The use of the interactance equation for estimating potential airline passenger traffic between city pairs in Alaska

Sofia Melanie Medzihradsky

The University of Montana

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THE USE OF THE INTERDUCTANCE EQUATION FOR ESTIMATING
POTENTIAL AIRLINE PASSENGER TRAFFIC BETWEEN CITY
PAIRS IN ALASKA

by
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A. B., The University of Chicago, 1989

Presented in partial fulfillment of the requirements
for the degree of
Master of Arts
The University of Montana
1993

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Chairman, Board of Examiners

Dean, Graduate School

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Date

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The gravity model is a useful technique of wide applicability that analyzes the movement of phenomena within a certain region. It mathematically forecasts the influence of population centers and their distance upon the flow of transport. Specifically, the analysis of traffic flows by the interactance equation provides a refined illustration of the amount of interaction occurring between two areas. The interactance equation predicts the relative amount of group interaction within specific probability limits, given the size of the interacting populations, the distance between them, the specific or socioeconomic indices, and the total time of interaction. This thesis reviewed a specific application of the gravity model and the techniques employed therein: the study evaluated the correlation between several predictions of the interactance formula and actual air passenger traffic between selected city pairs in Alaska, during a specified twelve month period.

The use of the interactance equation for estimating potential airline passenger traffic between city pairs in Alaska had not yet been thoroughly investigated. Air travel is Alaska's principal passenger transport system due to the state's size, topography, and distribution of population. The gravitational projection of the air traffic potential between two destinations could thus be useful for the planning of air transportation in Alaska, providing guidance and support to planners, analysts, and local airlines in evaluating the extent to which intercommunity air passenger traffic potentials are being realized and deriving levels of traffic resulting from changes in service.

The obtained results indicated a positive correlation, ranging from $r = 0.70$ to $0.97$ and significant at the 0.01 level, between the expected interaction according to several predictions of the interactance formula and the actual observed passenger counts. The data support the suitability of the interactance equation as a theoretical prediction device and utility in the management of the transportation of passengers via scheduled air service in Alaska.
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CHAPTER 1

INTRODUCTION

A. Statement of the research plan

The goal of this thesis was to determine the usefulness of the interactance equation in assessing the potential air passenger traffic between selected city pairs in Alaska. In order to achieve that aim, the study involved the development of an interactance formulation: various sociological measures of mass, specific socioeconomic indices, and direct airline distances between city pairs were employed. The correlation between predictions of the interactance formula with actual air passenger counts during the calendar year 1990 was computed and graphically depicted via a scatter diagram, and the variances determined. The validity of using an adjusted interactance equation as a method for estimating the theoretical volume of air passenger traffic between city pairs in Alaska, and its application as an approach for evaluation and management control, were assessed.

B. The gravity model and interactance equation

Geographers are concerned with the spatial distribution of a wide spectrum of phenomena. The analysis of spatial distributions invariably

1
emphasizes an interaction component, such as the existence or creation of a flow of people between two locations. Models of geographic relationships and interaction between population centers describe the flows through which these places utilize the geographical complementarities in a particular spatial system, and present insights about movements and spatial arrangements.

The gravity model is a simple, useful technique of wide applicability that analyzes the movement of phenomena within a certain region. It mathematically forecasts the influence of population centers and their distance upon the flow of transport. The gravity concept of human interaction proposes that the interaction between two geographical areas of human activity is created by the population masses of the two areas, and that a friction against this interaction is caused by the space over which the interaction must take place. This relationship is mathematically expressed as:

\[
Ie = \frac{(P_1)(P_2)}{D}
\]

---


where: $\lambda$e : the expected interaction;
P1, P2 : the populations of any two groups;
D : the distance between the two interacting populations.

The hypothesis is based on the following assumptions: (1) to produce interaction, individuals must directly or indirectly communicate with each other; (2) the interaction between two population aggregates will obscure the peculiarities of individual behavior; (3) group averages of human interaction are predictable on the basis of mathematical probability; (4) the potential for movement generated by an individual at a given origin is inversely proportional to reaching the destination; and (5) the friction against this transportation is directly proportional to the intervening physical distance between the individual and the destination. The model is thus adequate for measuring interactions over unit time for areas with similar intensities of activities, where the effect of distance varies uniformly over geographic space. It is possible, however, that under the influences of varying socioeconomic environments, interaction among different groups of people is subject to forces other than the sheer numerical influence of population and

---

distance, and that the exclusive use of the aforementioned dimensions may conceal important differences between regions.

