CARDINAL PRINCIPLES IN LOCATION AND DESIGN OF COMMERCIAL AIRPORTS AND THEIR APPLICATION TO THE WASHINGTON AIRPORT

By Howard H Houk

Resident Engineer, Washington National Airport

SYNOPSIS

The design of an airport is a complex problem Other forms of transport can stop on their traffic ways but aircraft must first be transferred to landways and in the transition changes from an atmospheric body to a motor vehicle

A master scheme for ultimate development functionally and structurally complete at all stages is essential to prevent waste, loss, obsolescence, reconstruction and future disturbance of operations This demands the cooperative collaboration of city planner, airport engineer, highway engineer, architect and landuse specialist

Site selection is of primary importance and since every site has its limitations, thorough investigation and good judgment are necessary to evaluate the advantages and disadvantages of a location

The future increase in traffic and the contribution to the efficiency and economy of an air transport system will depend upon prompt, rapid, and convenient surface transport to the airport from the center of the population served and upon its connections to regional subway and surface transport lines

To maintain the advantage of air speed, travel time consumed on the ground, in surface transport connections, ground movement of aircraft, and dispatching passengers and goods must be minimized

The landing field, the foundation of the airport structure, is the three-dimensioned traffic area of the airport

Theoretically the circular shape is ideal, the triangular is minimum in area, the unusual should be avoided, any compact figure can be used, and the quadrilateral is the most common

The size of the landing area is determined by the arrangement and length of the runways, which must safely serve operating aircraft Their ultimate dimensions for major airports will be determined by the requirements for future blind landing Runway schemes are not fixed but should be arranged to take full advantage of location surroundings

Investigation of site meterological conditions should be early and complete because of their influence on operations and safety of aircraft

Ultimately, fully automatic blind landing should become standard practice However, extra time consumed will tend to limit airport capacity

The location of the building plot is very important The best site is in a wedge-shaped sector projected into the landing field from the least-used flight zone This minimizes hazards and reduces time and travel between runways and buildings

Flexibility is the objective in the building scheme which must provide esthetic and economical stage development

The application of the principles of soil science plays an even greater role in airport construction than in highway construction

Different government agencies have devoted considerable study to the problem of providing a modern airport for the Nation's Capital The airport is not a model airport but it is hoped it will serve as an example of the utilization and development of the natural advantages of a particular site

The design of an airport is one of the most complex problems now confronting the engineer. The modern airport is no longer just a place for air liners to land It is a complex transportation transfer and junction station in the air and ground transport network and must be organized and equipped to receive, shelter, service and dispatch aircraft, passengers, mail and goods, with the utmost safety and speed.

Air transport is now in those early stages in the development which demand the best application of an engineer's knowledge and the fullest appreciation of his responsibility. An airport is a vital link in the world transportation system exerting a very important influence on the immediate and future development of a city, linking it to the progress of the world. The construction of a modern airport involves a very large capital expenditure and therefore offers the great challenge to the foresight and ingenuity of the engineer to supply the needs of the country with necessary airport facilities at a price the taxpayer can afford to pay.

THE MASTER PLAN

The location and design of a modern commercial airport is a real problem in modern city and regional planning. It is fundamentally wrong to plan for present necessity alone and ignore future expansion requirements and their probable effect on the layout. Too many airports have been built and expanded without any plan of ultimate development.

It is obvious that a master scheme for the ultimate development should be prepared before undertaking any construction work and that failure to do so will lead to many costly errors in design which will become apparent as the airport is further developed. No element should be left to chance because such an element may become critical as air transport expands and the demand for logical functioning and efficient operation increases.

The master plan should be flexible, provide for successive stages of future development of the airport and permit its orderly expansion from immediate needs to ultimate demands. The improvements made in each stage of construction should be architecturally complete and merge into the final development with minimum financial loss without demolition, and with minimum reconstruction, obsolescence and disturbance.

The plan should provide for the coordination of all proper activities, the safe, efficient, and convenient handling of the maximum density of air traffic, the safety, comfort, and convenience of passengers, operating staff, visitors and spectators, and for appropriate architectural treatment and landscaping. Preparation of such a plan is no easy task since it is necessary to forecast the future development of air transport while fulfilling immediate requirements.

In the past the largest and finest cities were those with the best water, rail and then motor transport facilities. Our great coastal cities were built around the best sites for boat-landings and ports. Many of our inland cities grew up around the railway stations. However, air transport is too young for any of our cities to have had, as yet, the opportunity to grow up around the airport that serves them. Instead they have grown over many of the most advantageous sites for airports.

The commercial airport is a transfer station or junction point between air transport and ground or water transport. The user's choice between transporting mediums or a combination thereof, depends upon the hazard involved, the time consumed, the cost incurred, and the convenience provided. The modern airport must be so located that it is quickly and conveniently accessible to those whom it serves in order to reduce the time consumed on the ground between the airport and points of traffic origin and destination. It may be necessary in the future to raze areas of obsolete or undesirable buildings to provide proper airport sites for some of our larger cities. Time is the true measure of the accessibility of an airport. The advantage of increased speed in the air is lost if one has to travel long distances on surface transport to and from ports at each end of the air journey. One minute of tedious travel through city traffic at 20 miles per hour represents 3 miles or more of flying distance.

Adequate highway, street, surface, subway, railway and even waterway connections are important factors in the efficient functioning of an airport and should be properly coordinated for ready exchange of traffic. As long as the motor vehicle remains the principal transportation link to the airport, it will be imperative that safe, high speed routes connect the airport to points of air traffic origin and destination. Where the surface transport route from the traffic center of the city to the airport site is through a traffic congested section that slows it down to half speed or less, and it is unlikely that the condition can or will be relieved, the site is no more advantageous than one on an unrestricted ground route twice its distance from the center of traffic origin and destination. Delay means time loss whether occasioned by distance or ground transport facilities.

Every effort should be made to develop a close-in airport unless all possible locations are decidedly unsafe. If no centrally located site is available, the next choice is an airport site served by rapid surface transportation direct to the center of gravity of traffic with frequent connections to all parts of the city. Location of the main air routes indicates the preferable position of the airport with respect to the city itself. Departing aircraft should not be compelled to cross congested areas at the most critical period after leaving the ground, nor to fly around restricted areas lying between the airways and the airport. Care should be taken to investigate and determine whether or not the use of a given site for an airport will interfere with or conform to the harmonious development of the city plan.

THE LANDING AREA

The term airport includes the landing field and all other facilities. The fully developed metropolitan commercial airport today consists of the landing field, the terminal or station building and hangars together with all the appurtenant equipment and facilities of a modern air transport station.

Marine, rail and motor transport vehicles can come to a standstill at a loading or unloading station along the traffic way on which they normally travel but the air transport vehicle must be transferred from an air way to a land way before it can come to a state of rest. If locomotives and motors could not be stopped until transferred to a particular type of waterway, the location and design problems of railway and bus terminals would be more nearly comparable to those of airports. In railway and highway transport, the vehicle moves on fixed traffic ways in the form of tracks and pavements without appreciable effect from winds and is brought to a desired destination by being directed along these narrow traffic ways by the rails in the case of railway transport and by hand steering in the case of highway transport. It is much more difficult to direct the movement of an airplane on the surface of an airport or in the air above the airport. In its transition from the ground to the air, its state changes from that of a motor vehicle to that of an atmospheric body subjected to the continuously changing direction and velocity of the wind and vice versa. If the airport is to successfully serve its primary purpose the designer must consider it as a three-dimensional traffic area.

The primary purpose of a landing field, air base, or airport is to provide a place to effect the safest, quickest possible transfer of aircraft from the air to the ground at or as near as practicable to the desired point and vice versa, regardless of the weather. The landing field, the aircraft traffic area, is the foundation upon which the airport structure is built. The best in other improvements and facilities will not compensate for a landing field that will not permit aircraft which it must serve, to land safely in all flying conditions. The problem of locating the airport whether it be a small town port or a large city terminal, improved and equipped with every facility known to modern air transport is actually that of locating the landing field, its fundamental element.

The design of the landing area involves consideration of many variable factors that occur in various combinations and which are never identical at any two airport sites. Each site therefore must be treated as an individual problem and the best layout sought in the light of all conditions governing that particular site. The arrangement should never be copied from another location but the designer should study the particular area and the fixed surroundings, and develop the best plan consistent with safe operation within the existing limitations.

SITE SELECTION

Selection of the site is of primary importance and the future of the undertaking depends largely upon the judgment of those responsible for its location. The disadvantages of an ill-chosen location will become more apparent and serious as time passes and traffic increases.

