APPROACHES TO AIRPORT SITE LOCATION THROUGH
STANDARD METHODOLOGIES AND APPLIED
DECISION ANALYSIS

by

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ABSTRACT

Transportation planning constitutes a comprehensive effort not only to formulate decisions to resolve existing transportation problems but also conditions that are to arise at a later date. Assuming that there no longer exists a set of monolithic techniques to be applied to the planning of a major transportation project; this thesis offers a supportive argument for the use of applied decision analysis in airport site selection.

The urgent need of well planned airports capable of accommodating an ever increasing volume of annual aircraft operations has compelled several large urban centers to instigate searches for a second airport site and thereby consider the air traffic node in regional terms. Methodologies most often employed in this type of investigation are reviewed with a summary of the report produced in search of a second major airport site for the Boston Metropolitan Area. This 1970 study relied upon what is termed in this thesis as the standard methodologies in reaching the final recommendation.

The second major part of the thesis is devoted to the explanation of decision theory basics. An example of an airport site investigation using principles of applied decision analysis is presented here.

A discussion of the advantages, disadvantages and byproducts of the use of applied decision analysis in major transportation planning projects composes the concluding remarks.
ACKNOWLEDGEMENTS

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I thank Professor Ralph L. Keeney of the Department of Civil Engineering whose work with applied decision analysis has acted as a basis for my research. His Mexico City Airport Study which is included in this work has been of special importance to the author through its indication of a more responsive look at transportation planning.

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To Professor Julian Beinart, Department of Architecture, I express special appreciation for his effort in the execution of this work. His ability to provoke new directions and paths of investigation on this topic was helpful throughout the writing of this thesis, and his optimism aided the author in some of the more vexing periods of research.

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The success of a planning scheme begins in its design phase. Dependent upon this initial approach taken is both the responsiveness of the planning solution to present conditions as well as its ultimate success in the accommodation of future demands. The designer has a difficult job involving his familiarization with present needs, which support the designing of a transportation improvement, and working with time factors, which represent a gap between the designing stage and actual time of implementation. In viewing this situation, the author has pursued an answer to the question: In a densely settled urban environment with established patterns of movement such as those now existing in the Boston area, how are effective changes in urban transportation decided upon and how do they get implemented?

Part of the answer to this question has been found in the capabilities of the methodologies available to the designer. To further the answering of this first question, the author attempts through this thesis to answer another
question pertaining to the approach that may be assumed by the transportation designer. The issue to be confronted in this work is based on the examination of whether a planner's design becomes more responsive, more corrective toward the apparent need through an approach which includes basic decision theory analysis components than with a package of monolithic prediction techniques alone.

The posing of this issue was made after the author had worked with the most commonly used prediction techniques which shall be referred to throughout this work as the standard methodologies. In the study of these methodologies an incongruous characteristic between the formal methods of predictions and the growth and change of the urban environment became apparent. With the products resulting from these techniques came a large investment of the design input dealing with prediction from one point in time with little mention of sequential or continuing design. Large scale facilities are designed at one point and years later, after construction, implementation occurs to respond to the expected shift in demand. The shift in demand, future demand, having been calculated in the design stage. This approach to transportation planning seems very limited as
it usually is executed, and it is often proven to be so by transportation facilities being obsolete upon their implementation.

As a result, this thesis represents a foundation to an argument for a more contingent planning approach to transportation planning through review of the benefits of decision analysis.
Chapter One: The Standard Methodologies

1.0 Examination of the complexities of the design and implementation of any proposed major transportation facility to be inserted into the urban environment has to begin with the definition of the roles of the decision-maker and the set of tools available to him in his decision-making process. The set of available tools or methodologies fall within two broad categories; 1) the standard methodologies which include assessment of existing conditions and the formal prediction of future demand, and 2) innovative techniques which would include applied decision analysis. Both of these categories will be reviewed in this work with discussion of their basic concepts, examples of their use and finally conclusions as to their use in airport planning. Planning or comprehensive airport strategy will be considered a flexible process here with the contributions of various methodologies due to alter and vary with each separate airport study. Also, definition of the decision-maker will be presented in light of the methodologies used.
Successful design of a major activity node such as an airport is greatly dependent upon the study of the urban system from a comprehensive viewpoint. It is the understanding of the over-all workings of movement patterns, analysis of surrounding land use and the like that presents the greatest challenge to the decision maker. This challenge is considered by the author to be increasing in magnitude and it will be the purpose of this thesis to give insight into the methods of examining the urban system that are now available by use of the standard methodologies and applied decision analysis.

1.1 Deciding who is the principle decision maker is an uncertain issue in urban planning today. The desire for a solution based upon comprehensive research into the workings of the urban environment has led to the inclusion of a small set of professionals from varying backgrounds, among these engineers, architects, and planners. While each of these roles can be justified as valid contributors to the shaping of the urban environment, specific areas of airport site selection are restricted from one or more of these assorted professionals due to their background. For example, architects, who usually work at a smaller
scale than the transportation engineer, lack the expertise to deal with trip generation studies. The issues involved in an airport study are so complex and numerous that total contribution of all these differing professionals cannot be accommodated by the investigative methodologies most commonly used. However, it would be to the benefit of a solution that none of these disciplines be excluded from the design team. In order to avoid favoring one of these disciplines over another, the decision maker referred to in this thesis will be termed "designer." The designer will represent a person or persons organized into a team or council who addresses an urban problem and is responsible for the evaluation of data in order to produce a recommendation.

1.2 The designer holds the two-purpose position of evaluator and prescriber of environmental changes which may result from the implementation of a new transportation facility. The evaluations of the designer are a function of his methods of data collection and interpretations, and lay the foundations for his predictions. The quality of the product of his study is the result of the sophistication and use of his methodologies and prediction techniques which illustrate his approach to the solution of an urban
transportation problem. It remains his task to consider such issues as for whom is the facility being designed; what are the goals and objectives of the area; what are the effects of his solution; what is the ranking of the differing alternatives; and how reliable are his techniques. In addition, other related social, economic, and environmental factors should be dealt with through the designer's study techniques. As these factors tend to increase in number and importance, his means to evaluate these factors, as affected by the proposed airport, should respond. There are limitations of the methodologies used. Therefore, it also becomes the task of the designer to improve the techniques he employs in his design approach to accommodate the changing number and character of the related factors.

The designer will also assume the task of making recommendations and site selections which will be tested in the future. In addition to dealing with an array of peripheral factors and multiple objectives, he is compelled to look ahead to the conditions of a future time in his design process. The use and interpretation of his techniques will determine the accuracy of his prediction of uncertain events in the future which will test his ultimate
recommendation.

The job of the designer changes in respect to the changing issues surrounding the formulation of an airport strategy and the success of his solution becomes dependent upon the products of the methods used. Ways in which the designer can meet the altering of his techniques through incorporation of decision analysis will be suggested in later text.

2.0 The design of a major transportation facility affects many of the components of the urban environment. The contribution of the facility to the resolution of the study region's transportation problems is dependent upon economic, social and physical features as well as institutional influences. The corresponding measure of effectiveness of the new facility is gauged from the efficiency of movement in and around the urban domain that it provides. An example of a transportation facility that generates far-reaching effects is the urban airport. This type of transportation facility was chosen to be reviewed in this thesis because: 1) it represents a large activity node occurring at the point of interchange of ground and air transit and 2) since it is a point situation and would require one site rather than a continuing space,
such as with a highway, it was thought to lend itself to the short time period (four months) of the development of this thesis.

2.1 It is evident that with the development of air travel a new dimension to travel has become available to increasing numbers of users while at the same time affecting, through location and operational functions, an increasing number of non-users. Air travel has the advantage of reducing travel time, but it has brought with it a new set of problems for urban life. Today, air travel, from airport to airport, is far more advanced in speed and comfort than ground travel to and from the airport. It is the air terminal that acts as the principle point of interchange between air transportation and ground transportation. The efficiency of the interchange is, in part, determined by the location of the airport in relation to the urban area it serves.

The airport has been considered both a desirable and undesirable part of the urban environment because it makes a good neighbor to a very limited set of land uses. Airports have not only grown in size since the days when an airport required a small field on which to operate, but it
has grown in intensity of use to a point where it is an active urban sub-system—a city within a city. The changing character of the airport has brought greater difficulty in selection of its site. Usually, the airport is already well-established in the city; its site having been selected at a past time when airport site location was a relatively simple matter. However, due to increased use of air travel, many of these airports are reaching capacity calling for the establishment of a revised airport planning strategy. This usually includes search for a new airport site.

2.2 The study of optimal airport location is in itself a broad and complex topic. It may include considerations relevant to varying types of air transportation, such as general aviation (private planes), military aviation, and long-haul air transport. This thesis will focus upon the challenge of investigating site possibilities for a second major airport in an urban area. This type of investigation has recently become more widespread as major metropolitan areas launch inventories of possible sites for a second major airport in their regions as the demand upon their present airport facility reaches its
Airport site selection requires the comparison of the associated advantages and disadvantages arising from the selection of one site from a range of possible sites. The search for a second major site location becomes a particularly complicated problem since there rarely exists a site that will not cause some degree of disruption to urban life through displacement or noise. At the same time, the designer must locate the new airport as close as possible to the potential market area of the region.

3.0 The techniques and methodologies used in transportation design increase in complexity and scope as each responds to the transportation problems' urgency. The standard methodologies used in transportation design, such as those that will be later reviewed, tend to examine and formulate recommendations from a comprehensive systems approach with careful study of existing conditions employed as a background for speculation as to the design's success. Each transportation study has developed its own pattern of examination in order to produce its own package of design recommendation. Proof of one technique being superior to others remains unestablished to date. Brian Martin remarks on the condition of the differing design studies by saying;
"The urgency of the problem has left little time for objective evaluations of the techniques presently available, since each new study creates new sets of principles and techniques."\(^1\)

The field of formulating design models to respond to the problems in urban transportation today remains an open-ended one with refinements in the process of problem definition and solution still being contributed. As is usually the case, each transportation study acquires an individualism through the specific sets of conditions and differences of the characteristics of the area examined, but most studies use as a foundation one or several of the techniques relied upon by previous designers. In this first section a review of this group of techniques is examined to act as a foundation to the approach of the specific problem of urban airport location dealt with in this thesis. This review will not attempt to be all-inclusive of the latest developments in transportation design techniques, but rather it is presented here to provide a rudimentary insight into the principles and techniques most commonly found in specific transportation studies of future airport location.

