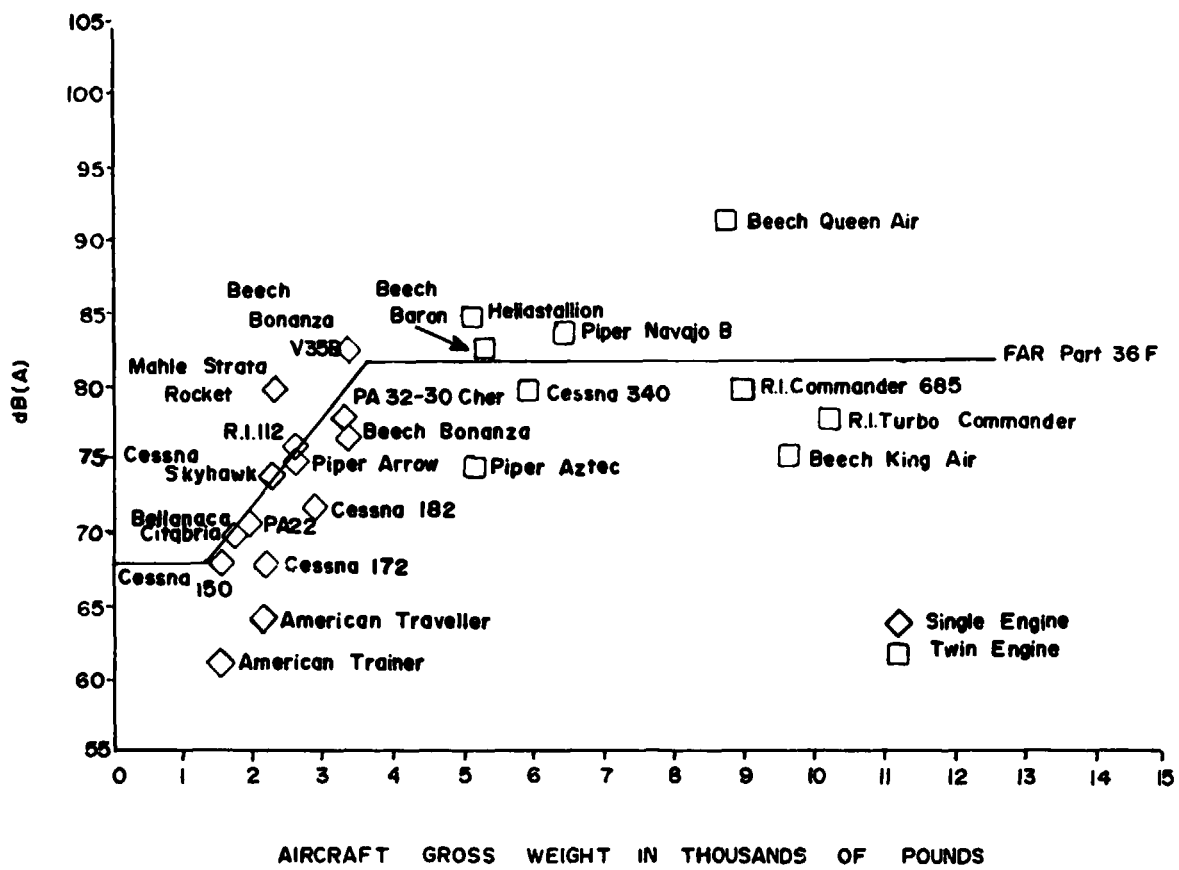
Air Quality

Aircraft air pollution first caused public concern in the 1950's when the turbine-engine was first introduced. The airplane produced visible exhausts which had a more noticeable smell than that of earlier aircraft. Combined with the greater visibility of the airplane in the public eye, it resulted in an increasing amount of public complaint.

Major pollutants caused by aviation are carbon monoxide, nitrogen oxides, non-methane hydrocarbons, particulate matter, and sulfur dioxide.⁴⁰ Section 231 of the Clean Air Amendments of 1970 called for the Environmental Protection Agency to study emissions of air pollutants from aircraft to determine: (1) the extent to which such emissions affect air quality in air quality control regions throughout the United States, and (2) the technical feasibility of controlling such emissions.