The ideal topographic location for an airport, viewed from the standpoint of safe and expeditious maneuvering of aircraft in the air, would be an easily distinguishable, level, circular plot of large diameter, on a fog-free plain near sea level, free from any man-made obstructions within, around and beyond its boundary that might hinder or curtail flight operations. All airport structures would be underground and nothing would extend above the surface of the site, or the area within maneuvering distance of its boundaries, that might offer a mental hazard to the pilot or endanger the safety of aircraft under any possible circumstances. In practice the ideal site is never encountered and even if such were found, it would probably be impracticable to utilize its natural advantages, except perhaps for emergency landings, just as the potential power of a great water-fall in the interior of a distant, uninhabited jungle cannot be utilized because it cannot be carried to the users.

Since no site completely fulfilling all desirable requirements is ever available at or near the center of gravity of air transport in a large city, every available site has its limitations or individual characteristics and must be studied to evaluate its merits and demerits. It is real economy, therefore, to spend the necessary time and money on the preliminary studies and investigations necessary to accomplish proper site selection. Such investigations are insurance against the exorbitant cost of future expansion to meet unforeseen demands, restricted use of the port or its later abandonment.

It is as unwise to select an airport site on the basis of the price of land as to so choose the location for a trunk highway or a railway terminal. Although it is necessary to make a compromise selection between the sites offering different advantages, unfortunately for air transport the most frequent compromise in the past has been to locate the airport far beyond the city limits.

Existing airports, with the exception of the very latest, are in general the results of successive development of early set-ups, possessing all defects inherent in improvements arising from immediate necessity, insufficiently studied

In the early days of aviation search was made for a flat field suitable for landing and taking off and if successful, the search ended Its location with respect to the city was then considered of secondary importance Many still remain little more than the original open fields and in some instances the old air field has proved a hindrance rather than a help in developing a satisfactory airport, on account of the tendency to think, "once an airport always an airport" and because continued improvements have made the cost of moving the airport almost prohibitive.

SITE AND SHAPE OF AIRPORT AREA

The boundaries of the airport must embrace an area of the size and shape required to permit the engineer to lay out and construct the traffic area of the dimensions and character required

The size of an airport is determined primarily by the size of the landing field and the required dimensions of the landing field depend upon the number and the useful or effective length of runways that must be provided to safely accommodate the aircraft that will initially use it, which are the actual lengths reduced by the necessary corrections for local temperature, barometric pressure, and obstructions in the flight paths Many existing airports of comparatively large acreage are unsafe and inadequate because runways otherwise long enough are too short because much of their length is ineffective on account of obstacles to flight clearance on the airport or beyond its boundaries

The acreage required varies from the minimum of a triangle, through the circle to that of a square Shushan in New Orleans (Fig 1), and Lydda in Palestine are examples where the triangular shape permitted the airport to be constructed on a much smaller area than a circular or other geometrical figure providing the same facilities In the absence of other limitations, the triangular shape will require the least volume of earthwork to construct, and may also be advantageous in cost where shore protection is necessary

The tiare pattern, a triangular-like symmetrical figure, with curved boundaries, proposed by Gavin Hadden, civil engineer of New York, permits the layout of line-width runways in all directions of

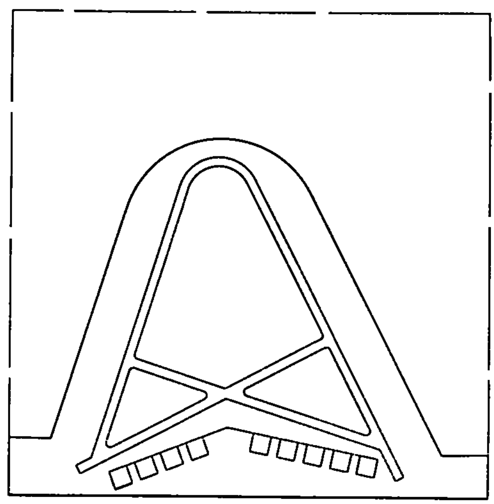

Figure 1. Triangular Shaped Field at New Orleans in Relation to 640 Acre Square

the compass on a field of minimum area However, the saving in acreage will seldom compensate for the increased cost of a tract with all curved boundaries Besides the convexity of the curve is difficult to estimate from the air and a pilot landing near one edge of the field for any reason, might easily run off the field

Where the choice of shape is open without qualification, rectangular and elliptical areas with the longest dimension in the direction of the prevailing wind are to be preferred over square areas, especially when the prevailing winds are fairly constant in direction and landing conditions are normal. These enable the maximum length runways to be placed in the direction of the prevailing winds parallel with the base of the rectangle or the major axis of the ellipse, and the minimum length runway to be placed in the direction of less frequent winds parallel to the height of the rectangle or the minor axis of the ellipse.

If it is assumed that winds are equal in velocity and frequency and may blow

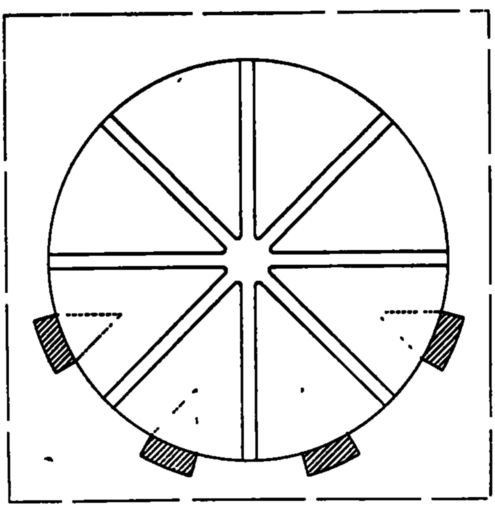

Figure 2. 4-Runway Scheme 8-Direction Layout on Circular Landing Area with Buildings along Periphery 640 Acre Square.

from any direction, the landing field should theoretically be circular in shape, so as to provide equal distance for landing and take-off in every direction (Fig. 2). Also theoretically it should be domed with slight grades rising toward the center with long radius vertical curves. This would be advantageous in draining as well as in landing and taking off. Any shape of landing field on which suitably oriented and graded areas for landing and taking off can be constructed will serve, and the actual shape is of no great consequence, except that landing areas of odd or unusual shapes or with ill-defined boundaries tend to confuse strange pilots and should be avoided. Preferably, of course, the shape should be triangular, square, rectangular, or some other compact geometric figure. Quadrilateral tracts are most common.

If it is possible that traffic will develop to the point where one set of runways will be insufficient to handle the traffic that could otherwise be handled at the airport, the size of the field should be sufficient and the master plan should provide for the installation of auxiliary parallel runways in the future, in case increased traffic makes it desirable to have planes land parallel, while others are taking off.

So far as landing is concerned the ultimate dimension of major airports will be determined by the margin required for error in blind landings. Improvement of blind landing technique will have a vital influence on the length of runways and therefore on the required field dimensions.

NUMBER AND LENGTH OF RUNWAYS

In the infancy of aviation and even more recently in foreign countries, the landing field was actually a grass-covered field on which planes were able to land in ordinary weather.

With the advent of heavier planes and the necessity for taking off and landing regardless of weather or soil conditions came the demand for an all-weather surface. The cost of paving, draining and maintaining an all-paved field or the minimum area required for aircraft to take off and land in any direction; i.e., a circle of a diameter equal to length required for take-off or landing, became increasingly prohibitive with the increase in the size and speed of aircraft and the consequent increase in distance required for take-off and landing. The fact that the only portion of the pavement of an all-paved civil landing field frequently used is that over those favored paths in line with the one or more frequent wind directions prevailing on the site, first led to the improvement of landing strips laid out at the most favorable flight locations in respect to the most frequent winds and, finally to the construction of stabilized or paved runways on paths chosen after careful consideration of prevailing winds, obstructions and buildings.

Each runway, with both ends clear of flight obstructions will serve for traffic in the two opposite wind directions. There are few geographical locations where the winds of appreciable velocity always come from one direction or its opposite, but it is apparent that at such locations, one runway will suffice. At locations where the wind blows constantly from but one or two directions or their opposites, obviously four runways are not needed.

All runways on the same airport need not be of the same length, or width. The length of runways lying in the direction of the principal winds may be safely reduced below that necessary for dead calm provided the airport has at least one runway long enough and with an obstacle zone ratio large enough to permit safe operation during dead calm conditions. The necessary reserve length increases with the percentage of calms. A four-way runway or eight direction airport may therefore safely include one short runway, provided it is long enough to safely serve for the critical low wind velocity in its direction.

It is desirable that runways be long enough to permit any aircraft likely to use the field to roll safely to a stop, with a reasonable reserve for safety in the event that during take-off, engine failure should occur just as the wheels are leaving the surface of the runway and to permit safe landing in case of aircraft failure while in the immediate vicinity of the field.

The required length for take-off for single engine craft is the sum of two distances, that required for the airplane to attain take-off speed plus a reserve distance required for the machine to roll to a stop after having attained this speed. The runway length should be such that if one engine of a multi-engine craft is suddenly cut when it is on the ground or in the air at the middle of the runway, it will be possible to continue motion safely with the remaining engine or engines, in a straight line flight path that will clear all obstacles ahead.

