THE RICE INSTITUTE

MASTER PLANNING FOR JET AIRPORTS

by

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I would also like to thank the Department of Architecture at the Rice Institute for enabling me to undertake advanced study through the grant of an Assistantship and Fellowship without which the furthering of my education would have been impossible.
On December 20, 1957, the first production model of a jet transport was flown on its maiden flight, the Boeing 707. This flight was the climax of months of anticipation by members of the commercial transport industry as to whether or not the jet transport era had actually arrived.

Following this event, periodicals and newspapers were filled with speculation as to the impact such a means of transportation would have in America. Most of the thoughts were positive but among airport planners and operators there was much negative thinking. What should have been the subject of serious, objective contemplation became, in many cases, a point of near hysterical rejection. As a result, articles in periodicals concerning jet facilities have been as much fancy as fact, that is, until very recently. Now the excitement has stabilized but there are still many questions in the minds of those who must plan for jet accommodations.

My interest in the subject of jet airport master planning stems not only from six and one-half years of architectural training, but also from four years of military flying during which I have accumulated 1200 hours of flying time, 1,000 of which are in jet aircraft. This experience has been very valuable in accumulating, sifting, retaining, and discarding data concerning jet airports.

The bulk of my research material has been obtained through isolated articles in periodicals, reports from airport conferences, and scholarly writings from the Proceedings of the American Society of Civil Engineers. There is very little
published on jet airport master planning in particular, but I have utilized the book, *Airport Planning*, by Mr. Walter Prokosch and Mr. Charles Froesch frequently and recommend it highly for general airport planning techniques and approaches. The problems presented by jet aircraft are treated very comprehensively in the *Journal of the Air Transport Division*, Volume 83 (December, 1957), a portion of the Proceedings of the ASCE.

JAMES W. BUCKLEY

Houston, Texas
February 15, 1959
INTRODUCTION

The Spirit of Jet Travel

As the jet age traveler settles himself in the luxurious-ly soft seats of the new jet transports for the first time, listening to the muffled whine of four mighty turbine engines being ignited, he will doubtlessly experience many emotions—anticipation, apprehension, excitement, and a sense of drama. The drama is heightened when he realizes that in only twenty short minutes he will be cruising six to eight miles above a sallowed earth with flight approaching the speed of sound.

The whine becomes a roar as the huge aircraft begins to slowly taxi toward the take-off end of the active runway one mile distant, and the panorama of a busy airport gradually unfolds, slowly approaching, then receding, until without a pause, the creeping giant eases into the number one position for take-off. Largely due to the soundproofed cabin, the deafening roar of the engines at 100 per cent power becomes little more than background for conversation tones and it, too, shall soon be left behind. Safety belts are fastened, cigarettes extinguished, and as the aircraft accelerates, a gentle pressure against the seat is perceived, fostered by thousands of pounds of thrust. Suddenly, almost imperceptibly, the jetliner slips the bonds of earth and ten thousand feet of runway fall away as the airplane enters the sphere for which it was designed. In a matter of minutes the jet passenger is cruising at 30,000 feet in a sparkling blue sky stippled below with a smattering of white puffy clouds. The silence is overwhelming, the smoothness beyond belief. While the speed at which he is 

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traveling is not evident at such an altitude, in only two short hours, the jet age traveler will be disembarking at his destination 1,200 miles distant; truly a new experience.

The Problem and Its Importance

With their slightly subsonic speeds the sleek, swept-winged jetliners have penetrated into the American scene from their lofty altitudes to become the symbol of a new era in winged transportation. Capable of cruising coast to coast in just over four hours, jet age flight can span the Atlantic in slightly over six. Now it is possible to have breakfast in San Francisco, lunch in New York, and dinner in London.¹

But the excitement and anticipation of jet flying is blunted by one-hour taxicab rides or three-hour custom delays before and after arriving at the airport. While speed, convenience, and engineering have advanced with tremendous strides in aircraft design, our airports lag far behind in utility and accommodation, so far in fact, that as the jet airliner approaches for its landing, no more than five or six airports will be capable of accepting it.

Why does it invariably happen that America finds itself constantly in a position of having to catch up? It seems to be inherent in our nature to allow a crisis (and the arrival of jet aircraft at this point has created a minor crisis) to

¹A Comet IV of B.O.A.C. made the first official Atlantic crossing in six hours and 12 minutes, traveling 3,650 miles from New York to London at an average speed of 580 miles per hour and a top speed of 640 miles per hour, October 5, 1958.
arrive and envelope us before we plan to counteract it. Jet flying began in the United States in 1943, and in 1946 the first tactical jet aircraft was placed in operation.¹ In 1948, huge jet bombers were constructed and flown.² It required only the feeblest of imaginations to see that in a few short years those same jet bombers would become the grandparents of our present jet transports. Few airport developers and city administrators considered this fact as evidenced by our present conglomeration of inadequate landing strips and terminal buildings. In the majority of our cities the immediate concern was for a fast dollar and memorials to the existing city administration while the municipal airport became more like a tolerated stepchild. In 1955, when the first jet transport was being tested, the airport directors and the city of Houston, Texas, constructed a five million dollar terminal building on an inadequate site. Now four years later, they are confronted with the problem of runways that are too short, inadequate land for expansion, and the loss of an expensive terminal building if a new site must be developed which seems to be the most feasible alternative to renovation. In contrast to Houston's lack of foresight, Friendship Field in Baltimore is only now beginning to receive the traffic which the planners anticipated ten years earlier.

Besides the planning problems confronting airport developers, which include ticketing, passenger accommodation, and

²Ibid., p. 100.
baggage handling at the airport, some of the jet age passenger's most painful dilemmas are beyond the reach of the airport operator. Chicago, for example, is still waiting for the expressway which will make O'Hare International Airport accessible to downtown customers. In New York City the huge jets will operate at Idlewild Airport on a conditional basis until they have proved themselves compatible to the ears of noise-conscious Port Authority officials.

These problems are very real and of vital importance to the cities that wish to become prominent as air centers of the world because the city which neglects its aerial development will become the city infected with the germ of decay. Jet transports capable of flying 2,700 miles per hour are on the drawing boards of aircraft manufacturers at this time and it is reasonable to assume that rocketships and space travel will be commonplace within thirty years. The city planners and airport developers must realize this tremendous impetus of aerial amplification, moving toward the future with a scope and stride never before conceived. In the words of Daniel Burnham before the World's Columbian Exposition, we "must make no little plans."

Historical Considerations

On December 17, 1903, Wilbur and Orville Wright launched their airplane on its maiden flight from a rolling sand dune. Since that date, the aircraft industry has grown to astronomical proportions with such rapidity that it is folly to attempt to design the new airports with "proven solutions." In fact,
very few conclusions can be drawn by studying the industry itself and its relation to city planning because of its decidedly young age. However, we can attempt to study historic parallels as an aid. Realizing that flying is simply another form of transportation, perhaps by reverting to the development of other modes, it may be possible to discover an analogous situation.

Mr. Walter Prokosch, architect in the engineering department of Eastern Airlines, Inc., feels "that the history of a city's growth will usually parallel the history of its means of transportation."¹ New York, Boston, Baltimore, all seem to support this statement in that each one has an excellent deep-water port. Chicago, Kansas City, and St. Louis became widely known as railway hubs while many other cities had their beginning with the intersection of roads. One cannot say that this was the sole reason why particular cities increased in size but it formed the early influence which molded their development. The seaports were strengthened by railroads and highways while many of the railroad centers were supplemented with inland waterways and roads. The important point to retain is this: Each mode of transportation opened an area which, in the beginning, was difficult or impossible to reach by other means.

But there is another interesting phase in the development of cities brought about by the motor car.² Whereas railroads

²Ibid., p. 3.
and ports tend to concentrate as much activity as possible in a small area, the motor vehicle has brought about the opposite effect, the process of decentralization. In Los Angeles and new cities, this mode of transportation has created an entirely different city pattern with the population spreading over a tremendous area. When this process will stabilize is a matter of conjecture but it is presenting city administrations with serious problems. It must be concluded then, that each form of transportation influences to a great degree the pattern of city development. The ever-important question to a homeowner, businessman, or any person who is investing his capital for the future remains, "By what mode of transportation shall I reach my investment?" The answer will become a part of the city plan.

A valid parallel may be drawn between these other modes of transportation and that of air travel. First, in studying the past, it is found that each new mode of transport serves to strengthen the position of the established city. In practice, the first new jet routes link only the principal cities as railroads and highways do today. Finally, certain areas inaccessible by any other means can often be reached by air and this unique ability of the airplane to overcome natural obstacles may become the prime reason for surpassing other methods.

But what does this comparison have to do with the jet age? The jet age has finally awakened city planners, architects and airport developers to the realization that no longer can patchwork planning be tolerated nor airports be regarded
as a necessary evil. They have been forced to recognize the airplane as they were finally forced to recognize the impact of the motor car. Now they cannot and must not be satisfied to attempt to merely land the 600 miles per hour jet planes and accommodate their passengers for the moment. They must think many years into the future and estimate, even guess, what it may hold and attempt to design for it. It is a tragic waste of manhours, money, and a city's prestige to accomplish only a stop-gap program. Time {{utilized} in planning will be regained in future accommodation.

Purpose and Scope

An airport is a functional portion of the city or region, taking its place alongside other functional areas, and as such, it certainly comes under the auspices of the city planning commission and not appointed committees whose sole function is to locate a site. Its proper location can only be ascertained following the considerations due any aspect of the city plan relative to highway arteries and tributeries, population centers, industrial areas, etc. Difficulties arise, however, in the attempt to correlate the airport to the other functions of the city because of the decided lack of material on the subject and the slow realization of the people that it has come of age. This situation is particularly true with reference to jet airports.

In an effort to aid those who are concerned with the problems of jet airports, this thesis is undertaken. It would be irrational to state that the conclusions expressed herein are
the best of all possible solutions. There is no such thing in airport design largely due to the varied complexity of each city and the difference in available sites. Each problem must be viewed from an original approach. There are items common to all airports that are adequately explained in other books on the subject; however, there is very little written concerning airports for the accommodation of jet transports and it is this particular aspect with which this thesis is concerned. I have, to be sure, included certain figures, dimensions, and references to existing airports, both good and bad, but it must be remembered that each of these airports was the outgrowth of a particular site, a definite level of financial backing, and varying degrees of thoughtful planning, all three of which were often insufficient.

I have not presented a specific design for a jet airport; however, I have advocated a relationship between the airfield and the terminal building which is not presently recognized as a standard design criterion. The jet age is not a final step in aerial development but more an infant maturing into youth. As the youth continues to grow, new clothes are required since alterations may only be performed to a degree. Similarly in all architecture, particularly in airport design, there are no finalities, but only guiding principles which give us direction and points of departure. It is the effort of this thesis to discover and acknowledge these principles.
CHAPTER II
THE JET AIRPORT: ITS NATIONAL, REGIONAL, AND COMMUNITY RELATIONSHIP

General

The proper relationship of the jet airport to the national, regional and community structure should be the culmination of an exhaustive period of research and interrelation of desirable objectives. This phase should encompass a study of population density trends, city land uses (present and proposed), geographical and characteristics, economic developments, transportation facilities, and available land areas. Surveys are required in order to reach valid conclusions, thus aiding to prevent the misuse of multimillions of dollars in city and national funds. The small amount required initially to conduct such surveys will be amply repaid when the relationships are correctly established.

This portion of the thesis will investigate the national, regional, and community relationships to the jet airport with respect to economics, convenience, location, and feeder airlines in an effort to establish their proper association to the airport and to each other. In fact, I feel that the relations are so linked and overlapped that it is extremely difficult to discuss one phase without touching upon another and this implication will very likely be observed as the inquiry develops.

The National Relationship

Despite the fact that flying in the United States began
in 1903, there was a twenty-three year lapse before a federal government agency concerned itself exclusively with aviation matters. Under the Air Commerce Act of 1926, the Aeronautics Branch of the Department of Commerce was created, assuming the responsibility for the examination and licensing of aircraft and airmen, the enforcement of air traffic rules, and for the collection and dissemination of aeronautical information. This organization remained the sole federal representative for civil aviation until June 13, 1938, when President Franklin D. Roosevelt signed the bill originating the Civil Aeronautics Administration, consisting of five members, an executive administrator, together with a three-man safety board.

These two bodies, the Civil Aeronautics Administration and the Civil Aeronautics Board (hereafter referred to as the CAA and the CAB respectively), are the agencies for federal promotion and regulation of civil aviation. "The Board is concerned principally with the issuance of certificates of public necessity, economic regulation, the formulation of safety regulations, and the investigation of accidents to civil aircraft. The CAA builds and operates air navigation aids, enforces the safety regulations, and promotes the development of a national airport system."

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2Shrader, op. cit., p. 65.

3Civil Aeronautics Administration, op. cit., p. 1.
The CAA is separated internally into eleven offices, each performing special functions. The eleven offices are as follows:

1. Federal Airways
2. Aviation Safety
3. Airports
4. Aviation Training
5. Aviation Information
6. Staff Programs Office
7. Technical Development
8. Research
9. Personal Flying
10. Washington National Airport
11. Administrative

Mr. Walter Prokosch, architect for Eastern Airlines, mentions in his book, *Airport Planning*, that the CAA also "maintains an urban planning section which may be freely consulted. The country is divided into seven regions, each of which is staffed with technicians whose services are available to any group which is planning airport facilities."\(^2\)

It is obvious after studying the preceding list of CAA units, that the two which would prove most helpful to a city or region undertaking the location and design of a jet airport would be the Office of Federal Airways and the Office of Airports. While the preliminary work in airport planning is not

\(^1\)Ibid., p. 481.

their responsibility, the consultation and advice of this office would help planners to avoid any dangerous or inadequate situations which could lead to disapproval of an airport and the discouragement of air traffic.

When the CAA assumed its responsibilities in 1938, it became custodian of 35,492 miles of airway and advisor to 2,314 airports.¹ During World War II, German air superiority stimulated an extensive program of U.S. Air Force expansion which was to accommodate heavy bombardment aircraft according to pre-war standards. Longer runways of unprecedented dimensions were required in such haste that construction had to come first and planning later.² Thus, in 1945, when the war subsided, the CAA found itself in control of 66,979 miles of airway and 3,917 airports.³

Such tremendous growth engendered by the war presented the United States with an airport system which had not kept pace with the great expansion of civil aviation. The necessity of more and better airports was recognized by the 79th Congress which created the Federal Airport Act of 1946, directing the CAA to prepare and revise annually a national plan for the development of public airports in the United States, Alaska, Hawaii, and Puerto Rico.⁴ The first Airport Act authorized

²Ibid., p. 481.
³Ibid., p. 482.
⁴CAA, op. cit., p. 5.
FIGURE 1. SYSTEM OF VOR¹ AIRWAYS IN THE UNITED STATES.

¹Very high frequency, Omni. directional radio.
Federal expenditures of $500,000,000 to be used over a seven year period, matched by equal sums from local sponsors.\(^1\) Since that date, the CAA has faithfully amended and revised the National Airport Plan until the present time. The National Airport Plan for 1958 lists a total of 3,061 landing facilities which meet the criteria establishing eligibility for inclusion in the Federal-aid Airport Plan.\(^2\) The plan is not a list of projects that will be accomplished with Federal aid, but a list of airport locations which, in the opinion of the CAA, require development in order to provide a national system of airports.\(^3\) It is noteworthy at this point to mention that the 3,061 airports included in the plan, which extends to 1965, are only a portion of more than 7,000 airports in the United States and its territories.\(^4\)

An example of the purpose of this plan may be demonstrated by referring to the tables listing Texas airports that are affected, and specifically, Houston. The listing in the plan is as follows:\(^5\)

\(^{1}\)Ibid.


\(^{3}\)Ibid., vi.

\(^{4}\)According to the CAA Statistical Handbook for 1957, there were 7,028 airports in the U. S. at the end of 1956, so the assumption is made that the number has increased substantially to "more than 7,000" during the previous two years.