The analysis of traffic flows by the interactance equation provides a refined illustration of the amount of interaction occurring between two areas. The interactance equation introduces additional variables as modifiers of the basic gravitational dimensions, in order to account for the socioeconomic differences in various geographical areas that affect the interaction. The underlying hypothesis postulates that the potential interaction for a given interval of time between two populations varies directly with the product of some measure of the two populations and with the socioeconomic homogeneity between each group, and inversely with some function and power of the intervening distance between the two aggregates. In notation the hypothesis is defined as:

\[ I_e = \frac{[(P_1)(I_1)][(P_2)(I_2)]}{T D^\alpha} \]

whereby the operational definitions are as follows:

- \( I_e \): the relative theoretical amount of interaction expected by the hypothesis, stated as the interactance index;
- \( P_1, P_2 \): the population of any two groups, expressed in units of persons or alternative sociological measures;
- \( I_1, I_2 \): the specific socioeconomic levels of interaction pertaining to each population, introduced as weighting factors to
equate the heterogeneity of the groups in various geographical areas;

D*: the distance between the two interacting populations, functioning as an index of friction. The exponent indicates the uniformity of interaction density, and in the present study specifically reflects the transferability of passengers and availability of transport;

T: the length of time in which the number of interactions has been observed.

C. Components of the interactance equation

a. The interactance index, Ie

This index represents the ratio expressed by the six dimensions, namely the size of the interacting populations, their intervening distance, the time of interacting, and the socioeconomic variations pertaining to each constituent. This figure expresses the relative theoretical amount of interacting and does not signify the actual amounts of expected interaction. Its utility comprises observable indices and computable components, thus facilitating exact quantitative testing by the closeness and goodness of fit.

b. The populations, P1 and P2

These two factors reflect the groups of interacting persons defined as distinct population concentrations, and has conventionally
been equated with the population size of cities or states in various geographical locations because of data availability. Several studies have maintained, however, that the appropriate measure of population depends on the class of interaction anticipated, and it is suitable that \( P_1 \) and \( P_2 \) reflect only those subgroups of a population that actually take part in the interaction, rather than the entire population.\(^4\) In examining air passenger traffic flows, for example, the coefficient of correlation between the predicted and observed number of air passengers between a city pair might be improved via the use of alternative sociological measures of population that symbolize those persons who utilize the respective airports, because the numerical populations of urban areas do not delineate the substantive populations that may make use of air transportation services at a particular airport.

The conjoint affect of the population sizes of the two interacting cities upon the volume of travel is equal to the population product in the following manner: 1) the population sizes of the two interacting cities mutually influence the number of trips participated in by pair relationships, one person in the city of origin who travels and one person in the city of destination to whom the trip is being taken; 2) the greater the number of possible pairs, the more numerous are relationships initiating travel; and 3) the number of all possible pairs between two cities is equivalent to the product of the two populations. Because the larger portion of all trips in intercity traffic comprises pair

to pair relationships, the population product estimates closely for this influence of population size.5

c. The specific levels of interaction, I1 and I2

These components represent adjusting factors that are introduced into the gravity equation as multipliers of the population concentrations in order to account for regional differences in socioeconomic conditions that may raise or depress the interaction examined. The specific levels may be explained as a measure of an individual's capacity for sociological interaction. It is inferred that each person has an equal probability of partaking in a specific type of interaction as any other person.

The influence exerted by a location often exceeds or falls short that which would be considered by the uncompounded formulation of the gravity concept. The frequency of interactions over a given distance between an origin and destination depends in part on their social and economic attributes, such as income, education, sex, age, and occupation. The diverse social and economic compositions of city populations therefore affect the number of interactions between city pairs. The variations in degree of influence which result from these distinct socioeconomic characteristics of the aggregates are signified and empirically measured via the assignment of specific multiplicative weights for the city populations in the interactance equation.