The lengths required for take-off and landing vary with the condition and surface characteristics of the runways. The lower the coefficient of rolling friction and the higher the coefficient of sliding friction, the shorter the take-off distance required. The lower the coefficient of rolling friction the greater the distance required to stop, but this is seldom critical.

The runway or runways used for blind landings should be longer than others and must be so oriented as not to be subject to influences which might interfere with the proper functioning of its extremely sensitive apparatus. The facilities for blind landing should be installed on the runway or runways in the direction of the prevailing wind during low visibility periods, if the wind during low visibility is appreciable in velocity. That direction in many locations is different from the prevailing direction.

Obviously it would be quite advantageous to be able to shorten the distance required for take-off and landing and so reduce the length of the runways and in turn reduce the required dimensions of landing fields. Future improvement in aircraft design and operating technique should achieve this objective, at least to the degree that present requirements will suffice to accommodate the larger planes of the future.

THE EFFECT OF INCREASE IN AIR TEMPERATURE AND DECREASE IN BAROMETRIC PRESSURE

Increase in air temperature and decrease in barometric pressure both indicate decrease in air density. Airplanes take-off at higher speeds and climb at flatter angles the more rarefied the atmosphere becomes. Also the power output of certain types of aircraft engines decreases as the air density decreases.

Therefore, when airports are to be located at altitudes above sea level it is necessary to take into account the fact that longer take-off distances and flatter glide clearances are required than under normal sea level conditions and consequently longer runways Even at some sea level locations the barometric pressures are so much below normal that the atmospheric density is appreciably less than normal sea level.

Extreme summer temperatures may greatly decrease atmospheric density. Based on standard temperature of 60 deg. and assuming constant propeller thrust, the take-off run required is approximately 11 per cent greater than standard when the air temperature is 130 deg. Normally the effect of 9000 ft. altitude above sea level is to increase a 4500 ft runway length requirement to 6550 ft.

Air temperature and density are important factors in the determination of the length of runways required and in some instances in the choice between the sites.

FLIGHT OBSTRUCTIONS AND THEIR CONTROL

The landing field should be such that the operations of flight will not be hindered or curtailed by flight obstructions of any kind. It should be as free as possible from obstruction to clear air approach. The feasibility and economy of completely removing existing obstructions in the vicinity of the site or reducing them to safe permissible heights should be investigated.

A landing field of minimum dimensions with unobstructed approaches and surrounded by open fields or water may prove superior from an operating standpoint to one of much larger dimensions, surrounded by buildings or other obstructions. Any obstruction, in whatever form, of greater height than $\frac{1}{30}$ of the distance from the edge of the landing field, decreases the available length for landing and taking off by a distance equal to 30 times its own height measured from the foot of the obstruction, and must be lowered or removed, if the larger transport planes are to use the field. It is desirable that there be no obstruction within a gliding angle of 50 to 1 from the extreme end of the landing strip covering a reasonable horizontal angular divergence from the landing strip.

The "approach zone" for normal usage runways now required is 500 ft. wide at the end of the runway increasing in width from 250 each side of the center line at the end of the runway to 1250 ft. each side of the prolonged center line of the runway two miles outward from the end of the runway.

There appears little doubt that, ultimately, fully automatic blind landing will become standard procedure. Provision should be made for at least one "blind approach" runway, equipped with a blind landing and approach system which will assist the pilot in finding the landing area in a condition of no visibility This runway should be wider than the others. Since the inclined glide path marked out by the radio landing beam is considerably flatter than the conventional visual approach, it is necessary to be able to fly into the blind landing runway at a gliding angle ratio of 1:40 or flatter In no circumstances should airport buildings or hangars be in the path of this runway making it necessary for aircraft to take off and land over them.

Due to the possibility of drifting slightly off the course the "approach zone" of the blind landing runway must have ample width and the flight path from outer approach marker to the end of the runway, should be absolutely free of obstacles to flight and suitable for the descent of planes to within sight of the ground so that they may come in along the landing beam from the outer approach marker to the inner approach marker and then glide to a landing. The present required width of the approach zone for a runway equipped for instrument landing is 1000 ft. at the end of the runway and 4000 ft two miles distant.

An isolated construction such as a tall chimney or radio mast constitutes a greater hazard than does a high building or a large tank Overhead telegraph and telephone lines are very difficult to distinguish and those near the airport landing field should be underground. High tension lines are extremely hazardous They also disturb radio services and may emit discharges that will strike metal aircraft during storms

Large illuminated signs in the vicinity of an airport may prove to be sources of danger to aircraft In times of bad visibility they are likely to be dark, and when lighted may be mistaken by the pilot for airport navigation lights or beacons. Illuminated sky signs, or beacons are likely to be confused with airport lights Since the effective landing area is measured by conditions beyond the limits of the landing field boundary, it is necessary to have sufficient control of the surrounding area to insure that the existing flight approaches will not be obstructed in the future and the airport made unsafe or inaccessible for aircraft. The erection of buildings or other structures, that will project above the safe glide angle within the flight paths of aircraft to and from the end of each runway, must be prevented to prevent effective shortening of the runways themselves

A large percentage of accidents occurs in the vicinity of the airport and the farther buildings are from the boundaries of the field, the better not only from the standpoint of their own safety and that of aircraft but also from the standpoint of the comfort of the occupants who, while air traffic may function less noisily in the future, will always be subjected to some disturbance from the racket of engines.

An airport may be compared to a dinner plate, the flat portion representing the landing field and the edge representing the permissible height of obstructions at that distance from the airport. The controlled area should continue as a more or less horizontal plane at the height above the ground of the plate edge extending outwards in all directions to the limit of the controlled area.

How the development of the area around the airport is to be controlled so that high buildings or other obstacles to flight will not spring up in the future is often a problem. Control may be exercised through public ownership or by the adequate zoning of privately-owned areas adjacent to the airport to insure that obstructions will not be erected or industries established that would be a hindrance or hazard to air traffic Buildings should be restricted to heights not likely to interfere with aircraft using the airport Where there is a hill or other elevation sufficiently near the airport to rise to or above the inclined glide plane to the end of any runway, all building should be prohibited on that portion of the hill which reaches to or stands above that plane The height of growing trees should be subject to regulation

Wherever feasible, it is desirable that the airport authorities purchase a marginal fringe of land around the airport and keep it free of all buildings, devoting it to some public use, such as a public park, playground or playing fields and other recreational purposes until required for use in expanding the airport or its facilities. The acreage acquired should be as large as practicable since, in most cases, the establishment of an airport will greatly enhance land values and any excess can later be marketed at a profit when certain that it will not be needed for public use.

METEOROLOGICAL CONDITIONS

The first step in the investigation of a site should be the investigation of meteorological conditions at the site. The directions of the prevailing winds govern the layout and alignment of the runways and influence the location and layout of the airport buildings. Horizontal and vertical movements of the air affect the safety and operation of aircraft

The actual effect of the wind on the performance of an airplane is dependent on its direction and velocity. It is necessary to ascertain the main wind direction, that is, the direction of greatest frequency, called the prevailing wind direction, because a greater number of take-offs and landing should be made in that direction. It is therefore the direction in which the first and principal, best-improved runway should lie. Wind conditions should be studied carefully and consideration given prevailing wind directions for day and for night and also to the direction of high velocity winds.

Wind roses indicate graphically the annual frequency and velocity of winds obtained by averaging as many observation years as available. The graphic base for the study of the disposition of the various facilities of the airport is a local wind rose for the site showing the frequency and velocity of cardinal and quadrental sectors of the compass. Calms have no direction and are therefore not included in the wind rose. Winds of 5 miles an hour or less are included with calms since they do not appreciably effect landings and take-offs and therefore do not influence location of runways. Observations are often taken for 16 points of the compass and reduction of such observations from 16 lines to 8 is affected by assigning to a main direction one-half of the value of each of the two lines on either side.

Meteorologic investigations of sufficient reliability are not always available for a site. To be valuable they must have been accurately taken over a period of years. Records taken in the vicinity of a site may not accurately represent conditions at the actual site, since differences in altitude and the immediate topography may cause variations in the weather conditions and in the direction and force of winds at the site. Wind data accumulated only a short distance from the site has been even so misleading that after an airport was placed in operation additional runways had to be built and buildings moved.

Turbulence of the air over and near the airport must also be considered. This while of little consequence at high levels, is inimical to ease and safety of flying at low altitudes. The contours of the site, the type and condition of the soil combined with local climatic conditions tend to produce local air currents over and near the landing field. Cross-air currents result from nearby hills or broken topography. Hills, buildings, and abrupt, undulating ground adjacent to a site cause turbulent air currents. Since forests in the immediate vicinity may cause disturbing air currents and air pockets, if practicable the trees should be felled or thinned out. Filled areas and sandy soils are heated to higher temperatures by the sun's rays than grass land or woodland and generate ascending currents. Mountains standing in the direction of the principal wind have a noticeable influx that may be felt as far distant as 50 miles. Immediately adjacent to mountains suction phenomena and vortices may be present.

