AN EXAMINATION OF URBAN AREA

S.T.O.L. AIRPORTS

BY

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School of Community and Regional Planning

The University of British Columbia
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Date: April, 1970.
This thesis is an examination of the problems that may arise from the location of S.T.O.L. airports within urbanized areas.

The role of air transportation as a passenger travel mode is considered and the problems facing the existing air transportation system are explored. The potential role of S.T.O.L. aircraft within the air transportation system is examined in detail. Additionally, the benefits that may accrue from the use of S.T.O.L. aircraft in a regional air transport system are discussed extensively.

The criteria to be used when looking for potential S.T.O.L. airport sites are examined in detail. These criteria are applied to three potential S.T.O.L. airport sites within the Vancouver urban area. In some cases the locational criteria were found to be difficult to operationalize. Data on community reaction to noise exposure is inadequate and noise standards are difficult to apply on a wide basis. The concept of land use compatibility around airports is useful but only to the extent that it does not obscure the fact that aircraft operations can cause community disruptions beyond the boundaries of the so-called compatible land uses.

With specific reference to Vancouver, the available data indicates, that on the average, very little terminal access or egress time will be saved if a S.T.O.L. airport were built at a suitable location between the existing airport and the downtown area.

Finally, the paper concludes by suggesting that despite the fact that S.T.O.L. aircraft cannot bring substantial time savings to regional air passengers, a S.T.O.L. air service may mean that many of the regions
under utilized conventional airports could be converted to S.T.O.L. airports and yield substantial savings in the money used to maintain and operate the publically owned airports in the province.
ACKNOWLEDGEMENTS

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CHAPTER ONE

INTRODUCTION

For I dipt into the future, far as human eye could see
Saw the Vision of the World, and all the wonder that would be
Saw the heaven fill with commerce, argosies of magic sails,
Pilots of the purple twilight, dropping down with costly bales.

Alfred Tennyson, Locksley Hall 1842

Background

The economic growth and urbanization of the major Canadian cities have outpaced the development of the transportation facilities that serve them. All modes of transportation make some contribution to the vitality of the urban centers. However, in recent years the congestion and delays that occur in the movement of goods and people in both inter-urban and intra-urban transportation have become increasingly evident.

Each mode of transportation that serves an urban area has its particular characteristics, capabilities and limitations and each requires some kind of infrastructure for its efficient operation. Attempts to increase the efficiency and the capacity of the various transportation modes often require the expansion of existing roads, railbeds, and harbour facilities, or the provision of entirely new facilities such as bulk shipping terminals, container terminals, or multilane expressways.

The air transport system is being faced with the problems of providing new runway, terminal and navigational facilities to accommodate the unprecedented growth in air travel and the new types of aircraft that will soon enter regular service.

The rapid growth that has taken place in commercial air transportation has occurred mainly on the long haul, heavily travelled routes. Large
turbo jet aircraft, operating over long stage lengths at high speed, have brought about significant reductions in costs per seat mile because of the increased productivity of transport aircraft. The more efficient jet transports have tended to be larger and faster. But as aircraft cruising speed and capacity have increased, so has the takeoff distance (fig.1-1). Consequently the land area, required for airports, has increased with the size of aircraft. New airports, which must accommodate the next generation of aircraft, may require up to 18,000 acres of land.*

As a result new airports, such as Montreal's St. Scholastique Airport, have been located far from the urban area, where sufficient land is available at a suitable cost. Not only has the distance to the airport increased in many cases, but the time it takes to get to the airport has increased because of surface traffic congestion. The time required for the ground travel portions of air trips that occur in the most heavily travelled corridors in Canada typically exceed the times for the air portion of the trip (fig. 1-2). The impact of increased airport access time is especially noticeable on the short haul routes. Modern jet aircraft, despite their 550-600 m.p.h. airspeed, have done little to reduce the total journey time for the short haul traveler. Furthermore, there is no improvement that can be made to the airliners now in service, that will reduce total travel time for the short haul traveler. However, short takeoff and landing aircraft (S.T.O.L.) can save time for the traveler making trips of less than 500 miles because these aircraft can be operated from city center or near-city-center airports.

Special infrastructure is required if S.T.O.L. aircraft are to be used effectively in the short haul regional transportation system: convenient, specially designed terminal facilities must be available. These terminals will form one of the novel and critical elements of the
FIGURE 1-1
TRANSPORT AIRCRAFT RUNWAY REQUIREMENTS

FIGURE 1-2
AIRPORT ACCESS TRIP TIME AS A PORPORTION OF TOTAL JOURNEY TIMES
short haul aviation system.

The development of the aircraft, the air traffic control system, the terminal area landing aids and the S.T.O.L. airports must proceed concurrently. An S.T.O.L. air transport system will not be afforded the luxury of evolutionary development as its use develops, as was the case with the airplane, automobile, and the railroad. The system will be put into service almost fully developed. A complete, functioning S.T.O.L. air transport system in an urban area will present many potential problems, that will have to be overcome by careful planning.

In the past, airports have been viewed as entities outside the community master plan, and planners in urban areas have been able to generally ignore the problems associated with aircraft operations. However, in 1973 S.T.O.L. airliners capable of operating from airports very near to the main traffic generating areas of the city will be available for commercial use. The potential contribution that S.T.O.L. air transportation can make toward increasing the efficiency of intercity travel cannot be realized, unless the airport fits harmoniously into plans for community expansion so that space is available for airport development and an adequate ground transportation system is available to move passengers to and from the S.T.O.L. terminals quickly and conveniently.

Statement of the Problem

This thesis is an examination of the planning problems that may arise from the location of an S.T.O.L. airport within an urbanized area.

Method of Solution

The planning problems that may arise from the operation of aircraft from an urban area S.T.O.L. airport can be best examined by
looking at:

1) The potential role of S.T.O.L. aircraft as an intercity transport vehicle.

2) The operational requirements of S.T.O.L. aircraft within urban areas.

3) The locational requirements of S.T.O.L. airports.

4) The community effects of the operation of S.T.O.L. aircraft from special urban area airports.

An examination of the broad spectrum of passenger transportation modes will be conducted in order to establish the role of air transportation as a passenger travel mode. The shortcomings of the existing air transport system will be considered and the potential improvements to the air transport system through the use of S.T.O.L. aircraft will be discussed.

Once the potential for a S.T.O.L. air transportation has been established, the terminal requirements of S.T.O.L. aircraft will be derived by examining the operational characteristics of S.T.O.L. aircraft. The next step will be to briefly examine the three types of Stolports that can be located in urban areas. Finally the more general considerations regarding S.T.O.L. airport locations will be derived by examining the possible effects of S.T.O.L. aircraft operations on built-up areas.

The information derived from the foregoing examination will then be brought together and applied to the Vancouver Metropolitan area in order to determine the problems arising from the location of a S.T.O.L. airport in an urban area.
Problem Limitations

In the analysis conducted in this thesis the following assumptions and limitations are accepted:

Assumptions

1) A National Aviation Plan exists.

2) A Regional Airport Plan exists.

3) A survey of the existing airport system has been conducted.

4) An inventory of existing local and regional development plans that may affect airport development has been carried out.

5) The Regional Airport Plan indicates the need for a S.T.O.L. Airport in the Vancouver Metropolitan area.

6) There will be no major changes in aircraft technology that will alter the present technical and economic relationships between the various types of aircraft.

Limitations

1) The analysis is limited by the availability of appropriate data. Where necessary, data gathered in other cities or countries will be used as a supplement to or a proxy for necessary data.

2) This thesis is confined to the analysis of the planning implications of the operation of S.T.O.L. aircraft from S.T.O.L. airports in urban areas.

3) This thesis does not examine the air cargo aspects of S.T.O.L. air transport.

Definitions

When the following terms are used in this thesis they have the following meanings:
Configuration: (As applied to aircraft) A particular position of movable elements such as wings, flaps, landing gear, etc. which affects the aerodynamic characteristics of the aircraft.

Air Service: Means any scheduled air service performed by aircraft for public transportation of passengers, mail or cargo.

Air Traffic Control: A service provided for the purpose of
1) Preventing collision
   a) between aircraft; and
   b) between aircraft and obstructions.
2) Expediting and maintaining the orderly flow of air traffic.

Airway: A controlled area or portion thereof established in the form of a corridor equipped with radio navigation aids.

Controlled Airspace: An airspace of defined dimensions within which air traffic control service is provided to IFR flights.

Glide Path Angle: The angle of the glide path above the horizontal plane.

Holding Procedure: A predetermined maneuver which keep aircraft within a specified airspace while awaiting further clearance.

Holding Point: A specified point or location identified by visual or other means in the vicinity of which an aircraft in flight is maintained in accordance with air traffic control clearances.

I.L.S.: Instrument landing system. A radio aid to navigation intended to assist aircraft in landing. It provides lateral and vertical guidance including an indication of distance from the optimum point of landing.

Procedure Turn: A manoeuvre in which a turn is made away from a designated track followed by a turn in the opposite direction, both turns being executed so as to permit the aircraft to intercept and proceed along the reciprocal of the designated track.

Route Segment: A route or a portion of a route usually flown without an intermediate stop.

Terminal Area Control: A control area normally at the confluence of air routes in the vicinity of one or more major airports.

Touchdown: The point where the nominal glide path intercepts the runway.

Threshold: The beginning of the portion of the runway available for landing.
CHAPTER 1

FOOTNOTES


4) The figure is derived from two sources. The airport processing times were provided by Air Canada and the travel times from the C.B.D. to the airport were taken from V. Setty Pendakur, A Discussion of Stiener.M. Silence., "A Preliminary Look at Ground Access to Airports," A paper presented at the 48th Annual Meeting Highway Research Board. Washington D.C.: (Jan. 1969) Table 1.


CHAPTER TWO

Passenger Transportation

There are three general reasons why people travel: to meet other people for business or private reasons; for holidays or recreational purposes; or to reach a work place.

Depending on the reason for travel, different factors are taken into consideration before deciding on which mode of travel to select. Time saving is especially important for business travelers. Trip time is influenced not only by the vehicle speed but also by such factors as frequency and timing of service, the number of transfers required, and the accessibility of the mode. The cost of the trip is not as important to the business traveler as it is to the private traveler. ¹, ².

Intangible factors such as comfort and perceived safety of the mode may also have a significant effect on the choice of travel mode. ³

Automobile Travel

The automobile has several characteristics that make it an attractive travel mode. These characteristics are speed, comfort, flexibility of routing, availability and low perceived cost. The automobile is available at any time and it takes the traveler from his point of origin to his destination without transfers and loss of time. It can also be used for both local and intercity travel purposes. ⁴, ⁵.

The attractiveness of the automobile as a travel mode declines when roads are congested or when travel speeds are reduced during bad weather conditions such as fog or snow. In addition, the driver cannot relax or work during the trip and parking can be a problem at the destination. ⁶
Bus Travel

Bus travel offers the traveler economical, comfortable transportation to many points not served by other modes of public transportation. In addition, bus transportation has the capability of making efficient use of the existing urban road systems. Another important feature of the bus mode is its potential capacity to move large numbers of passengers. Under ideal conditions, a system of passenger buses, operating on an expressway with televised traffic surveillance and lane control, can move up to 50,000 passengers per hour. The principal disadvantage of the bus mode is that its average travel speed tends to be rather low.

Rail Travel

Trains have a high passenger carrying capability, up to 40,000 persons per hour. They provide reasonable service during poor weather and restricted visibility. The principal attractions of rail travel are the spaciousness of rail cars and the downtown to downtown convenience that it offers the user. The disadvantages of train travel arise from the time lost in waiting for and changing trains. Also rail travel is generally more expensive than automobile travel (four passengers) or bus travel (see figure 2-1). Even so, the train passenger may not pay the full cost of his trip since most passenger services are operated at a loss and therefore have to be cross-subsidized from freight revenue or given a direct subsidy from the government. The travel speeds of trains can be fairly high, up to 150 m.p.h., but conventional trains are generally the slowest mode of travel. Moreover, the destinations that a traveler can reach by train are limited by the track system.
FIGURE 2-1
COMPARISON OF PASSENGER FARES

0 100 200 300 400 500

CENTS PER PASSENGER MILE

Auto Bus Air Rail

FIGURE 2-2
TRIP TIME VS. CITY CENTRE DISTANCE

0 100 200 300 400 500

CITY CENTRE DISTANCE - MILES

TRIP TIME IN MINUTES

Bus, Automobile & Train
Conventional air
Air Travel

First, in regions such as British Columbia with an uneven distribution of population, transportation links must often cross rugged areas where, there is little or no traffic, so the cost of surface transportation facilities can be very great. Under such circumstances the infrastructure for air transportation can be less expensive than would be the case for road or rail modes.

Secondly, air transport offers the advantages of speed and distances are often 15 to 25 percent shorter by air when barriers such as mountains or water bodies make surface transportation circuitous. Often air transportation offers a regularity of service that cannot be attained by surface modes. However, aircraft movements are occasionally severely affected by poor visibility conditions which cause flight delays or even cancellations.

Travel by air has a certain number of direct effects that are immediately appreciated by the air traveler. It offers speed, comfort, the reduction of fatigue, status and generally modern clean vehicles. Aircraft provide fast transportation between airports, but the time required to get to and from the airport can reduce the advantage of high speed on trips of less than 400 miles.

Aircraft have the advantage of not requiring an expensive track system so that there is a good deal of flexibility in the choice of the points served and the frequency of service that is offered.\textsuperscript{14,15}. Figure 2-2 shows city center to city center travel times for the four modes discussed above.
TABLE 2-1

Intercity Passenger Miles in Canada 1961-1962
Percent Distribution by Mode of Transport and Distance of the Trip

<table>
<thead>
<tr>
<th>Distance (miles)</th>
<th>All Modes</th>
<th>Automobile</th>
<th>Bus</th>
<th>Rail</th>
<th>Air</th>
<th>Combinations</th>
</tr>
</thead>
<tbody>
<tr>
<td>100-299</td>
<td>100</td>
<td>92</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>300-499</td>
<td>100</td>
<td>79</td>
<td>3</td>
<td>12</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>500-999</td>
<td>100</td>
<td>66</td>
<td>3</td>
<td>14</td>
<td>16</td>
<td>1</td>
</tr>
<tr>
<td>1000 &amp; over</td>
<td>100</td>
<td>49</td>
<td>2</td>
<td>28</td>
<td>18</td>
<td>3</td>
</tr>
</tbody>
</table>

Mode Choice and Travel Distance

As may be seen in the above table, as travel distance increases the percentage of total travelers using each mode changes markedly. For example, the automobile accounts for 92 percent of passenger miles in the 100-299 mile distance group, but only 49 percent of the 1000 and over group. As distance increases air and rail capture an increasing proportion of the passenger traffic. Rail and air carry only 4 percent and 1 percent respectively of the 100-299 mile traffic, but they account for 28 percent and 18 percent of all passenger traffic moving over distances greater than 1000 miles. Evidently, travel distance has little effect on the proportion of the public travelling by bus. Buses seem to carry about 3 percent of all travelers in each distance group.

As was mentioned previously, the mode that a traveler chooses depends in part on his trip purpose. Tables 2-2 and 2-3 show trip length distributions by mode for business and non-business purposes of travelers in the U.S. Northeast corridor.
TABLE 2-2

Business Trips
Percent Distribution of Trips by Mode

<table>
<thead>
<tr>
<th>Distance (miles)</th>
<th>Automobile</th>
<th>Bus</th>
<th>Rail</th>
<th>Air</th>
</tr>
</thead>
<tbody>
<tr>
<td>80-149</td>
<td>52.7</td>
<td>5.2</td>
<td>38.4</td>
<td>3.6</td>
</tr>
<tr>
<td>150-249</td>
<td>38.9</td>
<td>4.8</td>
<td>12.5</td>
<td>43.8</td>
</tr>
<tr>
<td>250-over</td>
<td>18.3</td>
<td>2.3</td>
<td>17.9</td>
<td>61.5</td>
</tr>
</tbody>
</table>

TABLE 2-3

Non-Business Trips
Percent Distribution of Trips by Mode

<table>
<thead>
<tr>
<th>Distance (miles)</th>
<th>Automobile</th>
<th>Bus</th>
<th>Rail</th>
<th>Air</th>
</tr>
</thead>
<tbody>
<tr>
<td>80-149</td>
<td>74.4</td>
<td>8.5</td>
<td>16.0</td>
<td>1.0</td>
</tr>
<tr>
<td>150-249</td>
<td>56.0</td>
<td>13.7</td>
<td>15.7</td>
<td>14.6</td>
</tr>
<tr>
<td>250-over</td>
<td>57.9</td>
<td>10.1</td>
<td>14.4</td>
<td>17.6</td>
</tr>
</tbody>
</table>

The foregoing sections provided a brief view of the range of passenger travel modes. The following sections will explore in more detail the principal features of the air transport system.

The Air Transport System

Basically, the air transport system (Figure 2-3) contains three sub-systems---the air vehicle, enroute services (airways, navigation, approach, control, meteorology), and the airport terminal with its surface transportation system. The sub-systems are interdependent and changes in one sub-system affect all the rest. User demand will rise or fall as the system provides or fails to provide service that is economical, fast, dependable, comfortable and safe. The air transport system functions in a dynamic environment composed of people and their
FIGURE 2-3
THE AIR TRANSPORT SYSTEM

DEMAND

AIRCRAFT

AIRPORT TERMINALS & ACCESS

EN ROUTE SERVICES

FIGURE 2-4
NORTH AMERICAN AIR PASSENGER TRIP
LENGTH DISTRIBUTION

MILLIONS OF PASSENGERS

LENGTH OF PASSENGER TRIPS - STATUTE MILES
economy. This environment influences and shapes the nature of the demands that are made upon the system, simultaneously offering both opportunities and constraints. On one hand, a growing population and economy creates new markets for air transport: on the other hand, factors such as noise, pollution, government controls and terminal access problems tend to restrain its growth.  

Figure 2-4 shows the distribution of air passenger trip lengths for flights occurring in North America. The median trip length is between 400 and 450 miles. The same general distribution of trip length exists for flights within Europe.

As was mentioned previously people travel for various purposes. The 1970 "Inter-City Passenger Transportation Study", conducted by the Canadian Transport Commission, found that people travel by air to and from various Canadian cities for six principal purposes. These purposes are listed in Table 2-4.

<table>
<thead>
<tr>
<th>Trip Purpose of Air Travelers</th>
<th>Ottawa-Toronto</th>
<th>Ottawa-Montreal</th>
<th>Montreal-Toronto</th>
<th>Toronto-Quebec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ottawa-Toronto</td>
<td>3.08</td>
<td>3.21</td>
<td>3.68</td>
<td>17.08</td>
</tr>
<tr>
<td>Ottawa-Montreal</td>
<td>11.30</td>
<td>7.08</td>
<td>8.16</td>
<td>7.95</td>
</tr>
<tr>
<td>Montreal-Toronto</td>
<td>.53</td>
<td>.23</td>
<td>.90</td>
<td></td>
</tr>
<tr>
<td>Toronto-Quebec</td>
<td>.20</td>
<td></td>
<td>.45</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>
In the U.S. there is proportionately more air travel for non-business purposes than there is in Canada. Table 2-5 shows trip purpose for U.S. air travelers.  

### TABLE 2-5

<table>
<thead>
<tr>
<th>Year</th>
<th>Business</th>
<th>Non-Business</th>
</tr>
</thead>
<tbody>
<tr>
<td>1955</td>
<td>63</td>
<td>37</td>
</tr>
<tr>
<td>1961</td>
<td>61</td>
<td>39</td>
</tr>
</tbody>
</table>

**Aircraft Types**

There are three basic types of aircraft used in the air transport system: conventional takeoff and landing (C.T.O.L.) aircraft, short takeoff and landing (S.T.O.L.) aircraft, or vertical takeoff and landing (V.T.O.L.) aircraft.

Air routes that these aircraft operate over are divided into short, medium and long hauls according to the length of flight stage. However, classification varies from one airline to another depending, as a rule, on the type of aircraft used and the route structure. There is no standardized system for designating route lengths. Lufthansa and Swissair even distinguish between short and very short routes. Table 2-6, shown below, lists some general route classifications used in Europe and Great Britain.