Section 231 further required that the Environmental Protection Agency (EPA) establish emission standards for aircraft engines that cause or contribute to air pollution endangering public health or welfare. The EPA was also required to provide a schedule for the implementation of these standards, based on a reasonable cost of compliance and on available technology.

Carbon monoxide (CO) results from the incomplete combustion of hydrocarbon fuels. It is colorless, odorless, and is absorbed in the lungs where it reacts with hemoglobin, thus impairing the ability of red blood cells to transport oxygen.



Source: Noise Certification Rule for Propeller Driven Small Airplanes
 (U. S. Environmental Protection Agency, Project Report, Washington, D. C.
 1974), P 11-1-11-31.

**NOISE LEVELS FOR PROPELLER DRIVEN SMALL AIRPLANES
 AT MAXIMUM CONTINUOUS POWER**

FIGURE 2-3

Nitric Oxide (NO) and nitrogen dioxide (NO₂) are formed by all combustion processes in the Earth's atmosphere. The effects of NO, if any, are unknown. Even low levels of NO₂, however, can cause respiratory problems and chronic lung disease.

Non-methane hydrocarbons are photochemically reactive; non-methane hydrocarbons produced by aircraft engine combustion and unburned fuel components produce several oxidants, primarily ozone, when exposed to sunlight.

Solid or liquid material (smaller than 500 microns) which is dispersed in the air is called particulate matter. Most of the particulate matter from airplanes is carbon and free sulfur. In high concentrations, particulate matter may injure the surfaces of the respiratory system.

Sulfur dioxide (SO₂) is produced by combustion of sulfur-bearing hydrocarbons. The concentration of SO₂ in aircraft exhaust is less than that for automobiles, because aviation fuel is relatively low in sulfur impurities. SO₂ can have a number of adverse effects on health, the most important of which is respiratory damage.

The only major study involving both air carrier and general aviation airports showed that non-methane hydrocarbons and carbon monoxide levels exceeded national ambient air quality standards at some air carrier airports. At general aviation airports, however, these levels did not exceed ambient standards, although the amount of lead approached a potentially harmful level.

General aviation aircraft and airports do not appear to be as significant a cause of air pollution as are automobiles. No instances have been found where concentrations of pollutants exceeded the national air quality standards at general aviation airports.⁴²

Water Quality

Water pollution is a potential problem during both the construction and operation of an airport. Anticipation and prevention of prob-

lems is much more effective than attempting to solve them after the fact. The problem of water with high concentrations of petroleum resulting from servicing airplanes, for example, is solved best by designing the system to separate foul water from other water. Proper airport construction procedures can prevent erosion and sedimentation problems.

The major factors which contribute to water pollution are: physical, construction practices, facility operations, and induced development.⁴³ Airport construction usually involves paving runways, taxiways, and roads, as well as building construction. This construction replaces the natural surfaces which allow infiltration with impermeable surfaces, with a resulting increase in surface water runoff and a decrease in the amount of time for the runoff. This situation creates large peak flows during short time spans, and increases the potential risks and dangers of flooding.

The ground surface serves as the groundwater recharge area. If the surface is sealed by impermeable surfaces, the effect will be to lower the water table.

Removal of natural cover during construction can lead to great increases in erosion and sedimentation if proper construction practices are not followed. An increase in sediment volumes of 5,000 percent, for example, has been reported in situations where there was unregulated stripping without any provision for sediment control.⁴⁴ Sediment load increases can lead to flooding problems due to filling in lakes and streams. They also can cause degradation of the biologic environment because of light filtering and change in substrate type.

This pollution problem covers water used in any part of the facility operation such as maintenance, air conditioning, fire protection, and associated industrial development. Much of this water picks up waste before it is returned to the system. The approach to dealing with these problems is not unlike that of a municipal waste treatment plant except that the water is more contaminated by oil and fuel in the airport area.