Where a site under investigation is near high buildings or other topographic features of different altitude, it should be tested by experienced pilots in flights over the site under varying weather conditions to disclose the existence and effect of hazardous local air eddies and currents. Where the topography of the site will be materially altered by the demolition or erection of structures, or the reforming of the land surface, wind tunnel testing of a model of the changed area may prove helpful in discovering the local effects of turbulence.

Air transport has now developed to the stage, as did motor transport, where it must move regardless of weather conditions. Therefore, visibility through the atmosphere is one of the most important factors to be considered in the selection of the location of an airport.

Visibility is defined as the greatest distance toward the horizon at which conspicuous objects obscured by fog, haze, smoke, dust or precipitation, can be seen and identified. Very low clouds constitute a menace to navigation second only to dense fog. Ceiling, the measure of vertical visibility is the distance from the cloud canopy to the ground when the sky is largely or entirely covered Airport sites where low ceilings are frequent should be avoided if possible.

Aircraft can take off in fog, fly in, or above fog, but cloud and fog formations can lower the visibility to the point where landings cannot be made at all unless the airport is equipped with the latest improved blind landing facilities.

An airport should not be located in the midst of a city's smoke nor on the side of an industrial town over which the vapors, smoke, fog, or mist is blown by prevailing winds nor to the windward of bare areas of fine or sandy soils. Radio-active radiation and industrial plants contribute to the formation of fog. Due to topography, visibility is often less impaired on one side of a city and it is therefore desirable that the airport be on that side.

Ground haze is less likely to occur on high ground locations, but elevated sites are often covered by low-lying clouds. Sites near swamps, on plains, near large bodies of water and in narrow valleys are usually subject to fogs and mists. Unpredictable clouds may form over a location in the bend of a river. Island or shore locations although often affording the advantages of unobstructed level approaches are likely to be subject to fog.

There should be no possibility of floods covering the site because it is vital that air service be maintained when floods interfere with other forms of transportation.

A low-lying plateau slightly elevated above the surrounding terrain would ordinarily be the ideal location.

EFFECT OF SOIL CONDITIONS

Soil conditions may be a very important factor in the selection of an airport site. The construction cost of grading, draining and surfacing the landing area on a given site, where soil composition or conditions are unfavorable may be prohibitive and later maintenance may be expensive or even impracticable.

Adequate soil investigations supplemented by tests are necessary to disclose those soil properties which may need to be controlled in design and construction, in order to produce a satisfactory landing area and building sites.

The cost and quality of the landing area will depend upon the character of the material in the subgrade and the availability and cost of usable foundation course, paving, and structural materials on or near the site. Full advantage should be taken of the practical applications of soil science developed through years of highway experience in selection, combination, manipulation and compaction of natural materials in the subgrade and foundation courses for pavements.

THE ORIENTATION OF RUNWAYS

It would appear simple to lay out one or more runways on the landing area, but in reality it is a complex problem requiring considerable detailed study to ascertain the proper orientation. Only in extremely rare cases can the ideal layout be used without modification to conform to the limitations of the particular site with its surroundings.

The designer should not hold to any fixed runway layout scheme but should develop a layout which fits the existing limitations to the best advantage from every standpoint. He should fit the runways to the site and its surrounding obstructions so that the ends of the runways are as free as possible from obstruction to clear air approach.

Since an airplane in flight depends for its dynamical support upon its speed in relation to the wind, it is safer and easier for aircraft to take off and land into a moderate head wind, regardless of the wind direction, provided it is steady in direction and velocity. Side winds are dangerous to the machine's stability when taxiing on the runway and runways should be oriented so as to enable the pilot to take off as nearly into the face of any wind as practicable, and in the case of winds of appreciable velocity the angle of a directional side current to the runway should not be more than 22½ degrees.

Therefore, runways are now laid out on the generally accepted basis that satisfactory take-off and landing of the present types of aircraft is possible up to 22½ degrees out-of-the-wind. Where wind directions are few and constant, the runways should lie in those directions, irrespective of the angle between directions.

The minimum requirements for a 4-runway field are best met by the so-called "scissors or shear system" on a minimum area by locating two runways bisecting each other with their intersection angle bisected by a line in the prevailing wind direction and two other runways supplementary thereto, so that each successive pair are at an angle of 45 deg. with each other (Fig. 3). If the prevailing wind blows diagonally across the section of land, a scheme such as shown in Figure 4 can be used instead of Figure 3. How-

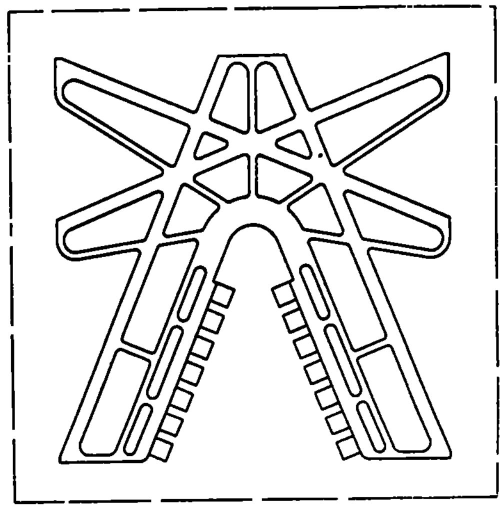

Figure 3. "Shear" Shape Scheme 4-Runway Layout 640 Acre Square

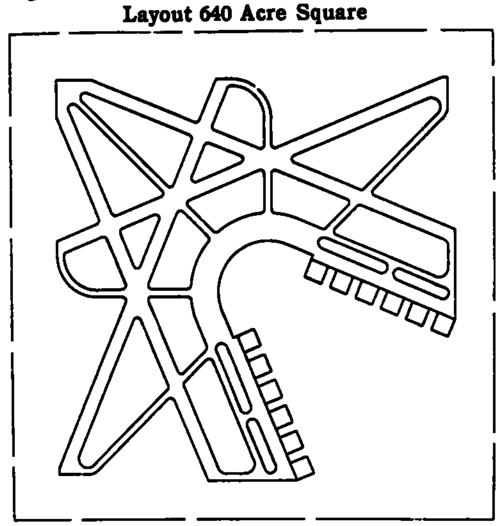

Figure 4. "Shear" Shape Scheme for Prevailing Winds Diagonal to 640 Acre Square Area

ever, this ideal layout cannot be applied directly and exactly to any particular site and no runway layout should be adopted until checked by inspection of the site on the ground and from the air It may be varied by rotation or separation to conform to the shape of the field, the number of future auxiliary parallel runways, the prevailing wind, the area of the building plot required and the surrounding approaches and obstructions. Figure 5 indicates how on an area one mile by one and one-fourth miles, full length dual runways may be laid out with provision for a third system shorter in length A layout

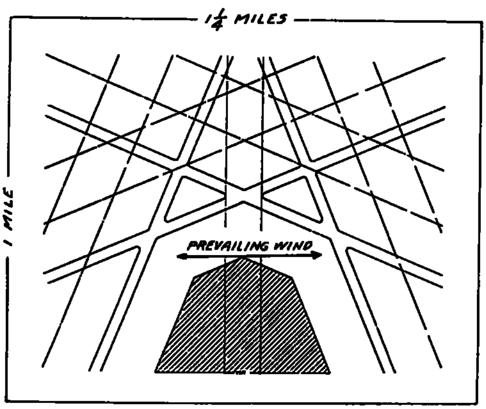

Figure 5. Triple Runway Scheme 8-Direction Layout 800 Acre Rectangle

scheme shown in Airport Design Information published by the Civil Aeronautics Authority is shown in Figure 6, which permits a triple system of parallel runways on a single section of 640 acres.

A scheme for a circular field is shown in Figure 7 Some maintain that for all practical purposes the six-way layout is as satisfactory for operating purposes as the eight-way layout. Such a dual runway layout with taxiways omitted is shown in Figure 8*

On an airport of very large dimensions, it is possible to locate runways around buildings and aprons in a central nucleus of the landing area and accomplish positive separation of air traffic by limiting each of the parallel runways on opposite sides of the nucleus to take-offs or landings for the respective wind direction

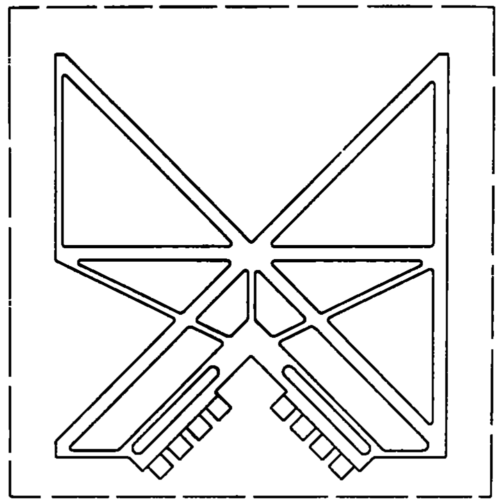

Figure 6. 4-Runway Stage Civil Aeronautics Development Plan 640 Acre Square

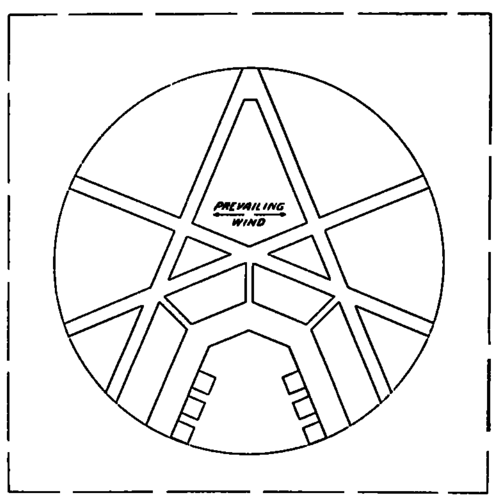

Figure 7. "Shear" Shape Scheme on Circular Landing Area in Relation to 640 Acre Square.