3.1 By recommending transportation improvements that can only be evaluated in the future, the designer has found value in a careful examination of past and present conditions of the area being studies. Conditions of the region such as land use and topography are necessary in the establishment of one location over another. Further study of existing conditions would include the dynamics of the land, specifically, the trip generation properties and existing networks of movement patterns. Familiarization of these existing conditions is sought in order to provide the designer with a frame of reference in which he might better formulate his design projections.

3.1.1 In a study of airport location, the establishment of the physical conditions of a group of site possibilities has great importance in matching the design requirements of an airport to the existing conditions. Through study of such physical conditions as land use, population, and inventory of existing transportation facilities the designer can construct a procedure of ranking one site over another through a comparative study of displacement, development costs and potential conflicts in the operation of the airport.
3.1.1.1 An inventory of land use can provide the designer with a means of measuring the relationship of land use to trip generation. Ideally, the airport should be located in an area of compatible land use and have a good relationship to center of trip generation. That is, interacting relationships between travel characteristics and the surrounding environment. Because the new airport will create large impacts on existing conditions, the decision to build and, to a like extent, the possibility of an airport being built in the area cannot help but alter not only the specific land parcel used for the airport but surrounding parcels as well. It becomes very important to develop a strategy to locate the airport on a site which makes the most positive contribution to the urban life by being located in an area of compatible land use and which is in prime relation to sources of trip generation. A comprehensive land use inventory would include breakdowns of the sites, kinds of activities, intensity of usage, and properties of accessibility. Land use surveys have become important tools in the prescription of the location of future establishments.
The procedure of making an inventory of site activities consists of a division of the region of possible airport location. This would include the site itself as well as a share of the surrounding properties. The region is broken down into zones whose incremental size varies with each study. A classification of activities is developed which might include categories of residential, industrial, and other uses. Each zone is then distinguished from others through the identification of the existing category of activity. The product is a diagramatic mapping showing the juxtaposition of the varying types of activities in the study region. The mapping is important to airport location because industrial areas have proven to be compatible neighbors to the airport providing an efficient cluster activity of air transport to certain manufacturing and distribution concerns. In addition, the location of the airport site in relation to residential activities has become crucially important since it is not the intent of the designer to force out this land use from the region. The site activity inventory acts as an important input in the selection of the airport site since it can give indication that the future development of the
study region is more apt to follow a certain path of development, say residential, without the development of an airport. This gives the designer some indication that the building of the airport could bring about potential conflicts in land use.

The intensity of urban land useages is an important companion to the land use inventory since the relative intensities of land useage do not appear on the first mapping. Intensity of land useage provides the designer with indications of sources of trip generation since high intensity of useage is associated with origin and destination points of trip generation. The land use intensity study uses the mapping system of the land use inventory as well as the activity categories. Exacting measurement is made through the comparison of either total building floor area to the site area or the total zonal floor area to the zonal land area. Transportation studies for improvements other than airports such as highways or mass transportation routes rely heavily upon the matching of the improvement with determined points of high trip generation. This is not the case in an airport location study. Building an airport in the nearest area of high intensity land use,
such as the CBD, is not always possible and rarely considered feasible. Several designs have been developed, however, which put the airport near the CBD. The obvious advantage of having the facility so close to a source of high intensity—therefore, and important node of trip generation—has often been dismissed. It is not an optimal situation due to the high development cost such as of floating airports, the compounding of congestion and environmental characteristics in the urban hub and the insoluble conflicts the operation of an "in-town" airport might raise with existing airports in operation. Conversely, the intensity map is useful to the airport designer as a means of determining accessibility and spatial relationships to the proposed airport site.

The determination of land use patterns is the third part of the inventorying of existing physical conditions that aids the designer in his selection of the preferred airport location. While the two previously performed mapping studies could be described as being a fine-grain illustration of existing conditions, the land use patterns study is a coarse-grain illustration of the structuring of the surrounding land around the point of highest intensity, the CBD.
Land use patterns, having origins in the historical development of the urban area, and growth, having been determined by developed routes of the movement network, give the designer a chronological picture of the development of the region. This picture of past development is important in the selection of the most appropriate airport location through the delineation of the major movement arteries in the region. The success of the second airport's location is judged, in part, by its accessibility to users. Accessibility, in this case, usually is a function of the efficiency of ground travel to the airport. The land use patterns indicate to the designer the degrees of accessibility of each site under consideration.

3.1.1.2 Population inventory of the study area accounts for another means for the designer to weigh the advantages of one site over another for purposes of airport location. Unlike the results of population inventories taken for transportation studies other than that concerned with airport location, the airport designer employs the results of such an inventory for purposes of estimating the numbers of persons who would actually be displaced by an airport as well as persons that would be affected on surrounding pro-
properties. In studies involved with highway design, population inventories act as the first stem in the estimation of residential trip generation. This contrasts with the purposes of the inventory for the airport designer, since it is not the residential trip generations in and around the study area that constitute the area of market potential of the airport. In terms of displacement, the population inventory would be recorded in terms of numbers of persons residing per unit area such as net or gross area, etc. Population patterns show degrees of intensity inversely proportional to the distance from the CBD.

3.1.1.3 The past methods of investigation have made it possible for the designer to familiarize himself with the set of properties that each site has. Consider the product of these past inventories as a descriptive map upon which is to be superimposed the fabric of the area's transportation system. This network represents the supply side of the picture with the previous inventories giving indication of an emerging demand. The capacity of the study region to supply a means to alleviate the transportation situation can be determined through an inventory of its existing transportation facilities.
Existing transportation facilities that could be directly incorporated into the area's air transportation system are established as possible sites. These are usually found to be existing military air fields or general aviation fields which could possibly be expanded to adapt to the use of a second major airport in the region. With major movement patterns delineated in the land use pattern inventory, locations of existing mass transit facilities are important to locate in order to study the possibility of points of modal change, i.e. air to ground transportation. Such studies are essential in the estimation of the development costs at each site, since it is usually necessary to improve through construction or alteration of the connecting links—highways and/or mass transit routes, to provide better accessibility between the airport and points within the potential market area. This is particularly important in the establishment of an efficient connector between the airport and the CBD. In the formulation of the design of improvements of existing ground transportation facilities, capacity is determined through the ability of the existing arterials and expressways to carry vehicles expressed by quantitative measure. Capacity is here studied in two cases; basic capacity, which is a theoretical number of vehicles that
can pass a point under the prevailing roadway and traffic conditions, and practical capacity, which is less than possible capacity and is intended to introduce a "quality of service" into the definition of capacity. It is these studies of ground transportation capacity, especially automotive travel, that will indicate development costs necessary to provide access to each site. Since this type of improvement represents a large sector of the development budget, it is an important means of judging one site over another.

An inventory of existing mass transit facilities includes notation of equipment used, and schedules and routes of all forms of public transportation used in the area. Extensions of existing public transportation systems to accommodate the demand brought about by the building of an airport contributes another consideration in the total development budget. In the case of rapid transit, extension of routes represents an enormous expenditure of millions of dollars per mile extended. Advantages of a site near or along the existing route of the public transportation system would give basis for its selection over those further away and less associated with the existing transportation facilities.
Examination of the existing transportation facilities is paramount in the use of the systems approach to the question of airport location.

3.1.2 The study of the dynamics of the area is necessary for the completion of the investigation of existing characteristics present in the area under study. With the data concerned with the physical components of the available sites (as produced from the previous techniques discussed), the study of the area dynamics helps complete the range of information required to assess the present and potential movement patterns. Included also as a dynamic aspect is the availability of monetary sources.

3.1.2.1 Trip generation is the study of the interacting relationships between travel characteristics and the surrounding urban environment. As such it represents an important means for the designer to familiarize himself with the existing nature and pattern of the study region's movement system. The trip generation study is one of several processes used by the designer as he faces the problem of predicting travel movement in the area under investigation. Used with other predictive techniques, trip
generation is usually found to be the first step in the travel forecasting process to be followed by studies of modal split, trip distribution, calculation of volume/capacity ratio, and others. As the initial step in travel-forecasting, trip generation represents a major input into the design process and eventual site selection, since it is his task to present arguments for his preferred site in respect to the expected patterns of movement in the urban environment.

Determination of trip generation is most simply an approach through a geographical representation of trip origins and destinations. This, in turn, becomes a graphic summary of the major points which define the movement pattern.

Taking the established points which represent the origin and destination of the trips in the region, a connecting line is drawn representing the route between the origin and destination pairs. Known as the desire line plot, the straight lines (airline distances) map out the maze of movement in the urban area. Zones are established in the diagram as means of consolidating trip volumes at origins and destinations. "The number of trips generated and attracted by each zone are calculated and, in virtually every study, this has been accomplished independently
from travel conditions or the price of travel and with empirical observations of existing trip-generation rates being used.\(^2\) The information provided from this simple geographical representation is by itself too general to be of great use by the designer. One of the major ways in which this method limits itself is by having the connecting line between points of origin and destination expressed by a straight line disregarding actual ground routes, i.e., streets. "Stratification of travel provides a better means for representing and studying the effect which different social, economic, and physical factors have on person and vehicular travel."\(^3\) Elements producing the categorical breakdown of the area's travel, the stratification, include family income, vehicle ownership, trip length, land use density, time of day, and others. These are, in fact, variables providing circumstances which affect the number and nature of those trips found in the study region.