### TABLE 2-6

<table>
<thead>
<tr>
<th>Type of Stage</th>
<th>Lufthansa</th>
<th>Swissair</th>
<th>Sabena</th>
<th>B.E.A.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Short</td>
<td>Up to 220</td>
<td>Up to 150</td>
<td>Up to 300</td>
<td>Up to 150</td>
</tr>
<tr>
<td>Short</td>
<td>220- 500</td>
<td>150- 900</td>
<td>300-1800</td>
<td>150- 450</td>
</tr>
<tr>
<td>Medium</td>
<td>500- 1800</td>
<td>900- 2200</td>
<td>1800</td>
<td>450</td>
</tr>
<tr>
<td>Long</td>
<td>Over 1800</td>
<td>Over 2200</td>
<td>Over 1800</td>
<td>Over 450</td>
</tr>
</tbody>
</table>
C.T.O.L. Aircraft

Conventional aircraft are classified according to the length of route over which they operate and the number of passengers they carry. Table 2-5 lists the characteristics of the major C.T.O.L. aircraft.

### Table 2-7
Conventional Aircraft Classification

<table>
<thead>
<tr>
<th>Operation</th>
<th>Type</th>
<th>Passenger</th>
<th>Cruise Speed</th>
<th>Range With Maximum Passengers</th>
<th>Runway Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long Haul</td>
<td>Concorde</td>
<td>128</td>
<td>1,176</td>
<td>3,500</td>
<td>9,450</td>
</tr>
<tr>
<td></td>
<td>Boeing 747</td>
<td>415</td>
<td>512</td>
<td>5,000</td>
<td>11,200</td>
</tr>
<tr>
<td></td>
<td>Boeing 707-320B</td>
<td>180</td>
<td>480</td>
<td>5,000</td>
<td>10,350</td>
</tr>
<tr>
<td></td>
<td>Douglas DC-8-63F</td>
<td>220</td>
<td>480</td>
<td>2,000</td>
<td>11,900</td>
</tr>
<tr>
<td>Medium Haul</td>
<td>Lockheed Tri Star</td>
<td>295</td>
<td>490</td>
<td>2,700</td>
<td>8,000</td>
</tr>
<tr>
<td></td>
<td>Boeing 727-100</td>
<td>119</td>
<td>119</td>
<td>2,000</td>
<td>7,400</td>
</tr>
<tr>
<td>Short Haul</td>
<td>B.A.C. Three Eleven</td>
<td>220</td>
<td>475</td>
<td>1,370</td>
<td>6,600</td>
</tr>
<tr>
<td></td>
<td>DC-9-30</td>
<td>109</td>
<td>460</td>
<td>1,000</td>
<td>6,800</td>
</tr>
<tr>
<td></td>
<td>F27</td>
<td>44</td>
<td>240</td>
<td>1,000</td>
<td>4,600</td>
</tr>
<tr>
<td></td>
<td>Twin, otter</td>
<td>18</td>
<td>175</td>
<td>400</td>
<td>2,000</td>
</tr>
</tbody>
</table>

Conventional aircraft are also classified according to the type of propulsion system they use. There are three principal types of aircraft propulsion systems: reciprocating engines and a propellor, turbo-jet engine and propellor (turbo-prop) and turbo-jet. Furthermore, an aircraft can be classified in terms of the number of wings, the shape of the wings and where the wings are positioned on the aircraft. For example, a typical modern commercial airliner might be described as a 100 passenger medium range, mid-wing turbo-jet monoplane. A typical jet C.T.O.L. aircraft is shown in figure 2-5.

V.T.O.L. Aircraft

Vertical takeoff and landing aircraft can be classified into five categories:
1) Helicopters
2) Compound helicopters including folding rotor aircraft
3) Tilt wing, turbo jet or turbo propellor
4) Lift fan in wing
5) Lift jets in fuselage

Helicopters gain lift in flight from a power driven rotor. In a compound helicopter the rotor system is generally used to provide lift during landing and takeoff. In flight, the rotor can either be stopped and stowed in fuselage of the aircraft, or it can remain in motion during flight to supplement the lift provided by the aircraft wing. The exact mechanism for providing lift for compound helicopters may vary depending on the type of aircraft under consideration.

Tilt wing aircraft are able to takeoff and land vertically by changing the angle of incidence of the aircraft wing, and then using the aircraft propulsion system to provide vertical thrust. The transition from vertical to horizontal flight is made by gradually rotating the aircraft wings so that they begin to provide lift as forward speed increases. During landing a reverse procedure is followed.

Lift fan and lift jets are fitted to aircraft to provide lift for vertical flight and for transition from vertical to horizontal flight and vice versa. Figure 2-6 illustrates a helicopter, Figure 2-7, a folding rotor aircraft, Figure 2-8, a tilt wing aircraft, and Figure 2-9 shows a fan-in-wing V.T.O.L. aircraft.

Before discussing S.T.O.L. aircraft it should be pointed out that the helicopter is the only V.T.O.L. aircraft certified for civil use. All the other types of V.T.O.L. aircraft have flown at one time or another but none has been given approval for regular airline use.
FIGURE 2-7
FOLDING ROTOR - V.T.O.L. AIRCRAFT

- 69 FT 7 IN.
- 12-FT 4-IN. DIAM
- 65 FT 7 IN.

- 49-FT 4-IN. DIAM
- 103 FT
- 32 FT 6 IN.
- 96 FT 6 IN.

FIGURE 2-8
TILT WING - V.T.O.L. AIRCRAFT

- 84 FT 7 IN.
- 22-FT 8-IN. DIAM
- 104 FT

- 102 FT
- 29 FT 7 IN.
- 96 FT 6 IN.
Although the production of a reliable V.T.O.L. aircraft is technically feasible, there is considerable dispute among aircraft experts as to when an economically feasible commercial V.T.O.L. aircraft will be available for airline service. 

**S.T.O.L. Aircraft**

S.T.O.L. aircraft have the same general configurations as C.T.O.L. aircraft. In effect S.T.O.L. aircraft are modified conventional aircraft which incorporate special devices to produce high lift at takeoff and high drag during landing. The important high lift devices used in S.T.O.L. aircraft are listed below:

1) Vectored thrust
2) Boundary layer control
3) Slipstream deflection
4) Jet flaps
5) Augmentor wings

S.T.O.L. aircraft, like C.T.O.L. aircraft, can also be classified according to passenger capacity, range, and propulsion systems. Figure 2-10 shows a proposed Boeing Aircraft jet S.T.O.L. aircraft. The S.T.O.L. type of aircraft appears to have an assured future in commercial aviation. Major research and development has already resolved many S.T.O.L. problems and it is expected to continue to yield improvements in efficiency, reliability and the operating characteristics that will make S.T.O.L. aircraft exceptionally attractive for civil use. But, wholesale supplanting of C.T.O.L. by S.T.O.L. is not anticipated.

**Comparison of C.T.O.L., S.T.O.L. and V.T.O.L. Aircraft**

The type of aircraft used to provide air service on a particular
FIGURE 2-9
FAN-IN-WING V.T.O.L. AIRCRAFT

FIGURE 2-10
PROPOSED BOEING S.T.O.L. AIRCRAFT
route, assuming sufficient demand, depends upon the available airports, route stage lengths, winds and distances to alternate airports and the operating costs of the aircraft moved. 

Figure 2-11 presents a comparison of the operating costs of each type of aircraft. Conventional aircraft have the lowest operating cost, 1 cent per seat mile. S.T.O.L. costs about 1.2 cents per seat mile and helicopters cost about 2 cents per seat mile. Tilt wing and jet lift V.T.O.L. aircraft operating costs are slightly more (1.3 cents per seat mile) than S.T.O.L. aircraft costs.

The total trip time for the various aircraft types can be seen by referring to figure 2-12. Conventional aircraft provide the longest trip times for journeys of less than 400 miles. The helicopter provides the most rapid journey for trips of up to about 80 miles. V.T.O.L. aircraft have the fastest trips for distances of from about 80 miles to the limit of the range of the aircraft. S.T.O.L. aircraft, have a longer trip time than V.T.O.L. aircraft, but they do provide faster transportation for journeys of from 80 miles to about 400 miles than do C.T.O.L. aircraft or helicopters. The foregoing comparisons are based on the assumption that V.T.O.L. aircraft can operate from the centre of traffic generating areas, whereas S.T.O.L. aircraft are assumed to operate from terminals geographically located somewhere between the centre of traffic generating areas and the conventional airport.

The landing and takeoff characteristics of each type of aircraft are of particular interest in this study because they ultimately determine the major dimensions of the airport facilities required for each type of aircraft.

Conventional aircraft generally require a minimum 6000 ft. runway. The normal glide slope for a conventional aircraft is about 3 degrees.
FIGURE 2-11

90 PASSENGER AIRCRAFT - 350 MILE TRIP

FIGURE 2-12

(Includes Terminal Time and Access Time)
U.S. NORTHEAST
V.T.O.L. aircraft are able to climb and descend vertically, thus making possible operations from small areas near the center of the city such as parks or parking lots surrounded by high buildings. In practice, however, this procedure is not practicable, at least at present, because of the difficulty of controlling a prolonged vertical descent. In addition, vertical flight operations require high engine power output that results in a correspondingly high fuel consumption. In practice, a V.T.O.L. aircraft would travel vertically to about 25 feet and then the climb path would become about 10 degrees. For landing, the final approach angle would be approximately 6 degrees. At a point about 100 feet from touch down the aircraft would make the transition from forward to hovering flight and then descend vertically the last 25 feet.\(^{39}\)

S.T.O.L. aircraft require a short run on the ground before takeoff or landing. The ground roll required for takeoff is normally longer than that required for landing. For example, the De Havilland D.H.C. 7 S.T.O.L. airliner (on a standard day at sea level with no wind) requires a takeoff roll of 1250 feet and a 760 feet landing roll.\(^{40}\)

Despite the fact that there have been rapid developments in the technology of the aircraft, there has been a simultaneous deterioration in other sub-systems of the air transport system which has tended to negate the gains, in terms of reduced trip times, which would have otherwise accrued to the travelling public.

Problems of the Existing C.T.O.L. Air Transport System

The rapid growth in air transportation in all branches of civil aviation has brought about serious problems in air traffic congestion and aircraft handling. At some of the larger U.S. airports congestion
is the rule rather than the exception, and the time is nearing when this congestion will cause enroute traffic backups and a spreading of the situation to otherwise uncongested areas. 41

The major problems with C.T.O.L. air transport are:

1) A highly constrained airways system
2) Inadequate runway acceptance rates
3) Radar limitations
4) Terminal area and ground maneuvering congestion
5) Conventional aircraft performance

The Airways System - The present airways structure, as well as approach and departure patterns are predicated and limited by the geographic location of radio navigation aids. The location of these aids imposes an inflexibility in routing and necessitates funneling aircraft in and out of common points. In theory, the vertical separation of aircraft should permit multiple convergence on radio navigation aids. In practice, however, inadequate altitude information, altimetry tolerances and excessive air traffic controller workloads force the controller to treat the problem of aircraft separation as if it were two dimensional: thus vertical separation benefits are lost. 42

Runway acceptance rates - The rate at which runways can accept aircraft is considerably lower than the rate at which aircraft can arrive in the airspace controlled by the terminal air traffic controllers. This difference in acceptance rates results in airways congestion in the airspace used to hold aircraft not able to land immediately at an airport. The congested conditions in one terminal can be propagated rapidly throughout the system so that aircraft may be forced to fly holding patterns hundreds of miles from their destination. In exceptional
cases aircraft may be prevented from taking off until a landing assignment is secured from the destination terminal. Poor weather can further aggravate the problem when aircraft must use the instrument landing system (I.L.S.) because a runway accepts fewer aircraft under instrument flight rules (I.F.R.) than it does under visual flight rules (V.F.R.). Furthermore, the high landing speeds and runway requirements of C.T.O.L. aircraft combine to yield high runway occupancy times.  

Radar Limitations - Radar is the most important instrument used by air traffic controllers. Operational experience with existing radar systems has revealed a number of limitations in the equipment. In order to compensate for these limitations the distance between aircraft is greater than would be necessary if the equipment were more reliable.  

Terminal Area and Ground Congestion - In terminal area operations, the navigation and control functions are carried out by air traffic controllers. The flight crew possess a minimum of navigation data and authority because most air traffic control is based on radar vectoring. The information provided by ground based radar is both supplemented and implemented by voice communication. Because of equipment failures and communication interference, the information transfer rates are slow and the time required to make decisions is extended. Air traffic controllers compensate for this delay by increasing aircraft separation or by directing aircraft to fly over time and distance consuming patterns.  

Conventional Aircraft Performance Characteristics - C.T.O.L. aircraft have been developed primarily from the standpoint of economical operation. These aircraft are designed for efficient cruise performance; runway lengths, maneuverability, climb and descent characteristics are
secondary considerations. As a result current C.T.O.L. aircraft require large airborne turning radii and a shallow climb and descent gradient. These operational characteristics of C.T.O.L. aircraft, combined with noise control procedures in terminal areas, effectively restrict the number of possible C.T.O.L. aircraft approach and departure patterns. These factors result in less than optimal use of runways and airspace.\textsuperscript{46}

In order to relieve congestion and accommodate passenger traffic growth, airports are using increasingly large amounts of land. Figure 2-13 shows the increase in airport land area required by major world airport authorities during the past 20 years. The upper curve shows the total land area used for airport facilities, including land for aviation-linked facilities such as access roads, car parking and air oriented industry. The lower curve indicates the actual land used for airport purposes.\textsuperscript{47}

The increasing size requirements of airports and the high cost of land means that airports have to be very far from city centers. The 1980"model" airport will require approximately 10,000 acres of land. Such a large amount of land is rarely found a convenient distance from a city.\textsuperscript{48}

As a result new airports may have to be located from 20 to 40 miles away from the cities they serve. Airports located at such great distances from a city require some form of rapid terminal transportation if they are to make a maximum contribution to the efficiency of the air transport system.\textsuperscript{49} There does not, however, seem to be an effective, inexpensive means of transporting people quickly to and from outlying airports.\textsuperscript{50}
FIGURE 2-13
GROWTH OF AIRPORT SIZE

YEAR

FIGURE 2-14
EFFECT OF TERMINAL TRANSPORT AND DELAY TIME

ONE HOUR TERMINAL TRANSPORT AND DELAY TIME

TWO HOUR TERMINAL TRANSPORT AND DELAY TIME
Airport Access

The problem of airport accessibility is becoming increasingly important as both air traffic and ground traffic increase in the areas served by airports. The travel time between transportation terminals has been reduced substantially by the airplane. At the same time the increasing size and traffic congestion of cities has made it increasingly difficult to gain access to the air terminal. Often the time saved by air travel is lost during the trip from the airport to the final destination. There is considerable evidence to suggest that an increase in the journey time to and from the airport has a negative effect on the popularity and use of the air transport system.

The importance of airport accessibility to air travel has been examined in a number of U.S. studies. Generally the studies are concerned with relocations of airports and the resulting passenger flows through them. The studies contain several flaws that make interpretation rather difficult. The first point to consider is that relocation of an airport may increase traffic generation from other areas. Consequently, the change in passenger traffic resulting from moving an airport may be understated, because new traffic could have been generated in areas not served by the original airport. Second in some cases the highway system was improved when the airport was relocated so that the change in travel time was not proportionately as great as the change in travel distances. Table 2-8 summarizes the results of five U.S. airport access studies.
### TABLE 2-8

Air Passenger Generation Versus Airport Accessibility

<table>
<thead>
<tr>
<th>Survey Area and year</th>
<th>Accessibility Factor</th>
<th>Traffic generation in the less favourable case compared with the more favourable</th>
</tr>
</thead>
<tbody>
<tr>
<td>21 California Airports 1950</td>
<td>Average passenger generation of cities at 10-20 miles distance compared with cities at 0-10 miles distance.</td>
<td>35%</td>
</tr>
<tr>
<td>Buffalo Airport 1952-1953</td>
<td>Average passenger generations of cities at 15-25 distances, compared with cities 0-15 miles distance.</td>
<td>60%</td>
</tr>
<tr>
<td></td>
<td>Average passenger generation of cities at more than 25 miles distance compared with cities at 0-15 miles distance.</td>
<td>25%</td>
</tr>
<tr>
<td>Detroit 1946</td>
<td>Airport relocation 6 miles from the city to 36 miles from the city.</td>
<td>55%</td>
</tr>
<tr>
<td>Fort Worth 1951</td>
<td>Airport relocation 5 miles from the city to 18 miles from the city.</td>
<td>65%</td>
</tr>
<tr>
<td>New York Met. Area 1956</td>
<td>Passenger generation of individual counties affected by a 1 hour difference in airport transport time.</td>
<td>50%</td>
</tr>
</tbody>
</table>

The different results do not fully agree with each other but they do demonstrate that airport accessibility is a very important factor in the attractiveness of air travel. This situation of decreased air passenger traffic generation with increasing distance from an airport was investigated by Bjørn J. Elle who has concluded that "The amount of travel over a certain distance is determined essentially by how long it takes to cover this distance". He developed the table, shown below, which relates the frequency of travel to the overall duration of the trip.
<table>
<thead>
<tr>
<th>Duration (hours)</th>
<th>Frequency Index</th>
<th>Duration (hours)</th>
<th>Frequency Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00</td>
<td>100.</td>
<td>3.50</td>
<td>6.45</td>
</tr>
<tr>
<td>1.25</td>
<td>67.3</td>
<td>3.75</td>
<td>5.17</td>
</tr>
<tr>
<td>1.50</td>
<td>46.6</td>
<td>4.00</td>
<td>4.40</td>
</tr>
<tr>
<td>1.75</td>
<td>31.1</td>
<td>4.25</td>
<td>3.76</td>
</tr>
<tr>
<td>2.00</td>
<td>25.2</td>
<td>4.50</td>
<td>3.18</td>
</tr>
<tr>
<td>2.25</td>
<td>19.3</td>
<td>4.75</td>
<td>2.70</td>
</tr>
<tr>
<td>2.50</td>
<td>15.1</td>
<td>5.00</td>
<td>2.35</td>
</tr>
<tr>
<td>2.75</td>
<td>11.7</td>
<td>5.25</td>
<td>2.00</td>
</tr>
<tr>
<td>3.00</td>
<td>9.50</td>
<td>5.50</td>
<td>1.74</td>
</tr>
<tr>
<td>3.25</td>
<td>7.82</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The table shows, for example, that if a total door to door travel time of 3.00 hours is reduced to 2.75 hours, the traffic will increase by a factor of $\frac{11.7 - 9.5}{9.5}$ or 23 percent. It appears, based on the above findings, that the need for a high degree of passenger accessibility and the need for large amounts of land for new C.T.O.L. airports are in conflict. However, a system of S.T.O.L. aircraft, operating from S.T.O.L. airports near the city center, can help to resolve this conflict.

**Advantages of S.T.O.L. Air Transportation**

The provision of city center S.T.O.L. air transport service opens up an additional airline service capability which is of great importance. Short range, less than 500 miles, city center to city center aircraft operation can have a significant effect on air travel. It can save the traveler time in reducing ground travel and in reducing or eliminating airline transfers; it can also relieve the major long haul airports of a significant amount of traffic and thereby reduce airport congestion. The removal of short range air traffic from the major airports may also prevent or reduce the need for new large airports that might otherwise
be required to accommodate the anticipated growth in conventional air travel.

The total trip time needed to complete a flight by S.T.O.L. aircraft can be less than that required for a comparable flight by C.T.O.L. aircraft because savings can be made in terminal access times. The following table details the components of total trip time between two representative central areas of Montreal and Toronto for a jet C.T.O.L. aircraft flight and a S.T.O.L. turbo-prop aircraft flight. Even though the S.T.O.L. flight phase is longer than that of the C.T.O.L. aircraft, there is enough time saving in the estimated S.T.O.L. airport access, egress, and terminal processing portions of the trip to make the S.T.O.L. aircraft trip time shorter.

**TABLE 2-10**

<table>
<thead>
<tr>
<th></th>
<th>Total Montreal - Toronto Trip Time (Hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S.T.O.L. Versus C.T.O.L.</td>
</tr>
<tr>
<td></td>
<td>60</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Access</td>
<td>.25</td>
<td>.45</td>
</tr>
<tr>
<td>Terminal Processing</td>
<td>.67</td>
<td>1.40</td>
</tr>
<tr>
<td>Flight</td>
<td>1.47</td>
<td>1.08</td>
</tr>
<tr>
<td>Egress</td>
<td>.33</td>
<td>.57</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>2.72</td>
<td>3.50</td>
</tr>
</tbody>
</table>

This potential time saving may not apply to the whole city and certainly does not to areas of the city situated near the C.T.O.L. airport.