(Fig 9). However, the available building area in the nucleus is limited and to provide safe access to the buildings is expensive. Hangars or buildings constructed outside the nucleus add flight hazards.

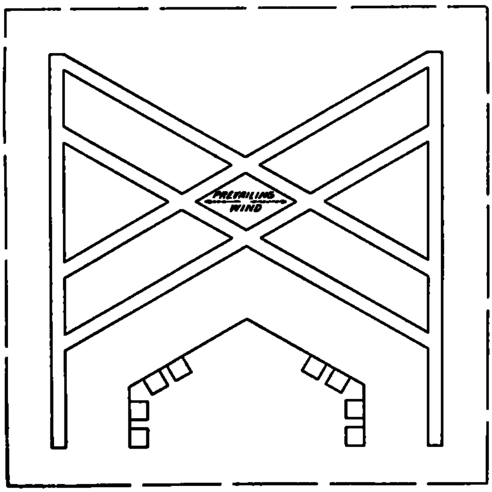

Figure 8. Dual Runway 6-Direction Layout 640 Acre Square

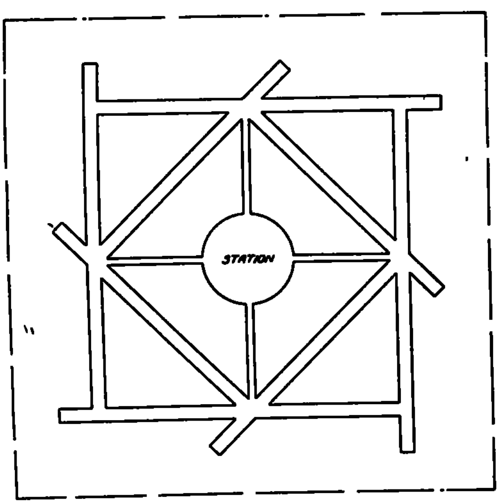

Figure 9. Parallel Runways around Central Nucleus Separated. Take-offs and Landings 640 Acre Square.

LOCATION OF THE BUILDING PLOT

The foremost principle in building location is to avoid endangering the safety or obstructing the movement of aircraft in the air. Next in importance to obtaining a building layout that offers the minimum hindrance and hazard to the movement of aircraft in the air is to obtain one that will permit the erection of whatever additional buildings may become necessary in the future without introducing additional flying hazards or hindrances.

In Europe especially in Germany, the circle with its circumscribing square or enclosing rectangle was formerly considered the basic form for the airport area, with the buildings and hangars, either placed in one group in the form of an arc concave to the landing field with the station building at the center, or in separate groups scattered around the margin of the field with vacant spaces left between for flying gaps (Fig. 2). This proved unsatisfactory because when assembled in an arc along the periphery of the field, the principal obstruction on the airport was its own buildings, and when scattered in separate groups, aircraft were compelled to fly over the buildings or through the gaps. Either arrangement creates operating hazards, decreases the effective length for landing and take-off and obstructs expansion of the landing field. When in groups separated by flying gaps or landing strips, the segregation of activities creates difficulties in supervision and management, causes loss of time in the movements of personnel and aircraft, and prevents the utilization of common walls possible in continuous lines of hangars.

More or less of the 360 degrees around the periphery of the airport will necessarily be encumbered by airport structures, but the obstructed zone of flight should be a minimum. With the advent of the runway, effort was made to fit the necessary buildings into a space or spaces parallel to and between the runways so that they would be conveniently close to the center of gravity of aircraft movements on the ground and safely clear of flight paths.

Mr. Albert Duval, of the French Air Ministry proposed that this minimum could best be achieved by placing all airport buildings in a dead sector or one so chosen that it would offer the least hindrance or hazard to flight into and out of the airport (Fig. 10). Ordinarily, the most favorable sector is perpendicular to the direction of the prevailing wind. The "Plan Duval" runway scheme for a circular field is shown in Figure 11.

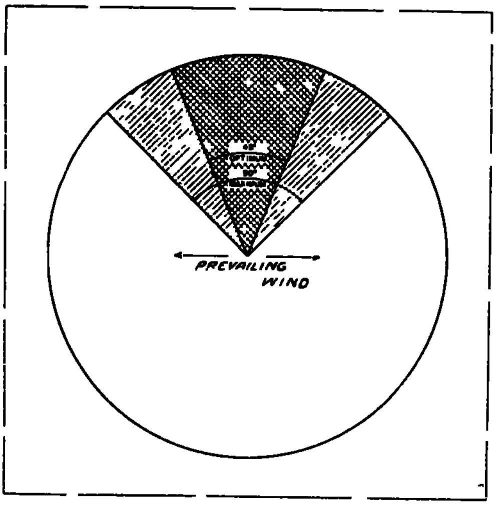

Figure 10. Building Plot Location in "Dead" or Least Used Zone

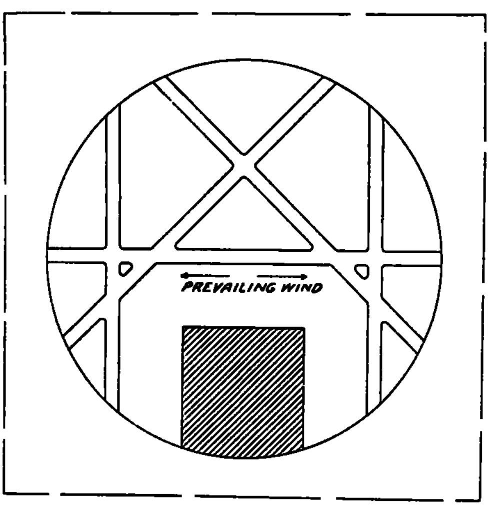

Figure 11. Plan Duval

If the buildings, on an all-surfaced landing area are located in such a "piece-of-pie" or wedge-shaped sector of 45 deg. or less, it is unnecessary to fly over them regardless of the wind direction, and they do not appreciably reduce the effective area of the landing field regardless of its future expansion in size Four runways can be so oriented on the landing area that a 45 deg. or 90 deg sector is reserved for buildings and yet a plane will never have to take off or land more than 22½ deg. out-of-wind, even when the direction of the wind bisects the building sector, the most unfavorable direction.

The best arrangement of the terminal building and hangars of a commercial airport is to project this wedge-shaped building plot into the landing field from the "dead" or least used zone of flight approach (Figs. 3–6 and 8) This minimizes their hazard, shortens the length of taxiways, and promotes safe and efficient operation. The terminal or station building should be located at the apex of the building sector, as near the center of the landing field as flight path clearances permit, with its field front at right angles to the prevailing wind.

Additional area in the sector, opposite the landing field, should be acquired and set aside for recreational, aeronautical or other appropriate purposes until required for additional buildings.

TAXIWAYS AND LOADING APRONS

Taxiways or taxistrips are the secondary surface ways of the landing field. Properly located taxiways provide smooth safe aircraft traffic channels and save fuel, reduce the wear and tear on aircraft, the time spent on the runways and the time and the travel distance to and from the unloading points.

The taxiway system should be laid out so that an airplane can leave the runway as soon as practicable after landing and proceed by as direct route as possible, without crossing the path of any other plane, from landing point to loading point and vice versa. Conversely it should be able to proceed from loading point to the end of the runway from which it must take off by as direct a route as practicable, without crossing the path of any other plane that might be landing or taking off. Taxiway centerline tangents should be far enough distant from runways at the ends to permit succeeding planes to close-up for take-off without interfering with the plane on the runway. They should be connected to the runway ends by spiral entrance curves of ample turning radius. The size of the loading apron depends upon the number and size of machines that should be handled simultaneously and should be fully adequate.

LAYOUT OF AIRPORT BUILDINGS

The greatest problem of an airport building scheme is to achieve the flexibility necessary to provide for the systematic development of the scheme in a series of progressive stages that will provide adequate facilities from the initial to the final stage.