Some of the variables incorporated in the trip generation study may be categorized as social characteristics of the region's travel. For example, trip purpose may be considered a social characteristic of travel and is the most

3 Martin, *Principles and Techniques*, p. 36.
often recognized stratifier of travel. In addition, family income stratifies travel and reveals increasing family income leading to greater trip production. Also, the social characteristic of vehicle ownership is influenced by factors such as family income, population density, and distance from the CBD. "Increasing vehicle ownership increases trip generation." 4

The land use surveys described previously play an important part in the study of physical characteristics of travel. Land use becomes a means to classify and study trip generation activities and is of particular importance in resolving a correlation of residential densities and the number of person and vehicle trips per dwelling unit. As produced from studies of land use at origin, increasing residential density decreases the number of person and vehicular trips per dwelling unit. This type of information is useful to the designer by noting the potential market area for the second airport and showing the type and number of trips in the region. This information is expanded through the continued study of other physical characteristics, such as distance from the CBD, length of trip, mode of travel, automobile occupancy, and land use

4 Ibid., p. 41.
destination.

Often the information derived from these variables is difficult to correlate in the production of a conclusion that would describe to the designer actual trends or characteristics in the region's travel pattern. In this case, mathematical devices are used to produce correlation coefficients which lead to the determination of those variables which are independent or are acting together. Other means of estimating resident trip generation may be used.

A series of trip generation relationships (either algebraic equations or graphical plots), with one relationship for each possible combination of the...variables, would be necessary to cover all possibilities ...This represents trip generation sufficiently detailed and refined for obtaining a precise answer, while retaining simplicity necessary in the practical application to the transportation planning process. 5

Estimation of future trip generation characteristics can provide the designer with yet another criterion, since it would be to the advantage of the airport to found strong relationships to principle point of trip generation. This is important at a city scale in the serving of the identified area of market potential--also at a regional scale with the service of regional air transport needs by the second airport location.

5 Ibid., p. 59.
3.1.2.2 Fiscal resources related to development of a second urban airport represent influential factors in terms of the actual implementation and scope of the proposed airport. It is the expected task of this survey to determine the total capital currently available for expenditure on the research and development of the second air facility. "Arriving at an estimate of capital resources to be made available in the future usually causes assumptions to be made that would predict that current tax rates will be raised, construction costs will increase, no change in the availability or apportioning of federal aid will occur and no increased borrowing will be contemplated." The allowable development costs of the second airport which would include expenditures on reinforcing paths of access to the airport site by highway or mass transit is defined by the restrictions of available monetary resources. This line of thinking is bound to point out certain advantages of one site over the others. Investigation into future available fiscal resources indicates the allowable expansion of the airport in the future and the capacity of a site to accommodate this future expansion would act as a strong point of comparison with the capacity of the other sites.

6 Ibid., p. 33.
3.2 To this point, the designer has been concerned with collection of data that describes to him the conditions that presently exist. This data is useful as a tool to show growth and development of the study region from the past up to the present point in time. It also notates specific physical and dynamic conditions that will aid him in his study of each examined site and ultimately lead to his final site selection. Studies of future urban growth have as prerequisites the previously collected data on existing conditions. In fact, they act as a foundation for the projections made by the designer. Ideally, the proposed airport will be congruent to the urban environment, not only at the time it goes into operation, but also in future times. Anticipation of these future conditions is founded in methodologies dealing with population forecasts, future economic activity and future land use.

3.2.1 Growth in population determines "the growth in urban area economic activity, the requirements for additional or new land uses, and the future levels of transportation demand." Since population does not grow consistently and evenly in the study region, it is important to find the areas

7 Ibid., p. 61.
of the most likely increase in population. This becomes particularly important to the airport location by giving an idea of any potential conflict in land use and intensity which may lead to the effects the airport might have in the future on the normal pattern of urban development.

One method of population forecasting is through examination of known estimates for specified years of population of large political jurisdictions, or census reports on standard metropolitan areas. These are usually found to be the most accurate. From this data a table can be constructed listing years in chronological order with matching population counts (Figure I-A). To this table, is added official estimates of future population for--ideally matching--specified years. From the table, an incremental unit of population growth is interpolated by calculating the past ratio of growth and prediction of a future ratio between the unknown unit population estimate and the next larger population unit. This method can be applied to several scales; national, state, and city. The construction of a means to approximate the quantity and location of the area most likely to grow in population is important to the selection of the airport location since the site possibilities usually lie outside the CBD in the suburban areas which are
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<td>61.1</td>
<td>3,397</td>
</tr>
<tr>
<td>1950</td>
<td>150,669</td>
<td>8,712</td>
<td>5,495</td>
<td>63.1</td>
<td>3,621</td>
</tr>
<tr>
<td>1960</td>
<td>179,226</td>
<td>10,000</td>
<td>9,500</td>
<td>69.0</td>
<td>3,650</td>
</tr>
<tr>
<td>1970</td>
<td>212,910</td>
<td>11,602</td>
<td>7,802</td>
<td>82.1</td>
<td>42,502</td>
</tr>
<tr>
<td>1980</td>
<td>259,081</td>
<td>13,775</td>
<td>9,500</td>
<td>69.0</td>
<td>42,502</td>
</tr>
</tbody>
</table>

Growth Rate 1950-1980: 72.0% 58.1% 72.9% 66.8% 0.8%

apt to show the most marked increase in population. There exists a degree of uncertainty in forecasting future population growth. The uncertainty, stemming largely from the interpolation performed, as well as from unforeseen future affects upon the population of an area, is offset by the long implementation time characteristic of a transportation facility. Construction rates may be retarded or advanced according to the experienced rates of population increase. This would imply that sequential planning may be affected, and modifications made to the transportation facility plans, during later years, as deemed necessary by urban population growth. 8

Population forecasts represent an effort to coordinate the development and expansion of the airport with the number and points of location of future population growth.

3.2.2 Forecasting the growth of economic activity in the study area aids the transportation planner in the determination of the future urban land requirements and indicates future trip generation characteristics. The forecast acts as an indication of the effects that will occur within the study region brought on by the expected

8 Ibid., p. 64.
increase in wealth of the urban area and the consumer. In respect to airport site location, such a forecast could provide insight into the stability of the region which is expected to provide the airport with its major sector of market potential. The forecast will also give an indication to the location of future market potential areas. It is essential that estimates of future employment and per capita incomes be included in the forecast which would produce insight as to the changing requirements and production patterns among industries, industrial and commercial employment and productivity.

There are several methods which can be employed to produce a forecast of future economic activity, the simplest being the establishment of a ratio between future employment and population. This ratio is produced from figures representing present employment and population. One of the most accepted method of constructing this type of forecast is the input-output model which distinguishes three forces initiating change. These are growth in population and productivity and changes in the urban area's trade with the outside economy. Future trade is projected on the basis of the trade estimates for the past years. With the establishment of the total urban area population and the
employment estimates for the future determination by the
designer of future residential and industrial development
are produced. This would be important in the assessment
of the advantages of one possible airport site over others
since it would benefit the airport to locate in close
relation to industrial centers and avoid location near
projected areas of residential use.

3.2.3 Forecasting future land use is intended to provide
a representation of the composition of the future urban
environment. It is necessary in the production of such a
forecast that the kind of activity in the area, intensity of
site usage, and location of future land use be considered.
Preparation of the forecast would require a complete and
accurate inventory of present land uses, estimates of
future population, and estimates of urban area growth.

Four main forces affect land development patterns. They
are: 1) topography, 2) population, 3) building costs and,
4) the level (quality) of service that will be supplied by
the future transportation network. These four factors
apply directly to airport location since they represent
prime points of judgement of one site over another.
Topography would affect development costs and indicate
suitability of a site for the second airport development.
Population would define future land use conflicts, such as the airport as neighbor to future residential locations.

Accessibility is important in determining future land use. Several formulae have been devised to describe accessibility in relation to future land use. A simple assessment of accessibility is provided in the study of measurements of interzonal distance in the urban area with distance being measured in terms of airline distance, ground distance or time. A more comprehensive index of accessibility is found in the use of the ratio of population over distance. In the examination of the expected changes in the future land use several factors that mold the changes have become evident and are to be considered in the forecast. Statistically based tools such as population forecasts and land use inventories should be included in the construction of the future land use study along with prediction of future economic activity, future trip generation, and land policy decisions. Since the future land use study includes predictions of future movement within the composition of the study region, it acts as a basis of the airport site selection criteria.
4.0 A study under the Boston Metropolitan Area Planning Council was executed in the summer of 1970. The Council addressed the problem of the establishment of a criteria for Boston's future air system development and concentrated upon the formulation of a development strategy for the twenty-year period, 1970-1990. Being forced into making an effort to examine how the local air system could expand by the single major air site, Logan Airport, fast reaching maximum capacity, the Council began an investigation for an appropriate site, as well as a justification for, a second airport in the Boston metropolitan area. "The Technical Committee agreed and recommended that it is now the time for the Commonwealth of Massachusetts to identify and reserve an appropriate second airport site to serve the eastern Massachusetts region."9

The study, as executed, is an example of the use of a highly technical methodology, since the data collected stemmed from the methodologies previously discussed.

There were several factors that led to the study. The situation existing in Boston had indicated that some plan for airport development was required to accommodate the predicted growth in aircraft operations

during the 1970-1990 time span. These conditions were summarized as being:

1) Logan cannot be modified to accommodate an annual aircraft volume in excess of 300,000 operations,

2) No new competitive transportation system (e.g. VSTOL or high speed ground transport) would be developed for passenger use in the forecast period,

3) General aviation will grow at Logan without economic and/or regulatory inhibition.

At the outset of the study, the Council established a site selection criteria to be applied to the six sites that were under review. The criteria was used to evaluate the transportation, economic, and social feasibility of the various sites. Points of their criteria were:

1) Market potential realization (maximum service to the air market and accessibility),

2) Air traffic control (air space compatibility),

3) Social impact (compatible land use).