Table 2-11 permits comparison of the travel time between downtown points in Canada and U.S. using various mode of transport and two types of aircraft.
TABLE 2-11

Trip Times (in minutes) Downtown to Downtown
By Road, Train, C.T.O.L. Aircraft and
S.T.O.L. Aircraft

<table>
<thead>
<tr>
<th>City Pair</th>
<th>Distance Air Miles</th>
<th>Distance Road Miles</th>
<th>Road</th>
<th>Rail</th>
<th>C.T.O.L.</th>
<th>S.T.O.L.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ottawa-Montreal</td>
<td>120</td>
<td>126</td>
<td>140</td>
<td>130</td>
<td>140</td>
<td>26</td>
</tr>
<tr>
<td>Toronto-Ottawa</td>
<td>215</td>
<td>281</td>
<td>300</td>
<td>350</td>
<td>150</td>
<td>39</td>
</tr>
<tr>
<td>Toronto-Cleveland</td>
<td>180</td>
<td>294</td>
<td>350</td>
<td>540</td>
<td>155</td>
<td>35</td>
</tr>
<tr>
<td>Cleveland-Chicago</td>
<td>300</td>
<td>349</td>
<td>420</td>
<td>480</td>
<td>205</td>
<td>57</td>
</tr>
<tr>
<td>Cleveland-Detroit</td>
<td>90</td>
<td>167</td>
<td>200</td>
<td>300</td>
<td>157</td>
<td>22</td>
</tr>
<tr>
<td>Toronto-Detroit</td>
<td>210</td>
<td>231</td>
<td>270</td>
<td>310</td>
<td>160</td>
<td>39</td>
</tr>
<tr>
<td>Chicago-Detroit</td>
<td>285</td>
<td>296</td>
<td>350</td>
<td>300</td>
<td>193</td>
<td>49</td>
</tr>
<tr>
<td>New York-Washington</td>
<td>200</td>
<td>208</td>
<td>250</td>
<td>250</td>
<td>190</td>
<td>37</td>
</tr>
<tr>
<td>New York-Boston</td>
<td>180</td>
<td>216</td>
<td>260</td>
<td>280</td>
<td>153</td>
<td>35</td>
</tr>
<tr>
<td>Toronto-Chicago</td>
<td>450</td>
<td>529</td>
<td>700</td>
<td>615</td>
<td>200</td>
<td>72</td>
</tr>
</tbody>
</table>

Aside from the savings in trip times that are possible with S.T.O.L. air transport there is a very substantial economic benefit that can result from the implementation of a S.T.O.L. aircraft passenger service. A preliminary study conducted by Eastern Airlines of the airports and terminal requirements in 24 major cities that it serves indicates that nearly 8 billion dollars could be saved by 1985 through the deployment and utilization of a S.T.O.L. air carrier system.

The airline estimates that preliminary study findings are correct within ± 20 percent. Table 2-12 shows the results of the study.

The total investment planned or likely to be required for conventional aircraft facilities is $6,217 billion. Comparable costs for a system of S.T.O.L. airports to serve traffic up until 1980 is forecast to cost $1,307 billion.

For the 1980-85 period Eastern Airlines estimated that an additional $3,601 billion investment for new C.T.O.L. facilities, while the same traffic could be accommodated using S.T.O.L. aircraft at a cost of $655 million.
### TABLE 2-12

<table>
<thead>
<tr>
<th>Major Airport and Terminal Investment Planned</th>
<th>for 1970 - 1985 Period (in millions of dollars)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970 through 1980</td>
<td>Additional by 1985</td>
</tr>
<tr>
<td>Atlanta</td>
<td>$300</td>
</tr>
<tr>
<td>Baltimore</td>
<td>400</td>
</tr>
<tr>
<td>Boston</td>
<td>125</td>
</tr>
<tr>
<td>Buffalo</td>
<td>200</td>
</tr>
<tr>
<td>Charlotte</td>
<td>45</td>
</tr>
<tr>
<td>Chicago</td>
<td>790</td>
</tr>
<tr>
<td>Cleveland</td>
<td>1000</td>
</tr>
<tr>
<td>Freeport</td>
<td>5</td>
</tr>
<tr>
<td>Greensboro</td>
<td>22</td>
</tr>
<tr>
<td>Huston</td>
<td>200</td>
</tr>
<tr>
<td>Detroit</td>
<td></td>
</tr>
<tr>
<td>Louisville</td>
<td>65</td>
</tr>
<tr>
<td>Orlando/McCoy</td>
<td>78</td>
</tr>
<tr>
<td>Miami</td>
<td>400</td>
</tr>
<tr>
<td>Montreal</td>
<td>169</td>
</tr>
<tr>
<td>Nassau</td>
<td>21</td>
</tr>
<tr>
<td>New Orleans</td>
<td>100</td>
</tr>
<tr>
<td>New York</td>
<td>1000</td>
</tr>
<tr>
<td>Philadelphia</td>
<td>100</td>
</tr>
<tr>
<td>Pittsburgh</td>
<td>197</td>
</tr>
<tr>
<td>St. Louis</td>
<td>350</td>
</tr>
<tr>
<td>Toronto</td>
<td>150</td>
</tr>
<tr>
<td>Washington, D.C.</td>
<td>75</td>
</tr>
<tr>
<td>Los Angeles</td>
<td>500</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$6,217</td>
</tr>
</tbody>
</table>

S.T.O.L. aircraft offers the potential of reducing the problems of airport and airways congestion. This conclusion was brought out in a U.S. Federal Aviation Administration (F.A.A.) study conducted to determine methods of increasing the runway acceptance rates of major U.S. airports. The study revealed that the operational characteristics of S.T.O.L. aircraft and their ability to use airspace, not now used by C.T.O.L. aircraft, would allow them to operate efficiently from the larger airports.

S.T.O.L. aircraft can also provide effective air service into small suburban areas or special activity points where only very modest
runway facilities are available.\textsuperscript{65} Also such aircraft can be used in less developed parts of Canada where large runways are expensive to construct and where the frequency of service would not justify extensive facilities.\textsuperscript{66} For example, in British Columbia alone, S.T.O.L. aircraft can operate from more than 200 airstrips from which it is not possible to operate C.T.O.L. aircraft.\textsuperscript{67}

S.T.O.L. air service has a number of important implications as a tool for directing the development of regions. In recent years the trend in aircraft development has been toward large aircraft which require long runways. Such facilities can only be justified in the larger urban centers.

The result of this trend has been the provision of greatly improved air travel opportunities in the large urban areas but there has been no comparable increase in service offered to the smaller centers. It may be possible to alter this trend by developing and operating a moderate capacity dispersed transportation system, as opposed to a high capacity "spinal" system. A S.T.O.L. aircraft system would appear to fill the requirements of such a system. A system of S.T.O.L. airports could be provided at a relatively modest cost to give improved travel opportunities to those people who dwell in the smaller centers. In contrast to the more permanent "spinal" system of transportation routes, a dispersed S.T.O.L. air transport system would be flexible and able to adapt to regional development needs in sparsely settled areas while still being able to handle high density short haul traffic in and around metropolitan areas.\textsuperscript{68}

One long term benefit considered possible if a S.T.O.L. air transport system were established might be the reversal of present
population trends which show people increasingly moving from rural areas to metropolitan areas. Another benefit that might accrue from the successful development of S.T.O.L. transportation is that the system may help to make possible the establishment of light industry in areas that are economically depressed.

Despite the fact that S.T.O.L. aircraft offer so many potential advantages, there is at present no S.T.O.L. airliner available for civil use that is capable of carrying more than 40 passengers. The De Havilland D.H.C. 7 S.T.O.L. airliner, programmed for delivery in 1973, will be the first S.T.O.L. airliner designed specifically for civil use.

The large U.S. airlines have recognized the need for S.T.O.L. aircraft service between the larger American cities. They anticipate that the introduction of S.T.O.L. aircraft will take place in three stages:

1) Introduction of an initial series of short haul S.T.O.L. aircraft which will be ready for service from about 1973-75. These aircraft should provide the impetus for the construction of S.T.O.L. airports near city centers.

2) The period between 1976 and 1978 should see the introduction of a second generation of higher capacity more efficient S.T.O.L. airliners.

3) In the years following 1980, during which considerable congestion at S.T.O.L. airports is anticipated, the introduction of V.T.O.L. aircraft is expected to take place.
Summary

People travel for three general reasons: to meet other people, for holidays or recreational purposes, or to reach a work place. The travel mode they choose depends upon the purpose of the trip, the convenience of the mode, the total trip time, and the trip cost. Each mode of travel, be it automobile, bus, rail, or air offers the traveler certain advantages and disadvantages. The principal advantage of air travel is its very high terminal to terminal travel speed, but this speed advantage is being eroded because airports are becoming congested and the surface travel time to and from many airports is increasing. However, recent developments in air vehicles such as V.T.O.L. and S.T.O.L. aircraft, which can be operated from small airports, near the principal traffic generating areas of a city, can reduce air traffic at the conventional airports and reduce surface travel on the airport access links. V.T.O.L. aircraft are still being developed but S.T.O.L. aircraft will soon be ready to enter airline service.

S.T.O.L. aircraft may also provide a less expensive more flexible transportation service to the less populated areas of Canada. The modest airport and terminal facilities required by S.T.O.L. aircraft will allow air service to be given to small communities not generally served by air transportation. Nevertheless, this does not mean that scheduled air service should be offered to every small community. The frequent stops would have a negative effect on the economics of airline operations and the level of service offered to passengers travelling between larger centres would decline.
FOOTNOTES

CHAPTER TWO


17) Ibid.


26) Ibid.


29) Ibid.

30) Ibid.

31) Ibid.


34) Ibid.


43) Ibid.

44) Ibid.

45) Ibid.

46) Ibid.

47) Stratford "Looking Ahead", P. 375.


55) See the studies done by John F. Brown and James C. Buckley listed in the Bibliography.


60) Ibid.


69) "Applications Decision is a Key Hurdle," Aviation Week and Space Technology, June 22, 1970, p. 146.

70) Ibid. p. 150


73) "S.T.O.L. or V.T.O.L. For Future Inter-City Air Transport?," Interavia, Jan 1970, p. 49.
CHAPTER THREE

S.T.O.L. Airport Planning Considerations

To derive the maximum benefit from S.T.O.L. aircraft in intercity-passenger transportation, special terminal facilities, or Stolports, will be required. The size, arrangement, location and support facilities required for the terminals will be determined in a large measure by the operational capabilities and limitations of the aircraft that use them.\(^1\) Therefore, the chapter will begin with an examination of the takeoff and landing performance of S.T.O.L. aircraft and the factors that determine the overall dimensions of a S.T.O.L. airport.

Once the basic dimensions of the S.T.O.L. airport have been established the discussion will turn to the question of the safety of urban area flight operations. Following the discussion of safety there will be a discussion of air navigation and the problems of air navigation in urban areas. Next there will be an examination of the locational considerations associated with urban area S.T.O.L. airports. These considerations are: wind, air pollution, noise, terminal access land use compatibility and implications for urban form.

Factors affecting the Dimensions of S.T.O.L. Runways

The space requirements of an S.T.O.L. airport is a basic factor to be considered with deciding upon a suitable location for a S.T.O.L. airport. The basic dimensions of an S.T.O.L. airport are derived from the performance of the aircraft.

One reason that S.T.O.L. aircraft can takeoff in a short distance is that they are generally fitted with powerful engines which permit
rapid acceleration and a high rate of climb. There is, however, a limiting value of thrust weight ratio above which the marginal gain in thrust is not reflected in increased take-off performance. Typical takeoff results for a S.T.O.L. aircraft of relatively conventional configuration are shown in figure 3-1 where the total distance, ground run plus airborne, to reach a height of 50 feet are shown in terms of thrust weight ratio. From this it can be seen that beyond a certain point increased power will not increase the performance of the aircraft.

The length of a takeoff run is also dependent upon the geometric design and the dimensions of the aircraft wing. In addition, the rolling resistance of the aircraft wheels is an important factor in takeoff performance.²

The landing distance of a S.T.O.L. aircraft is directly related to, approach speed, the steepness of the approach gradient, and the efficiency of the aircraft braking system and propeller pitch reversal system.³ (See Figure 3-2)

The landing and takeoff performance of the De Havilland D.H.C. 7 S.T.O.L. airliner illustrates the relationship between aircraft performance and runway dimensions. The estimated landing and takeoff profiles for the D.H.C. 7 aircraft are shown in figures 3-3 and 3-4. These figures illustrate the D.H.C. 7 operating from S.T.O.L. airport at an average gross weight of 36,000 pounds. Table 3-1 provides additional information on the D.H.C. 7 landing and takeoff performance.⁴
FIGURE 3-1
THRUST/WEIGHT RATIO VERSUS TAKE OFF DISTANCE

FIGURE 3-2
LANDING FIELD LENGTH VERSUS APPROACH SPEED

LANDING FIELD LENGTH FEET
FIGURE 3-3
TAKEOFF PROFILE
DE HAVILLAND D.H.C. 7 - S.T.O.L. AIRLINER

Associated Conditions
1) Sea level ISA
2) Aircraft Weight, 36,000 lbs.
3) All Engines at Takeoff Power.
4) Zero Wind.

TAKEOFF FLIGHT PATH
75 Feet
GROUND ROLL 1100 Ft.
DISTANCE TO 35 FEET
ACCELERATE-STOP DISTANCE 1680 FEET
TOTAL S.T.O.L. AIRPORT LENGTH

FIGURE 3-4
LANDING PROFILE
DE HAVILLAND D.H.C. 7 - S.T.O.L. AIRLINER

APPROACH FLIGHT PATH 7.5°
APPROACH SPEED 1.3\(V_s\)

GROUND ROLL (750 Feet)
DISTANCE FROM 35 FT. (1140 Ft.)
TOTAL S.T.O.L. AIRPORT LENGTH (2000 FT.)
TABLE 3-1

D.H.C. 7 Landing and Takeoff Profiles

(Sea Level, Zero Wind)

<table>
<thead>
<tr>
<th></th>
<th>Normal Operations</th>
<th>Emergency Operations Engine Failure at Lift Off</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>59°F</td>
<td>90°F</td>
</tr>
<tr>
<td>Take Off</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ground Roll Feet</td>
<td>1100</td>
<td>1220</td>
</tr>
<tr>
<td>Horizontal Distance</td>
<td>1540</td>
<td>1670</td>
</tr>
<tr>
<td>to 35 Feet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Take Off Climb Gradient</td>
<td>10</td>
<td>9.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ground Roll Feet</td>
<td>750</td>
<td></td>
</tr>
<tr>
<td>Horizontal Distance</td>
<td>1140</td>
<td></td>
</tr>
<tr>
<td>from 35 Feet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Field Length</td>
<td>1900 Ft.</td>
<td></td>
</tr>
<tr>
<td>(1140 x 1.67 factor of safety)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From Table 3-1 it can be seen that despite the fact that the aircraft requires only 1300 feet of runway under the most extreme take-off conditions, the required runway length is a minimum of 1900 feet to provide for a safety margin.


Safety

Safety margins are applied to the basic performance characteristics of all commercial aircraft. These margins may differ slightly from
The speeds at which aircraft may takeoff and climb or approach and land are defined as a function of a basic stalling speed. (The stalling speed is the speed at which the wings do not produce sufficient lift to maintain flight). The stalling speed of a propeller driven aircraft may vary with engine power setting and propeller slipstream because of the latter's effect over the wing and the varying downwash. For a typical S.T.O.L. aircraft the stalling speed with full power is approximately two-thirds of the stalling speed with power off.

Generally, take off safety speed \( V_s \) is the basic aircraft stalling speed plus 20 percent. For approach and landing the basic stalling speed is usually that which is obtained with the flaps in the landing position and zero thrust. S.T.O.L. aircraft are required to at least maintain the stalling speed plus about 30-50 percent at the runway threshold during landing.

Other safety margins are applied to the gross takeoff and landing distances that result when aircraft are operated at speeds discussed above. In Britain, for instance, government regulations require the takeoff distance to be increased by 25 percent and the landing distance to be increased by 43 percent.\(^9\)

Multi-engine commercial S.T.O.L. aircraft operations introduce another set of safety factors which further modify S.T.O.L. airport dimensions and obstruction clearances. It is normally accepted that an aircraft should be able to survive a single engine failure at any stage during landing or takeoff. Modern aircraft engines are remarkably
reliable and it is known that the chance of engine failure between lift off and 50 feet is one per 10 million takeoffs. It is assumed that the engine will not fail within 10 seconds after lift off nor will it fail during the last 25 seconds of approach. Ten seconds after takeoff the aircraft will have reached 300 feet at which time it will have the performance to continue climbing on one engine. An aircraft is also expected to be able to survive an engine failure during the last 25 seconds and make a safe landing with only an increase in the landing distance.

There is reason to believe that S.T.O.L. aircraft operation will be safer than C.T.O.L. aircraft operations because of the slow flight speeds attainable with S.T.O.L. aircraft. There are however, two opposing factors involved in achieving a safety level for S.T.O.L. aircraft that is better than the present level for C.T.O.L. aircraft. On one hand the added complexity of the S.T.O.L. aircraft requires more effort to guard against mechanical and system failures, but the slower landing speeds involved in S.T.O.L. operations should reduce the consequences of any accident that does happen because of the lower energy to be dissipated.

The safety of aircraft operations increases as the speed that an aircraft approaches the runway declines. But on the other hand, the shorter the runway the greater the reduction in reliability for any approach speed. However, from the pilot's point of view S.T.O.L. aircraft operations may be less safe than those of conventional aircraft because he will be pushing the aircraft to its maximum capability i.e. engine, high lift devices, landing aids, and shorter runways. At slow speeds S.T.O.L. aircraft are affected by crosswinds
to a much greater extent than are C.T.O.L. aircraft. Hence, under crosswind conditions S.T.O.L. aircraft operations may be just as hazardous as C.T.O.L. aircraft operations.

In a U.S. study of commercial aircraft accidents, it was shown that approximately 18 percent of the accidents occurred during cruise operations; about 25 percent occurred during takeoff; and the majority, about 57 percent, occurred during approach and landing. The study also showed that a direct correlation exists between takeoff and landing speed and accident rate. Although there are many other variables not considered in the accident rate versus landing speed, there does, however, appear to be a strong indication that air travel safety can be enhanced by the low landing speeds of S.T.O.L. aircraft. Since the landing speed of S.T.O.L. aircraft is one half that of jet transport aircraft it may be expected that the S.T.O.L. aircraft landing accident rate will be roughly one quarter the figure under existing circumstances.  

Airways and Air Navigation

An air traffic system reflects the complex inter-relationships of ground based facilities and the flight characteristics of the aircraft operating in the system. On the ground the main facilities consist of the airport navigational aids and enroute control facilities. In the air, the kind of navigational equipment used varies from one aircraft to another depending on the type of operations that the aircraft normally performs.

Where air traffic is light a minimum of external aircraft control may be necessary because standard pilot applied flight rules and procedures in conjunction with ground navigational aids may be sufficient. High traffic densities require that some centralized form of control be established over air traffic. This centralized control is placed in a
system called air traffic control.

Airways are the portions of commonly travelled air routes which are subject to air traffic control. In Canada there are two categories of airways; the high level airway, which is a prescribed track between radio navigation aids above approximately 23,000 feet altitude; the low altitude airways which extend upwards from 700 ft. to 23,000 ft. above the surface of the earth, are 9 miles wide and like high level airways, follow a prescribed track between radio navigation aids. \(^\text{13}\)

Radio Navigation Aids

There are two principal radio navigation aids used in the Canadian airways system. The instrument landing system (I.L.S.) which is used to guide aircraft to the runway within the terminal control area, and the V.O.R. (very high frequency omni directional radio range) which guides the aircraft during the enroute portion of a flight. \(^\text{14}\)

The instrument landing system emits radio signals along a path leading to the airport. A special radio receiver in the aircraft picks up these signals and indicates to the pilot the aircraft's flight path with reference to the signals.

The I.L.S. can be subject to errors which arise from the reflection of radio waves from objects such as metal doors and intervening objects such as hills or rough terrain. \(^\text{15}\)

V.O.R. ground equipment produces two radio signals that are picked up by an aircraft omni receiver which electronically measures the aircraft's direction of flight with reference to the ground station. \(^\text{16}\)

Radio Navigation Aids for S.T.O.L. Aircraft Operations

Instrument approaches by conventional aircraft at most large airports
require long, time consuming approach paths. Even under visual conditions it can take as much as 15 minutes for a landing approach due to routings dictated by other air traffic. Under instrument flight conditions, the holding of aircraft consumes additional time. If the S.T.O.L. air traffic were to be mixed with conventional air traffic, much of the time saving of the close-in S.T.O.L. airport might be lost even under V.F.R. (visual flight rules) conditions. As a result S.T.O.L. aircraft will likely require different air traffic control procedures, particularly in the terminal areas.  