Induced development may cause some important problems in waste control. The three main factors to be considered are: (1) water body capacity; (2) water supply and solid waste disposal; and (3) power source and new industry.⁴⁵

General aviation airports, because of their smaller size should cause fewer water problems than air carrier airports. The impact of

⁴¹ *Ibid*

⁴² Los Angeles County Air Pollution Control District, *Study of Jet Aircraft Emissions and Air Quality in the Vicinity of Los Angeles International Airport* (Los Angeles APCD, April, 1971), p. 18

⁴³ CLM/Systems Inc. *Airports and Their Environments, A Guide to Environmental Planning* (U.S. Dept. of Transportation, Washington, D.C., 1972), p. 18

⁴⁴ Schmidt, M. E., *Environmental Effects of Highways*, (*Journal of Sanitary Engineering Division, A.S.C.E.*, Vol. 93, No. SA5, 1967, pp. 17-26)

⁴⁵ CLM/Systems, Inc. *op cit.*, p. 265

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each airport on water quality degradation has to be evaluated individually. Factors to be considered include: rainfall (amount and frequency), topography, stream proximity, stream size and capacity, aquifer recharge areas, soil and rock types and permeability, plant cover, and surrounding land use.

ALTERNATIVE MODES AND TRAVEL SUBSTITUTES

Introduction

Mobility, contemporarily considered as a fifth freedom, has become an accepted, and often demanded, product of the American way. A lifestyle and a value structure founded in Westward expansion today holds freedom of movement in exaltation.

One may travel using public or private means. Aboard intercity public modes (bus, rail, passenger air carrier), travel is regulated as to route followed, fare charged, and quantity of route service provided. To be economical, public modes require the use of large vehicles and a scheduled service.

Private modes are those permitting an individual to transport himself or others in his own vehicle. Automobiles and some portions of general aviation fall into this category. Here, one is governed by his personal demand schedule.

Although general aviation constitutes only a small part of the total transportation system, its impacts tend to be very concentrated. Presently, a large portion of the work force in the United States is involved largely in the manipulation and flow of information. While much of this flow is necessarily personal, face-to-face contact at specific locations, significant amounts of data can, and are, transmitted and received by other means.

The era of "information explosion"—particularly in business, engineering, scientific, and social/behavioral fields—has led to dramatic advances in technological communications. In solid state electronics, the rapid growth and lowered costs of computers, communications systems, and instrumentation technology, plus lowered costs have enabled great advances in information flow. "In other words, we can transmit the products of the white collar worker—his ideas and thoughts (information)—electronically and relieve him of being transported physically so as to capitalize

upon his outputs."⁴⁶ Telecommunications appears to have frequent application as a reasonable and cheap substitute for travel.

Modes alternative to general aviation and the substitutability of telecommunications technology in lieu of intercity travel will be reviewed in this section.

Modal Choice

Transportation modes to be considered in this analysis are those which offer competition with general aviation for both passenger and priority freight. General aviation includes both public and private transportation, the former consisting of air taxis and commuter service; the latter, all other categories.

Highway, railway, and air carrier service are competitive with general aviation service. Highway transportation includes public modes such as intercity buses, priority freight, and common carrier trucking (firms represented by the United Parcel Service or the Railway Express Agency). Private modes using the highway system include the automobile and private trucking. For present purposes, railway services will be limited to passenger movement since railroad freight is not competitive with general aviation in the area of priority freight transport.

A transportation system consists of vehicles, ways, and terminals. The vehicle is characterized by its speed, capacity, range, and energy consumption. The way includes both the physical infrastructure and the control systems, the characteristics of which determine its capacity. The terminal is the point at which access to, and egress from the system occurs. Terminals usually represent a constraint on both the capacity and accessibility of the system.

The following paragraphs describe the technological characteristics of these components for general aviation and for each of the other competing modes, and discusses their integration into an operating transportation system.

The Vehicle

Speed and capacity figures of selected transportation vehicles for both passenger and priority freight are shown in Table II-V. General aviation vehicles are among the fastest, yet they are of limited capacity.

The Way

Three major classifications of the way that are of concern here: (1) airway, (2) highway, and (3) railway. The type of control system associated with the way often determines its

⁴⁶ Lathey, Charles E. *Telecommunications Substitutability for Travel: An Energy Conservation Potential*. Department of Commerce, January 1975.