4) Engineering design and development costs (topographical suitability, etc.).
The six sites under review were presented as likely candidates for second airport use. These were: 1) Dover, 2) Hopkinton-East, 3) Otis Air Force Base, 4) Plymouth, 5) Sharon-East, and 6) Uxbridge-Douglas. None of these sites are located in the air reservation space of Logan (Figure I-B). The area confined within the rectangle covering the area of densest settlement in Boston represented the air space required for the aircraft operation of Logan. Any site located within this rectangle was not considered since a second airport located in such close proximity to the existing major airport would cause operational conflicts as mentioned in the second point of the site selection criteria.

The first point of the criteria, market potential, was examined in terms of air trip origins. Here, trip generation studies were used to determine the center of the air travel market in eastern Massachusetts. Trip purpose studies concluded that the maximum market potential area fell within Route 128, with potential market growth happening in southwest, south, and southeast sectors beyond Route 128. Exacting definitions of the characteristics of this area were important to the
Figure I-B. Logan Airport Airspace Reservation.
evaluation of each site in terms of marketability. "Marketability and accessibility defines the volume of potential users of a new major air carrier facility and determines the degree to which the facility can financially support the capital and operating costs that would be incurred." 10 The air travel original destination studies gave considerations of ground access travel time and distance traveled between the proposed airport and air traveler origin and destination. This was a particularly critical establishment of expected volume of total airline passenger trips. Data collected from the trip generation studies were illustrative in prediction of cost of access to the sites. This prediction represented the cost of the right-of-way and construction from the regional highway facilities to the airport boundary. It was considered as a direct cost applicable to the capital outlay of the airport.

Air traffic control is a measure of the capability of a site to accommodate a specified level of aircraft operation in an operationally safe and efficient manner within the context of an area's total airport system. Location of the second airport should avoid aircraft operational conflict with other important existing, or

10 Ibid., p. 66.
planned, airports within the total system. To produce an indication of each site's air traffic control potential, the FAA investigated all of the sites from an air traffic point of view by employing an analysis based upon accommodating the maximum number of aircraft operations with minimum intervals between aircraft arrival and aircraft departures.

Land use studies were used to estimate the social impact of the airport's implementation. Social impacts, as gauged by land use activities, were considered in terms of the large land areas that would be consumed and the effect of the noise on existing land uses such as residential and educational. The Council was aware of "the possible human hardships that would be implicit in the acquisition of dwelling units, institutions and business firms and relocation of persons, activities and jobs that would be required." Social impact of the second airport was studied through cost/benefit analysis with cost being expressed in terms of land acquisition, access highways, rapid transit extensions and other costs relating to physical development of the airport. Benefit was primarily translated into terms of minimum displacement.

11 Ibid., p. 83.
Familiarization with future land use patterns, future economic activity, and available monetary resources produced various strategies for development of the airport. Observations were made in view of rapidly disappearing undeveloped land located within a reasonable ground travel distance from the CBD; the rapid growth of air transportation itself and the long lead-times required to design, construct and finance the airport. The concept of a land band where land could be set aside for the future airport development in advance of detailed planning was a serious consideration by the Council. Acquiring land in advance could allow integrated planning and development with the projected land uses. In this way, a more harmonious integration of the airport and its environment was hoped to be accomplished.

Recommendations resulting from the information secured by the technical methodologies led to no further consideration of Dover, Sharon-East and the Uxbridge area. Hopkinton, Plymouth and Otis Air Force Base were kept as sites which showed characteristics which most closely met the points of the site analysis criteria.
Chapter Two: Applied Decision Analysis

5.0 As the issues surrounding the formulation of an airport strategy grow in importance and number, the methodologies used by the designer should grow to accommodate them. Limitations in methodologies have produced inaccurate solutions to the needs of transportation. As a result, conditions exist which might be summarized as being:

--many transportational improvements are simply unsuccessful at meeting a need or checking its urgency,
--many improvements are obsolete before their actual implementation thereby only addressing a fraction of the need,
--often, improvements have limited expansion or alternative expansion patterns which produce a failure to correlate with both the dynamics of transportation and the resulting dynamics of urban growth.

The alleviation of these conditions is in part dependent upon the upgrading of the related technologies of design. One means to supplement the approach taken by the designer is to include a decision analysis framework along with the commonly used methods.
5.1 Chapter one reveals airport planning for an urban area as a highly complex topic subject to a varying set of considerations. Such factors as accessibility, physical components of the site and the operational characteristics of the airport are found to be necessary points of investigation in airport location studies. The methods by which these factors can be determined and contrasted between varying sites have been discussed in Chapter One. The methodologies included there should not, however, be considered all-inclusive. Each airport study undertaken becomes so individualistic that with each study a different approach is produced. Usually, these individualistic studies will include one or several of the methods discussed in the first chapter. Those included should be seen as major tools that have been used most frequently by designers and those that appear to the designer upon entering into air investigation of an appropriate second urban airport location. For example, trip generation and land use inventories are mentioned as factors which define the orientation of the designer. Use and variation of these methodologies are
determined by the designer thereby making each study, to some extent, individual. There is little evidence that there is in airport planning a standard method for determining site location.

5.2 Urban planning, like other professions, is not static. New means of examining large-scale urban problems are continually being developed. Decision analysis applied to large-scale planning projects is in an embryonic state today but promises to be an important tool to the designer in the approach to many urban planning projects. Not having been actually tested in the real world, applied decision analysis has been considered by some as merely an academic exercise. Chapter Two is intended to review crucial aspects of decision theory and applied decision analysis as they might apply to airport planning in order to suggest that the benefits that the designer might achieve from their use need not be considered only academic. Employment of decision analysis techniques in airport planning does not supersede the orthodox techniques discussed in Chapter One since inputs into the decision analysis format relys heavily upon the inventories produced from these methodologies. In the use of a
decision analysis approach to a planning problem such as airport location, the designer is required to acknowledge the existence of variables and a group of alternative design solutions which are affected by externalities such as political conditions and time. Methods of analysis included in decision theory are strategic to airport planning, since the implementation of the airport is contingent upon several random variables such as time of development, future tangential developments, etc.

Chapter Two will attempt to clarify what decision analysis is, what can be considered as its basic concepts, and what might be accomplished through its use. A recent example of its application to airport planning is included.

6.0 The designer approaching a large-scale planning project such as a suitable site location for a second urban airport addresses a situation which includes three pertinent questions:

1) What are the existing site conditions of the site under examination?

The answer to this question is largely produced from the materials collected through use of the standard methodologies discussed in Chapter One. Such studies of land use inventories
and trip generation studies are required to allow the
designer an understanding of the existing conditions,
thereby equipping himself to answer this first question in
his site selection.

2) What will be the unforeseen components in the
airport's implementation?
The establishment of a successful airport operating
within the urban environment is dependent upon many factors
which may not exist at the time of study but may at a
future date. An example of this anticipated development
which is likely to make one site preferred over another is
the planned development or improvement of a highway
system which would provide an increased ground accessibility
to the airport. Expected improvements which are depended
upon by the future airport yet whose actual development is
uncertain may indicate a prime site which is different
from the site chosen on the basis of existing inventories
and land characteristics. Potential improvements planned
for one area could outweigh the existing conditions of
another site. Anticipation of future events and their
effects upon the operation of the airport leads to the
third question:
3) Once the second airport is built and operation is underway, what effects will it have on the projected demand that led to its development, as well as its effect on the existing characteristics?

This is the most speculative question but an extremely important one. Questions of this type contain the most uncertainty since they address events which may, or may not, occur and can only be assessed at a later date. Today there exists a means for the designer to deal with important questions involving uncertain future events and effects: this is provided through the use of applied decision analysis.

Decision analysis applied to a large-scale planning problem is a system of ordering information, considering alternatives in sequence and a means of addressing the uncertain factors incorporated in the above Questions Two and Three. Through use of decision analysis, the designer is forced to order priorities and gauge his own subjective preferences regarding the planning decisions. The decision problem discussed in this paper is the selection of the optimal location of a second urban airport and this
decision can well be approached through use of decision analysis techniques. Use of these techniques require the designer to:

1) list the viable options available to him for gathering information for experimentation and for action,

2) list the events that may possibly occur,

3) arrange in chronological order the information he may acquire and the choices he may make as time goes on,

4) decide how well he likes the consequences that result from the various courses of action open to him and,

5) judge what the chances are that any particular uncertain event will occur.\(^\text{12}\)

These five steps constitute the basic format for a decision analysis approach. This format incorporates a systematic description of the problem as well as the orderly recording of the decision maker's perspective, i.e., the designer's judgement and preferences. The ordering of these inputs provides the designer with a tool of information synthesis--information attained through the standard methodologies--and

will in effect provide the designer with a way to handle the uncertainties of his problem by addressing an extensive set of alternatives that could occur in the future.

Two topics which represent problem-solving techniques in decision analysis are Utility Theory and Decision Flow Diagraming. Each one of these broad topics can be broken down into several sub-heads and each could be used in the airport locational problem. These two topics will be reviewed in their broader sense with explanations as to how they could be included in the solution of a large-scale planning problem.

6.1 Utility Theory is much like a lottery. The designer is placed in a lottery situation as a way to discover his preferences and ranks the preferences according to importance to him. Starting with the choice of one prize (A) over another (B), the designer makes a selection of which prize is most valuable to him. Going beyond this simple selection of A over B, use of utility theory requires that he place a value on his selection. To illustrate, say the designer was offered prize A or prize B and he selected A. Playing the game with utility theory techniques would require the designer to draw upon
his preferences in order to establish a utility assignment (a value) on his selection. This would represent how much he preferred A over B, and, at which point, in his own evaluation, would he consider a reverse selection, that is B over A. Introducing prize C as a possibility, the designer would be faced with a further selection of C over A, C over B, or keeping his initial preference of A. Use of utility theory is involved with the determination of that point at which A loses favor to C and/or does the choice of having both prizes B and C outweigh his preference of A. Simplistically, utility theory is allowing the designer an orderly method of considering the set of alternatives and providing him with a means to compare and establish his priorities.