In the instrument approach and landing phases of the S.T.O.L. aircraft flight special instrument landing systems will be required. S.T.O.L. airports will be small and they may be located at elevated sites in areas that are surrounded by other buildings, structures, and so on. The existing I.L.S. is not capable of providing adequate guidance under such conditions. The inadequacy of the I.L.S. does not result from the higher approach gradient of S.T.O.L. aircraft; it is the product of obstacles and irregular terrain at the ends of the runway.

It is expected that a microwave I.L.S. will have to be used at urban area S.T.O.L. airports. A microwave system would have small antennae apertures which would provide high signal directivity. In addition, the physical dimensions of the microwave transmitting components are small. Thus the problem of siting instrument landing aids at S.T.O.L. airports will be greatly reduced.

In the past the V.O.R. navigational system has been adequate but the growth in air traffic may require that new navigational systems be employed to help reduce airspace congestion. The movement of aircraft along the radials between V.O.R. stations may result in congestion when air
traffic from many directions is funneled to one V.O.R. along a selected radial (see Fig. 3-5). Moreover, for low level navigation or for flight in built up areas, where the presence of nearby objects may affect the V.O.R., a more accurate navigation system will be required. An area navigation system can increase the accuracy of air navigation and also increase the capacity of the airways. The area navigation system consists of an airborne computer that can process V.O.R. signals to permit point to point navigation instead of V.O.R. to V.O.R. navigation. (See Figure 3-6)

Wind

There are several characteristics of winds that should be borne in mind when considering S.T.O.L. airport locations. First, the average wind velocity varies from zero at ground level to the value of the so called "gradient wind" at higher levels. The speed varies because of the friction of the wind over the ground, and so the variation of wind velocity depends upon the roughness of the ground and the extent of the roughness. Hence wind velocity at elevated S.T.O.L. airports will be greater than it will be at ground level airports. The following table shows the decline in wind speed as ground level is approached.

<table>
<thead>
<tr>
<th>Height of Wind Instrument (Feet)</th>
<th>Ratio of Wind Velocity at 20 Ft. to Wind Velocity at Instrument Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>120</td>
<td>0.77</td>
</tr>
<tr>
<td>100</td>
<td>0.79</td>
</tr>
<tr>
<td>80</td>
<td>0.82</td>
</tr>
<tr>
<td>60</td>
<td>0.86</td>
</tr>
<tr>
<td>40</td>
<td>0.90</td>
</tr>
<tr>
<td>20</td>
<td>1.00</td>
</tr>
</tbody>
</table>
FIGURE 3-5
AIR TRAFFIC COLLECTING AT A V.O.R.

FIGURE 3-6
AN ILLUSTRATION OF AREA NAVIGATION IN PLACE OF V.O.R. TO V.O.R. NAVIGATION

V.O.R. RADIALS
FIGURE 3-7

WIND TURBULENCE - INTENSITY VERSUS HEIGHT

HEIGHT IN FEET

0 10 20 30

PERCENT TURBULENCE
A second characteristic of winds is their intensive turbulence. Figure 3-7 shows the typical variation with height of the root-mean-square longitudinal turbulence intensity, expressed as a percentage of local mean wind speed. Turbulence intensity for a wind blowing over rough ground decreases with an increase in altitude. Since turbulence appears to be a nearly random process, there could be occasional values much greater than those shown in the figure, and near the ground the wind direction may vary widely and it may sometimes even reverse.26

For S.T.O.L. operations in urban areas turbulence may be an important problem since there may be turbulent zones created in the wind wake of tall buildings. The extent of a turbulent zone will depend largely on wind speed.

S.T.O.L. aircraft are sensitive to gusts and crosswind components, i.e. a wind component perpendicular to the flight path, hence these factors must be considered when locations for S.T.O.L. airports are being considered.

Wind gusts can have a great influence on the precision of S.T.O.L. aircraft landing approaches, because this type of aircraft has a low wing loading and small changes in wind speed can have a relatively great effect on the lift generated by the wings. Thus a change in wind velocity will have an effect on the rate of descent and therefore on the angle of approach of the aircraft. E.G. Morrissey in his 1970 study, "An Approximate Method for Calculating Critical Gust Statistics for S.T.O.L. Operations," found that, "gusts may occur with sufficient frequency to necessitate their consideration during the design and formulation of Stolport operational practices." 27
Crosswind wind components can have a substantial influence on S.T.O.L. aircraft operations. For instance, a 10 knot crosswind component will cause a 13 degree heading changing on a S.T.O.L. aircraft approaching for a landing at a speed of 45 knots.

The distribution of wind directions in association with visibility and ceiling are of primary importance in deciding on runway orientation. Subject to all other factors being equal, runways should be oriented in the direction of the prevailing wind when it blows consistently from one direction.

Of course, beneficial effects of winds can also be realized in S.T.O.L. aircraft operations, if the aircraft can be operated directly into the wind. In takeoff or landing operations the horizontal distance required to reach or descend from a given height can be significantly reduced with even a moderate headwind. For instance, the horizontal distance required to get to or from 100 feet above ground level (as indicated in Figures 3-3 and 3-4) can be reduced as much as 25 percent in a 10 knot headwind.

Hazard and Obstruction Clearance

Local factors can be important in relation to the location of individual S.T.O.L. airports. For instance industry can produce smoke which may be concentrated in certain directions because of prevailing winds. As a consequence the visibility in some areas may be reduced and visual flight procedures may be precluded. Sites adjacent to refuse dumps and sewage outfalls may be undesirable because of the danger of aircraft collision with birds.
S.T.O.L. aircraft use steep flight path gradients in takeoff and landing to limit the constraints imposed on land use beyond the ends of the runway. However, aircraft must be able to clear all obstacles safely in the event of an engine failure during takeoff. This requires that obstruction free planes be established extending from both ends of the runway in the direction of flight.\textsuperscript{31} The U.S. F.A.A. has produced "Interim Design Criteria for Metropolitan S.T.O.L. Ports and S.T.O.L. Runways" which define the dimensions of the obstruction-free planes which should be secured around S.T.O.L. Airports. Figure 3-8 shows the F.A.A. recommended obstruction-free zones for a S.T.O.L. airport.

Any objects which limit the available flight path may reduce the efficiency of flight operations. If tall structures exist in or near areas suitable for instrument flight, non-standard flight procedures may be required and the duration of flight during landing and takeoff may be increased.\textsuperscript{32}

**Noise Problems**

In the past, airports were located away from the urbanized area and any community noise exposure problems from aircraft resulted from the growth of the community toward the airport. However, in the case of S.T.O.L. aircraft the situation will be reversed in that it is now possible to build S.T.O.L. airports within existing communities. This is inherent in the basic concept of S.T.O.L. intercity air transportation: the providing of convenient and rapid air transportation to populated areas. For this concept to succeed, S.T.O.L. aircraft operations must be readily accepted by the community.

The noise problem that is causing concern at some of the large
FIGURE 3-8 - PROTECTION SURFACES --- METROPOLITAN STAPLEPORT 33
airports that serve jet aircraft is likely to present even greater problems for S.T.O.L. city center operations because of (1) the high power or thrust required in takeoff and landing, (2) the need to locate the terminals as close as possible to the heavily populated city centers, and (3) the longer duration of noise because of the low approach and takeoff speed of the aircraft.\textsuperscript{34}

If S.T.O.L. aircraft are to be acceptable as an intercity transportation vehicle it is very important that the presence of such vehicles be acceptable as well as beneficial to the community. The goal is that S.T.O.L. aircraft should not generate noise above the ambient levels; however, in many cases it may not be possible to achieve this goal.

Noise

"Noise by definition is an undesirable or unwanted sound. Sound is composed of pressure waves whose magnitude and frequencies are sensed by the human ear. The undesirability associated with sound involves the subjective response of the observer, which includes not only the physical stimulus of the ear as a function of intensity and frequency of the perceived noise, but also psychological factors. Thus the observer perceives the noise in terms of whether or not the sound is loud, annoying, interferes with his speech or leisure activities. In effect, the observer establishes a criterion by which he personally judges the acceptability of noise.\textsuperscript{35}

The physical characteristics of noise, are described in terms of frequencies in cycles per second, or hertz, and in terms of sound power, intensity, or in a logarithmic unit, the decibel. The subjective effect of frequency is known as "pitch" and that of intensity as loudness. However, at present there is no universal method to quantify or describe the unwantedness of noise.\textsuperscript{36}

The most common measure of sound level measurement is of overall sound pressure level expressed in decibels. The decibel (dB) is defined as:

\[
\text{Sound pressure level, dB} = 20 \log_{10}\left(\frac{P}{P_0}\right)
\]
were $P$ is the root mean square sound pressure and $P_0$ is the reference pressure, normally 0.0002 microbars. This is a physical measure of sound intensity.

During the last 10 years the perceived noise level (PndB) has largely replaced the purely physical dB as a measure of the subjective "noisiness" of aircraft and other noises. The perceived noise decibel is a weighted dB average over a frequency spectrum. The weighting permits high pitched noises to be rated relatively "noisier" than low pitched noises of the same dB level. Thus as shown in Figure 3-9 turbo jet engine noise with its high frequency content is rated 6PndB noisier than a propellor which has the same sound pressure level in decibels. As a rule of thumb, when dealing with PndB a doubling or halving of a sound level results in a 10 PndB difference in noise levels.

In situations where speech communication against a noise background is of major concern, a measure known as the "speech interference level" (SIL) is often used. The speech interference level is a measure of the speech-masking effect of a noise.  

The frequency of aircraft takeoffs and landings as well as their individual noiseness of PndB is a strong factor in public acceptability of aircraft noise. (See Figure 3-10).

"In England, as a result of considerable investigation, the subjective effects of the two (frequency of flight and Pndb) have been combined into a "Noise and Number Index".

\[
\text{NNI} = \text{average of peak PndB Levels} + 15 \log_{10} N - 80
\]

Here $N$ is the number of individual occurrences, and the -80 implies that a level of 80 PndB has negligible annoyance. If we set NNI = 45 as an allowable daily upper limit then the allowable PndB depends on the number of events, as follows."
FIGURE 3-9
COMPARISON OF PERCEIVED NOISE LEVELS FOR SPECTRA HAVING EQUAL OVERALL SOUND PRESSURE LEVEL

Propeller 107 PndB
Turbojet 113 PndB

FIGURE 3-10
RELATIVE ANNOYANCE AS A FUNCTION OF PndB AND NUMBER OF FLIGHTS PER DAY

Intolerable
Very
Annoying
Intrusive
Noticeable
Quiet

Number of Flights per Day
TABLE 3-3

ANNOYANCE AS A FUNCTION OF PndB AND NUMBER OF OCCURRENCES

<table>
<thead>
<tr>
<th>N</th>
<th>PndB</th>
<th>Pndb</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>125.</td>
<td>115</td>
</tr>
<tr>
<td>2</td>
<td>120.6</td>
<td>112</td>
</tr>
<tr>
<td>4</td>
<td>116.</td>
<td>109</td>
</tr>
<tr>
<td>8</td>
<td>111.5</td>
<td>106</td>
</tr>
<tr>
<td>16</td>
<td>107.</td>
<td>103</td>
</tr>
<tr>
<td>32</td>
<td>102</td>
<td>100</td>
</tr>
<tr>
<td>64</td>
<td>98</td>
<td>97</td>
</tr>
<tr>
<td>128</td>
<td>93.5</td>
<td>94</td>
</tr>
</tbody>
</table>

The composite noise rating (C.N.R.) like the N.N.I. is another scale which is calculated by adding algebraically, PndB and certain other corrections which take into account other factors such as the number of aircraft movements, the time of day, and runway utilization.

As was mentioned previously, the decibel is a commonly used measure of sound intensity; it is also a convenient device for obtaining noise comparisons, especially for vehicles or objects in motion. Figure 3-11 shows the relative sound pressure levels associated with various sound producing events.

Noise Problems Created by S.T.O.L. Aircraft

To assess the possible effects of S.T.O.L. aircraft flyovers and S.T.O.L. airport operations, it is first necessary to examine, from a noise viewpoint the various environments that could be affected by S.T.O.L. aircraft operations. Once the existing environments have been described it then is possible to discuss the noise problems created in the variety of situations which may be encountered. Figure 3-12
FIGURE 3-11
COMMON NOISE LEVELS

Perceived Noise Level (Pn dB)

- Sonic Boom
- Threshold of Pain
- Boiler Factory
- Subway Passing
- Riveting Machine 35 Ft.
- Heavy Street Traffic
- Average Automobile
- Department Store - Noisy Office
- Minimum Street Noise
- Very Soft Music
- Rustling Leaves
- Threshold of Hearing

FIGURE 3-12
COMMUNITY NOISE x EXTERIOR AMBIENTS

S.T.O.L. AIRCRAFT FLYBY AT 1000 Ft.

Quiet Suburban (Night Time)
Urban Residential (Day Time)
Commercial (Light Traffic)
Industrial
Downtown (Heavy Traffic)
shows the ambient noise for a variety of community locations as a background for the perceived noise level of a current S.T.O.L. aircraft operating at a distance of 1000 feet.

An assessment of the possible noise effects that may result from S.T.O.L. city center operations should begin with a look at the residential area, the area where noise is least acceptable. The ambient noise levels in residential areas are generally low, and people are particularly sensitive to disturbances in their home environment. People are particularly annoyed about having their conversation, phone calls, and radio or television programs drowned out by an intrusive noise such as that from an aircraft flying overhead. Many of the complaints received by airports refer to this type of a situation. Although these cases are generally concerned with speech interference, the noise problem in residential areas is far more complex, involving annoyances, interference with tasks, and interference with sleep. Considering these factors, perceived noise level appears to be a useful measure of noise intrusion for aircraft flyovers. The acceptable value of perceived noise level will depend upon the type of residential community concerned. As can be seen from Figure 3-12 the perceived noise level of a 1000 feet above ground level flyover of the De Havilland D.H.C. 7 S.T.O.L. airliner is about 25 PndB higher than the daytime ambient noise level in urban residential areas.

The roofs and walls of the average home is sufficient to reduce noise annoyance substantially, probably to an acceptable level. Table 3-5 shows the acceptable interior noise level in buildings used for various activities.
### TABLE 3-4

**ACCEPTABLE EXTERIOR NOISE LEVELS FOR VARIOUS ACTIVITIES**  
**BASED ON AVERAGE NOISE REDUCTION BY BUILDING**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Acceptable Interior Noise Level (PndB*)</th>
<th>Acceptable Exterior CNR** (without modification)</th>
<th>Acceptable Exterior CNR with 10 dB extra Noise Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apparel</td>
<td>85</td>
<td>115</td>
<td>125</td>
</tr>
<tr>
<td>Painting</td>
<td>80</td>
<td>110</td>
<td>120</td>
</tr>
<tr>
<td>Food Processing</td>
<td>80</td>
<td>110</td>
<td>120</td>
</tr>
<tr>
<td>Metal Working</td>
<td>80</td>
<td>120</td>
<td>130</td>
</tr>
<tr>
<td>Offices</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Private - one floor</td>
<td>50</td>
<td>80</td>
<td>90</td>
</tr>
<tr>
<td>Private - multifloor</td>
<td>50</td>
<td>85</td>
<td>95</td>
</tr>
<tr>
<td>General - one floor</td>
<td>60</td>
<td>90</td>
<td>100</td>
</tr>
<tr>
<td>General - multifloor</td>
<td>60</td>
<td>95</td>
<td>105</td>
</tr>
<tr>
<td>Hotel</td>
<td>60</td>
<td>90</td>
<td>100</td>
</tr>
<tr>
<td>School</td>
<td>55</td>
<td>85</td>
<td>95</td>
</tr>
<tr>
<td>Store</td>
<td>70</td>
<td>100</td>
<td>110</td>
</tr>
<tr>
<td>Residence</td>
<td>60</td>
<td>90</td>
<td>100</td>
</tr>
<tr>
<td>Special Uses</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concert Hall</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Theater</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Church</td>
<td>45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hospital</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arena</td>
<td>70</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Noise Level in PndB  
** CNR = Composite Noise Rating

However, during the summer months when windows and doors may be left open, the average sound attenuation through buildings will be reduced. As a result, it seems obvious that a different noise criterion is required for a neighbourhood where windows are left open and backyard activities are performed, than in a neighbourhood composed of air conditioned, sealed, apartment houses.
In industrial and commercial areas the noise problems are somewhat different. In an office, a conference room, or a store, annoyance effects are likely to be of a lesser concern than is ease of communication. This assumption suggest that for industrial and commercial situations the speech interference level method of noise evaluation would be the most suitable way to assess noise problems.  

"For office environments, sets of curves called noise-criterion (NC) and noise criterion alternate (NCA) have been established, differing only in that the NCA curves are less stringent at low frequencies, where noise reduction is difficult and expensive to achieve. The criterion curves are based on satisfactory communication environments; the number refers to the associated speech interference levels. Three of the NCA curves are shown in Figure 3-13 ranging from an executive office criterion to that for a large, excessively noisy office. Superimposed on these NCA curves are the interior noise spectra, after transmission through a well built structure with double glazed windows, for a proposed S.T.O.L. aircraft at both 500 and 1000 feet distances. As can be seen from the figure there is no apparent noise problem from this... situation."  

There are no commonly used noise criteria for industrial establishments as there are for offices. Speech interference and annoyance are not of major concern until interference with work performance is evident. Naturally if noise does not intrude above the ambient noise level, no problem will exist. For the range of industrial interior noises shown in Figure 3-14 a flyby of an S.T.O.L. aircraft at 1000 feet poses no problems for a fully enclosed building with closed double glazed windows.  

The noise levels created by aircraft at the maximum power or thrust levels used during takeoff have been estimated in PNdB at various lateral distances from the aircraft track. The estimated ground or side line noise levels for the De Havilland D.H.C. 7 aircraft are shown in figure 3-15. However, the landing noise is generally greater than the takeoff noise because of the lower flight angle of the landing approach (7.5°) as opposed to the climb angle (9.8°). Moreover, the
**FIGURE 3-13**

Office Noise: Criteria and S.T.O.L. Aircraft Flyby at 500 Feet and 1000 Feet

- **OCTAVE BAND LEVEL**
- **dB RE. 0.0002 MICROBAR**

**FIGURE 3-14**

Interior Industrial Noise: Ambient Level and S.T.O.L. Aircraft Flyby at 1000 Feet

- **OCTAVE BAND LEVEL**
- **dB RE. 0.0002 MICROBAR**
duration of noise from S.T.O.L. aircraft may be two or three times longer than that for a C.T.O.L. aircraft, as a result the acceptable level of noise for S.T.O.L. aircraft may be lower than that for C.T.O.L. aircraft. It has been found that doubling the duration of noise exposure is equivalent to an increase of approximately 4.5 PNdB.  

In 1969 the U.S. F.A.A. issued noise level requirements for the certification of C.T.O.L. aircraft. It is expected that the F.A.A. will soon issue noise standards for V.T.O.L. and S.T.O.L. aircraft. The S.T.O.L. aircraft standards are expected to be a maximum noise level of 100 PNdB at 1000 feet on either side of the runway and 2000 ft. from the point of lift off. The noise contours shown in Figure 3-15 more than meet the expected F.A.A. criteria.  

By using the noise contours and the noise criteria outlined in the foregoing discussion it will be possible to choose a S.T.O.L. airport location that minimizes noise problems. It should be pointed out, however, that the noise criteria, mentioned previously must be applied with a certain amount of judgment because there are problems that arise when attempts are made to apply the criteria to specific situations. More specifically:

1) There are many types of aircraft engines in the civil aviation fleet.  
2) Noise transmission paths are affected by meteorological and topographic conditions.  
3) Aircraft noise produces varying behavioural responses.  
4) Aircraft noise produces little if any permanent structural changes (exclusive of sonic booms).  
5) Much of the psychoacoustic and sociacoustic data is limited in amount and poorly correlated.
NOISE CONTOURS DE HAVILLAND D.H.C. 7
S.T.O.L. AIRLINER

FIGURE 3-15
There does not appear to be a simple way to relate the profusion of methods and scales used for measuring and specifying noise levels. Noise measurement involves both physical and subjective elements. The physical components of noise can be measured with considerable accuracy, but the subjective elements of noise annoyance can change from one individual to another. For example, noise annoyance can be related to the hour of the day, a person's economic relationship to the noise source, the general noise level of the area, and whether other people are being subjected to the same noise levels. 56

In conclusion, it should be noted that some aeroacousticians remain dubious about the validity of PndB, N.N.I., C.N.R., etc., for assessment of community response to complex noise. Major companies (e.g. Boeing) are conducting their own research on the subjective response to noise in an effort to come up with better criteria for the evaluation of community response to noise. 57

Air Pollution

Air pollution at an S.T.O.L. airport can be the result of three factors:

a) the surface traffic generated by the airport

b) the industry attracted

c) the emissions of the aircraft operating from the airport

The last mentioned factor will be of primary concern since it represents a new and different source of air pollution for the urban area.