\(^{5}\)CAA, *op. cit.*, p. 123.
TABLE I
EXTRACT FROM THE NATIONAL AIRPORT PLAN FOR 1958

<table>
<thead>
<tr>
<th>City</th>
<th>Airport Name</th>
<th>Aeronautical Code</th>
<th>Necessity</th>
<th>Service Types</th>
</tr>
</thead>
<tbody>
<tr>
<td>Houston</td>
<td>International</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Houston Municipal #2</td>
<td>29</td>
<td></td>
<td></td>
<td>GF</td>
</tr>
<tr>
<td>Houston Municipal(1-A)</td>
<td>10</td>
<td></td>
<td></td>
<td>I</td>
</tr>
</tbody>
</table>

By interpreting the letter code from the index supplied by the plan itself, the meaning established is that, Houston International presently has a "permanent CAB certificate. . ." and the domestic traffic volume at the airport qualifies the community for an airport of the service type indicated. The two "C's" refer to a continental service type of airport for air commerce.

It also states that, Houston Municipal #2 is an airport "needed in the community for some special circumstance not listed. . ." by CAA criteria and "...the satisfaction of the need is essential to the public welfare." This refers, of course, to airports for general aviation, the "U" indicating that the community is undecided between a new site and an

1Tbid., II.
2Tbid., IV.
existing airport, and the "GF" signifying the requirement for a feeder airport.¹

Further the plan maintains that Houston Municipal (I-A), which is presently Houston International, has a "permanent CAB certificate."² and ". . . the domestic traffic volume at the airport qualified the community for an airport of the service type indicated."² The references "N" and "I" indicate that although an intercontinental airport exists, a new site is required that has not been selected, and the new site should be capable of accommodating intercontinental flights.

From this criteria established by CAA, the City of Houston has aid in planning its aerial future at least until 1965. The point that must be stressed, however, is that the people who formulate such plans are solely concerned with "The National Airport Plan" and cannot foresee the situation of each city and, in fact, do not attempt to do so. The local planning authorities should simply use this information as a guide, realizing that the plan provides for airports that would be eligible for Federal aid on a matched basis. Any diversions to different types of airports might permit the withdrawal of such aid.

Not only is it desirable to work with CAA from an economic standpoint, but it is equally beneficial to consult their office when considering the physical aspects of a jet airport with reference to the national situation. Airways

¹Ibid., iv.
²Ibid., ii.
traversing the country from north to south and east to west are for all practical purposes, simply "highways in the sky." As two airways intersect, the possibility of congestion is increased two-fold, a process which becomes even more tangled with the addition of other intersecting airways. To locate an airport directly under such an intersection would lead to a multiplicity of delays in approaching and landing, just as left turns at busy highway intersections cause delay. With jet aircraft burning fuel at the rate of twenty gallons per minute, deferments in landing are extremely costly and represent a delay in time for the passenger. An early conference with the CAA would determine whether or not they would consider altering their airway structure to permit construction of a new airport, whether they have any limitations to airports in the vicinity, and would reveal any additional information that would properly relate the new jet facility to the national structure.

The Regional Relationship

The fact was mentioned earlier that the process of decentralization is creating a new pattern for urban development. This situation suggests that we question the term "city planning" as a possible misnomer and perhaps to substitute instead the term "regional planning" which would encompass the shift of metropolitan populations to outlying areas of the city proper. This has implications for airport master planning.

The term "region" is defined by Mr. L. Hilberseimer in his book, The Nature of Cities, as "an organic entity, in
which the whole is related to the parts and the parts to the whole. . . something which can exist and support life."¹ With this definition in mind, I shall in the future refer to the city proper and the combination of cities as regions. For example, the City of Houston, including its suburbs, would be a region. Likewise, the combination of Baytown, Beaumont, Port Arthur, Galveston, Freeport, and Houston could qualify as a region.

An area sufficiently populated to support jet transportation should have a minimum population of 200,000. I base this figure on statistics presented by Mr. Jennings Randolph, assistant to the president of Capitol Airlines and a director of Transportation Association of America.² Mr. Randolph states that twenty large American cities are handling 66 per cent of the air traffic load as well as 75 per cent of the mail sent by air and 78 per cent of the air cargo. Twenty per cent of the passenger load is handled by thirty-nine other cities, 16.2 per cent of the mail, and 14.4 per cent of the cargo.³ The balance is divided between eighty-eight medium-sized cities.⁴ The first fifty-nine metropolitan areas to which Mr. Randolph refers have populations in excess of 285,000 while the one

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³Ibid.

⁴Ibid.
hundred thirty-seventh city has slightly over 100,000 people.\textsuperscript{1} From this information a mean of 200,000 persons was determined as a practical population to support air commerce and, in my own opinion, the minimum number to make jet airports and jet travel economically feasible. The Port of New York authority further substantiates this estimate of 200,000 persons from their findings in 1955 that 90 per cent of the total domestic air passenger traffic was generated by eighty-seven cities or metropolitan areas.\textsuperscript{2} Correspondingly, the eighty-seventh city in population in 1956 was Lansing, Michigan, with 200,000 people.\textsuperscript{3}

A city with a population of 50,000 would very likely be unable to support a jet airport from its own municipal budget unless, of course, private flying contributed greatly. If, however, several cities of 50,000 in the immediate vicinity pooled their populations and their finances, a regional jet airport could become quite practical at least from the point of view of passenger potential. Considering the smaller towns in the vicinity, such an airport would possess a potential patronage of over 200,000 people, the number which I estimate to be the minimum for jet airports at least at this stage of development. A regional survey of the population would reveal

\begin{itemize}
  \item \textsuperscript{2}Port of New York Authority, Air Travel Forecasting, 1965-1975, (Saugatauk, Conn.: The Eno Foundation for Highway Traffic Control, 1957), p. 61.
  \item \textsuperscript{3}Rand McNally, \textit{loc. cit.}
\end{itemize}
FIGURE 2. POPULATION CENTERS IN THE GALVESTON BAY AREA.
the feasibility of undertaking a regional airport plan. Figure 2 is an indication of such a survey in the Galveston Bay area.¹

The State of Illinois has a local option law which allows each county to vote its desires concerning the support of airports. The airport at Rockford, Illinois, is an example of this arrangement where several counties voted to finance the construction necessary. Thus, the Rockford Airport becomes the aerial hub for an area extending over several counties. This situation is in direct contrast to the Houston International Airport which is financed solely through the city even though Houston forms the greater part of Harris County.²

Airport planning, and particularly jet airport planning should invariably be done on a regional basis rather than a local basis.³ Every jet airport represents a large investment of capital and the building of several in a region incapable of supporting more than one would have ruinous results because of the ensuing competition. A perfect example of this situation presently exists in the Dallas-Fort Worth, Texas area. Love Field in Dallas has operated profitably since 1943, largely due to its location, only five miles from downtown Dallas and convenient to the North Dallas residential area where the majority of its businessmen live.⁴ Fort Worth

¹Based on figures from the 1957 edition of the Rand-McNally Commercial Atlas and Market Guide.

²This information concerning the Rockford Airport and Houston International Airport was received through an interview with Houston Airport Director, Mr. Paul Koonce.

³Prokosch and Froesch, op. cit., p. 8.

recently completed a new airport half-way between the two cities which has considerably safer approaches, doubtlessly speculating that the new field would attract Dallas traffic. In addition to the safety factor, Fort Worth officials further substantiate their position by presenting the obviously true argument that it would be more economical to use Amon Carter Field than to support two first-class terminals. However, Dallas officials refused, stating that it "... would not require its citizens to travel half-way to Fort Worth for airline service when it already had an airport within five miles of downtown."1 Because of this predicament Fort Worth is still operating with a financial loss. This situation further indicates that regional planning requires the cooperation of all concerned.

When conducting the population survey, aside from sheer numbers of people involved, consideration should be given to types of people and their income. In general, flying is more expensive than any other form of transportation. Because of this aspect alone, certain groups of people will provide little or no support for airline service. More often than not, these groups live in an area of the city where their land is at its minimum value already. Conversely, the people who do the most flying are in the moderate to wealthy financial class and live in the better residential sections of the city.

At this point, the airport planner is faced with a quandary. He must resolve whether to locate the airport away from

1Ibid.
the people who will use it and thus keep their property values high or rather locate the airport near their homes with maximum convenience available but lower the value of their property which inevitably happens to real estate near airports. Luckily this consideration alone does not have to be employed as the ultimate determining factor but it should be included for a realistic approach to airport planning.

Closely aligned in importance with the regional survey of the population is the analysis of the economic types of communities in the region. The CAA has classified communities under four headings according to their different travel needs:

(1) Marketing centers where goods are shipped for sale and distribution,

(2) Industrial centers from which pour the products of the manufacturing industries,

(3) Balanced cities that contain an equilibrium of marketing and industrial work, and

(4) Institutional cities such as Washington, D.C., seats of state government, health or educational centers.¹

"Each group represents a difference in per capita purchasing power..." and "...each provides a unique pattern of income distribution and business travel habits."²

²Ibid.
To locate a small airport for private flying, the question of a thorough economic survey would hardly be necessary, but to plan an airport as costly as that required for jet traffic, it is absolutely essential.

To determine the maximum allowable distance at which a jet airport should be located from a specific city, it is necessary to analyze the average air passenger trip length and the composition of air passenger trip lengths.\(^1\) It is at this point that we encounter the fourth dimension of airport planning, time. The fact is generally acknowledged that the distance traveled by an airplane is not measured in miles but in time, and it is measured from the moment the person leaves for the airport until he arrives in the home or office at his destination. "If an airport is located too far from city centers, and the passenger is required to travel a considerable distance by private car, a substantial fraction of the prospective passengers will make the trip by private automobile.\(^2\)"

For trips of less than 200 miles, geographical conditions not offsetting, there is a strong preference for highway travel.\(^3\)

If the results of the analysis reveal that the passengers are of the type that travel short distances by air, 300 miles or under, then it may be that a close-in airport is required (within ten miles). Conversely, if the trips prove to be in

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\(^2\)Ibid., p. 1109-4.

\(^3\)Ibid.
excess of 600 miles, the airport may be placed farther from the heart of the city.

In recent years the noise factor has forced many city planners to locate airports out of the city. This tendency may become more accelerated as the jets begin service. But the aftermath of such a practice can readily be shown by two examples of short distance air traffic. A substantial loss of Detroit's traffic from Cleveland was noted when the Detroit airport was moved from its centrally located site to Willow Run, some 32 miles from the center of Detroit.\(^1\) Similar results were noted in the Midland-Fort Worth traffic following the change from the close-in airport, Meacham Field at Fort Worth, to the new outlying airport, Amon Carter Field. In the period from 1947-1950, approximately 14 per cent of Midland's air traffic went to and from Fort Worth through Meacham Field. After the change to Amon Carter Field, the Midland-Fort Worth traffic reduced 50 per cent with Dallas gaining the greater portion of that which was lost.\(^2\)

From a special study of the airport distance factor on air traffic generation, one which necessarily had to be extended over several years, Mr. James C. Buckley, transportation consultant, has reached certain conclusions which I list in detail.\(^3\) Admitting that the available data is not as extensively

\(^1\)Ibid.
\(^2\)Ibid.

\(^3\)James C. Buckley is a former Port of New York Authority transportation expert and presently is President of James C. Buckley, Inc., Transportation and Terminal Consultants, New York, New York.
FIGURE 3. LAND USE MAP OF THE GREATER HOUSTON AREA.
developed as one would like, Mr. Buckley still finds that it is indicative of the following:

(1) There is a very substantial loss in air traffic when a community must accept its air service through a distant airport.

(2) This loss in air traffic has a direct and detrimental effect on the revenues of the air carriers.

(3) The communities concerned are put to a substantial added burden of determinable expense because of the necessity of using a distant airport, a cost which appears substantially greater than the added costs of developing and extending close-in airports.

(4) The communities using distant airports are placed under additional disadvantages by losing substantially ancillary benefits available from close-in airports, such as a strong payroll within the city limits, a strong force for attracting new and expanded industry, and a strong factor in maintaining and improving the competitive position of local industry.

The study of land use maps such as the one illustrated in Figure 3 will provide necessary information concerning the locations of business or industrial areas, residential locations and show open tracts which may prove adequate for the jet airport site.

A jet airport for cargo use alone might be very beneficial to small industries whose largest selling point is speed in delivery of their products. As more and more industries begin to rely on air travel for their business trips, jet travel will certainly have an appeal since the time spent in air travel is reduced about fifty per cent.

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FIGURE 4. AVAILABLE LAND AREAS FOR AIRPORTS IN THE GREATER HOUSTON AREA.
If the geographical characteristics of the area are carefully studied, considerable knowledge will be gained as to land desirable for the location of an airport. A typical study of this kind is illustrated in Figure 4. The jet airplane requires a large flat area for its approach and landing which, in mountainous terrain, is often difficult to procure. Areas subject to frequent flooding would also prove undesirable unless steps were taken to reclaim the land by extensive grading and filling to raise it above the flood level.

The highway network and railroad system, as illustrated in Figure 5, should be traced in an effort to discover the areas best served by the respective means of transportation. This study should include existing and proposed developments. Transfer of cargoes from waterways may be considered but this type of cargo is not such that demands speed of delivery or else it would have been flown initially.

From these studies, a number of important decisions can be made and many impossible situations may be disclosed. If the results are plotted with different colored strings representing different types of traffic, map pins representing available areas, and colored pencil areas locating the residential and industrial areas, not only will it be possible to discern the location of jet airports, but also air parks, business, and cargo airports.¹ Many conflicting flight paths, traffic patterns, and highway routes will doubtlessly appear

¹Prokosch and Froesch, op. cit., p. 15, recommends this procedure.
FIGURE 5. TRANSPORTATION NETWORK IN THE GREATER HOUSTON AREA.
also, but these must be adjusted and compromised until all traffic flows smoothly through the air.

The opinion of many authorities is that the regional airport will, in time, become the pivot for future air travel. The impact of regional airport planning on regional planning in general is expressed by George Howe, formerly Chairman of Yale University's Department of Architecture:

It doesn't seem impossible to conceive then, since government planning has been accepted at the regional and national levels in principle, that the authority in charge of an airport should go beyond the provision of subsidiary facilities directly connected with it to plan a whole town.

Such a town could be planned on a nuclear traffic and utility layout, with land use, land coverage, and height zoning provisions, as well as a diagram for gradual expansion. Admittedly, such an undertaking would involve a large expenditure, initially non-remunerative, and I believe such a new town at an important traffic center, developed by private enterprise within a planned framework, would grow at an astounding rate.1

Such a proposal as Mr. Howe's would become the forerunner of the "air city" with all facilities designed around and in conjunction with the airports. This ideal can only be achieved in an age when the airplane has become a vehicle for mass transportation but this age is not distant. Such a conception might evolve into a city of "greenbelts" as proposed by Eliel Saarinen. Mr. Saarinen admits that air travel for daily commuting is impossible until airports are

brought in from the city limits and made an integral part of
the city, suggesting that such sites for airports could be
obtained within a greenbelt system.¹

But can regional planning be used to develop further the
city already in existence? An emphatic, yet qualified "yes"
would be the answer. If the planners of today designed their
city as they dream it should become in the next 100 years,
and work toward that end, such a plan can be followed. How¬
ever, the qualifying circumstances involve the integrity and
vision of the city planners together with the powers that the
people allot to them. A far-sighted planner with no authority
is equally as handicapped as a planner with small dreams and
an abundance of power. It is not too late to incorporate the
jet airports with the city or regional plan but all speed must
be utilized to prevent costly errors.