The lottery situation applies to the selection of an airport site, for example, if prize A were low development cost, prize B representing accessibility by ground transportation, and prize C -- a good relationship with the established market potential area. Here the lottery would apply directly to the designer's information synthesis and ordering of priorities. Examining the hypothetical situation above, the designer could use the lottery situation in selecting one site from the
available three, each with their respective characteristics as shown in Figure II-A. Whether the preferences he uses to evaluate the three sites are those of his own (the decision maker) or more likely, preferences dictated by external interest groups such as planning councils and citizen groups, the designer is provided, through use of utility theory, an orderly means to evaluate and rank the varying combinations of the components A, B, and C to proceed into the final selection from the three available sites X, Y, and Z.

6.2 Decision Flow Diagrams represent the anatomy of the qualitative structure of the problem. The flow diagram uses utility assignment discussed above in addition to notation of chance situations which are not controlled by the decision maker. Referring back to the three basic questions, the designer asks himself, utility theory corresponded most directly to the solution of what are the existing conditions and the initial appraisal of one site over another. The chance situations representing uncertain conditions that might occur are incorporated into decision flow diagrams so that the designer can answer questions two and three;

2) What will be the unforseen components in the airport's implementation?
Figure II-A. Diagram of Three Site Possibilities and Their Characteristics.

SITE X
- low development costs (A)
- ground accessibility (B)

SITE Y
- low development costs (A)
- nearness to market potential area (C)

SITE Z
- ground accessibility (B)
- nearness to market potential area (C)
3) What effects will it have on the demand and on existing land characteristics?

Uncertain events that will happen in the future can change the value attained in the first selection produced from the standard methodologies alone. If a site such as site X in Figure II-A was chosen due to its combination of low development cost (A) and nearness to the market potential area (B) it is valued higher than the other combinations. With the expectation that characteristic (C), ground accessibility, would be developed in the future, as might be indicated by a projected highway improvements program, the chance situation of the future highway not occurring could shift the preference for site X to one of the other in the long-run. Decision flow diagrams are a means to anticipate uncertainty and map alternatives in the selection process. Figure II-B shows this type of situation using flow diagrams. The circular symbol at the junction represents the chance situation that the highway either gets built or not. The square symbol at the junction is a decision fork where the designer is allowed to make a choice. The values indicated are the utility assignments showing how much the designer prefers one site over another.
Figure II-B. Decision Flow Diagram of Hypothetical Site Selection.
In the top cluster, he preferred site X well over the other two under the condition that the highway gets built. In the bottom cluster, he preferred site Z over the other two if the highway was not built. Looking at the actual values assigned to site X in the top cluster of 6 and the value assigned to the site Z in the bottom cluster of 8, the designer has stated a preference of site Z over site X (8 greater than 6) which would conclude that site Z would be better for the airport location regardless of whether the highway was built or not and that site X would only be preferred if the highway were built. This simple model made up of utility assignments and decision flow diagramming shows in oversimplified form what can be gained by their use. The designer is capable of making graduated selections with different levels of contrasting alternatives. Anticipating chance situation over which he has no control, he can map out, in an orderly fashion, alternative strategies.

6.3 Having used utility theory to state numerical values for each site and, in a sense, listed the sites in order of preference, the designer is called upon to make
probability assignments. These values represent a likelihood--the probability of his making one decision over another. To create a probability assignment, the decision maker turns back to his previously collected data to assist him in placing a value on probabilities. In the case of subjective probability assignment, he "interprets action-outcome likelihoods in terms of personal perceptions." Using these perceptions, he establishes values to be incorporated into the decision flow diagram by placing the values on the respective decision branches keyed to his previously-set utility values. This is shown in Figure II-C with hypothetical probability values being added to the utility values used in Figure II-C. Notice that probability assignments only occur on diagram lines after decision junctions, the square symbols, and not after the chance junction, the circular symbol. This is because the designer is interested in evaluating the probability of his decision for a site and not concerned with stating the probability of chance situations over which he has no control. Now, having made both the required probability and utility assignments, how does this aid him in the recognition of which site to select in regard to

Figure II-C. Decision Flow Diagram with Probability Assignments.

HIGHWAY BUILT

.5

SITE X (6)

.3

SITE Y (3)

.2

SITE Z (2)

HIGHWAY NOT BUILT

.2

SITE X (4)

.2

SITE Y (5)

.6

SITE Z (8)
the two chance situations? The answer to this lies in the solution of the decision forks. This is done by multiplying the probability value by the utility value for each site. For example, in the top cluster, .5 is multiplied by 6 to achieve a resolved value for the decision of site X. The resulting values are shown in Figure II-D. As a result, under the condition that the highway gets built, the selection of site X is the best choice due to its resolved value of 3.0. On the other hand, if the highway does not get built, the best decision is site Z with the highest value of 4.8.

Probability assignment is essential in working with the decision flow diagram. Either subjective probability or objective probability, which is derived from a basis of objective measurable frequencies, may be used with utility assignments and flow diagramming, probability assignment provides the designer with a set of resolved values indicating the path to the optimal decision.
Figure II-D. Decision Flow Diagram with Resolved Values.

HIGHWAY BUILT

.5

SITE X \((6 \times .5) = 3.0\)

.3

SITE Y \((3 \times .3) = .9\)

.2

SITE Z \((2 \times .4) = .4\)

HIGHWAY NOT BUILT

.2

SITE X \((4 \times .2) = .8\)

.2

SITE Y \((5 \times .2) = 1.0\)

.6

SITE Z \((8 \times .6) = 4.8\)
Chapter Three: Decision Analysis Applied to Airport Development

7.0. The concepts behind applied decision analysis discussed in previous paragraphs indicate that elements of a large-scale planning project can be translated into a decision analysis format. One of the basic concepts of applied decision analysis which has not been discussed is the initial decision by the designer to do nothing. By attempting to make no decision at site selection at all, he has in fact made a decision. Applying this to the airport site selection problem, no investigation into a site appropriate for airport use would indicate that he, the designer, is relying solely upon the additional development of the existing airport facility to meet the projected demand. Often this dependence upon the development upon an existing facility is a limited solution to the problem of projected demand. An example of this "no choice" decision is found in the attempt to find the maximum expansion capacity of Boston's Logan Airport. It was thought, at first, by the Metropolitan Area Planning Council, that rather than investing in a second airport site, further expansion of Logan could perhaps accommodate the predicted air-travel demand of 390,000
aircraft operations by 1990. Further study indicated that ultimate expansion of Logan could only produce a maximum capacity of 300,000 air operations. In 1970 Logan was handling 290,000 operations which indicated a small increment of expanded capacity possible. The council moved from their "no choice" decision into a full-scale site selection process.

Turning from no decision to a site analysis made up of multiple decisions means embarking on a highly complex study which will include set after set of variables and alternatives that may include differing preceptions of future possibilities, existence of market-mechanisms, distortions of information flow, and others. Raiffa describes the complexity of large-scale projects and supports the use of applied decision theory by his remark:

> The deeper one goes into this area, the harder it becomes to isolate a problem for prescriptive analysis—everything seems to be intertwined with everything else. But still, decisions have to be made; and by studying various paradigms in detail one can begin to get a sense of perspective and begin to know what are first-order and what are second-order effects, what must be included and what can be left out of an analysis.

Employment of decision analysis techniques does not mean the

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15 Raiffa, _Decision Analysis_, p. 100.
use of a standard package which can be applied to any and all planning projects. Decision analysis is a format, a method of organization, and a means to deal with uncertainties and risk conditions rather than a standard program of research. The designer who uses this format should be familiar with what results he can expect. That is to say familiarization of what decision analysis can and cannot accomplish.

This type of analysis can deal in an orderly fashion with large amounts of complex factors thereby coordinating large areas of information. Keyed directly with the coordination of information is the assessment of preferences and priorities. As the priorities change so can the final decision path traced through the decision flow diagram to result in a distinctly separate decision. This type of operation of the analysis format can benefit approaches to contingency planning which uses a sequential development scheme. Contingency planning and decision analysis are conceptually similar by their prescription of planning/decision making in a step-by-step method. So many large planning project studies have produced a master plan or comprehensive plan scheduled for enactment over a set period of years only to find that final implementation supply if far from the
anticipated demand. This situation is very familiar in airport planning where large capital outlays are spent on facilities that are obsolete and unresponsive to volumes of use before they are completed. Decision analysis used as an aid to contingency planning can provide a means of response through its sequential planning characteristics. At each sequency where variables such as economic condition, political climates, and reordering of priorities might occur, realignment of the goals of the project can be performed. This would keep a project such as the implementation and staged development of an airport or airports in step with external conditions. Decision theory lead to more explicit recognition of the uncertainties of the consequences.

Decision theory is highly dependent upon the information and subjective inputs inserted in its format. Statements of preferences are subjective and by being such are subject to change and difficulty in exacting value. It may be an arbitrary selection the designer makes in his use of the lottery situation. Placing value on one characteristic over another may be a difficult job for the designer though it is a requirement in utility assignment. The designer should be aware that decision analysis intrinsically includes a degree of arbitrariness. Also decision
analysis is formed by information sources and should be used with other types of analysis such as economic analysis.

Wohl emphasizes:

that to make the best decision under uncertainty may not necessarily result in what turns out to be the best decision, after the fact; thus, using decision theory merely equips one to best account for chance or uncertainty but does not necessarily guarantee success. 16

Though decision theory has strong limitation it offers the designer an important tool to supplement the standard methodologies. By providing an alterable path to a solution, it can be well adapted to large-scale contingency planning projects. Synchronizing sequential planning decisions and alternative strategies, applied decision analysis is capable of reflecting external conditions such as priorities, demand and economic conditions. Though decision analysis is an embryonic stage by its having been used on so few planning projects, it promises to match the dynamics of transportation with the dynamics of planning.