There are two broad classes of air pollutants. The first is particulate matter consisting of solid and liquid particles ranging in size from large particles greater than 100 microns in diameter to suspended particles of less than 20 microns and aerosols from 1.0 to 0.1 microns in diameter. The larger particles eventually fall to the
earth, the smaller particles may remain suspended in the atmosphere for a considerable length of time. (Small particles will be discussed in greater detail later in this chapter.) The second class of pollutant is made up of gases and vapours including the permanent gases.58

The principal emissions from turbo jet engines are carbon monoxide, hydrocarbons, nitrogen oxides and particulate matter. Table 3-5 shows a comparison of the emissions from a turbo jet engine and an automobile engine, both of which consumed 1000 pounds of fuel.

TABLE 3-5
Pollutant Yields for Jets, Aircraft & Motor Vehicles59
(Per 1000 Lb. of Fuel)

<table>
<thead>
<tr>
<th>Engine Type</th>
<th>Operating Mode</th>
<th>CO</th>
<th>HC</th>
<th>NO</th>
<th>Particulates</th>
<th>Pb</th>
<th>SO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbo Jet</td>
<td>Idle &amp; Taxi</td>
<td>174</td>
<td>75</td>
<td>2.0</td>
<td>0.3</td>
<td>0</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>Approach</td>
<td>8.7</td>
<td>16</td>
<td>2.7</td>
<td>1.0</td>
<td>0</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>Landing Take-Off &amp; Climb Out</td>
<td>0.7</td>
<td>0.1</td>
<td>4.2</td>
<td>0.6</td>
<td>0</td>
<td>1.0</td>
</tr>
<tr>
<td>Automotive Piston</td>
<td>Total Average</td>
<td>300</td>
<td>55</td>
<td>27</td>
<td>4.5</td>
<td>0.4</td>
<td>2.3</td>
</tr>
</tbody>
</table>

Aircraft and automobiles can also be compared on basis of how much fuel they consume per passenger mile. An 80 passenger jet aircraft travelling at 250 miles consumes 4000 pounds of fuel per hour. Based on an average 50 percent load factor this amounts to 0.04 pounds of fuel per passenger mile. On the other hand an automobile which travels 15 miles per gallon of gasoline carries an average of 1.2 passengers. The average rate of fuel consumption for automobiles is thus in the order of 0.25 pounds of fuel per passenger per mile.60

In the U.S. the Department of Health, Education and Welfare has estimated that aircraft pollutant emissions as a percentage of total emissions
from all other sources were: carbon monoxide 1.2 percent; hydrocarbons 0.7 percent; nitrogen oxides 0.1 percent and particulate matter 0.1 percent.  

Since the first commercial S.T.O.L. airliner that is expected to enter service will be turbo prop aircraft it will be worthwhile to briefly examine the pollutant emissions of turbo prop engines. The products of combustion from turbo prop engines do not vary markedly, per pound of fuel consumed, from those of the pure jet engine. The basic engine operation is similar to that of the turbo jet, or pure jet engine, with the same factors influencing smoke production or changes in thermal decomposition products (i.e. design of combustion chambers, temperature humidity, power output, fuel consumption, and atmospheric pressure).

However, the exhaust system is cooler in the turbo prop engine than it is in the pure jet engine. This tends to enhance the production of smoke. Because of the slower speed of the turbo prop aircraft and the relatively cooler temperature of the exhaust a more distinct smoke plume will be noted on occasion.

Several approaches, which have had varying degrees of success, have been tried in order to alleviate problems of air pollution near airports:

1) The restriction of housing developments in the immediate vicinity of the airport.

2) The use of runways that direct aircraft over water or sparsely populated areas.

3) The use of increased glide slope.

Obviously, the above methods will not reduce the amount of pollutants emitted into the atmosphere, however, the methods may reduce citizen
complaints about aircraft exhaust emissions and noise exposure.

The only effective way to reduce air pollution is to control it at the source. There are three general approaches:

1) Improved engine design.
2) Improvements in fuels.
3) More conservative rating and operation of jet engines.  

Improved design of engine combustion chambers can reduce overall jet engine emissions by up to 75 percent for some types of pollutants. The new combustion chambers effectively reduce engine emissions of hydrocarbons and organic gases, which are the most visible pollutants emitted by jet engines. Nevertheless, the emission of carbon monoxide and particulate matter is reduced by less than 25 percent, and oxides of sulphur are not reduced at all, whereas the emission of the oxides of nitrogen is increased by nearly 40 percent. Thus improved engine design may serve to mask rather than reduce the problem of aircraft air pollution.

The reduction of the smoke emissions from aircraft may be a negative rather than a positive step because "many people still suffer from the delusion that visible plumes from smokestacks, incinerators, airplanes and autos are exclusively to blame" for air pollution.

As has been discussed above it is possible to make a visible source of air pollution invisible to all but the most knowledgeable observer. This can be done by passing large particulate volatile smoke through a hot flame or by diluting the smoke with a large amount of air as is done in an aircraft engine. Dilution tends to make the particles smaller.

The role that small invisible particles may play in health is not as yet known. However, Schaefer in his studies at the Atmospheric Sciences Research Center of the State University at Albany has shown that the lungs
capture about 66 percent of the small particles that are inhaled. Schaefer and his research group consider 200 particles per cc to represent the global background particle level of the lower atmosphere. Schaefer measured the level of small particles in the passenger cabin of aircraft and on airport access roads. On airport roads and during aircraft boarding, the particulate levels ranged from 80,000/cc to 1,000,000/cc. Upon takeoff, the cabin air became clearer and dropped a particulate level of from 320/cc to 500/cc.

These measurements show that the small particle pollution levels at large metropolitan airports can exceed the levels at the center of the cities they serve. For example, the particle level at Lexington Ave. and 51st Street in New York City on Tuesday, Dec. 3, 1970 was 170,000/cc.

Unlike water pollution, the source of which can be easily identified, the small particles and gases in polluted air are hardly affected by gravitational forces. Once they enter the atmosphere, their residence time is likely to range from a month to several years. The only important way they are removed from the atmosphere is through precipitation in which they serve as nuclei for either cloud or ice crystals.

The use of fuels other than kerosene could lead to substantially lower pollution levels. In general, however, these fuels tend to cost more than present fuels and they tend to be difficult to handle and to store. The possibility of using fuels that generate exhaust gases that will chemically combine with existing pollutants to produce more inert materials has been considered, but at present there have been no significant advances toward producing such a fuel.

The efficiency of jet engine operation is frequently sacrificed during
takeoff in order that maximum engine power can be produced. Such operation increases the smoke production of jet engines. More powerful engines would permit aircraft to take off at lower than maximum power levels and thus permit much lower levels of smoke generation. But until such a time as regulations require that aircraft be fitted with more powerful engines this method of reducing air pollution at airports appears to be merely a possibility.

The problem of air pollution at S.T.O.L. airports should not be dismissed lightly because about 70 percent of all the smoke emissions from S.T.O.L. aircraft will occur near the S.T.O.L. airport. But, on the other hand, there does not appear to be a presently available method of controlling the emission of pollutants from turbo jet engines.

Compatible Land Use

Generally it can be said that when two or more land based activities are carried on regularly in some proximity to each other without conflict they can be considered to be compatible.

The concept of land use compatibility implies some degree of separation of the different activities, so that differentiation among the various users is possible.

The compatibility of different land based activities may vary with the season, the hour of the day, the duration of the conflicting situation and the frequency with which the conflicting activity is repeated.

A S.T.O.L. airport has the potential of creating major land use conflicts because of its noise, its crash hazards, and its surface traffic generating capability.
Certain land uses are incompatible with airports given certain levels of air and noise pollution and the frequency of landing or takeoff accidents. The incompatible uses tend to be those for which a quiet non-toxic and safe environment is desired for the conduct of such activities as living, playing, learning and convalescing from illness. Thus residential areas, recreational facilities, schools, hospitals and similar land uses are unsuitable near an airport. Most of these land uses are unrelated in air transportation except in the case of residential uses for airport employees who may desire to live close to work.71

S.T.O.L. airports should be located so that a compatible land use situation is created or preserved and existing forms of land use are not affected by aircraft operations. Such planning may obviate the need for costly land control measures which may otherwise be necessary to avoid noise or obstruction problems. For example, surrounding industrial land uses are generally compatible with S.T.O.L. airport development, as are natural areas which are restricted from use due to terrain. Highways and railways, located within the approach areas, are good land areas for compatible runway approach use. In addition, sites with approaches over water, but free of bird hazards, and where radio navigational aids to approaches can be installed and operated, should prove to be acceptable.72

In Michigan a comprehensive study of compatible land use near airports was undertaken to determine the actual impact of jet aircraft noise on various surrounding land uses and to develop a plan of compatible land uses in the affected area. The study was published in 1964 by the Detroit Area Regional Planning Commission.73
The Detroit study resulted in several significant findings, including these:

1) The landing of jet aircraft produces greater problems of community annoyance than does taking off.

2) The higher the property (home) values and the greater the personal income, the higher the level of complaint will be.

3) There was no direct relationship between blighted areas and aircraft operations in the environs of the airport studies.

4) Land use in the area affected by aircraft noise is not suitable for residential development.

Fortunately, S.T.O.L. airports will tend to induce compatible land uses for adjoining land.

"Real estate authorities recognize that airports have a strong tendency to attract industry in a competition with other possible sites within the same metropolitan economic region, and can cause a concentration of industrial and commercial growth."

However, compatible land use does not entail simply ensuring that aircraft meet certain noise criteria and that industrial and commercial land uses surround the S.T.O.L. airport. Recent events in New York City suggest that residents in areas adjacent to "compatible" land uses are not necessarily in favour of urban area S.T.O.L. airports.

In June 1970 American Airlines was awarded a contract by the F.A.A. for a technical feasibility study of a floating S.T.O.L. airport. In order to obtain specific data, a site was evaluated which had been identified in earlier studies by the City of New York as being suitable for a S.T.O.L. airport. The proposed site is immediately to the west of an underused dock area on the Hudson River. The West Side Elevated Highway is immediately to the east of the dock area and it serves as a barrier between the dock area on the west and the Chelsea residential area on the east.
The residents of the Chelsea area did not want an S.T.O.L. airport at Chelsea nor did they want a study implying acceptance of an S.T.O.L. airport for the Chelsea site. The "Chelsea Against the Stolport Committee" could see no neighborhood benefits whatever for a nearby S.T.O.L. airport. The committee anticipated that an S.T.O.L. airport would bring nothing but noise, air pollution, threats to safety, and surface travel congestion.

American Airlines estimated that the noise levels that would be generated in the Chelsea Area by S.T.O.L. aircraft would be less than the ambient noise level in the neighborhood. However, the residents of Chelsea felt that the ambient noise levels were already objectionably high and that rather than attempting to increase the noise level, attempts should be made to reduce it.

This type of reaction to a proposed urban area S.T.O.L. airport points very cogently to the fact that a very detailed study of neighborhood attitudes toward an S.T.O.L. airport will be required before an S.T.O.L. airport at a specific site can be thought to be compatible with the surrounding area.

Because S.T.O.L. airports have the potential to attract development on adjoining land, this kind of a facility will require special attention so that it can be used as a tool to help achieve the planning objectives of the urban area.

**Implications for Urban Form**

The urban area S.T.O.L. airport can become a useful tool in helping to shape urban form.

"A central S.T.O.L. port could . . . . become a key element in a coherent and rational transportation system. Operated as a system with the present airport used for long haul flights, the S.T.O.L. port could become
a transportation terminal or the center for communication based industry, in contact with all parts of the central business district by members and closed channel T.V.. The S.T.O.L. terminal could thus become a form-creating force.

The S.T.O.L. port system represents an efficient mechanism for strengthening the downtown core in terms of sales dollars, jobs created, additional city revenues and induced investment potential."76

The S.T.O.L. airport may also become a new centralizing force which can contribute to the viability of central cities. In addition the S.T.O.L. airport has potential of creating direct economic benefits for urban areas.

"There is every reason to believe that the increased investment generated by a S.T.O.L. port would be greater than that for most urban development. This is borne out by the growing tendency for industry and consumer services to spring up around air terminals.

While there is little data on airport-induced investment values, it would seem that the dynamic image a central air terminal would bring to a city warrants the conclusion that induced investment would be far higher than the 5 or 6 to 1 rate used as a rule-of-thumb for federal (U.S.) urban renewal project. The small amount of data that is available indicates that a new industry, which a central S.T.O.L. port would induce, pays in taxes 3 to 5 times what they cost the local government for additional services."77

The Port of Seattle Commission in its paper entitled "Seattle-Tacoma Airport and its Impact Upon the Economy of King County" has estimated that each air passenger generates $5.65 in consumer sales. In addition, the Commission estimates that 83 jobs are created for each 1000 aircraft departures.78 These figures may, however, tend to overstate the primary economic impact of a S.T.O.L. airport because rather than generating new economic activity, S.T.O.L. airports may only redistribute economic activity among the existing airports.

Terminal Access

From the point of view of the short haul air passenger, the principal benefits of S.T.O.L. air transport will be the time saving that results from a reduction in terminal access time. Hence, the ideal location for an S.T.O.L. airport would be one that minimizes terminal
travel time. In theory, the geographic centroid of passengers origins and destinations, within the urban area, is the optimal location for an airport. But the centroid is only optimal if transportation facilities and services are uniform throughout the urban area. Nevertheless, for the purposes of this thesis the geographic centroid will be considered to be the point that minimizes terminal access time for short haul air passengers. This assumption is made because it is beyond the scope of this thesis to make a detailed analysis of surface travel conditions within the urban area.

Private automobile, taxi and bus are the principal airport access modes used in Canada and unless there is a significant change in peoples travel habits these modes will continue to carry a major portion of air travelers to and from the terminal. A significant part of S.T.O.L. airport planning, therefore, involves choosing a site for an airport that has convenient vehicular access to the arterial street system.

S.T.O.L. Airport Terminal Facilities

The function of any terminal, be it for C.T.O.L. or S.T.O.L. aircraft, is to expedite the flow of aircraft for hauling passengers and cargo. To perform this function the air terminal incorporates several facilities, among them are:

1) Landing and takeoff areas.
2) Aircraft navigational and guidance facilities.
3) Cargo loading and unloading areas.
4) Passenger loading and unloading areas.
5) Aircraft line maintenance facilities.
6) Fire prevention and control facilities.
There are, of course, certain functional differences in terminal requirements for S.T.O.L. aircraft as compared to C.T.O.L. aircraft. One of the more obvious differences is in the landing area size. S.T.O.L. airport operational areas are shown in Figure 3-16.

S.T.O.L. airports can be built at ground level on elevated structures, or they can be built to float in a river or a harbour.

Ground level S.T.O.L. runways have been built in the U.S. at La Guardia, Washington National, and Dulles Airports, and exploratory studies have been conducted on locating ground level S.T.O.L. runways at J.F. Kennedy and Newark airports. The experience gained from S.T.O.L. operations between Baltimore Friendship Airport, Washington National, and Dulles Airport indicates that S.T.O.L. aircraft can operate efficiently from existing C.T.O.L. airports.

The S.T.O.L. runways at these major airports are either portions of runways that are not frequently used or else they are specially built facilities that are parallel to existing C.T.O.L. runways. The dimensions of these runways are similar to those discussed earlier in this chapter. Ground level runways in other parts of a metropolitan area are feasible provided that the minimum obstruction clearances can be obtained; however, land costs tend to be too high to allow for this type of land use near the city center. In order to overcome the problem of high land costs there have been some proposals that S.T.O.L. airports could be built over freeways, railroad yards, and wharfs. Figure 3-16 shows a plan and side views of a S.T.O.L. airport that is similar to one proposed for the city of Los Angeles. The structure is to be built over the Union Railway Terminal. It will consist of a parking deck, a terminal
FIGURE 3-16
ELEVATED S.T.O.L. AIRPORT

- Flight Operations Level -

- SIDE VIEW -

- END VIEW -
and parking deck and a flight deck. The total floor area of the structure will be approximately 3,240,000 square feet. The first phase of this terminal development is estimated to cost $37,000,000, the final phase is expected to cost an additional $11,600,000. This terminal facility is expected to be able to process about 6 million passengers per year.

As was mentioned previously, there have been suggestions that a floating S.T.O.L. airport could be built and anchored in the Hudson River along the West Side of Manhattan. A floating S.T.O.L. airport could be built on barges and it would be possible to tow the airport to a different site, should community pressure require that it be done.

The three different types of S.T.O.L. airports can be compared on the basis of costs. The least expensive type of S.T.O.L. airport would involve the construction of an S.T.O.L. runway at an existing airport. The existing terminal facilities would be used by both S.T.O.L. and C.T.O.L. air passenger alike. A single 2000 X 100 feet runway would cost approximately $330,000 to build. In the urban area where land costs would have to be included in the price costs would rise considerably. For instance, in 1966 it was estimated that a ground level urban area S.T.O.L. airport would cost $10.5 million. This cost includes land, a terminal building and a runway.

The cost of the 2000 ft. floating S.T.O.L. airport is estimated to be $15.0 million, salvage value is expected to be $2.0 million. Since the only information available on this type of structure is of a preliminary nature it is not possible to discuss what the $15.0 million cost includes.

Both the ground level and floating S.T.O.L. airports require the provision of parking space. Since the land costs near a city center are
very high it can be assumed that parking will have to be provided in
garages adjacent to the airport. However, depending on the number of
passengers served, at some point it may be economical to build a parking
garage sufficiently large to accommodate an elevated S.T.O.L. airport.

The elevated airport can be more than twice as expensive as the
other types of airports. Estimates range from $21.9 million to $37.0
million. However, an elevated structure can provide on-site parking
for up to 3000 automobiles. In addition, space not required for parking
can be leased as warehouse space. A more detailed cost analysis of
elevated S.T.O.L. airports will be carried out in Appendix 1.

In summary the location, size and type of S.T.O.L. airport used in
the urban area will be influenced by a number of factors:

1) The operational capability of the aircraft operating from the
airport.

2) The origins and destinations of the passengers within the
urban area. Because S.T.O.L. airports are relatively small
they can be located close to the centroid of passenger
origins and destinations.

3) The high level of safety that will be required. Thus a
non-obstructed, safe approach to the S.T.O.L. airport is
needed.

4) The S.T.O.L. airport must be compatible with neighbouring land
use. It is especially important that the area be relatively
insensitive to noise.

5) The S.T.O.L. airport must be located so as to minimize problems
of interconnecting with the surface modes of transportation.
Thus, the terminal site must have good vehicular accessibility.

6) The S.T.O.L. airport location should be chosen such that
it will make a maximum contribution to the furtherance of the
planning goals of the area.
FOOTNOTES

CHAPTER THREE


8) Ibid.


14) Ibid.


24) Ibid.
26) Ibid.
29) Ibid.

38) Ibid.

39) Ribner, "Jets and Noise", p.34.


47) Ibid.

48) Ibid.

49) Ibid.


51) Ibid.


58) Lewis, "Residential Area and Airport Location," p. 70.


60) Dept. of Aeronautics and Astronautics, Stanford University, "A Design Study, , ," p. 3-54.


65) Ibid.

66) Ibid.


68) Ibid.

69) Ibid.


73) The Study findings were reported in Dorn C. McGrath Jr., "Compatible Land Use," p. 235.

74) "Technical and Economic Evaluation of Aircraft for Inter-City Short Haul Transportation" Vol. 3, McDonnell Aircraft Corporation St. Louis, April 1966, p. 137.


76) "Technical and Economic Evaluation of Aircraft," p. 137


78) Port of Seattle Commission, "Seattle-Tacoma Airport and its Impact Upon the Economy of King County," 1962.

79) Based on the results of a mail questionnaire survey of Airport Managers conducted by the U.B.C. School of Community and Regional Planning during the summer of 1970.


86) Ibid.


CHAPTER FOUR

A S.T.O.L. Airport in the Vancouver Metropolitan Area: A Case Study

Urban area S.T.O.L. airports will cause a change in the present city-airport relationship. Previously, the city grew outward toward an airport, but now the process can be reversed and an airport can be developed in the center of an already built-up area. This possible change in the location of the terminal facilities of a major transportation mode may have important planning implications.