Buildings and related facilities should be planned and designed to meet the immediate operating functions and requirements of the particular airport, and should be capable of being expanded to fulfill all foreseeable needs, technical, recreational and social. The scheme should permit extensions, alterations at minimum loss, and disturbance and the development should appear well-balanced and architecturally complete at all stages.

In siting the individual buildings it should be borne in mind that it may be desirable later to add buildings different in size and shape

Air traffic control is vitally affected by the terminal building location since all incoming and outgoing aircraft are cleared from the apron and loading points

Every effort should be made to bring the buildings into harmonious relation with the landscape The details should harmonize with the whole and the whole should blend with the details.

It is the function of the architect, working in close collaboration with the engineers, to provide the framing of the airport functions necessary to produce an esthetic, economical and efficient closely knit whole. All too often a monumental and otherwise architecturally beautiful terminal or administration building stands in the midst of a heterogeneous array of overgrown, barn-like steel structures, sprawled around the boundaries of the field. An airport should have dignity. An atmosphere of dignity and permanence creates confidence in aviation.

BUILDING DESIGN AND ARCHITECTURE

Few definite conclusions have hitherto been reached in the matter of the design of station or terminal building. The requirements of railway stations have been established by years of usage and their design has been standardized but this is not true of airport station buildings The dimensions of but few units of a terminal building have been fixed by established requirements. Many units are indeterminate and may require considerable expansion with successful use Still others may not be required at all in the initial stage.

The objective is to obtain an attractive building justified by traffic and yet avoid any semblance of its being unfinished or overbuilt It should be capable of enlargement without substantial alteration. The rotunda-type of building, if adopted, must necessarily be built too large to begin with, since it is not adapted to extension or enlargement.

The architectural motif of the station building should be modern, yet simple and dignified. Its appearance should be expressive of aviation on first sight, whether approaching the airport by air, land or water There have been suggestions for the incorporation of aeronautical motifs such as moving propellors and outlines of planes into buildings and their details This might be done, but architecturally it is as logical to design a railroad terminal to look like a locomotive, or a steamship pier to resemble a steamship Such diversion in design generally results in economic waste, functional derangement and inefficient operation The building should be a frank and straightforward expression of its functions without artificiality. There is no reason why modern forms cannot be developed that are not modernistic

The success in the design of any building depends upon how clearly its functions are understood by the architect The advantage of air transport in speed is greatly reduced in short flights not only because of time consumed in ground connections but in dispatching at the airports themselves. In order to minimize this loss, and secure the utmost in the time advantage of air transport, every effort must be made to save time in necessary operations in the airport itself Ticket selling, baggage handling and embarkation should be expedited, and buildings and related facilities planned and designed to meet the operating requirements of the particular airport

The terminal building should provide for the expeditious and convenient handling of passengers and goods and the comfort and convenience of passengers, spectators and employees It should be arranged for easy intercommunication Visitors and spectators should be able to obtain a full view of all operations without interfering with the movement or safety of passengers or vehicles

Access to all facilities should be plainly visible to the passenger on his way through the station and on arriving as well as departing, he should be unconsciously compelled to pass all indispensable services in proper order Passengers should not be able to gain uncontrolled access to the flying area, yet they should be able to come as near the point of departure of their plane as practicable, and wait standing or seated as they choose until ready for the loading. The loading points should be the minimum distance practicable from the waiting room and as near as possible to a central focus A plan convex to the landing area appears most logical although straight plans are common

The control tower is the station of the airport officer, who supervises all the air traffic of the airport and he must command a clear view of all the activities on the entire field, aprons and hangars, as well as all air approaches to the landing field The tower floor area should not exceed that absolutely necessary to house the necessary equipment in a compact arrangement and allow the airport officers easy access and free movement The tower and the entire terminal building should be kept to the minimum height practicable above the elevation of the landing field.

It is important that weather observers have convenient and clear outlook for at least 270 degrees of the horizon most favorable for weather observation It is also necessary to provide accessible spaces for the release and unobstructed ascent of large weather balloons and at least one convenient, protected station for the instrumental observation of their height and position

Hangars are difficult to treat architecturally and owing to their mass unless they are subdued, tend to dominate the site and dwarf the terminal and other buildings and make them seem even smaller than they really are

Safety demands that hangar roofs be as low as the necessary vertical door clearances will permit. Many hangars have been built unnecessarily high The total height of a properly designed hangar to house the largest sizes commercial land planes need not exceed 55 feet and may be lower without appreciable increase in cost

PLANNING AND TREATMENT OF REGION OUTSIDE LANDING AREA

The air traveler's view is an aerial perspective, the bird's eye view of man's handiwork, and the roof has become the facade central view to the man in the sky. It is in the approach by air that the city stands out in all its fascination and one's first view of the city may best be enjoyed as an air transport passenger. The airport reflects the whole city to an increasingly larger number of travelers. Their first direct view and impression of the city is obtained from observation at the airport and enroute to their first destination in the city itself. The attendance of thousands of visitors and spectators at any airport has an advertising value to the city that cannot be purchased for thousands in paid publicity.

An accessible airport on a site properly chosen is logically a part of a municipal park and recreational system and should be coordinated with that system. Properly planned, far more than any rail or water terminal, it lends itself to beautification. Ordinarily it can readily be developed into an open-air breathing space of stimulating interest and activity.

The standards for airport sites, terminal buildings facilities and services should be correspondingly higher than those for water, rail or motor terminals from the standpoint of traffic demands. Since air travelers pay extra to travel by air, they expect and demand high standards in cleanliness, comfort and service. The passenger who has been surrounded with luxury and super-service in the air should not be compelled to spend his time waiting in an uncomfortable, unattractive station building.

The airport should be able to accommodate large numbers of visitors and spectators with minimum interference in the movement, convenience and comfort of passengers The public wants to see airplanes at close range and in action, should be able to obtain a close-up view of the embarkation and debarkation of passengers, and the loading and unloading of mail and goods, but must be kept off the landing field and out of the service areas.

Attractive restaurants or dining-rooms with windows or plazas should face the landing area. Vantage points for watching flying activities should be provided from walkways, parking areas, balconies, roofs, bleachers or a combination of these.

Eventually the airport can rightfully be expected to pay its way and in many instances considerable return on the investment can be realized from proper activities and concessions tributary to air transport. Full advantage has seldom been taken of the opportunity to secure the revenue possible through the rendering of non-aviation services at the airport desired by both patrons and visitors The airport can be made doubly attractive to visitors and spectators by providing ample and conveniently accessible parking places where they can view the planes, and clean, comfortable facilities where they can secure inexpensive refreshments and meals.

Unfortunately, in the past, the public has been discouraged from visiting and enjoying many airports, particularly on occasions of general interest, because they must park far from the field, and when they do reach it, view of the activities is shut off by hangars, buildings and fences. Crowds attracted to the airport will not return if they cannot conveniently park and comfortably view the airport activities

Scant attention has been paid to parking space for automobiles which should not only be adequate but have ample provision for entering and leaving without interference or delay to other traffic. Where the site is not level or requires grading, advantage should be taken of natural topography or in reforming existing topography so as to provide building sites and parking areas. Areas reserved for future development, zoned for flight paths or outside the immediate landing area, can be temporarily or permanently used for recreational purposes. Care should be taken however that the development is not such as is likely to confuse and mislead arriving pilots.

Air transport is more restricted by landing conditions at the airport than by flying conditions on the airways. The operating efficiency of the principal commercial airport of a large city is measured by the frequency of take-offs and landings. The controlling element in the frequency of take-offs and landings is the average length of time which the runway in use must be restricted to one individual landing or take-off, under any but abnormal conditions. Take-offs can be made in rapid succession but an airplane is unable to stay in position ready to approach and land the exact instant the runway is freed. In unfavorable weather the minimum permissible interval will greatly exceed that normally required.

While dependable blind landing systems have been developed enabling airplanes to land regardless of atmospheric conditions and although these facilities no doubt will be greatly improved in time, the best technical aids in bringing an airplane to a safe and comfortable landing will never equal the degree of safety attained with the clear view of the pilot's eye and the correcting grasp of his hand.

It is time that it is recognized that regardless of its dimensions or the number of runways, the traffic capacity of a single commercial airport for aircraft of the current types is limited. The number of machines that can safely be operated in the air above the airport at an instant is limited on account of the danger of collision in the obscured atmosphere. Landing blind consumes time and in long periods of visibility so bad as to require assisted landings, the congestion due to the stacking up of a large number of planes at different elevations, each endeavoring to meet its time schedule, inevitably results in loss of time and dissatisfaction of patrons.

If in peak hours therefore, the traffic is more than can be safely served by blind landing methods, it is advisable to establish one or more auxiliary airports or improved landing fields, or a combination thereof, at those strategic locations in the vicinity most free from the respective atmospheric conditions that cause low visibility at the principal airport at the particular times, where planes can land and take-off, and discharge and receive passengers and goods to and from the principal airport. When normal traffic reaches the capacity of the principal airport it will be necessary to provide additional major airports at other favorable locations. It is obvious that there should be frequent, rapid, reasonably-priced ground transportation from these secondary ports direct to the principal port and the city.