8.0 Several advantages of applied decision analysis have been hinted at to this point. Specifically, the use of decision analysis concepts has been referred to in terms of meeting conditions subject to the passing of time and, therefore, considered as uncertain. Also the preferences of the decision maker have been illustrated as allowable inputs into the structuring of the analysis format. The set of variables which may be included in the decision analysis model have few bounds and may include factors strategic to the comprehensive investigation of airport locations—effects of their implementation and evaluations of their corresponding development strategies. An important advantage to the use of decision analysis is the point at which the model may be employed to reach a planning solution. Decision models are not a device to be inserted in a study only to find one set of answers. Rather, the models may be used in different forms at several differing levels of the decision-making process.

8.1 Site selection is but one step in the airport development process. There exists several other steps in the decision-making scheme which should be included in order to take into account indirect impacts on the economy and urban
and natural environment as well as the direct transportation effect. As will be shown in the following example of applied decision analysis to an airport strategy in Mexico City, implementation of a major airport is highly dependent upon interaction among governmental units at varying levels. An orderly decision model can indicate the points in the development program where other decisions should be made. In such a large scale project, decisions are often made simultaneously. The decision matrix can be employed to indicate which decisions should be made during the same period as well as in what sequence. Some of the tasks required in planning an airport are as follows:

1) forecast of demand of air transportation,
2) pattern of supply of air transportation,
3) site selection,
4) physical layout,
5) ground linkages,
6) financing,
7) management and maintenance. 17

A group of socioeconomic issues surrounds the issue of airport development and should be carefully studied to

give an indication of the impact of the airport upon the surrounding region. The five most apparent issues involve who pays and benefits from the new airport; study of the aggregate economic and income effects; effects on urban sub-systems; acceptability of ecological effects, and identification of who controls and manages the airport. The seven tasks of airport development can be keyed to the five socioeconomic effects through a decision sequence matrix as shown in Figure III-A. The filled in cells indicate the most likely stages in the decision process when principal issues must be addressed. The matrix indicates the points of intermeshing tasks and issues showing that a given issue will be met at several points in the planning process and a single planning response may deal with multiple issues. The on-going planning process will most likely have changing socioeconomic issues which emerge and become more important through the original set. However, a matrix identifying the decision sequency is useful to the design in the anticipation of which issues are likely to be so interdependent as to require simultaneous resolution.
Figure III-A. Decision Sequence in Airport Planning.

<table>
<thead>
<tr>
<th></th>
<th>Forecast of Demand</th>
<th>Pattern of Supply</th>
<th>Site Selection</th>
<th>Physical Layout</th>
<th>Ground Linkage</th>
<th>Financing</th>
<th>Management and Maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Who Pays?</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
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<tr>
<td>Who Benefits?</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aggregate Economic Income Effects</td>
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<td></td>
<td></td>
<td>X</td>
<td>X</td>
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<td></td>
</tr>
<tr>
<td>Urban Sub-System Effects</td>
<td></td>
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8.2 Few transportation studies which stress the use of applied decision analysis have been executed to date. Though this type of approach is being looked upon with more promise in the solution of planning problems, decision analysis is not at a point of wide use. A study performed by Professors Ralph L. Keeney and Richard deNeufville of MIT uses decision analysis applied to the selection of a strategy for developing the major airport facilities of the Mexico City metropolitan area. The report which was done under the auspices of the ministry of Public Works was involved with three primary issues of the Mexico City Airport System plan; 1) multiple conflicting objectives, 2) uncertainties about future events, and 3) long-range planning projection. This study is significant to the future development of decision analysis as a means to prescribe solutions to highly complex planning problems since it outlines a sophisticated adaptation of decision analysis concepts while at the same time integrating the complexities of the analysis inputs such as staged development and political motivations into a logical sequence of solution. This study represents one of the first attempts to apply decision analysis to a major strategic

18 Richard deNeufville and Ralph L. Keeney, Use of Decision Analysis in Airport Development for Mexico City, a Technical Report to the M. I. T. Department of Civil Engineering, Summer 1971.
problem involving multiple objectives. The design team working on the study was composed primarily of Richard deNeufville, Ralph L. Keeney, Howard Raiffa, and members of the Ministry of Public Works. Discussion of specific formulas and programming techniques have been omitted from the review of this study. The main importance of the study lies in the understanding of the basic model and approach taken in dealing with the complex strategy problem through decision analysis.

8.2.1 The Problem

Investigation into an appropriate strategy of airport development for the Mexico City region was brought about by prevalent conditions which are standard characteristics of any airport serving a large city. Rapid growth in the volume of air travellers combined with increasingly difficult operating conditions led to the seeking out of a new strategy with particular concentration on:

1) the location and/or the configuration of the elements of the system,
2) the operational policy which defines how the services are to be performed and where they will be located; and
3) the timing of the several stages in the development.

19 Ibid., p. 23-9.
The question at hand was not only which site should be further developed for future use but included the formulation of operating policy—specifically decision on what kinds of aircraft activity should be operating at each of the two sites. The question of future development of the two available sites was presented to the design team in terms of timing. This factor involving land acquisition and sequential development represented one of the most crucial aspects of the decision problem.

8.2.2 The Situation

8.2.2.1 Physical: Due to strong environmental constraints, there were only two sites in the Mexico City region that could accommodate an International Airport. These two site possibilities were the existing site at Texcoco near the city and Zumpago which is twenty-five miles north of the city. Since both sites are located at high altitudes within a mountain range that encircles the Mexico City region, maneuverability of the aircraft at this high altitude was low and required approaches to the landing field over the surrounding mountain range. This condition was true for both sites under consideration and required the
flight patterns to be broader than usual. A summary of the comparative advantages and disadvantages of each site would include:

**TEXCOCO (existing)**

**Advantages**

1) located within five miles east of central city
2) ground access is reasonable by dependence upon existing peripheral highway
3) facilities already exist, therefore decreasing acquisition development costs

**Disadvantages:**

1) aircraft maneuverability constraint
2) ground access is not directly connected to the central city
3) construction anticipated to be expensive since located on former lake bed
4) existing runway sinks, forcing closing of airport for months periodically
5) existing sites surrounded by mixed residential and commercial sections; problems created with noise, social disruption and safety
6) construction of new runways would require displacement of up to 200,000 people.

**ZUMPANGO**

**Advantages:**
1) located in undeveloped farming area with no nearby conflicting land uses
2) possible direct connection to business and tourist areas via existing expressway
3) site located on higher and firmer ground

**Disadvantages:**
1) located twenty-five miles from the city
2) development would require total new construction

8.2.2.2 Institutional:

As mentioned previously, this study was constructed to accommodate multiple objectives. One of the principal objectives was based on institutional considerations. To formulate an optimal strategy for airport development with the exclusion of evaluating political reaction and a study of the political climate would present a limited picture to a multifaceted project. The design team incorporated such political components in their study by assessing the rivalries surrounding the study.
The study was conducted under the auspices of the Ministry of Public Works for use by the Secretary and the President. Major decisions in regard to the capital's airport are the perogative of the President. Debate about this decision is expected to be conducted by three governmental agencies; 1) The Ministry of Public Works, (SOP), 2) The Ministry of Communication and Transport, (SCT), and 3) The Secretaria de la Presidencia. Rivalry exists between the SOP and the SCT. Both agencies strengthened their conflicting opinions from previous studies performed that produced differing solutions. The SOP study sponsored the suggestion of building a new airport at Zumpango, while the SCT study resulted in a master plan for expanding the airport at Texcoco. Neither study was adopted and the design team attuned themselves to the political situation through realization that "dissent with governmental policies, once they have been enacted, is further dampened by a strong tradition of submission to authority."\textsuperscript{20}

The government had hopes of solving the conflicting issues arising from the previous reports with a restudy, which was to become this study employing decision analysis.

\textsuperscript{20} \textit{Ibid.}, p. 23-6.
8.2.3 The Analytic Approach

The design team had the problem of developing a strategy for developing the airport facilities of Mexico City aware of the complexities involved and the potential of formal analysis as a resolution to the problem. A decision analytic approach was soon adopted by the design team for the following reasons:

The decision analytic approach—as distinguished from the more traditional analytical techniques—takes these multiple objectives, probabilistic uncertainties, and time effects into account. Furthermore, it formally encodes the subjective attitudes of the decision makers into the analysis of the problem. Decision analysis requires the analyst to consider these complexities explicitly, and it provides a framework for integrating them into an efficient structure for prescriptive decision-making.21

Relying upon the basics of decision analysis, the design team identified the alternatives, objectives and measures of effectiveness involved. Each alternative was examined through a joint probability function, then assessed over measures of effectiveness. Subjective preferences and evaluation enter into the model at this point with the assessment of the measures of effectiveness which were to

21 Ibid., p. 23-30.
indicate both present and future impacts of the various alternatives. The preferences of the decision maker, the design team, are keyed to the use of utility theory as explained in Chapter Two. The utility evaluations sought stemmed from the professional judgments of those in the government in order to select a strategy according to their expert assessments. The framework of the investigations provided for examination of differing opinions.

8.2.4 The Static Model

The design team devised two separate models in order to reach their recommendations—the static model and the dynamic model. The static model dealt with the discovery of the best developmental strategies over a period of thirty years. The projected period was divided into three sections with specified decision points at 1975, 1985, and 1995. Establishing preferred developmental plans in accord with passing ten-year segments meant that the static model would necessitate working with prediction strategies that were uncertain because of the required prediction strategies and conditions. The products resulting from the static model were planned to be
incorporated in the dynamic analysis along with important political factors to establish options open to the President.