The chapter is devoted to examining the possible implications of the operation of S.T.O.L. aircraft from a number of potential S.T.O.L. airport sites within the Vancouver Metropolitan area. The examination will begin with an estimate of how many people would use a S.T.O.L. airport if one were located within the Vancouver urban area. The next step will be to determine the optimal location for a S.T.O.L. airport within the metropolitan area. Once the optimal location for an airport has been determined, potential S.T.O.L. airport sites near to the optimal location will be examined in detail. The potential airport sites will be evaluated on the basis of the criteria discussed in Chapter three and on the basis of cost-revenue relationships detailed in Appendix 1.

The Demand for S.T.O.L. Air Transportation

There are two separate groups of travelers who are potential users of S.T.O.L. air transportation. The first group is composed of those people who normally travel distances of less than 500 miles by C.T.O.L. aircraft and will be able to save time by traveling by S.T.O.L. aircraft. The second group contains those people who are presently using other
modes of travel such as automobile or train and would change to S.T.O.L. air transport as the service between a city-pair improves.

The individual travelers choice among alternative transportation modes can be related to the following factors:

1) Total cost (aircraft, surface fare, handling and processing charges at both ends).
2) Total time (total elapsed time between two points).
3) Available departure frequencies.
4) Travel comfort level (seating, air conditioning, noise, etc.)
5) Convenience of terminals.
6) Schedule Reliability.
7) Safety.

The Lockheed California Company has developed an "Airline System Simulation Model" that includes a sub-model for predicting S.T.O.L. air traffic between city-pairs. Unfortunately the model requires data that are not available on travel within British Columbia. Nevertheless, a brief outline of the method is given below in order to illustrate a comprehensive method of predicting S.T.O.L. air traffic.

The basic premise of the S.T.O.L. demand model is that the air traveler is willing to pay more for a mode of transport that saves time. This value of time concept is used to evaluate the potential transfer of passengers to S.T.O.L. aircraft from the alternative modes of transportation. In order to apply the value of time method, the costs and the trip times of each mode of transport and the value of time to all intercity travelers must be known.

The value of time to air, auto, rail and bus travelers that was used as an input in the model was derived from the income distributions of these travelers. The income distributions were derived from various
passenger travel surveys. The average earnings per hour were calculated according to incremental income groups by dividing the average yearly income by the average number of hours worked during the year. The model assumes that business travelers value their time at \(1\frac{1}{2}\) times their average hourly earnings and that non-business travelers value their time at \(\frac{1}{2}\) their average hourly earnings. Using this assumption and a 70/30 percent split in business, non-business travel a value of time distribution for each mode was derived. (See Figure 4-1)

For each city-pair under consideration, the cost per hour saved by S.T.O.L. travel is computed and compared against each alternate mode. Using air travelers as an example, the cost per hour saved is derived by dividing the additional trip cost of S.T.O.L. as compared to C.T.O.L. aircraft by the time saved on journey between the city-pair. For example, assume that the total trip cost by C.T.O.L. aircraft is $20.00 and assume the total trip time (portal to portal) is 2 hours. Now assume also that the total trip cost by S.T.O.L. aircraft is $24.00 and the total trip time is 1\(\frac{1}{2}\) hours. The cost per hour saved is:

\[
\frac{20.00 - 24.00}{(2 - 1.5)} \text{ Hrs} = 8.00/\text{hour}
\]

Entering this value into the distribution shown in Figure 4-1 it will be found that 36 percent of air travelers value their time at $8.00 per hour or more. The potential demand for S.T.O.L. aircraft is found by taking 36 percent of the city-pair air passenger demand. This same operation would be conducted for each other competing mode in order to obtain total city-pair potential demand.

The actual demand that results from the potential demand is a function of the frequency of flights between the city-pairs. The model incorporates this factor by means of a frequency-allocation function. The function (Figure 4-2) is based on the normal probability distribution...
FIGURE 4-1
COMPOSITE VALUE OF TIME DISTRIBUTION
1964 U.S. AIR PASSENGERS

FRACTION OF TOTAL C.T.O.L. PASSENGERS

0 2 4 6 8 10 12 14 16 18

VALUE OF TIME - DOLLARS PER HOUR

Business Travel Time 1.5 X Hourly Income
Non-Business Travel Time .5 X Hourly Income
70% Business Travel
30% Non-Business Travel

FIGURE 4-2
DEMAND VERSUS FLIGHT FREQUENCY

PASSENGER DEMAND PERCENT

0 4 8 12 16 20 24

FLIGHT FREQUENCY
and it has been adjusted to account for variations in trip times for the competitive modes. On the basis of this figure, one can compute the percent of the potential air passengers who will seek air service for any frequency of flights per day.

The value of the forecasts, produced by the model, is open to some question. The model uses, cost, trip time, and departure frequency to determine demand, but, it does not use travel comfort, terminal convenience, schedule reliability or vehicle safety as forecasting variables. No doubt, the model includes the more important demand factors, but it seems to ignore the effects of one of the important differences between S.T.O.L. and C.T.O.L. air transportation, and that is increased terminal accessibility. Moreover, the basic premise of the model, the value of time concept, has come under some criticism in the transportation planning literature. A study of the problems of developing dollar values of time, saved by air travelers, was conducted for the F.A.A. in 1966. Some relevant conclusions of this study are:

1) The application of the value of time for all classes of passengers at all times of the day, for economic analysis seems to be misleading and less valuable than applying no value at all.

2) Willingness to pay is probably the best yardstick for valuing the time saved by air travelers, but because there is little data presently available, its use is not feasible.

3) Time saved in non-business travel has not been rationally evaluated in past highway studies as well as aviation facility improvement.

4) Non-routine occasions are characteristic of air trips and the value of these hours is generally maximum value time and greater than the value of the same persons average hours.

Demand for S.T.O.L. Air Transportation in the Vancouver Metropolitan Area

Because the foregoing model is theoretically unsound, and because no
local data is available, the model will not be used to forecast the demand for S.T.O.L. aircraft services in the Vancouver area. However, for purposes of this thesis, it is possible to establish a gross estimate of the demand for S.T.O.L. air transport, given the following assumptions:

1) 80 percent of the air passengers who travel within British Columbia will choose to travel by S.T.O.L. aircraft. S.T.O.L. air transport will provide fast, convenient transportation for persons travelling 500 miles or less, hence its greatest impact will be felt in the regional, or within British Columbia travel market. Nevertheless, S.T.O.L. air transport will be subject to competition from medium range C.T.O.L. aircraft that make intermediate stops within the region as part of a trip of more than 500 miles. For this reason it is thought that an 80 percent capture rate is the highest that can be expected.

2) The load factor of S.T.O.L. aircraft will be 60 percent. The load factors for various North American air carriers range from 50 to 60 percent. Thus a 60 percent load factor would appear to be the highest that can be reasonably expected.

3) 48 passenger S.T.O.L. will be used in British Columbia until the end of 1984 at which time they will be replaced by 120 passenger aircraft. A 48 passenger S.T.O.L. aircraft will be available for airline service by 1973. U.S. officials expect 120 passenger S.T.O.L. aircraft to be ready for service in the late 1970's or early 1980's, hence it is reasonable to expect a 120 passenger S.T.O.L. aircraft to be in service by 1984.

4) Passengers who transfer to S.T.O.L. air transport from surface mode will increase the estimated passenger demand for S.T.O.L. air transport by 10 percent. There is no simple way to estimate the percentage of persons who will change travel mode, thus the 10 percent transfer rate chosen is purely arbitrary.

Table 4-1 shows a forecast of air passengers arriving and departing at Vancouver Airport. It is from this forecast that the demand for S.T.O.L. Air transport for the period 1972-1992 will be estimated.

| TABLE 4-1 |
| Forecast Vancouver Air Passenger Volumes 1970-1990 |
| Arrivals plus Departures (00,000) |
| Total | Domestic(%) | Regional(%) | Trans- | Ocean(%) |
| Border(%) | |
| 1968 Actual | 1810 | 722 | 40. | 574 | 31.5 | 470 | 26.0 | 41 | 2.5 |
| 1970 Forecast | 2092 | 832 | 39.7 | 652 | 31.3 | 546 | 26.1 | 62 | 2.9 |
| 1975 | 3284 | 1214 | 36.9 | 954 | 29.1 | 982 | 30.0 | 67 | 4.0 |
| 1980 | 5286 | 1866 | 35.2 | 1462 | 27.8 | 1684 | 31.8 | 274 | 5.2 |
| 1985 Projection | 8678 | 2976 | 34.3 | 2352 | 27.1 | 2838 | 32.7 | 512 | 5.9 |
| 1990 | 11418 | 3836 | 33.5 | 3016 | 26.5 | 3836 | 33.6 | 730 | 6.4 |

* Regional Flights begin and end in British Columbia
The estimated demand for S.T.O.L. air transportation is outlined below:

**TABLE 4-2**

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Air Passengers</th>
<th>Regional Capture Rate</th>
<th>80 Percent Passengers</th>
<th>10 Percent Passengers</th>
<th>Total STOL Aircraft Movements</th>
</tr>
</thead>
<tbody>
<tr>
<td>1972</td>
<td>772,000</td>
<td>616,000</td>
<td>61,600</td>
<td>677,600</td>
<td>23,420</td>
</tr>
<tr>
<td>1975</td>
<td>954,000</td>
<td>763,000</td>
<td>76,300</td>
<td>839,300</td>
<td>28,930</td>
</tr>
<tr>
<td>1980</td>
<td>1,462,000</td>
<td>1,169,000</td>
<td>116,900</td>
<td>1,285,900</td>
<td>44,310</td>
</tr>
<tr>
<td>1985</td>
<td>2,352,000</td>
<td>1,881,000</td>
<td>188,100</td>
<td>2,069,100</td>
<td>28,740</td>
</tr>
<tr>
<td>1990</td>
<td>3,016,000</td>
<td>2,412,000</td>
<td>241,200</td>
<td>2,653,000</td>
<td>36,847</td>
</tr>
<tr>
<td>1992</td>
<td>3,321,600</td>
<td>2,557,280</td>
<td>255,728</td>
<td>2,813,000</td>
<td>39,000</td>
</tr>
</tbody>
</table>

The following table shows the 1967 percentage breakdown of the origins and destinations of air trips to and from major British Columbia points which began or terminated at Vancouver International Airport.

**TABLE 4-3**

<table>
<thead>
<tr>
<th>Destination</th>
<th>Passengers</th>
<th>Percent of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Campbell River</td>
<td>13,000</td>
<td>3.4</td>
</tr>
<tr>
<td>Castlegar</td>
<td>18,190</td>
<td>4.7</td>
</tr>
<tr>
<td>Comox</td>
<td>7,560</td>
<td>2.0</td>
</tr>
<tr>
<td>Cranbrook</td>
<td>10,120</td>
<td>2.6</td>
</tr>
<tr>
<td>Fort Nelson</td>
<td>2,880</td>
<td>0.8</td>
</tr>
<tr>
<td>Hudson Hope</td>
<td>10,160</td>
<td>2.7</td>
</tr>
<tr>
<td>Kamloops</td>
<td>11,530</td>
<td>3.0</td>
</tr>
<tr>
<td>Kelowna</td>
<td>25,480</td>
<td>6.6</td>
</tr>
<tr>
<td>Penticton</td>
<td>17,470</td>
<td>4.5</td>
</tr>
<tr>
<td>Port Hardy</td>
<td>31,060</td>
<td>8.1</td>
</tr>
<tr>
<td>Prince George</td>
<td>42,700</td>
<td>11.1</td>
</tr>
<tr>
<td>Powell River</td>
<td>30,070</td>
<td>7.8</td>
</tr>
<tr>
<td>Prince Rupert</td>
<td>37,110</td>
<td>9.7</td>
</tr>
<tr>
<td>Sandspit</td>
<td>19,150</td>
<td>5.0</td>
</tr>
<tr>
<td>Terrace/Kitimat</td>
<td>24,060</td>
<td>6.3</td>
</tr>
<tr>
<td>Victoria</td>
<td>66,870</td>
<td>17.3</td>
</tr>
<tr>
<td>Williams Lake</td>
<td>2,080</td>
<td>0.5</td>
</tr>
<tr>
<td>Fort St. John</td>
<td>10,870</td>
<td>2.8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>384,470</td>
<td>100.0</td>
</tr>
</tbody>
</table>
Based on this geographic distribution of air trips it can be assumed that Victoria, Prince George, and Prince Rupert will be the principal points served by a S.T.O.L. air transport system operating from the Vancouver metropolitan area.

The Optimal S.T.O.L. Airport Location in the Vancouver Metropolitan Area

From the regional air traveler's point of view the optimal location for an S.T.O.L. airport is one that minimizes aggregate terminal travel time. Assuming that straight line distance is an adequate proxy for travel time, it is possible to calculate the optimal location for an S.T.O.L. airport using a basic geographer's method for determining the centre of gravity of a series of weighted quantities spread over a plane surface.

The method used to calculate the centroid of passenger origins is quite straightforward. The passenger origins were first assigned to 59 traffic zones. These origins were then plotted on a grid. The moments of force were balanced about the x and y axes. The number of passenger origins in each zone was as a weight and the position of the weight on the axis was used as the moment arm. The balance point for each axis was then projected at right angles to both axis. The point of intersection of these two projected lines is the centroid of air passenger surface trip origins. (See Figure 4-3 for optimal airport location)

The data used to determine the centroid of regional air passenger origins was taken from the February 1971 "Canada Airport Access Survey" which was conducted at Vancouver International Airport by the School of Community and Regional Planning at the University of British Columbia.
Figure 4-4 shows the geographic distribution of air traveler-origins in the metropolitan area. Notice that 21.7 percent of all air passengers who make trips destined within the province transferred from other flights. (See Figure 4-4, Traffic: Zone 46.) The effect of such a high concentration of origins in a single zone was calculated. It will be noticed in Figure 4-3 that the transferring passengers cause the optimal terminal location to shift approximately one mile to the south-west of the point obtained if transferring passengers are not considered. But in terms of the practical location of an S.T.O.L. airport it would seem that such a shift makes little difference since both locations are equally unsuitable, both are in single family residential areas.

Potential S.T.O.L. Airport Sites in the Vancouver Metropolitan Area.

The criteria for S.T.O.L. airport location were detailed in Chapter three. In general, a potential S.T.O.L. airport site must be:

1) Insensitive to noise.

2) Easily accessible by surface vehicles.

3) Optimally located with regard to air passenger origins and destinations in the metropolitan area.

4) Free of obstructions and hazards to air navigation.

The criteria suggest that an industrial area near the centroid of passenger origins would be well suited for an S.T.O.L. airport. However, a similarly located site, adjacent to a recreational area might also be acceptable. In addition, wharf or harbour areas may also provide suitable sites for an airport.

An examination of a land use map of the metropolitan Vancouver area indicates that the following areas can be considered as potential S.T.O.L. Airport Sites. These areas are listed below in order of increasing
distance from the optimal terminal location.

1) The False Creek Flats area from Granville Street to Clark Drive.
2) The Vancouver Waterfront from Main Street east to Clark Drive.
3) The Fraser River Waterfront from Cambie Street east to Vivian Drive.
4) Sea Island - Vancouver International Airport.

**Area No.1 - False Creek Flats**

The False Creek Flats area is the industrial area closest to the centroid of passenger origins. Because of the extensive existing development in the area, it appears that an elevated S.T.O.L. airport above the C.N.R. and Burlington Northern Railroad yards would interfere least with the activities presently being carried out in the area. As may be seen in Figure 4-5 the railway yards are surrounded by industrial land uses that can provide buffer between the airport and surrounding residential land use.

**Wind**

There have been no official records kept of wind speed and direction in the False Creek area. However, Mr. J.B. Wright of the Ministry of Transport, Meteorological Branch in Vancouver, suggests that wind data that has been collected at the First Narrows Bridge can be applied to the False Creek area without any substantial adjustment being required. Figure 4-6 shows the wind rose for the First Narrows Bridge. Notice that the wind is calm, or it blows from the east or the west approximately 76 percent of the time. In addition, it should be noted that the greatest average crosswind component is about 6.5 miles per hour.

Runway alignment is a critical factor for both the maximum utility of an airport and the control of aircraft noise. S.T.O.L. runways should
FIGURE 4-5

INDUSTRIAL LAND USE - VANCOUVER
Percentage Frequency By Direction (1 Inch = 10%)  
Mean Speed for each Direction Shown by Figures  
Mean Wind Speed for Period  
7.1 m.p.h.  

FIGURE 4-6  
WIND ROSE  
VANCOUVER FIRST NARROWS  
1969 - 1970
FIGURE 4-8
OBSTRUCTION CLEARANCE: EASTERN APPROACH
TO FALSE CREEK SITE

F.A.A. RECOMMENDED
OBSTRUCTION CLEARANCE

SECTION AA

Earth Fill

Flat

20:1 Slope

700 Ft.

1000 Ft.

6000 Ft.

FIGURE 4-9
OBSTRUCTION CLEARANCE: CROSS SECTION
(Section AA Figure 4-8)

F.A.A. RECOMMENDED
TRANSITIONAL SURFACE

Earth Fill

Flat

4:1 Slope

25 Ft.

7500 Ft.
be aligned insofar as possible (1) to provide aircraft with the most favourable wind conditions, and (2) to avoid noise sensitive areas in the approach and departure paths. Selective runway alignment can minimize noise in the potentially noise sensitive areas, adjacent to the airport. Fortunately, in the False Creek Flats area, a runway oriented on a substantially East-West axis can take full advantage of the wind and minimize noise exposure at the same time. (See Figure 4-7)

Hazards and Obstructions

Figures 4-8, 4-9 show the F.A.A. recommended protection surfaces and the surface contours of the land along the S.T.O.L. airport approach and take off path, shown in Figure 4-7. The minimum protection surfaces can be achieved without modification of any structures along the flight path.

Present Land Use

False Creek Flats was created by filling in part of False Creek. It comprises the area bounded by Main Street on the west, Clark Drive on the east, Great Northern Way on the south and Prior Street on the North. The Flats include 403 acres, 240 of which are covered by railway track, yards and roads; the remaining 166 acres in the area are used for other industrial purposes. Of these 166 acres, 100 are used by railroad oriented industries such as freight forwarders, wholesalers, and cartage and warehousing firms.

The area west of Main Street is devoted to heavy industrial use. A large ready mix concrete plant is located directly opposite the C.N.R. Depot. The rest of the land between Main Street and False Creek bounded by Georgia Street and Fourth Avenue is used for a variety of industrial purposes.
The area bounded by Venables Street and Fourth Avenue between Clark Drive and the railway yards is also devoted to industrial use.\textsuperscript{22}

The industrial area that encircles the railway yards is skirted by commercial and residential land uses on all but the western side which abuts False Creek.

Future Land Use

The C.N.R. and Burlington Northern Railroads have substantial investments in the False Creek Flats area. The C.N.R. alone has assessed investments of $1.6 million in buildings and improvements in the False Creek Area. The La Farge Cement Company has also made recent capital investments in the area. These sizeable investments would tend to indicate that the area will continue to be used for industrial purposes for the foreseeable future.\textsuperscript{23}

The future of land abutting False Creek is much more uncertain. At present there are two residential developments proposed for the lands west of Cambie Street Bridge.

Marathon Realty has proposed a high rise apartment and townhouse development on 120 acres on the north side of False Creek. The land east of the Cambie Bridge and west of Main Street that abuts False Creek is owned by the Provincial Government, and it is presently used for industrial purposes. Marathon Realty Company Limited in their "Proposal for the North Shore of False Creek, Vancouver, B.C."\textsuperscript{24} suggested that this land may continue to be used for industrial purposes or it could be developed as a recreational area. The City of Vancouver, which owns all the land abutting the south side of False Creek from the Granville Street Bridge to Main Street, has recently asked for
proposals for an 85 acre residential development in this area. Moreover, the City of Vancouver Planning Department is presently preparing a policy paper on the development of city owned property between the Cambie Street Bridge and Main Street. Marathon Realty states that the city owned land east of the bridge, "has a fine south slope and beautiful view of the mountains and the city, it would be a prime site for terraced, family housing,"\(^{25}\) Hence it would seem that nearly all of the land abutting False Creek will eventually be used for residential purposes.