CHOICE OF GRAVELLY POINT SITE

For years, it has been obvious that Washington urgently needed an adequate airport, but there was violent difference of opinion as to the proper location. The limited area and hazardous obstructions of the existing airport long retarded the growth of air transport.

Intensive study of the question of the location of an airport for the National Capital and its environs had been under way for 13 years. Bills were introduced in the Congress and committees and commissions were appointed to search the District and vicinity for possible sites. Hearings were held and reports presented on the merits and demerits of many proposed sites. The possibilities latent in the Gravelly Point site were recognized by all and it had been tentatively reserved for airport use for years. While constructing the Mount Vernon Highway, the (then) Bureau of Public Roads purchased foreshore property, with the right-of-way, constructed a grade separation structure, and made studies of the landing areas on the site in 1930. The National Capital Park and Planning Commission began its studies of airport needs and airport sites in 1926 and after comprehensive studies of nearly 50 different sites in and around the District, repeatedly recommended the Gravelly Point site as the only appropriate area suitable for a central commercial airport on account of its accessibility to the business and government centers and the opportunity afforded for future expansion and the development of accommodations for seaplanes.

At various times, the District Engineer, United States Engineer Office, prepared preliminary plans and estimates for the construction of an airport at Gravelly Point, and the site was already, in fact, under construction by that agency.

A few engineers, honestly believed it undesirable, impracticable and even impossible to construct a landing field with fill material dredged from the river because of the probable character of the borrow material and of the apparent length of time required for settlement. Some testified before congressional committees that it would require at least five years before the fill would settle sufficiently to warrant the construction of runways or a proper development of grass.

The Civil Aeronautics Authority after examination, investigation and study of all other possible sites in and near the District of Columbia decided that the Gravelly Point site possessed a combination of advantages clearly outweighing its disadvantages.

PREPARATION OF MASTER PLAN

Intense study and concerted effort on the part of all the Government agencies concerned was devoted to the preparation of a master plan for the Washington National Airport, one that would give the Nation's Capital not only a first-rate landing field but also utilize to the fullest extent the natural advantages possessed by the site in its present and future development.

It was not expected that the result would be a model airport for other cities to copy exactly, but that it would reflect creditable leadership of the nation in the field of air transport and serve as an example of what it is possible to accomplish in that field by intelligent planning. Through the cooperation of Government agencies and the air transport industry, it was hoped that one of those happy interpretations of architecture and engineering would be produced of which the critic often dreams but seldom sees.

CONSTRUCTION OF THE LANDING AREA

The greater part of the landing area was a tidal flat, much of which was exposed at low tide, and the construction of the airport reclaimed a large swampy area, one to three feet under water, in the immediate vicinity of the Capital. For the past ten years, the U. S. Engineer Office had been using the site as a spoil basin deposit for the material necessarily dredged from the Virginia Channel of the Potomac to maintain its navigable depth and width. More than one million yards of material had already been placed behind the levee and normal maintenance dredging operations would have built the site up to grade in 35 or 40 years.

Fortunately, due to the vision of those who planned the Mount Vernon Memorial Highway all but approximately 50 acres of the landing field site was already owned by the United States Government While the use of any other site would have resulted in considerable loss of taxes by reason of the acquisition of title by the Federal Government, the use of the present site created additional land and withdraws but a small area of valuable real estate from taxation.

It is highly desirable that Washington have an airport with facilities for seaplanes as well as for land planes and the

Gravelly Point site offers the best possibility in the vicinity of Washington for the development of facilities for a combined seaplane and landplane airport. Quick transfer of passengers, mail and goods will be possible. Title to the site for the seaplane base is in the Government and a basin of sheltered water free from strong currents and shipping traffic can be easily completed at a nominal cost.

Primary consideration has been given to producing, conditioning and developing the runways on the landing area, which have literally been built from the bottom up Plans were completed and construction started on the landing area before work was begun on the buildings and other improvements The soft material was trenched out of the sites of the runways down to solid, firm material and replaced to the extent practicable with sand and gravel material by manipulating the dredges in the borrow area and the dredge discharge on the landing area Extensive explorations and investigations were made to ascertain the character and amount of the material in the available borrow areas and the leased dredges shifted about to obtain the best of this material for the runways from foundation to top

Sand gravel aggregate from selected portions of the borrow areas was dredged into position to serve as foundation material, subgrade material, and stabilization base course material It was also stockpiled for use in the preparation of hot mixed, hot laid bituminous paving mixtures, and in the preparation of concrete aggregate for use in the buildings, hangars, drainpipe, incidental structures and concrete pavement

The initial development reclaimed the full width of submerged flat between the upland and the established river line and sufficient length to construct a runway 6,855 ft long in the direction of the prevailing wind When, and if required, the length of the field can be extended up and down the river and the length of the North-South runway increased to 8,000 ft

METEOROLOGICAL AND SURROUNDING CONDITIONS

Terrain in the immediate vicinity of Washington is choppy and no site in the vicinity is wholly free from fog Usually fogs occur in the morning and are more or less general because of the streams and their valleys. Often the fogs over the river area are less dense than the general fog over the upland area in the vicinity of Washington, where there is also the hazard of low-lying clouds With few exceptions the heaviest fogs dissipate in the morning and flying can proceed later in the day Extremely stormy conditions that make flying hazardous or impossible throughout the day are limited to 5 to 10 in a year, and exist over the whole area in the vicinity of Washington Prevailing winds tend to carry smoke and fogs away from the airport site

Due to the peculiarities of weather conditions in and around Washington, one or more airports and several auxiliary fields should be chosen further out on strategic sites as free from cloud formations or fog, as can be found, for use during the small percentage of the time that congestion caused by weather and atmospheric conditions renders the use of the airport inadvisable or impossible These auxiliary ports should be distributed in such a way that at least opening of cloud formations or fog clusters, aircraft will be able to discharge passengers and cargo destined for Washington and receive passengers and cargo from the Washington National Airport When the normal weather traffic capacity of the Washington National Airport is reached in the future, the most favorable of these may be further improved to meet traffic demands

Very few major cities have had the opportunity to obtain or construct a site so close to the center of its civil and business activities. Particularly, it is necessary for a city located near other large cities to have a close-in airport, otherwise, in the short-haul air journey, the time saved and comfort gained over train travel is nullified by 30 to 45 minutes ride in a taxi-cab or bus through traffic to and from the airport at each end of the trip. The time to Gravelly Point from the average traveller's destination in the city is shorter even than the measured distance indicates.

It is located on the Mount Vernon Memorial Highway and, until the Highway Bridge is reached, provides excellent ground traffic facilities except for the portion between the clover leaf on Route No. 1 and 14th Street during peak traffic periods. However, steps have already been taken to relieve this traffic condition. The airport borders the right-of-way of the R.F. & P. R.R., which has freight yards adjacent to the highway and a spur track into the building area. A suburban railway station may be established at the airport for the exchange of rail and air traffic, if and when necessary or desirable. A connecting channel dredged to the Potomac allows aviation fuel to be delivered to an underground tank farm on the site from barges or tankers.

All types of motor transportation, such as private cars, taxis, public buses, and sight-seeing buses are provided with easy and convenient contact with the airport with a minimum of conflicting movements

The Navy had completed arrangements for removing the Arlington radio towers before the construction of the airport. The proximity of the Naval Air Station and Bolling Field lends itself to interchangeable use and the military and commercial flying activities can be so controlled that they will not seriously interfere with each other. All ports can be operated as a single unit under military control in case of war.

ORIENTATION OF RUNWAYS

The airport is oblong in shape containing an area of approximately 750 acres and is bounded on three sides by the Potomac and on the fourth side by the relocated Mount Vernon Memorial Highway (Fig. 12).

The Potomac and Anacostia Rivers, the highways, the railways and other distinctive landmarks help the strange pilot find and identify the airport and also assist the familiar pilot to locate it in bad weather.

The runway layout is along the lines of the theoretic "Plan Duval" modified to fit the surrounding topography. The four runways have excellent open aerial approaches and are of ample length for take-offs and landings. The three sides of the landing field fronting the river can never be obstructed. The fourth is bounded by the highway right-of-way which in turn adjoins the railway right-of-way.

The longest runway, the North-South, is in the direction of the prevailing wind and the Northwest-Southeast and Northeast-Southwest runways are in the direction of winds of next frequency. The East-West, or shortest runway is in the direction of the least frequency of wind. The North-South runway will be equipped for blind landing from the south end which has a clear safe approach over the Potomac for four miles. This runway and the Northwest-Southeast runway have a 200-ft. width of paving in the center of the landing strip with a 150-ft. strip of firm sand gravel covered with turf on either side of the paving. One hundred-fifty feet of the 500-ft. landing width of the other runways will be paved. The lengths of the runways are North-South, 6,855 ft.; Northwest-Southeast, 5,210 ft.; Northeast-Southwest, 4,892 ft.; East-West, 4,100 ft.