Success of the static model was dependent, among other things, upon the establishment of measures of effectiveness which were to be applied for evaluation purposes to each of the alternatives. Each alternative was studied as to its effect upon a set of groups; 1) the government as operator, 2) the users of the new facility, and 3) the non-users.

The underlying objectives that were established as a criteria were:

1) minimize total construction and maintenance costs
2) provide adequate air demand capacity
3) minimize access time
4) maximize safety
5) minimize social disruption
6) minimize noise pollution.

These objectives were taken as considerations in relation to the three sets of groups above.

The alternative strategies for the static model were defined as the feasible set of all combinations of these
designs that might be established by different decisions about location, operational configuration, and timing. The design inputs included the three time segments, the two sites, and four categories of operations (domestic, international, general, and military), and resulted in a possible 4,000 alternatives. Of these 4,000 possibilities many of the less feasible were eliminated from consideration at the start. The remaining viable alternatives were dealt with through a computer model which dealt with a six-dimensional set of attributes for each alternative. The computer program calculated the expected utility (value) for specified alternatives.

8.2.5 Results of the Static Model

Out of the remaining alternatives, two types of general developmental strategies proved to be better than all the others. These were:

1) phased development of Zumpango (the remote site) with some continuing activities at Texcoco (the nearer site)

2) complete transferral of all activities to Zumpango by 1985.

It was noted by the decision makers that the optimal plans did not translate directly into decisions since the design
team was dealing with planning over a period of thirty years, which meant that long-range unpredictable events would have to be considered. They felt that, rather than revise strategies, a better course of action would be to make some initial decision based on the direct information gained by the static model. In order to provide the designers with a means to account for significant shifts in political preferences and community values over a thirty-year time span, a second model was needed to combine the factual evidence produced by the static model with other considerations that could (in the future) become significant. The dynamic model was constructed for this purpose.

8.2.6 The Dynamic Model

The dynamic model had the prime purpose of aiding the President by recommending what action should be taken immediately (1971). The second step in the decision process was assumed to be four or five years later at the end of the president's current term. The action taken at that time depended upon the action taken now (1971) and the events that might occur up to 1975.
The alternatives available to the President in 1971 were expressed in terms of the degrees of commitment to immediate construction at the two sites. Categorizing the staged actions at both sites constituted the main fabric of the dynamic model. Sixteen nominal cases were included in the model with each case representing varying degrees of commitment to each of the two sites (Figure III-B). The two strategies resulting from the static model would be compatible with most of the nominal presidential options in the dynamic model with the exceptions of numbers eleven, twelve, fifteen, and sixteen. Definition as to what each degree of development included was made for each site. "The alternatives at Texcoco (for the period 1971-1975) were defined as follows:

- minimum--maintenance and introduction of safety equipment only;
- low --extend the runways, upgrade support facilities such as terminals, do all routine maintenance and introduce new safety equipment;
- moderate--in addition to that done with a low strategy, buy and prepare land for building a new
Figure III-B. The 16 Nominal Presidential Alternatives for 1971.

<table>
<thead>
<tr>
<th>LEVEL OF COMMITMENT TO TEXCOCO</th>
<th>minimum</th>
<th>low</th>
<th>moderate</th>
<th>high</th>
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</thead>
<tbody>
<tr>
<td>minimum</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
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<tr>
<td></td>
<td>no major</td>
<td></td>
<td>commitment to Texcoco only</td>
<td></td>
</tr>
<tr>
<td>low</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
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<tr>
<td></td>
<td>commitments</td>
<td></td>
<td>major commitment to Texcoco with Zumpago backup</td>
<td></td>
</tr>
<tr>
<td>moderate</td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>12</td>
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<td></td>
<td>commitment to</td>
<td>major commitment to</td>
<td>commitment to</td>
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<tr>
<td>high</td>
<td>13</td>
<td>14</td>
<td>15</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Zumpago only</td>
<td>Zumpago with Texcoco backup</td>
<td>two airports</td>
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</tbody>
</table>
runway, expand passenger facilities, etc.;
high --build a new runway and passenger facilities, improve the airport access; in short, build a totally new airport at Texcoco.

Similarly, for Zumpango, we defined the commitment levels:
minimum--at most, buy land at Zumpango;
low --buy land, build one jet runway and very modes passenger facilities;
moderate--buy land, build a first jet runway and plan others, build major passenger facilities, and an access road connection to the main Mexico City highway;
high --build multiple jet runways, major passenger facilities, and access roads, that is, a complete new airport at Zumpango." 22

The alternatives itemized in the matrix represented actions which could be initiated at a beginning point, specifically 1971, and led to sequential development in the future. These actions, as listed, did not include responses to unpredictable changes that might occur during their long-range implementation. Critical events that could occur during the 1971-1975 period were

22 Ibid., p. 23-25.
identified as being:

1) safety factors and air disasters
2) shifts in demand in terms of passengers and aircraft
3) technological innovations
4) changes in citizen attitudes toward the environment, and
5) changes in priorities.

Each of these factors were identified and studies as to what impact the 1971 decision would produce.

Deriving from the alternatives outlined in the dynamic model matrix, a type of cost/benefit analysis was produced from the ranking of the alternatives in regard to four set attribute categories. These four attributes were:

1) the effectiveness
2) political consequences
3) externalities—a composite category including access roads needed, distribution of federal funds, etc., and

4) flexibility

Eight alternatives produced from the dynamic model matrix were listed and evaluated in each attribute category from one to eight, (Figure III-C). The rankings were arrived at by open discussions, thereby representing
# PRELIMINARY EVALUATION OF PLAUSIBLE PRESIDENTIAL OPTIONS FOR 1971 BY RANK ORDER

<table>
<thead>
<tr>
<th>ALTERNATIVE</th>
<th>Flexibility</th>
<th>Political Effects on Presidency</th>
<th>SOP</th>
<th>SCT</th>
<th>Overall</th>
<th>Externalities due to Pres-Reg. Bal. of Roads</th>
<th>Overall</th>
<th>Effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>2*</td>
<td>1</td>
<td>1</td>
<td>8</td>
<td>2</td>
<td>3</td>
<td>4</td>
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<td>7</td>
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* Dominant on overall ranking of four attributes
the consensus judgement. These rankings were the preliminary evaluation. The final evaluation of the nominal alternatives depended upon the precise definition of the dominant alternatives. This was done by the design team through the itemizing of exactly what would be recommended with each remaining alternative. For example, alternative 2 was defined as buying land at Zumpango; at Texcoco, extending the two main runways and the aircraft apron; constructing freight and parking facilities and no control tower--no new passenger terminals were to be built.

The final evaluation listing five alternatives was performed and alternative 6 was chosen to present. Alternative 6 which was chosen as the best presidential strategy in 1971 was defined as extending one runway at Texcoco and make other improvements enumerated in alternative 2. This option also included the recommendations for the purchase of land for a major international airport at Zumpango and construction of one runway with some passenger and access facilities. The advantages of this alternative were weighed by the SOP and were found to be that it ranked better on effectiveness, externalities, and political considerations. It allowed the President a means to react effectively to all the critical events which might occur between 1971 and 1975.
Chapter Four: Implications of Decision Analysis Use

9.0 Of the airport system studies that have been executed, many have been found to vary in their approach to the specific characteristics of their study region through differences in several vital areas. One of these is the employment of methodologies. What is being referred to here as methodologies should not be assumed to constitute a standard method representing the overall planning process. These methodologies—the most familiar of these discussed in Chapter One—are tools used by the designer to deal with existing conditions in the study region as well as provide formal means of prediction of future demand based upon statistical projections.

The methodologies used need not always be expected to be the same and will differ with each study. As seen in the Boston Airport Study, included in Chapter One, the criteria can also be expected to differ within the study. In this case different optimal sites were chosen from the same list of possibilities due to the attitudes incorporated in the search for a second airport location, thereby producing criteria based upon factors of contrasting priorities.
With the designer unable to depend upon a prototypical process of airport system planning, he is encouraged to seek out innovative combinations of methodologies and other applied aids in the resolution of his specific planning needs. Decision analysis is a likely technique to be incorporated in this type of planning problem.

By using decision analysis as a principle means to deal with the multiple objectives involved in the airport strategy and prediction of future events, the implications of its use should be familiar to the designer. The importance of his subjective evaluations should be apparent to the designer.

9.1 With the use of decision analysis, the set of most commonly used methodologies will remain as important inputs into the investigative process. Their role, however, will alter slightly by the addition of decision analysis. Studies using techniques like trip generation, land-use inventories and the like have been greatly depended upon to produce results that are interpreted directly into the product of the investigation. Applied decision analysis would add something to the products of demand resulting from
these techniques through consideration of demand upon an interim basis--matching existing demand with staged decisions made at differing points along the development process. The quality of the data collected from the established techniques would remain important to the influencing of the accuracy of the designer's decisions.

"If the detailed data are condensed, or never estimated, some relevant information is lost, and the decision process is less soundly based."23 Where the typical methodologies which have produced the detailed data in the past led to a final solution, use of decision analysis constitutes an intermediary step between data and solution.