The Community Relationship

. . . The human being is a confounding species.
He likes to talk about the obscure and the unknown.
Humans are inclined to become experts with alacrity,
critics with intensity, and believers with timidity.
And with civil turbo-jet transport operations still
more than a year off [actually they began October 5,
1958] we find the airport neighbor in rather poor
psychological condition as he awaits the event. Like
a patient awaiting a tooth extraction by a strange
dentist, amid the pained outcry of his predecessor
in the chair.²

¹Eliel Saarinen, The City, (New York: Reinhold
²Charles Rosenzahil, "The Jet Age Airport and Its
Neighbors," Journal of the Air Transport Division, Pro¬
The preceding comment of Charles Rosendahl very likely typifies the feelings of the people who comprise the community adjacent to or within a short radius of the jet airport and this type of thinking is unfortunate. The support of the people for the jet transports tends to decrease at a time when maximum support is required. And, as Mr. Rosendahl continues, "...Like the dental patient, they may well find that the anticipation of the dental work was far more trying than the work itself."¹

However, the fears of the communities are not entirely unfounded. The earlier jet transports which were inaugurated by Great Britain were grounded following several crashes. Homes have been destroyed by occasional transport crashes. The danger aspect, however, can be minimized because the causes of the majority of the crashes were determined and steps taken to prevent a recurrence. Further, the CAA reports of 1957 indicate that the fatal accident rate for 1956 was .006 per 1,000,000 miles flown.² While these figures have reference to passenger fatality, they are indicative of the accident rate which communities could expect to occur nationally. It is obvious that the chances of an accident occurring at one particular community are exceedingly remote unless a dangerous local situation exists.

The relationship of the jet airport to the community with respect to noise cannot be dismissed so easily. In San Diego,

¹Ibid., p. 1481-2.

FIGURE 6. AREAS AFFECTED BY JETS AT MIRAMAR NAVAL AIR STATION, CALIFORNIA.
California, the Veterans Administration and the Federal Housing Authority refused to guarantee or insure homes within 20,000 feet of the Miramar Naval Air Station because of jet traffic. It can be observed by reference to Figure 6 that this is nearly a four mile radius. The city, in an effort to make the land useful, re-zoned the area for industrial development. However, when they later discovered that the Navy requested no construction to exceed 50 feet in height, they were obliged to re-zone once more.¹

In 1955, the Federal Housing Administration, supporting a 1952 technical bulletin, stated that with a 4,000 foot runway, the off-limits area where they will not provide financial aid extends one-half mile from the end of the runway and 1,000 feet wide excluding the width of the runway. The Federal Housing Authority also designates approach zones, which extend one mile from the end of the runway zone as areas demanding "special consideration" of depreciation factors.²

In a similar vein, the Veterans Administration became more specific. They refused to appraise any new property within the first one-half mile at all; on the few that existed, appraisals were cut 20 per cent. In the next 2,000 feet after the first one-half mile, the appraisal was cut 10 per cent, 7-1/2 per cent in the next 2,000 feet, and for the next 1,280

²Ibid.
feet the penalty was 5 per cent.¹

Although the regulations described above were primarily results fostered by military jet aircraft, it would be unrealistic to refuse to admit that civil jet transports will not create the same situation. Idlewild Airport in New York City has allowed the jet transports to land only when their engine noise is suppressed to a decibel rating equal to or below that of reciprocal type airplanes. Yet, one need only drive to our present commercial airports to see how homes built adjacent to airport boundaries depreciate in value to an extent that would make them an unwise investment. This fact is evident with propeller driven aircraft and it is not unreasonable to assume that it may be even more true when jet aircraft are introduced.

It is paradoxical, however, that a large jet airport which bears the earmarks of a local nuisance may become the economic stimulus for a community. A commercial airport the size of O'Hare International in Chicago may eventually employ as many as 40,000 persons.² Aside from the taxes that these people could provide, a payroll of nearly $12,000,000 per month would be available, most of which would be spent in the immediate area. The prime commodity of air travel, speed, would certainly become an attraction to small and large industries. Transient traffic could be attracted by proper publicity thus tempting another potential source of income.

¹Ibid.

If a new jet airport is to be created, the community which its very presence will generate should be part of the airport master plan. There are those persons who will live near their work regardless of the conditions in which they must live. And there are speculators that will build such buildings knowing full well that they will be sold. Thus, the seeds of decay begin to sprout even before the new airport is completed with a disoriented, unplanned, creeping form of development. The houses justify stores and the stores spring up with little concern as to what is best for the community.

It is hoped sincerely that city and airport planners will view the new jet airports as the hub of a community and plan the surrounding area to enhance its growth, to guide its development, and to save it from self-destruction.
FUNDAMENTAL AIRPORT REQUIREMENTS

General

The airport by its very nature has certain characteristics and necessities which are basic regardless of the type of aircraft it is to accommodate. The Air Transportation Association of America lists these fundamental requirements as follows:

(1) Accessibility
(2) Relative freedom from obstructions
   a. Fixed
   b. Mobile
(3) Expansion possibilities
(4) Suitability of approach terrain
(5) Meteorological conditions
(6) Cost
   a. Construction
   b. Maintenance
(7) Airways

While analyzing these requirements, any deviations which jet aircraft may demand will be mentioned specifically.

Accessibility

Probably the most important requirement for an airport to possess is easy accessibility. This does not infer that mere existence of a road system makes the airport easily accessible. The approach highways must be first-class members of the regional system to allow air passengers to reach the airport in the minimum of time. Too often planners have placed airports in areas of the city where property was low

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In value and the street system was inadequate for traffic which it already supported. To locate an airport near such an area only aggravates the existing inadequacies resulting in the frequently quoted situation, "downtown-to-airport bottlenecks."

At the present time accessibility by means of private automobiles and taxicabs is probably the most important form of transportation to consider and I can visualize no rapid departure from such means in the near future. When Mr. Leigh Fisher's firm was engaged to integrate the Minneapolis-St. Paul terminal area with over-all community growth, sources of passenger traffic, and general area development, a comparative study of transportation to the airport was made covering the period from 1947-1955. The results of this study indicated that "... airline passenger use of private cars increased from 10 per cent to 13 per cent, while limousine or airport coach service dropped from 33 per cent to 14 per cent." Mr. Fisher feels that the same situation is happening at most metropolitan airports throughout the United States. If this is true, then we may certainly expect the increase to continue until a better or faster method of reaching the airport is implemented.

If a faster, more convenient mode of transportation such as helicopter service is provided, we may generally predict the automobile's prominence as a town-to-airport carrier to

1Fisher, op. cit., p. 1109-2.
2Ibid., p. 1109-3.
decrease. Helicopter service is already in operation in Chicago. Located at Meigs Field on The Loop, helicopters transport air passengers the seventeen air miles to O'Hare Field in eleven minutes, a drive which requires no less than one hour and ten minutes by private car. The greatest obstacle to using helicopters at the present time is their small load capacity of twelve passengers which is not enough to pay the expenses of the airline. However, larger models capable of carrying twenty passengers are being manufactured and, once in use, the lower seat-mile cost should place helicopter service on a firm economical basis.

Rapid ground transit may supply the ideal solution for reaching the outlying airport. At speeds exceeding 100 miles per hour, the electric train could become the perfect link between the high speed jets and the city. While the first cost of installing such a rapid transit system might seem high, I feel that the accommodation which it provides would quickly stimulate use, eventually causing it to become the major form of city transportation. Monorails are also under consideration for several cities. However, regardless of the type of rapid transit, the cities that wish to have a working system installed by 1970, must at least begin the basic planning now.

2Ibid., p. 57.
4Ibid., p. 27.
Relative Freedom from Obstructions

a. Fixed Obstructions--Prior to beginning the airport design, a survey of the obstructions in the vicinity should be made, noting those which may be removed and those that must remain as their presence will have a great deal to do with runway layout. The glide angle of the jet transports is the same as that for existing reciprocal aircraft, so existing obstruction clearance standards remain valid.

b. Mobile Obstructions--Mobile obstructions are generally airplanes from other airports in the vicinity or planes passing over the airport. The jet transports, traveling faster, naturally cover more area with their traffic patterns. Therefore, the danger of overlapping flight paths from any two airports located close together is increased with the turbine aircraft. This situation would present itself early in the planning stage if the plotting procedures mentioned in the previous chapter were employed. There is no set minimum distance which one airport must be placed from another but the governing criteria are the types of aircraft traffic that each supports. Conflicting traffic patterns may possibly be prevented by the correct orientation of runways at the new airport. Likewise, the traffic patterns at the existing airport may be revised in an effort to achieve compatible flight paths.

Expansion Possibilities

When designing for jet aircraft, the expansion of existing facilities must be considered. Past experience with short

\[\text{\textsuperscript{1}}\text{Ante., p. 27.}\]
range planning and inadequate sites indicate that an airport which cannot expand may eventually be rendered useless by the encroachment of its surroundings. Forecasting the future development of jet traffic is difficult, but with airplanes in the design stage exceeding three times the speed of sound and atomic powered aircraft engines under construction, it is reasonable to assume that future aircraft will have higher landing speeds, hence requiring longer runways, thus, more land. Even though short take-off and landing (Shortol) aircraft and vertical take-off and landing (Vertol) aircraft are being tested presently, I feel their use as commercial carriers is not to be expected in the immediate future. In a sense, this situation creates a paradox, the requirement of land for the extension of runways to accommodate jets, followed by an excess of acreage when aircraft requiring only small areas to land are placed in service. But nonetheless, the land should be obtained at an early stage so that when the time arises for expansion, the space will be available. If it cannot be purchased all at one time, the master plan should designate the order in which land should be acquired.

Suitability of Approach Terrain

Airport approaches, as a result of the increased speed of jets while in the traffic pattern, necessarily must be extended. In addition to the necessary approach lighting and radio aids required in the approach zone, the noise factor forces the extension of the approach zone even more. The recent Doolittle Report from the President's Airport Commission
recommends that a fan-shaped area two and one-half miles long and six thousand feet wide at its outer limits be adopted as the desired approach zone.\(^1\) The zone would restrict the use of the land against places of public assembly and allow residential development only in the more distant portions of the zone.\(^2\) Such a zone would substantially alleviate the problems of jet noise in the approach areas.

The best procedure to use when orienting runways, wind direction permitting, is to place them so that the approach zones will extend over land which is unproductive or unsuitable for any other purpose. When unproductive land is not available, the best approach to the runway is over water.

Mr. Fisher tells of selecting an airport site for the city of Tulsa, Oklahoma:

> It was possible to find a site meeting all the criteria and located within 9 miles of the center of Tulsa and within 5 miles of the center of air passenger and executive aircraft ownership. Runways were oriented so that the approach zones passed over the river-bottom lands of the Arkansas River and floodlands of Coal Creek and Polecat Creek.

> Thus, the total site requirements for an 'express category' airport comprised some 800 acres and the flight paths over the river bottoms and natural drainage channels will maintain acceptable noise levels.\(^3\)

Meteorological Conditions

The importance of meteorological conditions upon a jet

\(^1\)Fisher, op. cit., p. 1109-5.
\(^2\)Ibid.
\(^3\)Ibid., p. 1109-6.
airport site is relatively the same as that for airports accommodating reciprocal aircraft. May it suffice to briefly mention here the sites which are least desirable for airports from the standpoint of weather.

Marshy, swampy, and valley sites are undesirable because of fog. Normally they are the first areas to "close in" and the last to clear. Also, valley sites usually have obstructions nearby such as mountains or hills which make it difficult to forecast an average wind since the obstacles tend to make the wind gusty. This, of course, makes runway orientation for maximum use rather difficult.

Another location made undesirable by meteorological conditions is one where smoke or industrial by-products pass freely into the air and drift across the site. The existing Houston International Airport is frequently under instrument conditions on clear days solely because of smoke from the oil industries to the northeast and south. The northeasterly and southerly winds literally blanket the area with smoke. Because fog requires a minute solid particle to condense, the smoke becomes excellent "condensation nuclei" for its formation on days when it might otherwise be unable to form.

Cost

Construction Costs

"An airport is a long-term investment and those factors which appear to minimize the original construction cost may,
in the long run, prove extremely expensive.”\textsuperscript{1} While it may appear that a particular site is expensive, the cost may actually be kept to a minimum if certain factors are considered.

One of the factors which can keep the cost of developing a site lowered is that of topography and natural drainage. The most desirable site would have a minimum of grading required, yet enough slope to insure good drainage. If grading must be done, equal amounts of cutting and filling will eliminate unnecessary purchasing of fill material and waste. Grading should be carried out in accordance with the ultimate design as shown on the master plan in order to preclude the possibility of having to destroy work done in the preceding stages.

With jet airliners weighing as much as 287,500 pounds, soil characteristics which will support such tremendous loads should certainly be obtained.\textsuperscript{2} If a poor soil seems to make the first cost of the site seem inexpensive, difficulty in supporting such heavy aircraft over two-mile runways could develop into tremendous costs. Exhaustive studies of the soils at all sites under consideration should be made with a view toward determining the amount of stabilization and other treatment required to make the areas usable. But quite often the excellent soils for airport purposes may be so poorly located relative to the city that the money saved from soil preparation would be offset by the loss in passenger traffic.

\textsuperscript{1}Air Transport Association of America, \textit{op. cit.}, p. 5.

Such a conflict, once again, should be introduced at the master planning stage and a decision resolved.

The ease with which power, telephone, water, sewer and gas lines may be extended to the airport is another cost factor which should be given consideration prior to final determination.

Maintenance Costs

Maintenance costs may exceed construction costs over a long period of time unless long-wearing materials and proper facilities are provided from the beginning. If a firm base for the runway is not prepared and allowed to settle prior to the actual paving, the inevitable cracking and settling will soon demand replacement with better materials. In any event, the least expensive manner by which an airport may be maintained is by the installation of durable materials at the time the airport is constructed, and providing easy maintenance where it will be required.

Airways

Careful consideration should be given to existing airways and future routes when attempting to select a site for integration into the existing transportation system. Likewise, military traffic should be given special study since their flying is subject to less control than civil traffic.
CHAPTER IV
STRUCTURAL AND FUNCTIONAL PROBLEMS INFLUENCING JET AIRPORT DESIGN

General

The entry of the jet airplane into the air transport field is typical of all new developments, regardless of the type. The "new discovery," while certainly being unknown when introduced, is still the outgrowth of the developments which preceded it. As such, the jet airplane is unavoidably linked to its predecessors by its very function. Although propelled in an entirely different manner from conventional aircraft, the new jet transports are still commercial airplanes and retain many of the characteristics of the older, reciprocal types. Because of this fact, the jet airplane, in many instances, may be accommodated in the same manner as were the transports of the preceding era.

But as new developments appear, corresponding problems arise, requiring original solutions, and the advent of jet transportation is no exception. Increased speeds require longer runways, heat and blast from the jet engines demand different methods of approaching the terminal, increased fuel capacities fix a need for faster refueling methods, etc., all pointing toward the necessity for re-evaluation of our airport design principles with the aid of solving these problems to the satisfaction of the new needs.

Present and Proposed Aircraft

Most of the present jet transports are, in reality, the future aircraft of the jet age in that only two have thus far been placed in service. The estimated life of these aircraft
is ten years. However, faster and improved models are already being designed. Some observers feel that the first step in advanced aircraft for transport flying will just barely cross the sonic barrier at speeds of 800 miles per hour. The next step will approximate one and one-half times the speed of sound at 1,200 miles per hour. Lockheed Aircraft Company has already begun to design a jet transport with a speed of 2,700 miles per hour.

It is, indeed, difficult to forecast the development of the proposed jet transports. We can assume that they will be faster and heavier with greater capacities but this is about the limit of our trusted imagination. Lack of standardization in aircraft prevents much future planning, yet if planes are standardized, we may inhibit a revolutionary design which could only stem from a free imagination.

Figure 7 and Table II include data of primary interest to airport planners concerning the dimensions of the jet transport. The table is compiled from information distributed by the individual manufacturers of the new jet transports.