The layout provides for the development and construction of an auxiliary system of parallel runways as needed to

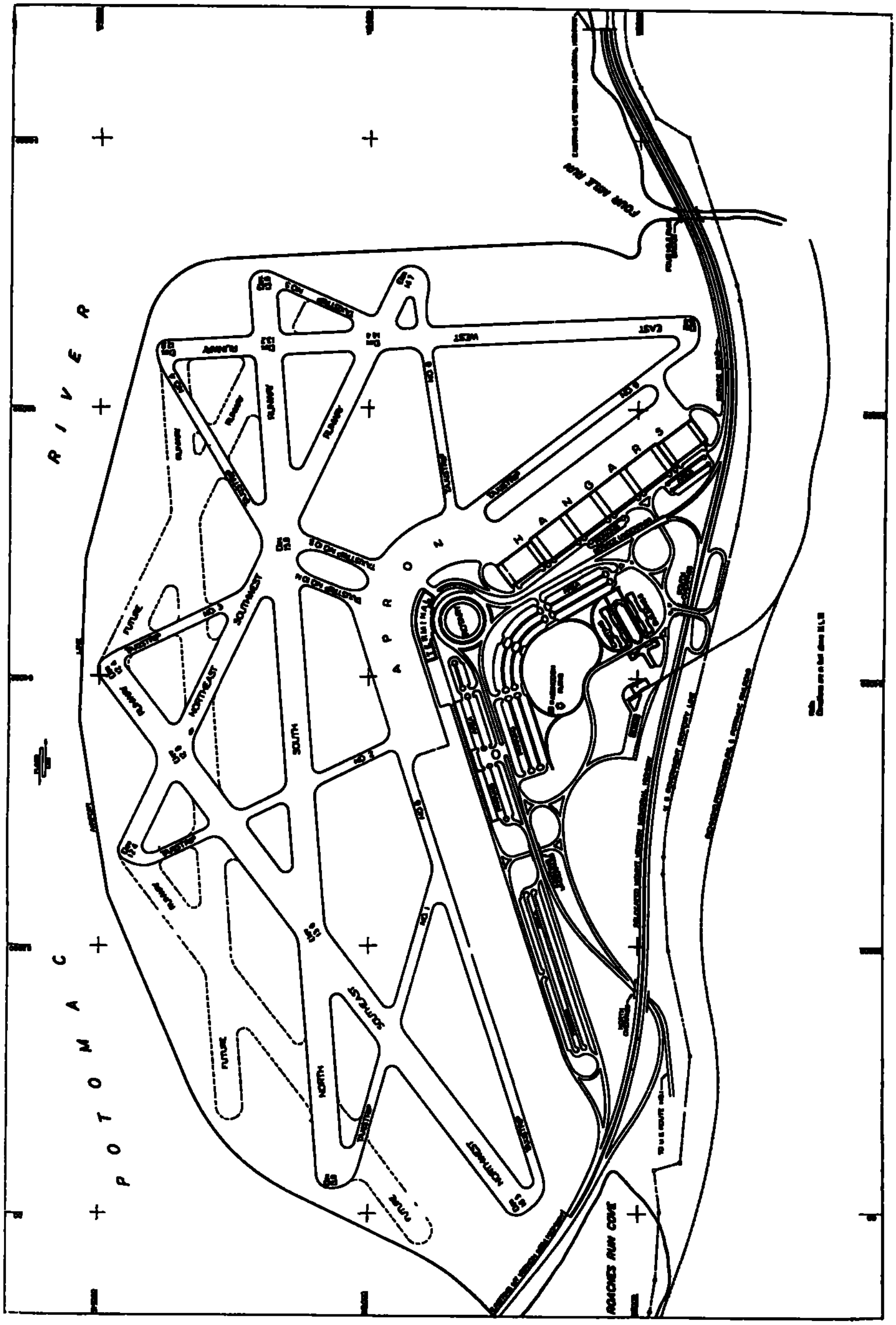

Figure 12. Master Development Plan Washington Airport

handle increased traffic making it possible for a plane to land parallel while another is taking off. The runways are above the highest known flood height of the river and tide, and the average elevation of the landing field is 2 ft. higher The runway ends adjacent to Memorial Highway were raised above the roadway in order to eliminate the attraction and hazard of planes taking off over motorists on the highway. Elevating the west end of the runway at Four Mile Run also reduced the glide angle and the hazard due to the electric lines of the R.F. & P. R.R.

UPLAND DEVELOPMENT

The location and plan of the airport fits in ideally with the plans of the National Park and Planning Commission and will be coordinated with the parks and recreational areas. Facilities will provide comfort and convenience for spectators and visitors as in other parts of National Parks and Monuments. Nearly two miles of the Mount Vernon Memorial Highway were relocated to obtain additional length for the East-West runway, to increase the area available for hangars and buildings and to by-pass the large volume of through traffic not concerned with the airport so it would not impede or be delayed by strictly airport traffic. In so doing the alignment was improved and the traffic lanes separated. Simple, direct, unobstructed access roads lead from the relocated section of the highway to and from the terminal building and the parking areas.

The sightseer can view the entire airport development from auto or bus, including front and rear of the hangars by traversing the Mount Vernon Memorial Highway and the access roads through the building area. Visitors and spectators may park their automobiles on terraces formed on the low bluffs above the field, and obtain a clear view of activities at the loading points and on the landing field.

As viewed from the plane, from the terminal building, and from the parking areas the Capital City stands out in all its fascination Bleachers in front of and below the level of the conventional parking area opposite the center of the landing field are included in the ultimate development from which spectators may observe all planes landing and taking off on the field while enjoying the view of Potomac Park and the Capital skyline across the Potomac.

The site lends itself to beautification more than any other airport site proposed for Washington and exhaustive studies were made and comprehensive plans prepared for reforming the contours of the site in borrowing from the upland area and ultimate landscaping and planting plans were prepared by landscape architects of the Public Buildings Administration and the landscape engineers of the Public Roads Administration.

LAYOUT OF BUILDINGS AND HANGARS

Air lines cooperated with the Civil Aeronautics Authority in the fixing of the location of the runways and the arrangement of the details in the terminal building and hangars.

The buildings are grouped behind the hill on which old Fort Scott stood and within a V or L-shaped sector projecting into the landing field, bringing all the traffic together close to the geographical center of the field and the logical center of operations, yet leaving ample clearance for flight operations. This arrangement offers the least possible obstruction to flight and it will never be necessary for aircraft to take off or land over any of the airport buildings. The terminal building is at the apex of the sector and the control tower, atop its center is so located that every plane loading point, the entire length of each runway and the full length of all hangar frontage is clearly visible to to the operator.

Hangars were placed along and in the

side of the bluff in line with Fort Scott where they offer the least hazard to flight and the least prominence in the foreground. They will be large enough to house the largest planes, yet will present a pleasing appearance and being low and partially concealed, appear smaller than they really are.

The ground floor of the buildings and hangars is above any possible flood height.

TERMINAL BUILDING

Passengers will enter the waiting room of the terminal building from the plaza level one low story above the field level from which they may proceed along a glass enclosed concourse where they may seat themselves opposite the plane loading point until their plane is ready. This concourse is 10 ft above the field with steps leading down to vestibules from which the passengers proceed directly to their plane.

From the moment the passenger enters the waiting room to purchase his ticket and check his baggage, planes may be seen in the air or on the ground and will continue visible throughout his stay in the terminal, whether standing or seated in the waiting room, in the mezzanine, in the passenger concourse or in the vestibule opposite his plane loading station.

The walls of the dining room along the field are continuous glass, affording a splendid view of the landing field, the Potomac River and the Parks, with the Cathedral, the Jefferson Memorial, the Lincoln Memorial, the Washington Monument, the Capitol and other notable buildings of the Capital City in the background. There is a broad outdoor dining terrace a few short steps below but some 20 ft above dust particles that may be swept from the loading apron. Fortunately, the field front of the terminal building is the shady side and the dazzling rays of the sun do not enter the expanse of continuous glass, except in the very early morning.

The conventional fence directly in front of the building is unnecessary and has been eliminated, and the length of the walk to the planes correspondingly decreased. The incoming passenger cannot miss the baggage distributing station and checkroom, which is at the exit close to departing cabs and buses.

The motive of the entire plan is to provide visitor and patron with as extensive and unobstructed view of the field and its activities as practicable with the least possible interference to passengers, and with complete separation of mail, baggage, express and service traffic.

The architectural motif of the terminal building is modern and structurally it impressively expresses the purpose of the building. The objective has been a union station of the air worthy of its place in the Capitol group and one that will provide air traffic efficient and convenient service commensurate with that provided rail traffic by the modern railway terminal.

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