9.2 To view the selection of an appropriate site for a second airport as the weighing of related characteristics from an array of possibilities to produce an unreserved recommendation for one site is not telling the entire story of this particular planning problem. In like manner, to advise the use of decision analysis solely for the weighing and selection of the optimal site is to understate the use of this technique. Throughout this work, examples

have been included to illustrate how decision analysis can be used in a variety of related decision-demanding issues which surround airport site selection. There are issues such as immediate political action, which from the start of the study can dramatically influence the second airport's actual implementation. There is versatility in meeting these issues provided in the decision analysis format—both in open and closed models. These two types of modeling are defined as:

**closed**, to describe the classical situation where a decision maker faces a known set of alternatives and selects a course of action by a rational selection process...**open**, often incorporates adaptive or learning features. 24

Use of these two types of modeling are not mutually exclusive and can be applied to the realm of issues surrounding the airport strategy formulation. For example, the closed model is applicable to selection of one site from a set of alternatives. Here the designer would be aided in the factual orientation produced from his collected background data stemming from the standard methodologies. The open model, dealing with uncertainties, can be applied to prediction of non-quantifiable conditions such as

future events which might include shifts in demand and environmental effects. Contrasting the closed decision model, the open model:

...parallels an 'open system.' Like the open system, it is continually influenced by its total environment, and, of course, it also influences the environment...Contrary to the assumptions of closed decision models, the open model does not assume that the decision maker can recognize all goals and feasible alternatives.25

What can be the expected gains that these two types of decision models can net the airport planning process? The most significant gain would be a more responsive strategy--responsive to the present conditions as well as the ultimate demand. Because decision modeling deals with a sequential format that makes interim decisions in view of certain and uncertain conditions, it gives a basis to the anticipation of a more responsive end-result. Contingency planning based upon an initial decision of the amount of commitment to one strategy over another allows future planning decisions to be made in respect to the conditions at that time. Transportation studies involving future conditions usually address likely future events over a twenty-year time span. Large capital investments poured

25 Ibid., p. 158.
into the establishment of a facility designed twenty years before its ultimate demand assume a great deal as to the capabilities of the designer. Use of an open ended model does not enforce an assumption of this magnitude but rather a more realistic view of the designer's capabilities can be realized through the understanding that, at that point, the designer cannot recognize the effects of future events and the ideal alternative.

Therefore, use of decision analysis can be expected to have strong implications upon airport planning with gains in the responsiveness of planning to be expected by its use. It is capable of outlining the best decision for immediate action, while at the same time accounting for surrounding institutional aspects which influence time and scope of implementation.

Under these conditions, this type of analytic approach is likely to produce a preferred set of long-run effects closely aligned with the initial goals of the designer and the conditions existing at that future time through its interim decisions.
10.0 While the use of decision analysis in planning represents a device of great potential in aiding the designer in reducing guesswork and in making choices with more assurance and confidence, it should not be considered as being without limitations. This analytic approach can be expected to constructively embellish the methods of transportation planning most commonly used due to the set of advantages it provides. Decision analysis can be well incorporated in the systems analysis approach in transportation planning. The systems analysis perspective is being more commonly accepted by the leaders in the transportation planning field. This comprehensive view deals with the macro and micro effects of transportation implementation. This step of overall design process involves the utilization of system models and predictive techniques to measure and in turn evaluate the consequences of alternative system designs; that is, to determine the costs and benefits of systems of differing make-up, of varying levels and kinds of service. Decision analysis provides an easily adaptable format for the predictive techniques required in the system analysis approach.

Consideration of all possible alternatives and their corresponding effects upon the study region can provide the designer a means of more realistic anticipation of the effects of the airport's implementation through its servicing of present and future demand situations. "It is important that all consequences of importance to decision maker's (and thus presumably to the community) be accounted for and be valued to a degree and extent representative of the entire society"\textsuperscript{27}

Though applied decision analysis in planning problems is better than the use of the standard methodologies alone, formalization of its limitations is paramount to the designer for its most effective use. One of the major shortcomings of the analytic approach is the subjectivity involved in its use. It is necessary for the designer and/or consultants to establish priorities initially through subjective evaluations. In addition, the designer is called upon to both assess his evaluation to an exacting degree as well as "play the odds" with uncertain events through establishment of probability values. Performing these required tasks may be both difficult and at times impossible to do.

\textsuperscript{27} Ibid., p. 158.
Since it is the designer who is called upon to establish these strategic evaluation and formulation of the decision model used there is no guarantee that the assessments of the designer necessarily aligns with those of the community, in particular those who would be disbenefited by the new airport. Exacting translation of external values, such as those of the community, is the duty of the designer. There is no way that use of decision theory commands the most exact translation of these external values due to the required subjective components of the format. Ideally, the alignment of this set of external values and those of the designer as he incorporates them into the decision format should be identical but this is subject both to the designer's personal frame of reference and his orientation data.

Decision analysis does not stand alone as the single device required in the planning process. It is highly dependent upon the backup data produced from supplementary methodologies. These other inputs play an important role in the best directed use of the analytic approach. Wohl defines decision theory as used in transportation planning
as a dependent method and suggests its utilization in conjunction with modern economic analysis.¹²⁸

One of the principal techniques that has been used in the evaluation of alternative plans to be later used in the overall decision model is cost/benefit analysis. In this technique impacts of a system which can be identified are evaluated in dollar terms, the benefits and cost are added up separately, and a cost/benefit ratio is completed. This ratio often dictates the optimal strategy projected by the decision model. As a result, flaws in this background technique became flaws in the model. There are serious problems in the cost/benefit technique. Specifically, these are: 1) it presupposes that all inputs can be expressed in quantitative terms such as dollars. Therefore, unquantifiable inputs such as social or environmental quality are omitted from analysis. 2) the technique assumes that dollar values can be obtained and that they reflect the 'value' to society of differing levels of inputs on various groups. 3) cost/benefit analysis is generally applied 'post facto' after alternatives have been produced. It does not influence

²⁸ Ibid., p. 20.
the development of the alternatives presented.\textsuperscript{29}

In addition to cost/benefit analysis, the other backup data drawn from the standard methodologies can also contain flaws, therefore leading to poor conclusions by the designer. Accuracy in working with these methodologies becomes directly proportional to the sensitization of the designer as he works with the decision model.

11.0 As use of decision analysis is likely to alter the overall approach that the decision maker will assume in looking at a large-scale transportation project, it will also redefine who the designer may be. This redefinition is brought about through the related disciplines that may be added to the design team. At the beginning of this thesis, an effort was made to present an exacting definition of who, exactly, the designer is, with indication of his background. In this first definition, prior to the discussion of decision theory and analytic applications, the designer was spoken of as being an engineer, architect, or planner. Now, after a review of the numerous impacts and conditions involved in the development of an airport system, and after a survey of the basic concepts of decision analysis, a new definition of who can be the designer of a project of this nature can be established. Due to the

subjective and intuitional components of decision analysis, the list of professions to be included on the design team may be extended to other related professionals such as sociologists, economists, less technically oriented planners and the like. Where these professions might have been excluded from the transportation design team prior to the use of decision analysis, they can be brought into the role of valid, participating members of the design team with the introduction of decision theory to airport site location. It can hardly be expected that a professional such as a sociologist will feel comfortable in working with engineering methodologies such as trip generation; but, on the other hand, he may be quite capable of working with methodologies dealing with social characteristics, such as population forecasts. By incorporation of decision analysis principles to the planning process, the sociologist would be better able to contribute to the evaluation of alternatives and prediction of demand through this common framework. The decision framework is here considered to provide an improved means of communication for the highly-technical and less-technical professionals. It is capable of doing
this because of the basic subjective inputs the framework uses and also the familiarity of making one decision over another through some kind of evaluation—in effect, utility theory. The lottery situation which illustrates the concepts of utility assignment described in Chapter Two is common to many professionals and, therefore, would provide a means to unite professionals from varying backgrounds to make a more comprehensive design team aimed at the development of an airport strategy. The type of interchange of design and policy inputs spoken of here is similar to the case in the Mexico City airport design process where the design team approached government officials for their expert assessment of the political situation and used a lottery analogy to rank their preferences of alternative over another. Here, through an analogy made up of decision analysis components, the highly technical design team had help from professionals familiar with local political conditions to form an appropriate political strategy for use by the President.

Because of the diagramatic properties of decision analysis, redefinition of the designer is capable of doing more than including a larger number of differing professionals in the design process. It also has the
potential of acting as a vehicle for better interpretation of community values. The decision flow diagram could be brought before a community meeting to show residents the alternatives available and, in turn, lead to the establishment of their priorities. By bringing the evaluation of the alternatives to a community level, the professionals need not exclusively rely upon technical inputs. The decision framework could act as a means of presentation and communication in working with the resident; thereby producing community input at different points during the decision-making rather than seeking this input after the prime decisions have been made and the airport development strategies well on their way to being established. Since the community cannot be expected to fully understand all of the highly technical methodologies used by the design team in dealing with the complex issue of airport development, decision analysis—a simplified presentation of alternatives with explanation of related conditions (existing and projected)—could at least make possible the orientation of the designers and, through attainment of the community's values, include them in the decision-making process. Such efforts against "from-the-top-planning" should be made. Particularly,
since the community group would include non-users of the airport and those who will be eventually disbenefited from the airport's development.

Decision analysis used in conjunction with methodologies producing a technical orientation has the potential to redefine those who may be included in the decision-making process. This resulting redefinition would involve the inclusion of both a greater range of professionals and community residents.

12.0 Decision analysis, as applied to large-scale planning projects, should not be considered a panacea for all of the ills that exist in the planning process today. Neither should it be endorsed as a replacement of the standard methodologies. These methods provide valuable information which is essential to the transportation study. The argument presented in this thesis is for the incorporation of decision analysis to achieve the benefits described. The methodologies described in Chapter One have an emphatic value to transportation planning and are assumed to be included, in some varying form, in every comprehensive transportation study. On the other hand, the value of applied decision analysis used in transportation planning promises also to be of
value from a contingency planning viewpoint.

Not all decisions on airport development can be put off to a later date. Some decisions must be made at an initial stage. However, a process using decision analysis can be applied also in the initial design stage, such as in site selection, to better equip the designer to anticipate events that are uncertain.

The final point of this discussion of applied decision analysis lies in a supportive argument for increased use of decision analysis in large-scale planning.
BIBLIOGRAPHY


Jerome, Axel and Nathanson, Josef "Socioeconomic Implications of Airport Planning." Ekistics, XXXIII (January, 1972), pp. 30-34.


Stanford University, Department of Aeronautics and Astronautics, *A Design Study of a Metropolitan Air Transit System.* SUDAAR No. 387, Standford, California: Standford University, 1969.