Jet Airport Pavement Problems

The United States Air Force has the benefit of more than ten years experience in accommodating jet aircraft and with the entry of jets into the commercial field, airport managers and engineers will be faced with similar pavement problems which confronted the Air Force.1 The most prominent of these

Figure 7. Aircraft dimensions of primary importance to airport planners.
<table>
<thead>
<tr>
<th>Specifications</th>
<th>French Caravelle</th>
<th>British Comet IV</th>
<th>Convair 880</th>
<th>Douglas DC-8</th>
<th>Boeing 707-120</th>
<th>Boeing 707-320</th>
<th>Lockheed Jetstar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Span (B)</td>
<td>116' - 6½&quot;</td>
<td>114' - 9&quot;</td>
<td>120' - 0&quot;</td>
<td>139' - 6&quot;</td>
<td>130' - 10&quot;</td>
<td>141' - 8&quot;</td>
<td>63' - 8&quot;</td>
</tr>
<tr>
<td>Length (L)</td>
<td>104' - 10&quot;</td>
<td>111' - 6&quot;</td>
<td>129' - 4&quot;</td>
<td>150' - 6&quot;</td>
<td>144' - 6&quot;</td>
<td>153' - 4&quot;</td>
<td>60' - 2&quot;</td>
</tr>
<tr>
<td>Height (H)</td>
<td>+ 28' - 6&quot;</td>
<td>36' - 0&quot;</td>
<td>42' - 4&quot;</td>
<td>56' - 3&quot;</td>
<td>38' - 11&quot;</td>
<td>20' - 6&quot;</td>
<td></td>
</tr>
<tr>
<td>Take-off Gross Weight</td>
<td>94,800 lb</td>
<td>155,000 lb</td>
<td>176,500 lb</td>
<td>287,500 lb</td>
<td>248,000 lb</td>
<td>295,000 lb</td>
<td>37,980 lb</td>
</tr>
<tr>
<td>Landing Weight</td>
<td>90,400 lb</td>
<td>113,000 lb</td>
<td>130,000 lb</td>
<td>182,100 lb</td>
<td>165,000 lb</td>
<td>140,000 lb</td>
<td>26,000 lb</td>
</tr>
<tr>
<td>Max. Static Load on Main Wheels (RT. or LT. Side)</td>
<td>+ 110' - 10&quot;</td>
<td>110' - 10&quot;</td>
<td>110' - 10&quot;</td>
<td>110' - 10&quot;</td>
<td>110' - 10&quot;</td>
<td>110' - 10&quot;</td>
<td>+ 110' - 10&quot;</td>
</tr>
<tr>
<td>Max. Static Load on Nose Wheel</td>
<td>+ 9' - 6&quot;</td>
<td>9' - 6&quot;</td>
<td>9' - 6&quot;</td>
<td>9' - 6&quot;</td>
<td>9' - 6&quot;</td>
<td>9' - 6&quot;</td>
<td>+ 9' - 6&quot;</td>
</tr>
<tr>
<td>Landing Gear Tread (T)</td>
<td>17' - 11&quot;</td>
<td>26' - 2&quot;</td>
<td>18' - 10&quot;</td>
<td>22' - 1&quot;</td>
<td>22' - 1&quot;</td>
<td>12' - 2&quot;</td>
<td></td>
</tr>
<tr>
<td>Landing Gear Wheel Base (G)</td>
<td>38' - 62&quot;</td>
<td>46' - 8&quot;</td>
<td>53' - 0&quot;</td>
<td>53' - 0&quot;</td>
<td>53' - 0&quot;</td>
<td>53' - 0&quot;</td>
<td>53' - 0&quot;</td>
</tr>
<tr>
<td>Tire Footprint Area, Sq. in., Main Wheel</td>
<td>+ 235 sq. in.</td>
<td>235 sq. in.</td>
<td>235 sq. in.</td>
<td>235 sq. in.</td>
<td>235 sq. in.</td>
<td>235 sq. in.</td>
<td>+ 235 sq. in.</td>
</tr>
<tr>
<td>Loading per Sq. in. per Tire Area, lb</td>
<td>+ 200 lb</td>
<td>200 lb</td>
<td>200 lb</td>
<td>200 lb</td>
<td>200 lb</td>
<td>200 lb</td>
<td>+ 200 lb</td>
</tr>
<tr>
<td>Turning Center to G.L. of Aircraft (A)</td>
<td>33' - 2&quot;</td>
<td>19' - 5&quot;</td>
<td>32' - 15&quot;</td>
<td>34' - 16&quot;</td>
<td>34' - 16&quot;</td>
<td>34' - 16&quot;</td>
<td>34' - 16&quot;</td>
</tr>
<tr>
<td>Min. Turning Radius (R)</td>
<td>90' - 5&quot;</td>
<td>66' - 0&quot;</td>
<td>62' - 9&quot;</td>
<td>90' - 0&quot;</td>
<td>100' - 0&quot;</td>
<td>109' - 2&quot;</td>
<td></td>
</tr>
<tr>
<td>Clearance Diameter for Complete Turn (D)</td>
<td>150' - 6&quot;</td>
<td>150' - 6&quot;</td>
<td>150' - 6&quot;</td>
<td>150' - 6&quot;</td>
<td>150' - 6&quot;</td>
<td>150' - 6&quot;</td>
<td>150' - 6&quot;</td>
</tr>
<tr>
<td>Fuel Capacity, gal.</td>
<td>4,650</td>
<td>10,770</td>
<td>20,000</td>
<td>17,400</td>
<td>23,550</td>
<td>2,678</td>
<td></td>
</tr>
<tr>
<td>Cabin Door Sill Height from Ground</td>
<td>6' - 11½&quot;</td>
<td>9' - 6&quot;</td>
<td>10' - 4&quot;</td>
<td>10' - 7&quot;</td>
<td>10' - 7&quot;</td>
<td>10' - 7&quot;</td>
<td>10' - 7&quot;</td>
</tr>
<tr>
<td>Runway T.O. Length, Std. Day, Zero Wind</td>
<td>5,460'</td>
<td>6,700'</td>
<td>7,000'</td>
<td>8,750'</td>
<td>8,600'</td>
<td>8,900'</td>
<td>5,800'</td>
</tr>
<tr>
<td>Runway Landing Length, Std. Day, Zero Wind</td>
<td>3,300'</td>
<td>6,250'</td>
<td>8,000'</td>
<td>8,350'</td>
<td>8,350'</td>
<td>9,000'</td>
<td>1,500'</td>
</tr>
<tr>
<td>Oil Capacity, gal.</td>
<td>M</td>
<td>E</td>
<td>L</td>
<td>G</td>
<td>I</td>
<td>B</td>
<td>L</td>
</tr>
</tbody>
</table>

* Data unavailable
# Approximate capacity
problems are:

(1) Jet fuel spillage, plus heat and blast of jet engine exhausts,

(2) High pressure tires with their small contact area,

(3) Heavy wheel loads, and

(4) Channelized traffic.¹

Developments used by the Air Force leading to present day pavement design techniques were slow in their progression and very expensive. Estimates are that since 1948 the Air Force has spent in excess of $8,000,000 in support of pavement investigation programs.² It would be senseless not to utilize the knowledge gained by such programs as the jet moves into the commercial field.

More than six years of controversy over the type of material desirable for runway paving has raged between supporters of Portland cement and supporters of asphalt. The supporters of asphaltic pavements had in their favor a substantially decreased first cost and, in 1951, the Air Force decided that the selection of pavement types would be on a first cost basis.³

Experience proved, however, that this basis for selection was erroneous since the asphalt pavement disintegrated from

¹Ibid.
²Ibid.
³Ibid., p. 1480-2.
FIGURE 8. AIR FORCE CRITICAL AREAS REQUIRING PORTLAND CEMENT PAVING.
repeated fuel spillage. In addition, the heat and blast eventually ripped off the top surface deteriorating the paving beyond use. The loosened pavement particles became serious hazards for jet engines because of the possibility of being sucked into the intake. The heavy wheel loads and channelized traffic (See Figure 10) caused deep ruts in the asphalt surface.

In August, 1952, the Air Force was finally forced to reverse the previous policy and place portland cement concrete paving in the "critical areas" illustrated in Figure 8. Such critical area paving was applied to aprons, holding pads, the end 1,000 feet of runways, wash racks and calibration platforms. This method of paving has been widely used in civil airport design as well but I do not feel that it will support the jet transports satisfactorily because of the increased loading. The maximum weight of conventional transports is approximately 162,000 pounds, but one fully loaded Boeing 707 intercontinental jet transport weighs 295,000 pounds. Existing asphalt runways will simply not support the increased loads under repeated use.

The results of the Air Force Program to date indicate the following conclusions concerning pavement for jets:

Pavements must be unaffected by the solvent actions of jet fuels. They must be heat resistant

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1Ibid.
2Ibid., p. 1480-5.
3Ibid.
4From the Boeing 707 Manual, Airport and Terminal Operations, p. 5.
FIGURE 9. TRICYCLE GEAR ARRANGEMENT ON PRESENT JET TRANSPORTS.

FIGURE 10. TWIN-TWIN GEAR ARRANGEMENT ON B-52 HEAVY BOMBERS CAUSING CHANNELIZED TRAFFIC.
to withstand the hot, high velocity exhaust of jet engines. They have to be abrasion resistant, durable, and structurally adequate to support heavy wheel loads, and to withstand high unit contact pressures and high frequency loadings.

Based upon its experience with design, construction, and service behavior of airfield pavements, the Air Force has concluded that these requirements can most nearly be met by the use of Portland cement concrete.  

Design Load Criteria for Paving

Although concrete seems to be the best material for jet airport paving, the design load must also be resolved to determine the thickness required. The 295,000 pound weight of the Boeing 707 is supported primarily by two main gears, each equipped with four wheels, and a nose gear comprised of two wheels. The main gear may be assumed to support the majority of the load since, on landing, the nose wheel touches down last. Theoretically, if the gears are spaced sufficiently apart, the design load would be one-half of the weight or 150,000 pounds per wheel group.

But other factors must also be considered and, in a measure, predicted. There is little doubt that aircraft will get heavier, in which case, we must estimate the extent of the increase. There is also the problem of twin-twin wheel arrangements where, instead of the conventional tricycle gear, a tandem arrangement such as is in use on the B-52 heavy bomber is provided. In any event, to design for a load of 150,000 pounds would be a faulty approach. The Air Force is presently designing

1Leslie, op. cit., p. 1480-23.
NOTE: REMAINING PORTION OF RUNWAY REQUIRES ONLY 13" OF PORTLAND CEMENT CONCRETE.

FIGURE II. TYPICAL CROSS-SECTION OF THE FIRST 1,000 FEET OF RUNWAY USED BY THE U.S. AIR FORCE TO ACCOMMODATE B-52 JET BOMBER TRAFFIC.
for a load of 240,000 pounds with a twin-twin gear arrangement. I feel civil airports would do well to design for 300,000 pounds. Figure 11 illustrates the typical cross-section of an Air Force jet runway for heavy bombers. It is interesting to note that no reinforcing is used in runways over eight inches in thickness.

When designing concrete pavements to sustain such tremendous loadings as 300,000 pounds, thicknesses naturally increase until such dimensions as 18 and 22 inches are required.¹ Economically, there is a point where increasing the thickness and strength of portland cement concrete is no longer feasible and it is because of this fact that designers will be investigating new methods for providing airport surfaces.²

Water-Borne Runway

One such design for runways is introduced by Mr. David Williams—a water-borne runway.³ In essence, the runway would be little more than a carpet with comparatively thin concrete slabs being the carpet material and thin water-filled bags becoming the carpet pad. As a carpet pad distributes the stress evenly to the floor, so such a water-filled bag would distribute the airplane’s weight as Figure 12 illustrates. Mr. Williams states that a slab no more than eight inches thick can

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¹Leslie, op. cit., p. 1480-22.


³Ibid., p. 1658-1.
FIGURE 12. DEFLECTION OF CONVENTIONAL RUNWAY AS OPPOSED TO THE DEFLECTION OF A WATERBORNE RUNWAY.
support a 100 ton airplane with such a design. The runway is made of 20 x 20 feet concrete squares resting on water-filled bags of the same dimensions. The squares are linked by metal pins and hinges allowing them to work as one continuous unit. Tests are presently underway and the results have been very satisfactory. The major disadvantage is the expense of the water bags but this, too, may be overcome in the near future.

Runway Planning

The jet transport differs from its predecessor, the reciprocical airplane, in its ability to land in stronger crosswinds. Increased landing speeds and better control techniques make this possible. Most of the jets are certificated for ninety degree crosswinds of 20 to 30 miles per hour and one is certificated for 40 miles per hour.1

Such capabilities invite drastic changes in airport planning with a resulting increase in traffic accommodation, i.e., fewer runways, less acreage, simplified taxi routes and a general increase in over-all efficiency.2

While the premise is true that fewer runways may be necessary, it is not necessarily true that less acreage will be required. Certainly, it becomes possible to orient the primary runways with the prevailing winds and, in a sense, eliminate the need for a multi-directional runway system.

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2Ibid.
However, this only gives a very high percentage of coverage. The problem of landing aircraft still remains when the wind does not fall into the proper pattern for a short while. This indicates the need for a secondary runway system requiring additional acreage and this should be procured in the initial planning stage for a minimum expense.

Airport design studies of various areas in the United States indicate that in certain localities a single direction runway system will give 98 per cent coverage for 25 mile per hour crosswind components.\(^1\) Houston, Texas, according to the meteorological studies, could provide 100 per cent coverage with a system of runways oriented 315 degrees and 135 degrees. Oddly enough, expansion in those directions at Houston International Airport is somewhat impractical because of the obstructions in the vicinity.

Ideally, the general runway layout should provide for a minimum of two primary runways in the direction of the prevailing winds, one for take-offs and one for landings, with a secondary runway 90 degrees to the primary system for extreme winds. Such an arrangement could easily accommodate 60 IFR\(^2\) movements per hour. It was my personal experience at Tyndall Air Force Base, Florida, to operate jet aircraft from a dual runway system with two secondary runways. In two years of almost daily flying, I was never obliged to use a secondary runway for landing or take-off. If two additional runways are placed in the primary system and the runways are sufficient

\(^1\)Ibid.

\(^2\)Instrument Flight Rules, or flight maintained by reference to the aircraft instruments alone.
FIGURE 13. RUNWAY LAYOUT FOR TWO SIMULTANEOUS INSTRUMENT APPROACHES.
lateral separation, the capacity can be doubled to 120 IFR operations per hour provided adequate radio aids are available. Figure 13 indicates how simultaneous approaches could be made with two minute separation between aircraft. With this arrangement, sixty aircraft per hour could land on the landing runways while sixty aircraft per hour could take-off on the corresponding runways for take-off.

Mr. Miller, in his article concerning jet airport design, states that 6,500 feet between the ends of two approach runways is sufficient. In normal situations, such a separation would be adequate, but extreme weather conditions are not normal situations and cannot be treated as such. Such variables as pilot proficiencies, high variable crosswinds, and extreme turbulence cannot be satisfactorily predicted to insure against collision with dual instrument approaches and only one and one-quarter mile separation. In my own opinion, to separate the approach ends of the runways by two miles would only be adequate during poor weather conditions.

Another change which the jet transport will demand is a revision in the method by which an airplane clears the runway after landing. The method of taxiing to the end of the runway for a 90 degree turn-off is obsolete due to the time consumed. To accommodate more aircraft on the same runway, "roll-out" lanes should be provided allowing landing aircraft to turn-off

1Ibid., p. 26

2Such an opinion is based on personal experience while making more than 400 jet instrument approaches.
FIGURE 14. HIGH SPEED RUNWAY EXITS.

LOADING APRON

DETAIL OF HIGH SPEED EXIT.
the runway at 50-60 knots. ¹ "The controlling requirement is that the landing aircraft must clear the runway before the following aircraft reaches its last safe 'wave-off' position on final approach."²

The location of a point at which the roll-out lanes should leave the runway depends on variables such as wind, landing speed, condition of runway, etc., and cannot be determined. Therefore, it is necessary to design a roll-out system which will satisfy the requirements. Figure 14 indicates distances which would be appropriate for the majority of jet airports.

A turn from the runway greater than 30 degrees, except at the end, is to be avoided and the roll-out lanes should continue straight to the ramp as often as possible.

The length of runway required for jet transports is one of the major problems which concerns airport designers. Mr. Ralph Glasson, in his article on runway length, lists twenty-one items to be considered in determining runway length.³ Such factors as the Civil Air Regulations, airport elevation, obstructions, runway gradient, trip length, weight of aircraft, temperature, etc., must all be considered. But the airport planner should not design for the average condition. He should plan runways for the most adverse take-off or landing

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¹Miller, op. cit., p. 27.
²Ibid.
FIGURE 15. TAKE-OFF LENGTHS FOR BOEING 707 STRATOLINER.

FIGURE 16. TAKE-OFF LENGTHS FOR BOEING 707 INTERCONTINENTAL.
conditions. There are those who would say that this is not practical; however, since it is likely that planes will become increasingly heavier and therefore require longer take-off rolls, the runways will not be wasted. To my knowledge, I have never heard a pilot complain of too much runway.