**Noise**

In order to minimize noise exposure in the surrounding residential areas, the best location for an east-west oriented S.T.O.L. airport is one that is near the centre of the False Creek Flats industrial area. A site approximately 3500 feet south of the C.N.R. Station will minimize lateral noise exposure. Noise exposure during landing and takeoff will be minimized if the western end of the airport abutts Station Street.

When the noise contours in Figure 3-15 are superimposed on a land use map the number and type of buildings that will be exposed to each noise level can be determined.\(^{26}\) Beginning first with the area east of Main Street, and using the above method, it was determined that there are 67 single family dwellings within the 90 PndB noise contour. There are also three old hotels which are used as low rental rooming houses, and six apartments located above commercial establishments within the 90 PndB contour.\(^{27}\) There are approximately 1018 single family dwellings between the 85 and 90 PndB noise contours. Assuming 3-4
persons per dwelling unit, an estimated 3,461 persons would be subject to this noise level. In addition, there are two schools within the 85 PndB contour. Between the 85 and 80 PndB contours, there is one high school, two elementary schools, and 1690 dwelling units, or approximately 5,746 persons.

Given the existing land use there will be virtually no noise exposure problems created by S.T.O.L. aircraft operations over the western end of False Creek. There is no residential development at all within the 85 PndB contour and it is estimated that there are fewer than 121 dwelling units within the 80 PndB contour. Nevertheless, should the proposed development of the north and south shores take place, the situation will change markedly.

Marathon Realty has estimated that their False Creek Development will eventually house 14,000 persons, all of whom would be within the 85 PndB noise contour. Using the same ratio of persons per gross acre, the development on the south shore of False Creek would attract 9,350 persons. All of these persons would be within the 80 PndB noise contour.

Table 3-5 suggest that the acceptable interior noise level for a home is 60 PndB. Assuming a 25 PndB sound attenuation through the roof and walls of a home, it would appear that the average noise level will be raised 5 PndB in the 67 homes and dwellings within the 90 PndB contour. However, during the summer the increase in sound levels will be considerably greater when windows and doors are left open and more family activities are conducted out of doors. Persons living in the developments west of the Cambie Street Bridge would presumably be less
affected by sound generated by aircraft because apartments generally have better sound insulation than private homes. Nevertheless, in the summer apartment dwellers would suffer the same problems as persons in single family dwellings. Additionally, apartment dwellers on the upper floors of the high rise towers would be exposed to higher noise level because they will be closer to the source of noise. The nature of this difference in noise level is not known.

Air Pollution

The air pollution created by S.T.O.L. aircraft operating from the Vancouver urban area can be calculated by using fuel consumption figures provided by the aircraft manufacturer and the data outlined in Table 3-5. The pollutant emissions resulting from 1975 S.T.O.L. aircraft operations in the Vancouver urban area are calculated below using fuel consumption data for the D.H.C. 7 S.T.O.L. Airliner and the estimated 1975 aircraft movements from Table 4-2.

- Fuel Consumption - 0.587 pounds per equivalent shaft horsepower per hour.
- Engine Power Output - 919 equivalent shaft horsepower.
- Number of engines - 4
- Estimated time aircraft will be operating within the urban area - 6 minutes
- Total annual S.T.O.L. movements, 1975 - 19,758
- Fuel Consumption per aircraft movement within the urban area - \( \frac{587 \times 919}{60 \text{ min.}} \times 6 \text{ min.} \times 4 \text{ engines} = 216. \) pounds
- Total fuel consumed within the urban area during 1975 S.T.O.L. aircraft operations - 19,758 x 216 = 4,267,728 pounds.
TABLE 4-4

ESTIMATED POLLUTANT YIELD FOR D.H.C. 7 AIRCRAFT OPERATING IN
THE VANOCUVER METROPOLITAN AREA - 1975

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Monoxide</td>
<td>2987.4 lbs.</td>
</tr>
<tr>
<td>Hydro Carbons</td>
<td>426.6 lbs.</td>
</tr>
<tr>
<td>Nitrogen Oxides</td>
<td>8962.3 lbs.</td>
</tr>
<tr>
<td>Particulates</td>
<td>2560.6 lbs.</td>
</tr>
<tr>
<td>Sulphur Oxides</td>
<td>426.6 lbs.</td>
</tr>
</tbody>
</table>

The figures shown above must be considered gross estimates because as is evident in Table 3-5, the amount of each type of pollutant that is emitted varies with the operating mode of the engine. However, for the purposes of estimation of pollutant yields, it was assumed that the engine would be operated in the landing, takeoff and climbout mode indicated in Table 3-5.

Terminal Access

The proposed terminal site is conveniently located with respect to the Vancouver C.B.D. and it is central to the urban area. The terminal site is adjacent to one of most heavily travelled surface transportation corridors in the region, the Main Street - Kingsway Corridor.28

The major streets in the area are Main Street and Terminal Avenue. Access to the False Creek Flats area from the C.B.D. is presently being up-graded. A new Georgia Street Viaduct is presently under construction. The structure will provide a 6 lane arterial connection between Main Street and the C.B.D.. The new viaduct which consists of three east-bound and three west-bound lanes will cross Main Street at two points. The east-bound lanes, which connect on to Georgia Street, will cross Main at Prior Street and the West-bound lanes, connecting onto Dunsmuir Street, will cross Main at Union Street. The 6 lanes will join at Gore and Prior Street. At this point they will link to a proposed East-West
Freeway. This freeway with adequate entrance and exit ramps will greatly increase vehicular access to the False Creek Flats area for those potential S.T.O.L. air passengers who travel to the airport from the C.B.D. and the eastern parts of the city.

There are also a series of proposals for transportation system improvements which could greatly increase surface travel conditions in the False Creek area.

For instance, the C.B.D. bypass route from the proposed second crossing of the First Narrows is expected to connect to the proposed Quebec - Columbia Street connector which will provide additional north-south road capacity parallel to Main Street. (See Figure 4-10)

A 1968 transportation study, conducted for the City of Vancouver, suggested that a site near the C.N.R. Station is suitable for one of the stations of a proposed rapid transit line that would follow an alignment from the C.B.D. via Pender Street, Main Street, Great Northern Way, and the abandoned B.C. Hydro "Central Park" right of way to Willingdon and Kingsway Streets in Burnaby.

Moreover, the same transportation study suggested that a railroad commuter service could also be operated from Burnaby to Vancouver along the C.N.R. Burlington Rail-line. The study stated that,

"The existing C.N.R. line from the (C.N.R. Depot) through Vancouver and Burnaby provides a ready made route through the most difficult and built-up part of the Metropolitan area."30

However, considering modal transfers, the waiting time required to complete a journey, and the slowly increasing affluence of passengers it seems that such a service would not be attractive to the travelling public. Nevertheless at a future date a commuter service to the C.N.R.
Station, in conjunction with a rapid transit system, may prove to be attractive to commuters as the metropolitan area grows eastward up the Fraser Valley.

Considering the existing transportation system and the proposed system improvements, it seems that the False Creek area may become one of the most accessible areas in the Vancouver Metropolitan area.

Area No. 2 - The Vancouver Waterfront from Main Street, East to Clarke Drive

The land along this section of the Vancouver Waterfront contains the largest piers in the harbour, Centennial and Ballentyne Piers. The rest of the shoreline in the area is taken up by a grain elevator, a sugar refinery, and several smaller piers used by the Burlington Northern Railway and several fishing companies.

Wind

The Ministry of Transport Meteorological Branch records wind velocity and direction at a recording station above Centennial Pier. The Wind Rose for 1969-1970 shown in Figure 4-11 summarizes the important wind data for the area. Notice that the wind blows from the east or west, or is calm approximately 62.4 percent of the time. For about 22.5 percent of the time the wind blows along a northwest-southeast axis. This wind data indicates that a S.T.O.L. runway in this area should be aligned on a substantially east-west axis.

Hazards and Obstruction Clearance

It is not possible to build an elevated S.T.O.L. airport in this area without making substantial changes in the cargo handling machinery on Centennial pier. A container crane stands 200 feet above the pier, two other cranes on the pier are 160 feet high. Moreover, there are
Percentage Frequency by Direction (1 Inch = 10%)
Mean Wind Speed for Each Direction Shown by Figures
Mean Wind Speed for Period 6.3 m.p.h.

FIGURE 4-11

WIND ROSE
VANCOUVER–CETENNIAL
1969–1970  PIER 33
several buildings approximately 200 feet high immediately east of
Centennial pier. These machines and buildings would project into the
obstruction-free zones recommended by the F.A.A. even if the S.T.O.L.
airport were 125 feet above the ground. An elevated S.T.O.L. airport
in this area would have to be at least 200 feet above ground to
obtain obstruction clearances. Since the economics of a 125 feet
high structure over a dock is questionable, (as may be seen in Appendix 1)
an elevated structure 200 feet high can be considered to be out of the
question.

A floating S.T.O.L. airport, anchored approximately 1,000 feet
north of Centennial Pier, can be aligned on an east-west axis and
achieve the desired obstruction clearance and still minimize noise
exposure.

Figure 4-12 shows the noise contours and takeoff and approach
path associated with the floating S.T.O.L. airport.

Present Land Use

The land, north of the Canadian Pacific Railway tracks, is devoted
mainly to port oriented facilities such as piers and grain elevators.
The land immediately south of the tracks is used for warehousing and
manufacturing purposes. There are also some older hotels and retail
outlets in the area.

Future Land Use

The waterfront land in this area is classified as being suitable
for deep sea general cargo facilities. The present shipping terminals
are not being used to capacity, primarily because the area is handicapped
at present by an abundance of obsolete port facilities. Cargo tonnage
Figure 4-12
Centennial Pier Runway Alignment and Noise Contours

PROJECT 200

(BURRARD INLET)

80 PNdB

95 PNdB

90 PNdB

(Centennial Pier)

ENGLISH BAY

FALSE CREEK

2000 ft.
forecasts for Vancouver Harbour indicate that a strong demand for shipping terminal space will continue until 1985. Nevertheless, a 1970 Vancouver study of the urban-influence on port development indicates that an urban location for a port is no longer necessary due to changes in cargo flows and service links. But, despite the changing relationship between the port and the city, it seems that the recent National Harbours investments in plant and equipment on Centennial Pier indicate that the area will be used for port oriented activities well into the foreseeable future.

The land use immediately west of this area is beginning to undergo a dramatic change. The first stage of Project 200, a major comprehensive development, is now being built. Project 200 will eventually cover an area of 28.6 acres. It will consist of three basic elements, an office-hotel-trade center, eight high rise apartment buildings, and a department retail-store area. The development, in its final stage, will provide over two million square feet of office space, 1.5 million square feet of hotel/office space, and about 2.5 million square feet of residential floor space. This residential floor space will allow for about 3,000 dwelling units or housing for from 5,000 to 6,000 persons.

**Noise**

The community noise exposure, that would result from S.T.O.L. aircraft operations from an airport anchored in the harbour, would be generally low. There are no dwelling units within the 90 PndB noise contour, and there is only one hotel within the 85 PndB contour. But there are many office buildings, stores, hotels and apartment buildings in the area along the waterfront from Coal Harbour to Main Street, that are within the 80 PndB noise contour. In addition, when Project 200 is completed, the number of people who would be exposed to a
80 PndB noise level will increase significantly.

Terminal Access

Centennial Pier is immediately north of False Creek Flats and traffic in the pier area may benefit to some extent from the road system improvements planned or in progress in the False Creek area.

Nearly 55 percent of the traffic destined to the central business district of Vancouver from the eastern part of the city, is funneled through the section of land between False Creek and Vancouver Harbour. The principal routes are Georgia, Pender, Hastings and Powell Streets. The heavy traffic volumes along these streets results in average vehicle speeds of from 0 to 13 miles per hour at peak traffic hours. (See Figure 4-13)

Not only is the congestion high on the east-west streets, but it is also high on the north-south streets close to the waterfront. Average vehicle speeds on these streets is from 0 to 13 miles per hour during the peak hours. Thus the streets immediately adjacent to the area under consideration suffer from congestion and under-capacity. Hence it can be concluded that the siting of a S.T.O.L. airport adjacent to Centennial Pier would worsen traffic conditions in an already badly congested part of the city.

A S.T.O.L. airport located on the sea-ward side of an actively functioning shipping pier would also present a series of localized traffic problems. It is not possible to discuss these problems in any detail, but there are several points that deserve to be mentioned. First, it seems that in order for the pier and the airport to operate efficiently, vehicular traffic for each function should be grade separated.
Second, parking garages must be provided in order to minimize the wharf space used by air-oriented surface vehicles. Third, passenger transportation between the parking garage and floating airport will pose an additional problem. There does not appear to be a convenient way to move passengers between the parking garage and the floating airport. Ferry boats may be the only feasible way to transfer passengers, but this additional mode change might tend to reduce the attractiveness of the air service.

Area No. 3 - The Fraser River Waterfront from Cambie Street, East to Vivian Dr.

This area is unsuitable for an S.T.O.L. airport. Aircraft operations from anywhere within this area would conflict with aircraft operations from Vancouver International Airport.

Area No. 4 - Sea Island, Vancouver International Airport

As has been mentioned previously, the U.S. experience has shown that S.T.O.L. aircraft can be operated efficiently from C.T.O.L. airports. There is no reason to suspect that the same result cannot be achieved at Vancouver Airport.

Wind

The existing runways at Vancouver International Airport are aligned to take advantage of the prevailing East-West winds and this alignment will be adequate for S.T.O.L. aircraft operations.

Hazard and Obstruction Clearances

Since the obstruction clearances for C.T.O.L. are more stringent than those recommended for S.T.O.L. aircraft, no obstruction problem would be encountered in the Vancouver Airport area.
Present Land Use

Sea Island is situated in the North Arm of the Fraser River. It is bounded by the Strait of Georgia on the west, the City of Vancouver on the north, and Lulu Island on the south and east.

Nearly all of the more than 4,000 acres of Sea Island is devoted to airport or airport oriented uses. C.P. Air, Air Canada, and Pacific Western Airlines maintain large maintenance facilities on the island. Other aircraft support services such as aircraft sales and service depots, and overhaul shops are also located on the island. About 300 acres of the island is used for an Indian Reserve, a small residential area, and national defense purposes.

The land on Lulu Island, immediately east of Sea Island, is used for mixed industrial, commercial, and residential purposes. The land toward the eastern end of Lulu Island is largely open space with some industrial uses along the Fraser River and a few small subdivisions near Highway 499.

Future Land Use

The Ministry of Transport's $60 million investments in terminal facilities, air traffic control facilities, and $21 million for a new bridge to the island indicate that Sea Island will be used for airport purposes well into the future.

The official Regional Plan indicates that land uses on Lulu Island will remain much as they are at present. However the plan does suggest that the industrial areas on the Fraser River will increase in size.

Noise

The people who live in the vicinity of the Vancouver International Airport are already exposed to aircraft noise levels greater than those
which would be created by S.T.O.L. aircraft operations. At first glance, it might appear that S.T.O.L. aircraft operations might substantially reduce any community annoyance, created by the aircraft operating from Vancouver International Airport. However, the community disruption from S.T.O.L. aircraft may still be important because the duration of the noise created by S.T.O.L. aircraft will be about twice that of C.T.O.L. aircraft and the frequency of S.T.O.L. flights will be greater because the first generation of S.T.O.L. aircraft will seat only 48 passengers; whereas aircraft presently in regional service seat from 50 to 100 passengers depending on the area served. Nevertheless, without extensive tests, it is not possible to say to what extent the combined effect of noise duration and frequency, created by S.T.O.L. aircraft, offset the higher PndB levels created by C.T.O.L. aircraft.

Terminal Access

The 1967 N.D. Lea and Associates "Sea Island Access and the North Arm of the Fraser River Crossing" study indicates that the Hudson Street Bridge, being built across the North Arm of the Fraser River, will ensure that vehicular demand will not exceed capacity on the access routes to the airport. 43

Summary

Four industrial areas, within the Vancouver metropolitan area, have been examined with a view toward determining their suitability as a potential site for a S.T.O.L. airport. These areas are:

1. False Creek Flats
2. Centennial Pier
3. The Industrial area along the North Arm of the Fraser River
4. Sea Island
The industrial area along the North Arm of the Fraser was not examined in detail because air operations from this area would conflict with those being conducted from Vancouver International Airport. It was found that S.T.O.L. aircraft operations could be conducted from sites within the other areas.

False Creek Flats, Centennial Pier, and Vancouver International Airport can be compared from three points of view:

(1) How well they fulfill the locations requirements for an S.T.O.L. airport site.

(2) The additional social costs imposed upon the community as a result of aircraft operations into the urban area.

(3) Economic Costs.

The most important locational requirements of a potential S.T.O.L. airport is that it be situated so as to minimize passenger terminal travel time. It can be seen in Figure 4-14, that the average access trip length for a journey to the optimal terminal location, is 5.7 miles. The average access trip length to the False Creek location is 6.0 miles. (Figure 4-15) For Centennial Pier (Figure 4-16) the average access trip length is 6.6 miles and for Vancouver International Airport the average access trip length is 6.9 miles. (Figure 4-17) Based on the foregoing data it is evident that a S.T.O.L. airport located at False Creek will minimize passengers terminal access distance. Moreover this area of the city may eventually benefit from major improvements to the surface transportation facilities.

A floating S.T.O.L. airport, anchored near Centennial Pier is the next most accessible airport site in terms of average terminal travel distance, but the present traffic congestion in the
FIGURE 4-14
OPTIMAL S.T.O.L. AIRPORT SITE
AIRPORT ACCESS TRIP LENGTH DISTRIBUTION
(Regional Passengers)

Average Trip Length
5.7 Miles

Distance in Miles

FIGURE 4-15
FALSE CREEK AIRPORT SITE
AIRPORT ACCESS TRIP LENGTH DISTRIBUTION
(Regional Passengers)

Average Trip Length
6.0 Miles

Distance in Miles
FIGURE 4-16
CENTENNIAL PIER AIRPORT
AIRPORT ACCESS - TRIP LENGTH
(Regional Passengers)

Average Trip Length
6.6 Miles

Distance in Miles

FIGURE 4-17
VANCOUVER INTERNATIONAL AIRPORT
AIRPORT ACCESS TRIP LENGTH DISTRIBUTION
(Regional Passengers)

Average Trip Length
6.9 Miles

Distance in Miles
area and the problems of transferring passengers to and from a floating airport suggest that the area is unsuitable for a S.T.O.L. airport.

Vancouver International Airport has the longest average access trip length. Nevertheless, vehicular access to Sea Island will be adequate until 1985. However, unless there are savings in terminal access time at other regional destinations, a trip by S.T.O.L. aircraft from Vancouver International Airport would take longer than would the same trip by jet, C.T.O.L. aircraft. Without a reduction in terminal access time, S.T.O.L. aircraft cannot offer air service that is an attractive alternative to C.T.O.L. air services.

The principal social costs that would result from S.T.O.L. aircraft operations into urban areas are increased noise exposure, and increased safety hazards. It is possible that S.T.O.L. aircraft may also cause localized increases in air pollution, but it is not possible to determine where the increases would occur, and if there would be compensating reductions in pollution in other areas.

A problem arises when an attempt is made to compare the potential airport sites in terms of increased community noise exposure. This situation arises because a whole series of physical and subjective variables combine to create noise annoyance. Noise is measured on an ordinal scale and it is not possible to equate the noise annoyance experienced by one group of people exposed to one noise level with the annoyance experienced by another group of people exposed to a different noise level. Hence it is not possible to aggregate noise data from one potential airport site and compare it to aggregate data from another site. However, with respect to the False Creek and Centennial Pier sites this problem of noise
exposure comparison does not arise because community noise exposure at False Creek would be greater than it would be at Centennial Pier for all noise contour levels. (Except for the 80 PNdB contour where exact figures are not known.)

It is not possible to compare the potential noise exposure at Vancouver International Airport with the exposure that might occur at the other sites because there is no common base for comparison. At False Creek and Centennial Pier, noise exposure from aircraft would be a new phenomenon whereas at Vancouver International Airport, the community noise exposure would only be a change in an existing situation. Since it is not possible to measure the changes in community noise exposure between sites, the evaluation will have to be done purely on the basis of the number of people who would be exposed to increased noise levels. On this basis a S.T.O.L. airport on Sea Island is the most preferable, Centennial Pier is next, and False Creek is the least acceptable.