Figures 15 and 16 from the Boeing Aircraft Company give an indication of the length of runway required for Boeing 707 take-off. These charts are based on present Civil Air Regulations and the operating conditions as noted. Since the take-off roll generally exceeds the landing roll, landing diagrams are not included. Tables are based on no-wind conditions and a temperature of 80 degrees Fahrenheit.

From the diagrams, a runway length of 3,300 feet is required for an airport at sea level when the temperature is 98 degrees Fahrenheit and the distance to be traveled by the Boeing Stratoliner is 2,500 miles. Under the same conditions, an Inter-continental Boeing transport requires 9,800 feet for take-off when traveling 3,800 miles. For take-off from airports at high altitude such as Denver, the take-off roll required for the Stratoliner exceeds 12,000 feet.

By accommodating the Boeing 707 series, the largest jet for both continental and inter-continental flying, it is possible to provide for all of the jet transports being flown. For sea level airports, a runway length of 10,500 feet will be satisfactory for maximum weight inter-continental flights while for trans-continental flights from the same airport, 9,000 feet will be acceptable. Even the smaller jets such as the Convair 880, require 8,400 feet while operating from a sea level
FIGURE 17. JET RUNWAY SYSTEM CAPABLE OF ACCOMMODATING 120 IFR OPERATIONS PER HOUR.
airport when the temperature is 95 degrees Fahrenheit. It is interesting to note that only 6,000 feet of runway is required to bring an aircraft to a stop upon landing.

Extensive research has been done concerning runway layout to provide the shortest taxi distances after landing and before take-off. Without exception, the trend is toward a tangential system of runways. Four graduate students at the Rice Institute intensively explored various runway schemes while preparing an airport master plan. They, too, eventually returned to the tangential pattern of runways as the most efficient. Figure 17 indicates an efficient, reasonable runway system which could accommodate up to 120 IFR operations in one hour. The point should be stressed that site restrictions, obstructions, and community locations may prevent such a scheme from being used; however, a desired direction is indicated.

Aprons, Taxiways, and Pavement Shoulders

The airport apron is located adjacent to the terminal building or, in a satellite arrangement, at a convenient distance from the terminal area.¹ The apron area provides parking space for the airplanes as well as the services which the aircraft require. It should be of sufficient size to accommodate the estimated peak traffic load while permitting, as much as possible, unobstructed taxi patterns.

¹See Figure 22 for satellite arrangement.

-55-
The apron must have the same strength as the landing runway, particularly since trucks and other heavy machinery may be operating in the immediate vicinity of the concentrated wheel loads.

Facilities which should be located on the apron and adjacent to the airplane parking area include fueling nozzles, air conditioning outlets, sewage disposal equipment, electric power, compressed air, and a supply of water and distilled water. Each of the preceding facilities are discussed in detail under "Ground Handling Problems," but they are mentioned here because they are essential elements of the apron.¹

Baggage and passenger loading occur while the aircraft is parked on the apron and special consideration should be given to these functions.

Airport taxiways serve as connecting links between areas that the airplane must use. In effect, they are the road system over which the airplanes operate while on the ground. Thus, the arrangement of taxiways becomes as much a traffic problem as planning a superhighway, particularly when the traffic to be considered includes both vehicles and pedestrians in addition to the airplanes.

The airport specialist will be of invaluable aid in smoothing the flow of aircraft from the parking area to the runway and vice versa. Intermittent traffic to maintenance areas would also enter his sphere of control. However, as the planes enter the terminal area, they approach a circulation pattern which

¹Supra, p. 65.
FIGURE 18. FORMATION OF VORTEX AT JET ENGINE INTAKE AND CORRECTIVE MEASURES PROVIDED BY AERO-SCREEN.
Already contains people and vehicles, a situation that could easily become as tangled as a poorly designed shopping center. These particular circumstances may be as easily resolved by an architect as an airport specialist.

Taxiways should be straight when possible and ninety-degree turns should be kept to a minimum.

The wingspan of the largest jet transport is 150 feet with a center to center distance between outboard jet engines of 102 feet and 10 inches. Taxiways 150 feet wide are sufficient for the present and should continue to be adequate for some time; however, airports with taxiways only 75 feet wide should increase the width to a minimum of 125 feet. Mr. W. E. Rhoades, manager of flight engineering, United Airlines, told the United States Senate Interstate Commerce Committee:

Where less than 125 feet of suitable taxiway exists, it will be necessary to add shoulders on each edge to make not less than 125 feet of surfaced area available. . . . Shoulders are necessary to decrease the probability of engine damage by foreign objects such as stones, etc., which might be sucked into the engine if it were overhanging an unsurfaced area. . . .

Figure 13 shows how a vortex which sometimes forms in front of the inlet is capable of sucking pebbles and small bits of metal into the engine. While this obviously doesn't

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Figure 19. Engine Inlet and Exhaust Clearance Areas.
happen a large part of the time, it still remains reason enough to surface the shoulders of inadequate taxiways. This is particularly true with jet engines costing roughly a quarter of a million dollars each.\footnote{J. B. Edwards, "Operational Characteristics of the Douglas DC-8," \textit{Journal of the Air Transport Division}, Proceedings of the ASCE, Vol. 83 (December, 1957), p. 1470-8.} Although Douglas Aircraft Company has developed an "Aero-Screen" which is supposed to prevent a vortex from forming, they still recommend that the ramps, taxiways, and runways be kept clean at all times.\footnote{Ibid.}

Heat, Blast, Fumes and Noise

The four topics of this section, heat, blast, fumes and noise, are all by-products of the turbine engine and one unaccompanied by the other three is virtually impossible at this stage of engine development. Research may eliminate one or the other but that end is not in sight. Each of these phenomena represents a potential source of annoyance to the jet passenger and attention must be given them to minimize their disturbing characteristics.

Figure 19 illustrates the correlation between heat and blast at the various stages of engine performance for the Convair 880.\footnote{Convair Aircraft Company, \textit{Convair 880 Orientation}, (San Diego, California: Convair, 1958.)} The engines of the Boeing 707 have a comparable heat-blast relationship. One important point which the diagram fails to indicate is the increased thrust required to establish sufficient inertia for taxiing. Because the aircraft
will generally be in the terminal area when initiating its taxi roll, these figures become important. Approximately 70 per cent power is required to establish the roll prior to retarding the throttle to just above the idle position. At 70 per cent power, the exhaust temperature at one hundred feet behind the airplane reaches 120 degrees Fahrenheit with an exhaust velocity of approximately 60 miles per hour. When winds in excess of 75 miles per hour are considered to be hurricane force, the blast of the jet exhaust certainly warrants consideration.

Fumes do not create serious problems. The most important point to consider is that the air conditioning inlets should be located on the opposite side of the buildings from the ramp thus preventing an intake of kerosene fumes.

The noise problems created by the turbine engine may be divided into three categories: (a) community noise which is largely caused by the low frequency exhaust sound; (b) terminal noise, consisting primarily of the high frequency compressor sound forward of the engine; and, (c) maintenance and run-up noise consisting of both compressor and exhaust noise.

Because of public concern about jet aircraft noise, it is advisable to examine this problem with respect to the community. The criticisms are based solely on public exposure to military aircraft and, as yet, few of the critics have actually had an opportunity to listen to the sound of the civil jet transports. Basic differences exist between military jet noise and the noise of the jet transports.
There are three types of jet noise with which the general public is familiar; one is the sonic boom; another is the jet afterburner; and finally there is the jet noise at take-off.

At the present time the sonic boom is exclusively a military phenomenon, since our present jet transports will travel slightly under the speed of sound. This will not remain the case, however, because supersonic planes for transport use are now being designed. But these planes will not be permitted to exceed the speed of sound while operating in the control zones of airports. Civil Air Regulations presently require jet airplanes to operate at or below 180 knots in control zones or at their minimum flying airspeed if 180 knots is below their operating limitations. It is obvious that if increased speeds were used, control of aircraft for landing would be virtually impossible, because of the "see and be seen" factor.¹

The jet afterburner is another exclusive military feature which civil jet transports will not use. This device simply mixes additional fuel with the exhaust gases providing additional thrust but at the same time, creating tremendous noise.

The third type of jet noise with which the public is familiar, take-off noise, also differs from military jet noise. The civil jets will be equipped with specially-designed noise suppressors which are reported to lower the noise level to that of present large piston-engine aircraft.

¹The "see and be seen" factor refers to the necessity of an aircraft being seen by the tower and, at the same time, having an airspeed slow enough to allow the pilot to see the airport.
Note must be taken that noise suppressors absorb a small percentage of the power of the jet engine which, in turn, causes a decrease in jet thrust, an increase in runway length, and increased aircraft weight and fuel consumption. United Airlines has asked for an additional 240 feet of runway to compensate for the loss of thrust. Using the figure of thirty dollars per cubic yard of reinforced concrete in place, such an increase for a runway 150 feet wide could well cost upwards of $30,000. But the cost of the additional runway is trivial when compared to the estimate of one airline that figures it will lose approximately $50,000,000 from their fleet of 30 jets over the operational life of the airplanes because of the noise suppressors and the fuel penalties which they impose. The airlines are willing to accept this economic penalty, however, to reduce the noise level so that their airplanes will be as small an annoyance as is possible.

The jet airplane has several advantages over piston-type aircraft which, in the opinion of the CAA, should help to reduce the noise level to the community:

(1) The jet transport, because of considerably higher power, can climb at higher angles and rates than larger piston-engine aircraft and, therefore, be higher above the community than piston-engine aircraft. [The jet is quieter when landing because the power is reduced for its glide.]

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1Rhoades, loc. cit.

(2) The jet transport travels faster and, therefore, exposes the community to its noise for a shorter period of time.

(3) Civil jet transport noise is of a higher frequency than the low frequency rumbling of piston engines and propellers. Jet noise, therefore, is absorbed more rapidly as it travels through the atmosphere and hence covers a smaller area than piston engine aircraft.

(4) The civil jet transport, generally, has a greater flexibility of climb-out paths from the airport as well as descent paths for landing, which will enable it to use flight paths best adjusted to the community layout to cause the least noise.\(^1\)

Points (2) and (4) of the preceding quotation need added comment to prevent what tends to be an overly optimistic viewpoint. Although the jet does travel faster than the piston-engine aircraft, its rate of acceleration is slower, which fact would not expose its noise to the community for a shorter time up to the point where its speed exceeds that of the piston-engine aircraft. Secondly, with take-offs from a busy airport at the rate of one per minute or faster, the absence of noise between airplanes would be practically negligible. Thus, point (2) does not retain much of the validity that it assumes.

Point (4) has little value for existing airports because the aids to navigation and approach are, in the majority of cases, fixed installations. Because of the orientation of existing runways, the flight patterns will also be fixed. For a new airport such problems would be solved in the planning

\(^1\)Ibid., p. 8.
stage and doubtlessly utilize the flexibility of the jet from the beginning.

Terminal noise remains the chief concern of airport planners. Starting the engines at the terminal as opposed to a tow-away operation, has been the subject of considerable discussion but, as yet, no definite decisions have been made. The decisions will vary from airport to airport depending on local conditions, but when possible, I would prefer to see the beginning and end of a 600 mile per hour trip initiated and terminated by the aircraft under its own power. It seems a bit incongruous for a jet airplane to stop some distance away from the parking area and travel the remaining portion of the trip behind a ridiculously slow tractor.

A test pertaining to terminal noise was conducted at the San Francisco Air Terminal by the Douglas Aircraft Company and the results were extremely interesting:

... Some 150 observers representing airlines, airports, consultants, etc., were stationed at 15 positions on the ramp and inside the terminal while a jet transport taxied to the ramp. In addition, over 80 general public visitors and passengers were canvassed in the waiting room, coffee shop, and passenger loading fingers. Of the latter group, some 27 per cent had, so to speak, been around jet aircraft, and the remaining 73 per cent were unacquainted with them.¹

The questions asked the group and their respective answers were as follows:

¹Edwards, op. cit., p. 1470-6.
1. What part of the jet noise bothers you most?

12% - rumbling exhaust.
88% - high pitched whine.

2. When does the noise seem worst?

46% - when plane comes toward me.
25% - when plane is going away.
21% - when plane turns in front of me.
8% - didn't notice.

3. In your opinion, should engines be stopped far away from the ramp, and planes towed to the passenger ramp?

22 1/2% - yes.
77 1/2% - no.¹

From this test, the conclusion was made that the glassed-in terminal and passenger fingers would provide adequate protection for taxi to the ramp operation.² If the noise or any portion of the noise had been particularly obnoxious, the percentage of the observers preferring taxi-in procedures would have diminished substantially. Having worked in the immediate area where jet engines were idling, I can recall no instance when the noise was injurious; generally the annoying element was the heat which is uncomfortable at one hundred feet.

The problem of maintenance noise may easily be resolved by locating the test and run-up areas at a position on the field personnel and the surrounding community. The only restriction imposed on its location is that it be directly connected to the maintenance area by a smooth, hard-surfaced taxiway to accommodate the airplanes as they are towed or

¹Ibid., p. 1470-6 to 1470-7.
²Ibid.
taxied to the run-up area. If the taxiway is extremely long, a by-pass is desirable to accommodate traffic from both directions.

A concrete pad backed by blast fences would also be desirable for running up the engines when checking their performance following maintenance. The blast fence, while aiding against blowing debris, also diverts the sound waves at a point where the noise occurs, about 50 feet behind the engine exhaust, thus reducing the noise level appreciably.

The heat, blast, and noise of the jet engine are small annoyances accompanying the jet age, just as the smoke and noise of the railroad accompanied its introduction to the world. They are not problems of the magnitude that we have been led to believe but they do require careful study to reduce their annoyance to a minimum. The airport of today and the future pleads for a solution that will segregate the passenger from the unpleasant features created by jets and yet allow him to savor the excitement and drama that a busy airport creates.

Ground Handling Methods

General

To meet the requirements of passenger comfort and aircraft support as well as the loading and unloading of various compartments demands considerable revision of ground handling techniques.

When a jet airplane lands and taxies into its parking position, a myriad of activities begin, all with the common
purpose of putting the aircraft back into the air in the minimum of time. If the airport has not changed its ground handling techniques, equipment such as trucks, carts, trailers, and dollies, will converge on the aircraft as soon as the engines are shut down. Because jet transports accept so much more fuel, water, baggage, etc., than the piston-engine aircraft, such a situation could lead to complete chaos.

While the passengers deplane, baggage carts are brought into position, refueling hoses are connected as quickly as possible, and the water car is placed in position. The sources of supply for ground air conditioning and electrical power are attached. As the passengers leave by the two main doors, oil checks are performed while baggage and cargo unloading as well as aircraft refueling continue.

When refueling is nearly completed, the center of activity shifts to the right side of the aircraft where the galley service truck has been driven into position. The empty cargo and baggage compartments are now filled with outgoing loads as the unloading process is completed.

While fuel and water replenishing progress, the interior of the airplane is cleaned and the lavatory service begun while the galley service nears completion.

The service doors are spaced to eliminate conflict between cargo loading, galley service, and lavatory water service.

While the servicing is being completed and the baggage is being loaded, passengers board the airplane. The loading ramps are removed, baggage compartments are secured, and the area is cleared of vehicles and personnel. Then the engines are prepared
for starting and taxi.¹

The foregoing operations cover only one of the several phases of ground handling and each one requires further explanation. In addition, there is taxiing to the loading gate position, parking, departure from the gate position, taxiing in general, towing and the safety precautions attendant to each of these maneuvers.

For safe and efficient ground operations, movements of the aircraft by its own power must always be conducted so as to avoid injury to persons or damage to equipment. Use of excessive thrust should be minimized while the exhaust outlets are directed toward the terminal, other parked aircraft, or public areas. Jet transports should always be parked so that marked danger areas may be vacated prior to starting engines.

Certain hazards unique to jet aircraft require that personnel be indoctrinated prior to their first contact with jet aircraft. The engine intake area is quite hazardous because there is no visible indication of the great force of the in-rushing air. The exhaust danger area is less likely to cause harm since the heat and noise provide their own warning. However, it is good practice to teach personnel to expect a rapid increase in the area of hazard whenever the throttles are advanced.

¹The procedures for airplane turn-around outlined here are taken in part from the Convair 880 Orientation Manual published by the Convair Aircraft Company, pp. 17-18.
While the handling of jet transports on the ground is essentially the same as handling other aircraft, the increased quantities of servicing materials, passengers, and baggage create new difficulties in ground handling techniques.

Refueling

The Boeing 707 Inter-continental accepts a maximum fuel load of 23,550 gallons, burning fuel in cruise at the rate of 2,000 gallons per hour.\(^1\) The Convair 880 has a maximum capacity of 10,770 gallons.\(^2\) When compared to the amount of fuel which the DC-3 normally uses, 750 gallons, the scope of the refueling problem is evident.

The largest refueling truck in use by the Air Force and a type which the jet transports could use, has a capacity of 5,000 gallons.\(^3\) If the airlines find it necessary to use truck-type refueling methods, as many as five trucks would be necessary to supply an inter-continental airplane with sufficient fuel to make the trip. The confusion that would exist under such conditions, trucks backing up, passengers unloading, baggage carts arriving, would be very undesirable and should be avoided, particularly at large airports.

The need for special lines to satisfy the fuel appetites of the jets is obvious but besides the enormous quantities required special filtration is necessary. For mechanical reasons,

\(^1\)Boeing 707 Airport and Terminal Operations Manual, p. 5.
\(^2\)Convair 880 Orientation, p. 65.
\(^3\)Petroleum Supply Officer, Ellington AFB, Texas.
the kerosene or JP-4 must be clean of foreign matter such as dirt, water, or rust of 5 microns or greater in diameter, a dimension which is a fraction of the diameter of a human hair.\(^1\) The equipment is available for this degree of filtration but new handling techniques will be necessary.

Hydrant refueling seems to satisfy this problem better than any other method. The typical hydrant system consists of a bulk storage area, either underground or above the surface, where the fuel is segregated according to suppliers, i.e., Esso, Shell, Phillips, etc. This area may be situated at any convenient place on the airfield. On demand of a user, the brand of air fuel selected is pumped to fueling hydrants at fixed points on the airport apron. Pumping rates are from 1,000 to 1,200 gallons per minute but those engaged in this process anticipate that the rates may be increased to 3,000 per minute.\(^2\)

Although the hydrant system requires a substantial capital investment, it is my feeling that the accommodation which it provides justifies the expense. In areas where oil refineries are located, pipelines may extend directly from the refinery to the airport as is the case in California where one pipeline already in operation stretches four miles between El Segundo, California, a refinery for Standard Oil Company, and Los Angeles International Airport. The supply line is composed

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\(^1\) Whitlock, op. cit., p. 46.

of three 4-inch pipes which distribute fuel to United Airlines, Pan American Airlines, and Continental Airlines maintenance bases.1

When not in use, the underground hydrants can be hidden below the apron surface with a cover whose upper surface is flush with the surface of the apron and which is strong enough to support the 295,000 pounds of a Boeing 707. Steel would be a satisfactory material to use for this purpose so long as precautions were taken to prevent metallic sparks from occurring if the cover were allowed to fall closed.

Ground Electrical Power

Mr. Marvin Whitlock, Vice President of American Airlines reports, "By comparison, the Boeing 707 airplane uses more than 100 times as much electrical energy as the DC-3 airplane."2 Mr. Whitlock further states the trend is toward 400 cycle alternating current power, in which case, most airports will require a substantial increase in the amount of power brought to the field by the local power company. Of course, mobile diesel-driven units can supply sufficient power, but, in addition to being an obstruction, the space which they require is 3 to 4 times that of existing units and ramp space is valuable.3

The ground power supplied to the airplane will be in lethal quantities, therefore, requiring protective devices and

1Ibid.
2Whitlock, loc. cit.
3Ibid., p. 47.
additional care on the part of the ground crews.

If possible, I feel the power should be supplied via underground conduit. Two important points should be stressed, however. First, the cover of the electrical supply should be strong enough to support the airplanes and finally, steps must be taken to insure against water reaching the outlet.

Water Supply

Two types of water are required when servicing jet transports, distilled water and regular city water.

The turbine engine suffers considerably more from the effects of high temperatures than does the piston engine. As a result, take-off rolls are longer and some landing weight restrictions may be imposed.

However, the manufacturers of the jet have discovered that the addition of water to the engine increases the mass flow through the exhaust and adds extra thrust. Thus, for each take-off, the jet transport utilizes some 750 gallons of de-mineralized water.¹

Regular water is used in the servicing of the lavatory and general cleaning. Both types may be best supplied by an underground hydrant system.

Compressed Air

If the respective airports decide to allow engine starting in the terminal area, a supply of compressed air will be

¹Ibid.
necessary. This service may also be supplied from an underground system or a portable compressor. The compressed air supplies pressure to a starter turbine which, in turn, is geared through a clutch to the engine shaft.\textsuperscript{1} The remaining engines are started by bleeding pressure from the operating engine through the aircraft pneumatic system.

The compressed air may also be used to service the tires of the transport.

Sewage Disposal

The lavatory service truck is generally equipped for sewage disposal; however, if a direct line to the sewer were connected by flexible hose to the airplane, this particular problem would be considerably less involved.

Taxiing and Towing

All four engines of the jets will be used when leaving the gate position, if the airplane is parked in the 45 degree position. The engines idle at about 60 per cent rpm and the taxi roll is sustained just above this point. However, an increase of power to 75 per cent will normally be necessary to initiate the roll. At these power settings, the heat and blast effects are relatively unimportant when the loading gate parking circles are 180 to 200 feet in diameter.\textsuperscript{2} Above these settings, a rapid increase in blast, heat, and noise will

\textsuperscript{1}Edwards, \textit{op. cit.}, p. 1470-6.

\textsuperscript{2}Convair 880 Orientation Manual, p. 19.
result. Excessive rpm should be avoided in the terminal area.

The turning radii of the transports vary slightly. The Boeing 707 requires from 101 feet to 109 feet and 2 inches, depending on the model. The Douglas DC-8 requires "about 90 feet," and the British Comet IV requires 86 feet. These dimensions are measured from the center of turning to the end of the wing tip. In addition, the minimum width of pavement to accommodate the wheels in a 180 degree turn varies from 115 feet and 8 inches for the Boeing 707 to 87 feet for the DC-8. The desirability of taxiways 150 feet wide is made more evident by these figures.

All of the jet transports may be towed forward or in reverse by attaching rigid bars to the nose-wheel and pulling or pushing with a tug. The nose-wheels of all transports may be disconnected to permit a 360 degree swivel. However, towing at angles in excess of 50 degrees may result in excessive scuffing of the main tires on the inner radius of the turn.

Keeping these conditions in mind, it would be well to observe the various procedures that may be used when operating in and out of the terminal area. Generally, these procedures will be determined by the local airport although in satellite terminal arrangements built by the individual airlines, the owners may adopt their own procedures with the approval of the airport management.

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1Dimensions are taken from manuals supplied by each manufacturer.
FIGURE 20. GROUND OPERATIONS AT CONVENTIONAL TYPE TERMINAL.

1. JET HAS TAXIED IN ON TWO (OR FOUR) ENGINES. IS SERVICED AND LOADED IN GATE POSITION PARKED AS SHOWN.

2. JET STARTS ONE OR MORE ENGINES (IDLE RPM)

3. TUG PUSHES JET OUT TO START POSITION

4. JET STARTS OTHER ENGINES AND TAXIES TO RUNWAY

DC-6B

CONVAIR 880

DC-6B

CONVAIR 440

TERMINAL BUILDING
The three ground operating procedures which have been considered are:

(1) Taxi-in and taxi-out under power.
(2) Taxi-in and tow-out backwards.
(3) Tow-in and tow-out.

**Taxi-in and Taxi-out.** Two situations immediately present themselves when the taxi-in and taxi-out procedure is considered for terminal area operation. The first is created when the jet transports load and unload in the vicinity of the terminal building proper. The second one occurs when loading and unloading are conducted at a remote area from the terminal.

If the jet transport is operated in the vicinity of the terminal building under its own power as the piston-engine aircraft are at the present time, the ideal situation is achieved from the operator's standpoint. He does not have to wait for tugs to push or pull his aircraft and he can start engines and taxi at his own discretion with no delays because of having to wait for a ground crewman's clearance. Psychologically speaking, I also am inclined to believe that the jet passenger would prefer such an operation. The noise is not unbearable nor is it harmful unless a person is exposed to it for a long period of time such as would be the case for the servicing crews. The heat would perhaps be discomforting especially in hot-weather areas but in cool-weather the reverse would probably be true. The blast would affect people

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who were not protected or at least out of range of the exhaust but critical area marking could prevent undesirable results from blast.

Plywood blast fences erected between the gate positions are helpful but they block the view of the ramp and occupy valuable apron space that could be utilized for other purposes. In my own opinion, wood used in this manner would deteriorate rapidly due to heat, blast, and weather, becoming a constant maintenance problem.

Where finger configurations exist relative to the main building, it would be wise to reserve the extremities for the jets, thus keeping the inner portions relatively free of the undesirable features which they generate. It seems unfair, however, to penalize a particular carrier because of its nature. A new design for an air terminal should take these problems into consideration, allowing freedom of movement for the jet as well as protection for the passenger.

Permitting the transport to taxi in and out from a loading area remote from the main terminal may be desirable at some airports but such a procedure has many awkward features. Some form of conveyance must be used to transport the people to the planes, either by bus, moving sidewalks, carts, or some similar device. Unless two-level separation is provided, this type of parking could lead to a dangerous situation with trucks and buses crossing aircraft operational surfaces. Tunneling under would require great expense to build ramps capable of

\[1\text{Ibid.} \]
supporting the weight of the jets. Then, too, the vision of a ride through a lengthy tunnel conveys little enthusiasm to a human being who is about to climb six miles above the earth. The same problem of heat and blast remains if several of the remote loading stands are located too close to each other.

**Taxi-in and Tow-out.** This procedure offers the advantage of better apron utilization in the terminal area and tends to relieve apron congestion while the aircraft is waiting for its take-off clearance. Using tow-out procedures, the pilot would allow the jet engines to idle or start them while being towed. From an appropriate area where the tug is disconnected, the jet would taxi without delay under its own power. Remote loading positions would be unnecessary with tow-out operations.

Some disadvantages of the tow-out method of departure are that the pilot would have little view as to what was actually happening in his path as he was pulled backwards out of his parking position and it is possible that the passengers would feel that the operation was extremely slow. In actuality, the tow-out method would be faster than the taxi-out operation in that the pilot could be receiving his take-off clearance and starting his engines while being towed to an appropriate point from which to taxi.

**Tow-in and Tow-out.** Towing in and out, while being perhaps the most inconvenient, is the most flexible method of approach and offers the minimum of space requirements for parking. This procedure does consume considerable time in a business where time is at a premium and appears to be a disappointing climax to a 600 mile per hour ride. Faster tugs
FIGURE 22. GROUND OPERATIONS AT SATELLITE TYPE TERMINAL.
are not a solution because heavy aircraft should not be towed very fast anyway because of the tremendous inertia which makes braking difficult. Seldom may an aircraft be towed over fifteen miles per hour.

All three of the procedures for approaching the terminal have their disadvantages, but the taxi-in and tow-out operation seems to offer more advantages to most of our existing airports. It requires less space, does not expose personnel to exhaust blast, allows immediate deplaning, and provides for the minimum of ground time.

I remain unconvinced, however, that the taxi-in and tow-out procedure should become the guiding ideal in airport master planning. The jet transports possess approximately 50,000 pounds of thrust in their four engines. To tow such a powerful machine when passengers are aboard presents a ridiculous situation. It is my belief that future designs should accommodate the jet transports adjacent to the terminal or at least within walking distance and provide for taxi-in and taxi-out procedures.

Airport Approach Procedures

Jet airplanes possess enormous rates of fuel consumption and it is to the advantage of all concerned to land the aircraft as rapidly as possible upon arrival at the airport. If the weather is good with no low ceilings, landing is accomplished with little or no delay. However, if the weather is unfavorable and instrument approaches are required, the immediate question in the mind of the pilot becomes, "How long will
Figure 23. Enroute Penetration Procedures.

Above 20,000 feet

Penetration Path

Radio Fix

Overcast Cloud Conditions

Airport

Final Approach Path

Terrain

6 miles

50 miles and greater distances

1 See glossary, "Radio Navigation Aid."
my fuel last?" To preclude having to consider such a question, the most expeditious methods of approach during bad weather should be provided.

Rapid descents in jets at rates of 4,000 to 5,000 feet per minute are easily accomplished; however, the comfort of the passenger must be considered. If the pilot descends to the airport too fast, the ears of the passengers may tend to "pop" which is normal and generally not harmful; however, if someone suffers from a severe head cold, the possibility of ear blocks exist and permanent damage could result. Ideally, a descent should not exceed 2,000 feet per minute but if a plane were flying at 35,000 feet, simple division indicates that slightly over seventeen minutes is required to descend to sea level. At 600 miles per hour or 10 miles per minute the pilot must begin his descent 170 miles away from the airport.

Figure 23 indicates how such an approach would be made.

Due to weather conditions, it is often impossible to make the straight-in approach as mentioned above so a penetration procedure should be formulated in the immediate vicinity of the airport. This penetration would be best designed if it were similar to that illustrated in Figure 24. Normally, the penetration is initiated at an altitude of 20,000 feet with the descent beginning away from the airport. At one-half the initial penetration altitude, in this case, 10,000 feet, a descending turn toward the station is begun so that upon completion, the airplane is proceeding back to the airport at an altitude of approximately 1,500 feet above the
OTHER AIRCRAFT HOLD ON THE SAME RADIO FIX WITH 1000 FEET SEPARATION BETWEEN, DESCENDING IN TURN, UNTIL EACH LEAVES 20,000 FEET.

NORMAL 20,000 FEET

TO, 000 FEET RADIO FIX TURN NORMALLY BEGINS AT OR NEAR 12,000 FEET

AIRPORT 1500 FEET ABOVE THE TERRAIN

OVERCAST

5 MILES 15 TO 20 MILES

FIGURE 24. TERMINAL PENETRATION PROCEDURES
terrain. When reaching the radio navigation aid from which it penetrated, transition is made to the instrument landing system for a precision approach to the landing end of the runway.

At most large airports, all of these maneuvers are monitored on a radar screen to insure maximum safety and protection from collision. The radar unit often directs the pilot in a ground controlled approach (GCA) which brings his plane within 100 feet above the end of the runway and 1,300 feet from the touchdown point before the pilot must break out of the weather to effect a landing under visual flying conditions.

Bell Aircraft Corporation has perfected a landing system by which the airplane may be landed completely without the controls being touched by the pilot. Such an approach system will greatly aid in expediting landings under poor weather conditions.

Traffic control of jet aircraft for approaches to the airport may extend for a distance of thirty miles or so which should give an indication of the scope of airport master planning for jet airports. The CAA can be of great help in organizing the approach and departure systems and should be consulted prior to the layout of approach zones and flight paths.
CHAPTER V
Are airports designed for airplanes or do they owe their existence to people? In the past, the airport was primarily a facility for handling airplanes and under such a premise the engineering aspects of airports dominated the design.1 In recent years and particularly following World War II, the emphasis has shifted from "planes flying" to "people flying." As air freight continues to increase in volume, the probability is that another shift in emphasis will occur to "bargo flying."2 It is this movement from machines to people that involves the architect so completely in airport design. The advent of jet flying will demand architectural planning and organization even more. When a jet transport unloads its passengers in quantities of 150 and more, there is the possibility of flooding a terminal area with 1,300 or so air travelers at one time, a figure double that of existing airplane capacities. Further, if these people are only the air travelers, the individuals required to serve them are proportionally larger also. In reality the modern airport is becoming a small town with a steady influx of tourists. What they see, what they do, and the manner in which they are treated thus becomes extremely important. A terminal characterized by dark interiors, poor circulation patterns, and inadequate facilities will certainly be by-passed


2Ibid.
in the future if an alternate, more desirable terminal is available. Since people make flying the profitable enterprise that it is, then we must design for people. This is the architect's problem and it is eloquently expressed by Mr. Lionel Brett:

...They [the architects] are on the side of life, and they must never do anything which makes life duller, more uniform, or more undramatic.