The increase in community safety hazards that may arise from S.T.O.L. aircraft operations will also be examined on the basis of how many people would be exposed to additional risk. Since the people who live near Vancouver International Airport are already exposed to the safety hazards that might arise from aircraft operations, no additional risk would result from aircraft operations from this area. The approaches to the floating S.T.O.L. airport are mainly over water so air operations from this facility would present less of an additional risk than would operations from an elevated structure at False Creek.
Finally, based on the brief cost-revenue analysis in Appendix 1 it appears that the floating S.T.O.L. airport would be the most expensive facility. Over a 20 year period the floating structure would require a $5.4 million subsidy. The elevated structure would require a $756,000 subsidy over the same period. The capital cost of a S.T.O.L. runway at Vancouver International Airport is approximately $330,000, but beyond this figure it is difficult to determine the costs and revenues resulting from S.T.O.L. operations because maintenance and operating costs would be shared by both S.T.O.L. and C.T.O.L. operations, and revenues would accrue to both operations. A complete lack of data makes it impossible to allocate the costs and revenues that might arise from S.T.O.L. aircraft operations at an existing conventional airport. Thus it can only be assumed that S.T.O.L. operations from an existing C.T.O.L. airport would cost less than operations from a completely new S.T.O.L. facility.

In summary, the important characteristics of the three potential S.T.O.L. airport sites are outlined below:

<table>
<thead>
<tr>
<th>Site</th>
<th>Average Terminal Access Distance</th>
<th>Number of Persons exposed to Higher Noise Levels</th>
<th>Additional Safety Hazard</th>
<th>Net Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>False Creek Creek</td>
<td>6.0 Miles</td>
<td>Approx. 9000</td>
<td>Greatest</td>
<td>Elevated Structure</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$756,000</td>
</tr>
<tr>
<td>Centennial Pier</td>
<td>6.6 Miles</td>
<td>Not Known</td>
<td>Moderate</td>
<td>Floating Structure</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$5.4 Million</td>
</tr>
<tr>
<td>Vancouver International Airport</td>
<td>6.9 Miles</td>
<td>No Additional Exposure</td>
<td>Least</td>
<td>Assumed to be</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Least</td>
</tr>
</tbody>
</table>
It is not possible to say which of the three sites is most suitable for a S.T.O.L. airport without reference to a specific planning goal and a series of objectives.

It was pointed out in chapter three that a S.T.O.L. airport can be used as a tool to help realize the planning goals of an area. For instance, if one of the objectives of the city plan is to rebuild the waterfront area then the floating S.T.O.L. airport near Centennial Pier may be a device that can be used to channel development to the waterfront area. Alternatively, if the planning objective were to concentrate transportation facilities in a single corridor, then False Creek might be chosen as the most suitable airport site because it offers a unique opportunity to integrate rail, road and air transportation facilities into a single system.

However, in the absence of specific planning goals and objectives there does not appear to be any justification for building an S.T.O.L. airport at False Creek or Centennial Pier. The saving in average terminal travel distance that would arise by operating S.T.O.L. aircraft from either of these two sites when compared to the average terminal access distance to the existing airport at Sea Island is minimal. In addition, the brief cost-revenue analysis that has been conducted indicates that S.T.O.L. airports at these two sites would not be economically viable. Furthermore, air operations from these two sites would expose additional people to the noise and increased hazards that may arise from aircraft operations. Hence the best location of an S.T.O.L. airport is at Vancouver International Airport.
FOOTNOTES

CHAPTER FOUR


4) Ibid, p. 308.


12) Ibid.

13) The wind recording instrument is located 380 feet above sea level.


15) Greater Vancouver Regional District Planning Department, Metro Land Use Maps, updated 1970.

17) Derived from Figure 3-15.

18) Derived from topographic maps of the area and Figure 3-8.

19) See 18 above.


25) Ibid. 32.

26) Greater Vancouver Regional Planning Board, Metro Land Use Maps.


29) N.D. Lea and Associates Ltd., "An Apprasial of Transportation Systems for the City of Vancouver," Vancouver Traffic Department, City Engineering Department, Nov.1968.


32) 95 Feet above surface level.

33) Mr. J.B. Wright - Ministry of Transport Regional Office, Vancouver March 1971.

34) Derived from Figure 3-15.


38) Ibid. pp. 49-50.

39) Tassie and Griggs, p. 115.


41) Vancouver Sun, Saturday Nov. 1, 1969, p. 30.


CHAPTER FIVE

This chapter includes a summary of the main points examined in this thesis. It also includes some of the conclusions that can be drawn from the material that has been discussed.

Summary

In chapter one it was shown that S.T.O.L. aircraft have the potential of alleviating some of the problems facing the air transport system. In addition it was also shown that S.T.O.L. aircraft can provide air transportation to some of the smaller communities not presently served by scheduled airlines. The chapter concluded by pointing out the need for an examination of the potential problems that may arise from S.T.O.L. aircraft operations into urban area S.T.O.L. airports.

The important passenger transportation modes were examined in Chapter two. The characteristics of the three major types of aircraft were discussed and compared. The potential role of S.T.O.L. aircraft and the benefits that could accrue from their use as an inter-city travel vehicle were discussed.

In Chapter three the discussion focused on the factors that must be considered when planning for a S.T.O.L. airport within an urban area.

Chapter four is a brief study of the possible effects of operating S.T.O.L. aircraft from S.T.O.L. airports within the Vancouver urban area. This study includes an estimate of passenger demand for S.T.O.L. air services and the calculation of the optimal location for a S.T.O.L. airport in the urban area. Four areas near to the optimal airport site were examined with a view toward determining their suitability as locations for a S.T.O.L. airport. The study revealed that it is possible.
to operate S.T.O.L. aircraft from three of the four sites examined. The three sites were compared; however, it was not possible to state which area is the most suitable for a S.T.O.L. airport. Such a comparison would involve both objective and subjective factors, and in such cases, judgements can only be made with reference to specific planning goals and objectives.

Conclusions

The evaluation of the potential S.T.O.L. airport sites within the Vancouver metropolitan area has shown that it is possible to find S.T.O.L. airport sites within the urban area that meet the minimum technical criteria for S.T.O.L. aircraft operations. However, during the course of this study it became evident that there are rather serious shortcomings in some of the S.T.O.L. airport locational criteria. For example, a dependable method of forecasting the community responses to aircraft noise has not be developed.

"Psychoacoustic measures are generally obtained by comparing different sounds in the laboratory environment. The methodology for predicting the psychological reactions of a populace as a whole from laboratory or contrived experiments is very unsatisfactory. One of the most difficult aspects of developing valid community noise criteria is the restricted ability to identify these other elements of aircraft operations, community environment, and semantic content that result in a gross reaction of a community to noise, and that there are not physical dimensions of noise."¹

This statement is supported by the findings of studies conducted in both the United States and Great Britain which found that the threshold of annoyance for intermittent sounds in a community varies between 40 and 90 PndB.² Therefore, it is evident that estimating community reaction to noise exposure is a very complex matter. To simply report that the perceived noise level resulting from aircraft operations is below that which is normal for an area may be very inadequate and misleading.
Given the present state of the art in noise exposure forecasting, it is apparent that selection of a location for an urban area S.T.O.L. airport that will minimize community reaction to aircraft noise will be a difficult and complicated task.

In the literature that deals with the operation of S.T.O.L. aircraft from within urban areas there is considerable emphasis placed on the fact that the S.T.O.L. Airports should be surrounded by compatible land uses which will minimize community acceptance problems. This rather narrow view often ignores the fact that the possible disruptions from S.T.O.L. aircraft may extend several miles beyond the actual airport site. Moreover it is unfortunate that compatible land uses around a S.T.O.L. airport may often imply that aircraft operations will be conducted over the areas of the city that contain the older homes and the poorer residents of a city, simply because lower income residential areas are often contiguous to land uses that are compatible with S.T.O.L. airports. This point is given some local support by the fact that air operations from both the False Creek area and the Centennial Pier area would cause increased noise exposure and safety hazards for the people who live in the lower income eastern part of Vancouver.

Another point that is occasionally discussed and frequently implied by spokesmen for aviation interests, is that air transportation brings benefits to the community at large and is an important part of our economy and way of life; therefore, the annoyance and disturbance suffered by some is a price that must be paid. In the case of S.T.O.L. inter-city air operations, this could mean that the lower income groups of the city would have to pay the greater part of the social costs.
Such a situation involves a form of social tax upon the lower income groups of the city. However, if the contribution that S.T.O.L. air transportation can make to the economy and to increased travel convenience is so great that its benefits out weigh its costs, then there is no reason why some compensation cannot be given to the people who live near a S.T.O.L. airport and pay the major portion of the social costs that arise. If such a service is required, fairness would suggest that the social costs that arise should be minimized. There are two potential methods for creating a more equitable distribution of these social costs.

The first method involves the purchase of air easements. An air easement is a method of gaining some control of land use short of outright ownership. It is the purchase of the right for aircraft to fly over property without recourse by the private owner against the aircraft owners or the airport operators. This method has been used in the United States with some degree of success by both military and civil authorities. The U.S. experience indicates that the method is flexible and that the property owners have been able to recover from the easement holder when the use of the airport changed and noise levels were increased.³ One disadvantage of this method is that only property owners are given compensation for the increased annoyance and disruption while persons renting dwellings would presumably be given no compensation.

The second method which has been suggested for a more equal distribution of the social costs involved is that the cost of insulating dwellings against aircraft noise exposure be borne in part by the public. This method has only limited usefulness because it reduces only a portion of the problem, and it does nothing to alleviate outside noise levels.
These two methods of minimizing the social cost of aircraft operations are only partially effective in reducing the community costs that may arise from aircraft operations. What these solutions would cost the public in dollar terms is not known.

An important function of the S.T.O.L. aircraft inter-city transport system is the minimization of passenger terminal travel time and distance. In the case of Vancouver, there does not appear to be any substantial time saving that could be realized by operating S.T.O.L. aircraft from sites at False Creek or Centennial Pier. For example, a S.T.O.L. airport located in the False Creek area would reduce the average terminal access trip length for regional air passengers by 0.9 miles. Assuming that the journey to the S.T.O.L. airport could be conducted at speeds ranging from 6 to 60 miles per hour, a 0.9 mile reduction in the trip to or from the terminal would mean a time saving of from one to six minutes, depending on the passenger's origin or destination, the surface travel mode chosen, and the route taken. Whether such a small time saving has any significance to a traveler is an open question, but such a minimal terminal access time saving could hardly be the basis for an inter-city S.T.O.L. air service that would compete with conventional air services on the same routes.

While it is not the purpose of this thesis to examine the economics of a possible S.T.O.L. air transport system, some attention was given to the cost-revenue relationships that might arise from operating an urban area S.T.O.L. airport. Appendix 1 indicates that the revenue generated by a S.T.O.L. airport in the Vancouver urban area will not be sufficient to cover the capital and maintenance costs of the required
facilities. In addition, the very minimal average terminal travel distance that would be saved, to say nothing of the additional social costs generated, point very forcefully to the conclusion that there is no apparent economic or social justification for building a S.T.O.L. airport at False Creek or near Centennial Pier.

This is not to suggest, however, that there is no role for S.T.O.L. aircraft within the regional air transportation system. Quite the contrary, there may be an important area of secondary cost savings that could result from the operation of S.T.O.L. aircraft from Vancouver International Airport. For instance, many of the fully licensed airports within the province have very low annual traffic volumes. During 1969 the airport at Terrace, B.C., which has three paved runways of greater than 5000 feet in length, handled only 1,304 scheduled flights. Moreover, there were at least 7 other licensed airports in the province that handled less than 2,000 annual scheduled flights during 1969. In the complete absence of cost and revenue data for the government operated and maintained airports in the province, it can only be assumed that such low traffic volumes do not generate enough revenue to cover the costs of operating these airports. While it is recognized that some of these airports must be maintained to fulfill international aviation obligations, there would seem to be ample scope to convert at least some of the province's less used airports to S.T.O.L. airports in order to save part of the cost of operating and maintaining these airport facilities.

Finally, despite the fact that there does not appear to be a significant time saving for an air passenger flying by S.T.O.L. aircraft
from the Vancouver urban area, there may be significant savings in public funds resulting from the operation of a regional system of S.T.O.L. airports. The extent of the possible saving of public money and the implications of converting conventional airports to S.T.O.L. airports are matters that should be carefully researched.
FOOTNOTES

CHAPTER FIVE


4) Information provided by the Ministry of Transport, Vancouver Regional Office, Airports Branch, Sept. 1970.
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APPENDIX ONE


The purpose of this appendix is to estimate the basic cost-revenue relationships that might result from the construction and operation of an S.T.O.L. airport in the Vancouver urban area. The cost-revenue relationships are calculated for an elevated two level S.T.O.L. airport built over a road or railway yard in one case, and a structure built over a wharf or pier in the other case. Calculations were also made to determine the cost-revenue relationships of a floating S.T.O.L. airport. It is assumed in that the airports would begin operating on Jan.1, 1972. The period under consideration extends from 1972 to 1992.

The cost-revenue relationships will be examined from the point of view of the Ministry of Transport.

The elevated S.T.O.L. airport is assumed to have two levels, or decks, each of which will have 550,000 square feet of floor space. The upper deck would be used entirely for air operations and the lower deck would serve as a terminal area and car park. Any unused space could be leased for use as warehouse space, until the passenger traffic increased to the point where the space would be required for car parking and terminal needs.

All of the space on the floating S.T.O.L. airport is assumed to be required for aircraft operations and terminal needs.

What follows is a discussion of the method used to calculate the basic cost-revenue relationships. First, the yearly number of passenger
trips was determined by linear interpolation of the forecasts detailed in Table 4-2. The total number of flights per year was determined by dividing the total yearly passengers by an average number of passengers per flight. It was assumed that from the beginning of 1972 until the end of 1984 a 48 passenger S.T.O.L. aircraft, having an average load factor of 60 percent, would be the principal aircraft in use. It was further assumed that in 1985 a 120 passenger S.T.O.L. aircraft, also having a 60 percent load factor, would enter service. The number of peak hour passengers per day was calculated using the ratio of one peak hour passenger per 2000 annual passengers. Once the peak hour passenger volumes were determined, the number of parking spaces that would be required was calculated using a standard of 1.5 parking spaces per peak hour passenger. The total area needed for parking each year was calculated using a standard of 276 square feet per parking space. Terminal area space requirements were calculated using the standard of 100 square feet per peak hour passenger.

<table>
<thead>
<tr>
<th>Year</th>
<th>Estimated Annual S.T.O.L. Flights</th>
</tr>
</thead>
<tbody>
<tr>
<td>1972</td>
<td>23,420 (48 passenger aircraft, average load factor .60)</td>
</tr>
<tr>
<td>1975</td>
<td>28,930</td>
</tr>
<tr>
<td>1980</td>
<td>44,310</td>
</tr>
<tr>
<td>1985</td>
<td>28,740 (120 passenger aircraft, average load factor .60)</td>
</tr>
<tr>
<td>1990</td>
<td>36,847</td>
</tr>
<tr>
<td>1992</td>
<td>39,000</td>
</tr>
</tbody>
</table>
TABLE 0-2

S.T.O.L. TERMINAL BUILDING REQUIREMENTS

<table>
<thead>
<tr>
<th>Year</th>
<th>Peak Hour Passengers</th>
<th>Parking Spaces Required</th>
<th>Parking Area Square Feet</th>
<th>Terminal Building Area Square Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>1972</td>
<td>309</td>
<td>464</td>
<td>127,000</td>
<td>30,000</td>
</tr>
<tr>
<td>1975</td>
<td>380</td>
<td>570</td>
<td>157,000</td>
<td>38,000</td>
</tr>
<tr>
<td>1980</td>
<td>585</td>
<td>875</td>
<td>242,000</td>
<td>58,500</td>
</tr>
<tr>
<td>1985</td>
<td>940</td>
<td>1420</td>
<td>392,000</td>
<td>94,000</td>
</tr>
<tr>
<td>1990</td>
<td>1200</td>
<td>1800</td>
<td>496,000</td>
<td>120,000</td>
</tr>
<tr>
<td>1992</td>
<td>1312</td>
<td>1970</td>
<td>545,000</td>
<td>131,000</td>
</tr>
</tbody>
</table>

Capital Costs (1970 Dollars)

Elevated S.T.O.L. Airport

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural and Architectural</td>
<td>$10,000,000</td>
</tr>
<tr>
<td>Site preparation</td>
<td>730,000</td>
</tr>
<tr>
<td>Heating and Plumbing</td>
<td>1,230,000</td>
</tr>
<tr>
<td>Electrical</td>
<td>1,140,000</td>
</tr>
<tr>
<td></td>
<td>$13,110,000</td>
</tr>
<tr>
<td>Design Fee 4%</td>
<td>524,000</td>
</tr>
<tr>
<td>Contingency 10%</td>
<td>1,311,000</td>
</tr>
<tr>
<td></td>
<td>$14,935,000</td>
</tr>
<tr>
<td>Land (air rights 75% of land cost)</td>
<td>2,052,000</td>
</tr>
<tr>
<td>Parking expansion</td>
<td>714,400</td>
</tr>
<tr>
<td>TOTAL</td>
<td>$17,701,400</td>
</tr>
<tr>
<td>Additional cost to build an elevated</td>
<td>2,100,000</td>
</tr>
<tr>
<td>S.T.O.L. airport over a wharf or pier.</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>$19,801,400</td>
</tr>
</tbody>
</table>

Floating S.T.O.L. Airport and Terminal Building

(no details available) $15,000,000

Maintenance and Operating Costs

Terminal building $1.50 per square foot per year.
Airstrip and Parking Lot $320,000 per year.
Using the S.T.O.L. terminal building requirements outlined in Table 0-1 and a discount rate of 5 percent the present values of operating and maintenance costs were determined for the twenty years under consideration.

<table>
<thead>
<tr>
<th></th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terminal Building</td>
<td>$1,044,800</td>
</tr>
<tr>
<td>Airstrip and Parking Lot</td>
<td>4,361,770</td>
</tr>
<tr>
<td>TOTAL</td>
<td>$5,406,570</td>
</tr>
</tbody>
</table>

Revenue

Parking fees are assumed to be 25¢ per hour. It is also assumed that the parking lot will have a 50 percent daily occupancy for a 16 hour day. The twenty year discounted value of these fees is $9,190,300.

Warehouse space was assumed to rent for $1.20 per sq. ft. per year. It was further assumed that all space offered would be rented. The present value of warehouse rental income is $3,804,200.

Terminal rent was calculated assuming 6,000 square feet of terminal space would be required for public space and airport administration. All other space was assumed to be rentable at $2.50 per square foot per year. The discounted value of rental income is $1,557,800.

The revenue from landing fees was calculated based on a fee of $7.50 per arrival for the 48 passenger aircraft and $15.00 per arrival for the 120 passenger aircraft. The present value of this income is $2,022,500.

The revenue from terminal fees was calculated on the basis of $1.00 per 5 arriving seats. The discounted value of this income is $5,776,500.
### Elevated S.T.O.L. Airport

<table>
<thead>
<tr>
<th></th>
<th>Total Cost</th>
<th>Total Revenue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terminal</td>
<td>$17,701,400</td>
<td>Parking Fees</td>
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<tr>
<td>Building</td>
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<tr>
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<td>Warehouse Rent</td>
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<tr>
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<td></td>
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<td>Terminal Rent</td>
</tr>
<tr>
<td></td>
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<td>1,557,800</td>
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<tr>
<td></td>
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<td>Landing Fees</td>
</tr>
<tr>
<td></td>
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<td>2,022,500</td>
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<tr>
<td></td>
<td></td>
<td>Terminal Fees</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5,776,500</td>
</tr>
<tr>
<td><strong>Net Cost</strong></td>
<td><strong>$756,670</strong></td>
<td><strong>$22,351,300</strong></td>
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### Elevated S.T.O.L. Airport over Wharf or Dock

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<td>Warehouse Rent</td>
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<td>Landing Fees</td>
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<td></td>
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<td>Terminal Fees</td>
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<tr>
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<td>5,776,500</td>
</tr>
<tr>
<td><strong>Net Cost</strong></td>
<td><strong>$2,856,670</strong></td>
<td><strong>$22,351,300</strong></td>
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### Floating S.T.O.L. Airport

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<td>Landing Fees</td>
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<tr>
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<tr>
<td></td>
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<td>Terminal Fees</td>
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<tr>
<td></td>
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<td>5,776,500</td>
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<tr>
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<td><strong>$2,997,380</strong></td>
<td><strong>$20,793,500</strong></td>
</tr>
</tbody>
</table>
FOOTNOTES


2) Ibid.

3) Ibid.

4) Ibid.

5) Ibid.


11) Information provided by the Airport Managers Office, Vancouver International Airport. April 6, 1970.

12) Information provided by the Downtown Parking Corporation, Vancouver British Columbia, April 6, 1970.