For the essence of travel is drama, and the role of the architect is to heighten the drama by the way he sets and shifts the scene.¹

Such a statement as Mr. Brett's is very timely in a period where the kind of space provided by the architect has been neglected in favor of mere space alone. Sometimes little thought appears to be given to what the passenger will think, feel, or do in a particular enclosure of space but instead the objective is simply to provide a space, large and neatly detailed, then leave the passenger to his own devices.

Probably more than any other form of architecture, the architect has in travel terminal designs the chance to plan the views, vistas, and spaces for the people who will use his building. They will be moving in a way that he can control from one moment of climax, the touchdown of the airplane, to another, the emergence into a new city or country—no mere passage from the everyday to everyday, but a measured progress

of contrast and surprise. Through this means, the architect can heighten the drama of travel and add to the enjoyment of life.

The Necessity of the Terminal Building

The terminal building at airports has long been the major problem of airport planners. Hardly have the terminals been completed before they become obsolete. Part of the trouble may be attributed to the rapid growth of the industry, part to changes in aircraft design, and part to lack of standardization in aircraft but the foremost reason for obsolescence is the lack of broader planning techniques.

The thought of airport planners as to whether or not the airport terminal building is necessary is, very likely, seldom considered. The architect who has a big fee in store for the design of a multi-million dollar air terminal would find it very unprofitable if he questioned its necessity and, as a result, the question seldom arises. But the question is real, particularly when terminals costing upwards of several million dollars are inadequate only a few years after completion. Chicago's O'Hare Airport terminal building, built as a laboratory type of experiment, is already taxed to its capacity and it is barely ten years old. Such a rapid depreciation of air terminals warrants consideration of a different form of solution.

If we consider only the jet transports when preparing a master plan for the airport of tomorrow, the chances are quite good that our final design will become obsolete rather quickly.
We cannot forecast aircraft design exactly. Whether the jet, the rocket, or the atomic power plant will become the next method of propulsion for air transport will entail only speculation on our part. As to how they will affect the terminal building proper, we can guess even less accurately. So why attempt to provide an air terminal for a method of transport of which we know very little and one whose characteristics may not even permit a terminal near by?

Of several things concerning air transport we may be reasonably certain as long as our form of government and method of free enterprise exist:

(1) People will continue to use some form of air transport.

(2) Because of this fact, commercial aviation will continue in operation.

(3) Relatively, the requirements of the passenger will not change, i.e., he will require a ticket of some sort and he will carry varying amounts of baggage.

(4) The passenger must reach the field from his home or office and board the aircraft.

(5) At his destination, the passenger will have to disembark and be transferred from the airplane to wherever he is going.

The interim activities between the basic procedures above such as eating, sleeping, custom inspections, public viewing etc., are by-products of the major process previously described. As such, they should be treated as secondary problems.

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Functions of the Terminal Building Group

The air terminal as we know it today has many functions, some of which are essential and some of which are extraneous. The functions presently attributed to the terminal include:

1. General public accommodation;
2. Passenger and cargo handling;
3. Governmental administration;
4. International processing;
5. Commercial enterprises: hotels, cinemas, public garages for auto storage, dining rooms, coffee shops, assembly and exhibition halls, and shops;
6. Plane loading;
7. and, more often than not, the control tower.

Only the first four functions are directly related to the major reason for the air terminal's existence; preparing the passenger to board the airplane. Commercial enterprises are simply added attractions and conveniences; the plane loading actually occurs away from the terminal whether remote or at the ends of "fingers," and the control tower is associated with the terminal only because the terminal building has generally held the most central position on the field which, in turn, was ideal for air traffic control.

Based on the premise that the process of aircraft loading and the control tower are the only two functions which are necessarily located at the field, I would prefer to locate the air passenger terminal near the center of the city or region as part of a transportation center providing buses or rapid transit direct to the jet, rocket, or atomic transport.
The Transportation Center Concept

The transportation center as visualized would provide a terminus for air transportation, railway travelers, and buses with local rapid transit and helicopters bringing passengers from outlying districts. Such a conception would bring the railway into the center of the complex at the lowest level, probably below grade. Buses would enter at grade level while helicopters and airport buses arrive and depart from the higher levels. Commercial enterprises such as movies, hotels, barber shops, and stores could either be centralized to accommodate the transportation center as a whole or localized to provide for each type of transport respectively. In view of the existing differences in types of passengers using each form of transport, the latter scheme might be preferable.

To trace the procedures by which an air passenger would arrive and depart from the transportation center will aid in recognizing the benefits of such an arrangement. The passenger would either buy his ticket at the counters in the transportation center, which would be similar to the method used today, or he could order his ticket if he knew far enough in advance about his trip. He could take his baggage to the center early, send it by an employee, or the airlines might provide a daily baggage pick-up service, obtaining the passenger’s luggage at his home or office.

If an international flight requires customs inspections prior to leaving, the air passenger may send his baggage early and have it inspected prior to his arrival at the center so that no delay on his part is necessary. If the international
traveler is arriving, he may travel by airport bus directly from the airplane to the customs location in the transportation center and either leave his baggage for inspection or wait for it. In the event that he left his baggage, the inspection of his person would have to be completed prior to his departure to prevent the possibility of smuggling.

The connecting link between the center and the airport would be one or two buses per flight which would contain the entire load of passengers and baggage. The buses would drive directly up to the jet planes and unload, the passengers moving easily into the aircraft while the baggage is loaded in the baggage compartments. If the baggage were placed in some form of standardized containers with perhaps twenty pieces of luggage per container, this phase could be greatly expedited. The reverse procedure would apply to incoming traffic.

The question of in-transit passengers who have a very short wait before transferring to another aircraft presents a problem. The trip to the center, which would seldom exceed fifteen minutes, is not necessary and somewhat impractical. In view of this situation, a light, air-conditioned, pavilion-type structure would be necessary to accommodate those who did not wish to go downtown to the center. The arriving and departing buses could make brief stops at the pavilion, having their particular flight called over a loud-speaker system, thus allowing in-transit passengers to still reach their flight by this method. Such a pavilion would also provide a point from which the general public could view the airport activity.
FIGURE 25. PAVILION ARRANGEMENT OF PASSENGER ACCOMMODATIONS AT THE AIRPORT.
I can foresee that the individual airlines would eventually provide their own type of pavilion structures at the airport to house their flight planning areas and provide in-transit passengers with the waiting space required. In this event, some regulations pertaining to maximum heights, minimum floor areas, and other building restrictions would necessarily have to be imposed. Space requirements would, of necessity, be based on air travel forecasts. An inter-connecting walk-way or a shuttle bus would allow passenger inter-change.

Additional transportation to the airport proper would be by rapid transit arriving desirably by underground routes and private automobile; however, the major means of reaching the plane would be by bus. Figure 25 indicates how the transportation facilities would be related to the pavilion arrangement in section and in plan.

The transportation center approach to jet airport master planning is not an attempt to provide a temporary solution but a long range program striving to solve the airport obsolescence problem. In the twilight period between piston-engine aircraft and jet aircraft many transitional problems are going to be pressing for solution. It will be easy to lose sense of one's direction while providing for the moment. But to prevent the present rapid rate of obsolescence of our airports, we must change our concepts. The downtown transportation center with pavilion-type waiting areas at the field, loading from buses which have picked up the passengers at the center, and parking the aircraft as indicated in Figure 25, are all parts
of the solution which I propose.

The advantages of this concept are numerous:

(1) A clean parking ramp, uncluttered by terminal fingers is possible, thus eliminating drifting snow and permitting easy cleaning.

(2) This parking method utilizes taxi-in and taxi-out procedures.

(3) The future size of aircraft is no problem; open ramp space allows more flexible parking.

(4) Taxiing may be accomplished at low power settings.

(5) No tractors are necessary for towing.

(6) Exhaust blast is no problem unless aircraft are parked too close in a nose-to-tail position.

(7) Front door deplaning begins within 30 seconds after the plane stops.

(8) A downtown transportation center relieves the airport commission of having to provide an expensive terminal at the field that may very likely be obsolete within a few years.

(9) Airlines may build their own light, air-conditioned shelters for those who do not wish to make the 15 minute trip to the center.

(10) When a city requires more than one airport, the transportation center relieves the necessity of providing two terminal buildings.

(11) The transportation center permits near-perfect interrelation of travel facilities for passengers that find it
necessary to change to a different form of transport.

(12) Commercial enterprises located in the transportation center enjoy the combined patronage of three different forms of passenger traffic: railway, bus and air travelers.

(13) While the city is in the process of decentralizing, the transportation center becomes the hub.

(14) Passengers may have their baggage checked earlier and at their convenience instead of waiting in long lines.

(15) Passengers requiring customs inspections may easily be segregated by unloading them directly at the customs station.

(16) Less building area is required at the field, leaving more space for unobstructed circulation.

(17) The ease of reaching downtown may be appealing to tourist traffic.

(18) Expansion of ticketing and baggage facilities is not inhibited because of aircraft clearances.

(19) Where height is necessary for additional space no restrictions normally exist in the downtown areas.

(20) Heliports could easily utilize the roof of the transportation center for landing thus providing convenient taxi service.

The disadvantages of the transportation center and the bus loading concept are:

(1) Passenger loading must be performed under portable shelters during the inclement weather which may be
a source of discomfort.

(2) Using bus loading methods, the passenger may feel a sense of regimentation. This may be avoided since he still may reach the airport by car or rapid transit.

(3) Such a total concept would be very expensive and require several years to complete, particularly where rapid transit must be installed from the beginning.

The concept of a transportation center is not impractical. At Los Angeles International Airport $21,879,585 is to be spent in 1958 for ticketing and satellite terminals alone.¹ The new passenger terminal area is to cover 295 acres.² If the railroads and the bus companies could contribute a proportional amount, the city of Los Angeles would have available at least $50,000,000 to provide a magnificent transportation center, one which would not be obsolete in a few short years.

Using Chicago's Midway Airport as an example, the busiest airport in the world, the following statistics may give an indication of the activity occurring in such a center. During 1956, this airport accommodated 8,865,268 passengers and 369,579 arrivals and departures.³ Dividing the total number of passengers by 365 days, the figure of somewhat over 24,000 passengers per day is reached. Breaking down the total still further indicates roughly 1,000 passengers per hour processed.

²Ibid., p. 41.
through the Midway terminal building. If we investigate the arrivals and departures in the same manner, the results indicate a take-off or landing every 86 seconds during each 24 hour period.

Air travel forecasts predict the passenger volume statistics to double by 1965. If this is so, the desirability of separating the confusion inherent to passenger processing from the confusion of airfield activity seems to be even more evident.

Design Principles for Transportation Centers

The transportation center, because it replaces the field terminal building, would utilize the same design principles which experience has found valid for air terminal design. Because such principles are rather vague and intangible, I merely list them here as a reminder to airport planners. Ideally, the object should be to provide:

(1) Smooth passenger and baggage flow,
(2) The correct size for the generated traffic,
(3) Economical expansion,
(4) Best positioning of concessions for maximum profit, and
(5) Functional, expressive architecture.
CHAPTER VI
CONTROL TOWER AT SAN ANTONIO AIRPORT
THE CONTROL TOWER AND MISCELLANEOUS BUILDINGS

The Control Tower

The heartbeat of every airport is the control tower. The personnel that man the transmitters and receivers govern to a great degree the safety of operations and field capacity. They direct the aircraft, assure adequate landing separation, clear for take-offs, and supervise ground movements. As traffic increases simultaneously with speed much greater attention must be given to aircraft circulation about an airport.

The control tower is usually centrally located to allow the operator to control the approach ends of each runway. A tangential system of runways, some of which may be 10,000 feet long, creates a problem. On a clear day, good visibility may be reduced to 5,000 feet or so because of haze or smoke. Personnel in a centrally located tower could not see the end of the approach runway under such conditions because of the distance. One answer would be to use a mobile control unit that could be plugged in near the approach ends of the runways to operate the control tower transmitters by remote control.¹

Extending the height of the control tower beyond 100 feet is no solution either. Some airports have weather minimums as low as 100 feet and 1/4 mile visibility. Under such circumstances a control tower over 100 feet in height would actually have its control room in the clouds.

¹Prokosch and Froesch, op. cit., p. 54.
The control tower should also contain, besides the glassed-in control room, a weather office, a radar approach control, a radio station, and any other office which the airport planner deems necessary for closely coordinated aircraft control. The CAA representative will be very helpful in organizing this facility.

The increased speeds of jet transports will cause a major change in control techniques but these will be more of an electronic nature than such as would alter the relation of the control tower to the airport.

Maintenance Areas

Maintenance areas, containing hangers and workshops, will not be affected appreciably by jet transports. The increased size of the aircraft will be an influencing factor and the ability to expand the maintenance area should be provided.

A jet run-up area with blast fences should be provided. The transports are towed or taxied to this area and turned with the exhaust outlet toward the fence. With the aircraft in this position the brakes are locked, the wheels chocked, and the engines are run-up, often to 100 per cent power, to allow the mechanics and engineers to check the various mechanical components of the aircraft. The noise can be quite disturbing during such procedures hence a relatively remote area is preferable.

The maintenance area and engine run-up areas should be inter-connected by taxiways to each other and the aircraft parking area.
The Fire Station

The danger of fire from crashes involving jet transports is greater than that associated with piston-engine aircraft because of the tremendous fuel loads and it is for this reason that the fire station, relative to the airport as a whole should be capable of particularly easy access to the runways. In case of crash landings, roads are not required as the runway and taxiway system provide this service. The fire station should have little relation to the surrounding community but should be primarily obligated to the airport. It is the policy of the United States Air Force to suspend flying operations when, for some reason, fire and crash equipment is not available at bases where there is considerable jet flying.
CHAPTER VII
CRITICAL STUDY OF FOUR MAJOR AIRPORT MASTER PLANS

General

To critically examine master plans of four major airports is difficult and possibly an injustice may be done because of the method I am obliged to use. Having been unable to visit three of the airports, O'Hare International being the exception, drawings, photographs, and written descriptions of the master plans are necessarily the objects from which the analysis must be made. Under such circumstances, situations which may be very charming and efficient in actuality may seem to be very ineffective in plan. Conversely, items that appear well designed and brilliantly conceived on paper may easily be dull and undesirable when finally constructed. Paper criticism is not entirely fair and the liberties that I take in criticizing the master plans of four major airports should be considered from this point of view.

The analysis of the four airports, New York International Airport, Los Angeles International Airport, O'Hare International Airport, and Boston's Logan International Airport, is based on the thoughts presented in this thesis and special reference is made to their ability to satisfy the needs of the jet age. All four are in the construction stage at this time and the mistakes which have been made shall stand as footnotes to posterity. Unfortunately, we learn best by doing and the process is often painful; however, the mistakes of others are very beneficial if heeded.

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Figure 26. Plan of New York International Airport (Idlewild).
Idlewild International Airport, New York City

Idlewild Airport, often called the "aerial gateway to the United States," completed its first full year of operation in 1949 with 18,115 plane movements and 222,620 passengers. Only seven years later, 1956, these figures skyrocketed to 149,825 and 4,473,120 respectively. Estimates by the Port of New York Authority anticipate 11,000,000 passengers annually by 1965. From these figures it is evident that expansion of facilities should definitely be a consideration in the design of Idlewild Airport.

The basic site plan of Idlewild Airport (Figure 26) includes a tangential system of runways around an elliptical central core. Although seven runways are indicated, it is doubtful that more than two can be used at one time. Two of the runways are utilized for aircraft parking and because of the "X" intersection of four others only one of them may be used at one time. Aircraft control procedures would not permit simultaneous landings on the intersecting runways because of the danger of a collision. As a result, in fair weather only runway 13R-31L may be used with one of the intersecting runways. Traffic is further slowed because of a lack of high-speed exits from the runways with the long runway, 13R-31L, being the exception. Runway lengths are generally satisfactory although as jet flights increase, a few of the runways

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may require lengthening, a situation which will present problems because of the restricted area.

Circumferential taxiways provide good one-way taxi routes with ample exits and 360 degree circulation.

The location of the bulk fuel storage area is very good in that tankers and fuel barges may reach the area from Jamaica Bay. Access from the highway is convenient and the New York Central railway is nearby in the event jet fuel should be brought in by train. Hazards to the airport from fire and explosion are minimized.

The disposition of hangers and maintenance areas all over the airport complex is unfortunate so far as concentration of facilities and tidiness in housekeeping is concerned. One of the first views of the airport include the rear elevations of two hangers. Also, with such dispersion of maintenance areas, a common jet run-up area is difficult to procure. Several run-up areas only create greater noise problems.

The decentralized terminals at Idlewild have an advantage over the centralized schemes in permitting the passenger to reach his airplane without being thrown with passengers of other lines. Such a scheme also allows each airline to express its preferences in design of its terminal.

The disadvantage of having to take a taxi or other form of transportation when transferring to other airlines is not desirable; however, New York is peculiar in that only five percent of its total passenger traffic change to flights operated
FIGURE 27. PLAN OF LOS ANGELES INTERNATIONAL AIRPORT.
by other airlines.¹

The problem of expansion with respect to passenger facilities is typical of designs which include a central core. If expansion is undertaken the obvious area to suffer is the parking area because this is the only direction left to expand. The parking area for 6,000 automobiles is adequate right now but if buildings must expand into that area, a potential bottleneck exists.

The 11-story control tower at the center of the complex makes an excellent focal point and should easily command the view of all runways during good weather. It is approximately two miles from the end of the longest runway and this may present problems on days when the visibility is poor.

To summarize, Idlewild has done a good remodeling job while having to work with facilities which were fixed and far from ideal. This airport will be taxed to its capacity in ten years and will have no way to expand, yet, because land for an airport is at a premium, this situation is unavoidable.

Los Angeles International Airport, California

International Airport at Los Angeles (Figure 27) has the distinction of being the only airport in existence which utilizes the satellite plan and decentralized ticketing areas in combination. Passengers arrive and park their cars underground near check-in points, remaining at this level through ticketing and baggage operations. They then walk through passageways into the satellite terminal, where they mount an

¹Ibid., p. 76.
escalator to arrive at the lobby level for loading. Average walking distance from entering ticketing area to airplane loading is one block.\(^1\)

Circulation at Los Angeles International should be excellent from the passenger's point of view and the aircraft's operator. The passengers who may dislike the system will be those who are changing airlines; however, plans call for a low cost shuttle service between buildings.\(^2\)

With the dual parallel runway system which is another variation of the tangential pattern, aircraft traffic will be generally moving in one direction at all times. For example, a landing aircraft taxis to its satellite terminal and, after loading, continues taxiing in the same direction to take-off on the runways across the field from the landing pair. When the wind changes, the direction is reversed.

The existing runway system is satisfactory for Los Angeles traffic because 95 per cent of the landings and take-offs are made to the east or west.\(^3\) However, in bad weather the airport would be taxed to land aircraft on only one instrument runway. The spacing of the dual runways is not adequate for landing aircraft in clear weather simultaneously and in bad weather it would be virtually impossible.

Adequate runway lengths of 10,000 feet are available. High speed exits are provided and the taxiways are very convenient.


\(^2\)Ibid., p. 42.

\(^3\)Ibid.
FIGURE 28. PLAN OF O'HARE INTERNATIONAL AIRPORT SERVING CHICAGO.
However, the general appearance from the air is one of considerable confusion.

Hanger locations and maintenance areas are well placed out of the way but with easy access and compactly arranged.

Parking at Los Angeles Airport is provided in the center of the complex with areas directly adjacent to the respective airline ticketing offices. Parking may be expanded to two decks. Access and egress is very easily accomplished.

The control tower is centrally located and serves as an identifying marker as well.

Los Angeles International Airport marks the successful wedding of passenger and aircraft circulation. The whole design has been handled competently and efficiently. The runway system, although efficient as planned, will soon reach its capacity particularly when bad weather occurs. Additional runways are virtually impossible to build because of site limitations. In essence, Los Angeles has an airport designed for people but the airplanes will soon begin to suffer.

O'Hare International Airport, Chicago

Probably the finest airport in the United States and one which is tailored for jet transports is O'Hare Field serving Chicago illustrated in Figure 28. Comprising nearly 6,000 acres, O'Hare boasts six runways, all of which may be used simultaneously in fair weather. If radio aids are available, as many as three instrument approaches may be made simultaneously.

The 60 degree tangential pattern of runways permits simultaneous take-offs and landings on any two of the three pairs.
of runways. Distances which the airplanes must travel on the ground are equalized with no airline occupying a "poor" position at the terminal. High speed exits are provided for all runways and one-way taxiways circle the entire terminal area.

Because Chicago has a high percentage of inter-connecting flights, officials elected a centralized terminal scheme with "fingers" extending from the central unit. The use of "fingers" in a place subjected to so much snow is unfortunate because they do create large snowdrift problems against their sides. The ramp will also be more difficult to keep clean because of the extensions. Perhaps bus loading methods would have been more appropriate at O'Hare. Then, too, any expansion from the final stage is practically impossible because of the central core solution; however, I know of no way to avoid this with a tangential system of runways unless the terminal is provided off the site.

The maintenance area at O'Hare is neatly placed in a location away from the public areas with easy access from the apron. A common run-up area thus becomes available.

Parking is handled adequately; however, the people forced to park near the extreme edge of the parking lot will be obligated to walk over one-quarter of a mile.

Access to the terminal by automobile and bus is good, but, as in the case of New York and Los Angeles, no rapid transit facilities come directly to the airport. In cities of this size, rapid transit would appear desirable. Idlewild Airport is served by bus lines which make connections with subways.
FIGURE 29. PLAN OF LOGAN INTERNATIONAL AIRPORT IN BOSTON.
The control tower is centrally located with a clear view of the entire field. The problem of seeing the approach ends of the landing runways during periods of poor visibility becomes acute in this instance.

In conclusion, Chicago's O'Hare International is a near perfect field from the pilot's standpoint, but the terminal area will fast reach its capacity particularly as more traffic diverts from Midway Airport. Although the finger design was the logical approach for extending from the central terminal, flexibility and future expansion was sacrificed. The increasing size and development of different types of aircraft will penalize the present terminal concept, yet, until its capacity is reached, O'Hare Field will remain a splendid example of airport planning.

Logan International Airport, Boston

Boston's major airport, Logan International (Figure 29), differs in almost every respect from the preceding airports which were discussed. The runway system is different and the terminal area is a combination of two design approaches. Logan's final design, while having its shortcomings, is not the result of haphazard planning or an unsure approach but, probably more than the other three airports, its final form was the result of working with a limited site. Protruding into the main ship channel of Boston Harbor, Logan Airport forms a peninsula and further expansion must be effected by building up land area from the channel. Yet even with this restriction, Logan has two 10,000 foot runways.
The designers of Logan International have used a sixty degree parallel runway pattern because the airport must have a capacity greater than that available with a single runway layout. With two of the three pairs, one runway is longer to permit take-offs of long range aircraft. The shorter runway may be used for landings. It is unfortunate that the longest northwest-southeast runway could not have been placed on the outside to permit landing aircraft to turn off the runway as soon as possible. While the separation of parallel runways would permit simultaneous landings and take-offs, aircraft taxiing to the outside runways would have to cross the path of landing aircraft. If the situation were reversed, landing aircraft would have to cross the path of take-off aircraft. Traffic would have to be regulated for these crossings and it is doubtful that simultaneous landings and take-offs at a maximum rate of efficiency could be achieved. Logan's capacity is definitely limited because no more than two runways are ever available for simultaneous use.

Taxiways are practically non-existent and no rapid exits could be satisfactorily included in the airport's design. Runways become taxiways for reaching the apron after landing and the major taxiway from the end of the southeast runway crosses four other runways before connecting to the terminal area. Taxi distances are long for most of the take-offs and landings; this will prove costly for jet transports.

Access to the airport appears good with highways, railroads, and ship channels available. The ship channel will prove very valuable for bringing in large quantities of fuel.
in the most economical manner. The railroad may later become part of a rapid transit system.

Although parking appears to be convenient, the 2,300 spaces provided will probably be inadequate. To increase the parking, areas distant from the terminal will have to be utilized.

The design of the terminal area is good, well-developed, and allows excellent segregation of traffic types. The centralized concession area with the decentralized airline offices provides a very good circulation pattern. It is interesting to note that the designers discarded the "finger" system of loading because it committed them to centralized operations and limited future development. With the arrangement used at Logan International, blast and heat will be no problem if the passengers are kept behind the glass doors while the engines of the jet transports are running.

Hangers and maintenance areas are compact and unobtrusive in their locations. The placement of the seaplane base in conjunction with one maintenance area indicates good forethought.

Boston's Logan Airport is both good and bad. For the passengers, the airport design seems to be highly desirable and the designers have solved their circulation problems well. However, for the pilots and the airplanes, Boston's Airport may well become a nightmare as traffic increases.

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SUMMARY AND CONCLUSIONS

The jet airport of the future is only the further development of an existing mode of transportation that has expanded with a rapidity that is beyond belief. The advent of jet transportation will cause a few radical changes in airport design; however, there are some phases which only require expansion and refinement.

The facilities which the jet air transport will require and its impact on the people who will use it have been examined and studied. This is the real content of this thesis. Why do our airports rapidly become obsolete? What role will the architect play in jet airport planning? How can we approach the problem of master planning for the jet age? The questions and many others are discussed in terms of principles in an effort to discover some direction through which we may end the inadequate approach to jet airport master planning.

Having presented a survey of the problems which jet transportation will introduce, it is only natural that certain observations and conclusions must be made stemming from a close association with the subject and the problems which it introduces.

The approach to airport master planning, in the majority of cases, is often accomplished with little more than a study of land areas available; however, the problem goes much deeper than this. Extensive investigation is required, just as in all city planning problems of industrial, residential, population, and transportation relationships. Intensive surveys
of passenger trip lengths, passenger preferences, and passenger inclinations, all go into the preparation of a master plan for a jet airport. Only when these surveys are completed and the information assimilated can a satisfactory location for the airport be determined.

In like manner, no longer can the master plan exclude the surrounding community, but it must protect its approach zones and plan the developments which its presence will generate. This protection even extends to planning subdivisions adjacent to the airport and the shopping areas required to sustain them.

Regional airports may well become the solution for jet transportation and particularly for space travel. When this day comes, as it invariably will, a turning point in city planning will be attained. No longer will the airport exist for the city, but the city will owe its existence to the airport. The trend of today to push the airports out of the city will thus be reversed. The airport will be the center and a pattern of cities will develop around it.

Because of the heat, noise, and blast problems created by contemporary jet aircraft and the expectation that to obtain comparable thrust in the future will entail even greater problems of heat, blast, and noise, the concept of bus loading techniques is recommended. Such an arrangement offers greater flexibility than any other method regardless of the form which future aircraft may take. As space travel begins, the best way to approach the space vehicle will be by motorized means because of the hazards involved when close to a rocket vehicle about to start its engine. An adaptation of the bus loading
concept, inasmuch as it would create a ground traffic problem unless excellent highways to the airport are available, would be to use the helicopter as a crane carrying capsules filled with passengers from downtown to the airplane. The future of this method may have more possibilities than bus transportation because of the relief to ground traffic problems which it offers.

Expansion of passenger and baggage facilities is the major reason airports become obsolete and, because the bus loading concept does not inhibit the location of the terminal area, the transportation center would largely eliminate most of the problems which airport planners face today. It would provide ideal centralization of transportation facilities and allow the airfield to accomplish its primary function of landing airplanes. While I recommend that such a development be near the center of the city, it is not a prerequisite; however, it is important that it be located off the airfield site where it will not inhibit expansion. A practical place for its location would be over the existing railway terminal since the railroads would have the most difficulty in moving their facilities.

The transportation center would be the ideal solution for a regional airport around which a city would eventually grow. For hundreds of miles people would travel by bus, train, and helicopter, all arriving at a central building from which they could depart on their inter-continental flights or trips to outer space. It is true that this is a concept for the future, but it is a future that is very near at hand.
GLOSSARY

Aircraft. Any weight-carrying device designed to be supported by the air either by buoyancy, as an airship, or by dynamic action, as an airplane, autogiro, or helicopter.

Airfield. The area of an airport designated for the landing and take-off of aircraft as distinguished from the area occupied by buildings.

Airpark. A community landing facility for personal aircraft providing a convenient landing area built within the confines of residential areas or business districts.

Airplane. A mechanically driven fixed-wing aircraft, heavier than air, which is supported by the dynamic reaction of the air against its wings.

Airport. A tract of land or water which is adapted for the landing and take-off of aircraft and provides facilities for their shelter, supply, and repair; a place regularly used for receiving or discharging passengers or cargo by air.

Airway. An air route along which aids to air navigation, such as radio beams, radio ranges, beacon lights, and intermediate airfields, are maintained.

Approach Light. One of several lights to indicate a favorable direction of approach for aircraft landing on a runway.

Approach Pattern. A prescribed course over which an airplane maneuvers preparatory to landing at an airfield.

Approach Zone. The area surrounding an airfield within which landing aircraft must fly a prescribed course.

Apron. The hard surface adjacent to buildings or hangars used for loading, unloading, and servicing airplanes.

Boundary Light. Any one of the lights designed to indicate the limits of the landing area of an airport or landing field.

Capacity, Airfield. The number of movements per hour which can be safely accomplished.

Ceiling. The height of the lower level of a bank of clouds above the ground.

Contact Light. A light used to outline runways on an airfield.

Flight Path. The path of the center of gravity of a flying aircraft with reference to the earth.

Flight Stop. An airstrip located adjacent to highways with service station accommodations, used as an intermediate stop for refueling or located where community landing facilities would not be available.

Gate Position. The space allotted to one airplane for parking at a terminal building.

Glide Path Ratio. The ratio of any horizontal flight distance to the altitude loss for such distance.

Hangar. A shelter or shed for aircraft.

Helicopter. A type of rotor plane whose support in the air is normally derived from airfoils mechanically rotated about an approximately vertical axis.

Instrument Runway. The runway of an airport designated for and equipped with devices permitting the landing of an airplane under conditions of minimum visibility.

Landing Field. Any area of land designed for the take-off and landing of aircraft. It may or may not be part of an airport.
Landing Strip. A narrow and comparatively long area forming part of a land-plane airport or of an intermediate or auxiliary field, which is suitable for landing and take-off of airplanes under ordinary weather conditions.

Movement, Aircraft. The landing or take-off of one airplane at an airport.

Obstruction Light. A red light used to indicate the position and height of an object hazardous to flying aircraft.

Penetration. The descent of an aircraft from high altitudes to lower altitudes, generally for the purpose of making an instrument approach to the airfield.

Pressurization. The maintenance of atmospheric pressure in the cabin of an airplane which approximates lower altitudes while flying at higher altitudes.

Radio Navigation Aid. Any radio apparatus, device, or system designed to guide or orient flying aircraft.

Ramp. A sloping way used sometimes for the beaching of seaplanes. The term is also used as a synonym for apron particularly in the Air Force.

Rapid Exit. Taxiways which turn off the runways at a slight angle enabling the aircraft to clear the runway at high speeds.

Runway. An artificial landing strip designed for the landing and take-off of airplanes.

Taxi. To travel along the ground or on the water under the aircraft's own power, when picking out a starting place or coming in after landing.

Taxiway. A prepared strip to enable aircraft to taxi to and from the end of a runway.

Tire Footprint. The area of the tire of an aircraft wheel in contact with the landing surface when the aircraft is at rest.
Visibility. The greatest distance at which conspicuous objects can be seen and identified.

VOR. A very high frequency omni-directional radio, radiating an infinite number of lines of position; a radio navigational aid.

Wind Rose. A diagram of the points of the compass with lines indicating the relative velocity and direction of winds.

Zone Ratio. Obstacle clearance requirements expressed as the ratio of horizontal distance from the end of the runway to the obstacle height above the elevation of the runway.
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