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The two indices of specific levels are constants particular to each group, for a given class of interaction in a given population and time frame, and are established as the per capita socioeconomic activity of that unit. If a different characteristic of a group raises the predictance correlation between the expected interactance as stipulated by the interactance equation (Ie) and the directly observed interacting (Io), the variable is accepted as a significant specific level in the interactance formulation. Within a homogenous population possessing a common level of activity, the testing of particular variables will achieve a differential of unity and will not influence the amount of interaction for practical purposes. Conversely, the differences may be substantial along with the examined variables significantly modifying interaction patterns as designated by the equation.

d. The space dimension, Dx

This factor expresses distance and may be indicated in spatial units such as miles, transport cost, ease of access or time of travel whenever these units measure the effect of distance in regulating flows more favorably than a linear treatment. If the distance component is defined in physical units, the range of distance for which a particular mode of traffic is competitive must be considered.

An effective view of distance in the examination of traffic flows may be achieved via modifying linear measures by time saved, differential cost, and schedule frequency and quality in areas where alternate modes of transportation are available and are within a contending distance range. For instance, a time-cost measure of distance may be especially suitable in evaluating intra-urban traffic for which punctuality is of significant concern. However, the alteration of the distance variable negates the simplicity of the interactance equation, and defining distance via a social term introduces topological difficulties when mapping the distribution of distances between points.

The dimension of distance is expressly geographic in that it comprises the concept of distribution. Distance affects the flow of traffic for a variety of reasons. Money, time, and effort constitute valuable and scarce resources applicable to the majority of the population and are thus inclined to be apportioned to the extent that the most interaction is generated involving the least expenditure. The greater the distance between two centers of population, the greater the cost, time, and personal effort required of persons to undertake the journey. As distance increases, therefore, fewer individuals will be prepared to travel, and the probability will diminish that a person will develop an interest in other persons and that a relationship between a potential pair of persons will become established, thus leading to a trip.

The situation of \( D \) in the denominator of the interactance equation reinforces the resistance if the intervening distance is large and decreases the friction if \( D \) is small.\(^8\) Although the inverse-linear function has conventionally been utilized to represent the influence of distance, a better fit between the model and the data may be rendered when the distance factor is raised to some power other than unity, suggesting that the potential for population movement between places does not decrease regularly as distance increases. The relationship between traffic and distance may not be an inverse-linear one and the impact of distance on the specific interaction not become uniform.\(^9\)

As a result of empirical testing, various distance exponents, ranging from 0.5 to 3.0, have produced more accurate predictions of actual interaction. Several studies have indicated the exponent to vary according to the mode of transportation involved in the interaction.\(^10\) The Civil Aeronautics Administration, for example, determined the inverse-linear function as most appropriate for intercommunity air transport in their study on the influence of population characteristics upon the volume of airline traffic.\(^11\) A high exponent indicates that


movements are diminished with an increase in distance from the origin and reflects a greater relative difficulty of interacting between two populations. The figure is small when it is manageable to move from city to city and distance constitutes only a minor barrier to the interhuman interaction investigated.

e. The time dimension, T

This dimension signifies the length of time during which the number of interacts are observed, and may be held constant if all the observing occurs in one period. The interactance hypothesis assumes that the period used for calibration is a typical period during which the relationships identified remain constant. The majority of research employing the interactance equation has examined data collected for one or more months of observed data, therefore permitting the influence of seasonal variation upon traffic flows and preventing a generalized indication of the specific situation.

f. The interacting, io

This factor is not included in the interactance equation, however it refers to the amount of actual observed interacts, and may comprise any type of communication between two persons when clustered into units for examining, regardless of its quality or form (i.e. whether it is cooperating, competing, or conflicting).

The classes of interaction that have been analyzed have included, although are not restricted to, traveling via bus, rail, and air transportation between cities; passenger automobiles by states or counties entering a city, national park, and crossing state boundaries; visiting between communities, and states; migrating from communities to other communities; commuting between the city center and the suburbs; moving household goods via moving vans between cities; shipment of cargo via railway between cities; sending written communications between communities; telephone conversations between communities; transfers of money between cities; attending colleges or universities from other states; and newspaper circulation from the point of publication.12

D. The application: Alaska aviation

The interactance hypothesis is a theoretical concept that proposes the factors determining the quantity of an observed empirical group interaction predicated on quantitative mathematical principles, and provides a basis with which data may be applied to aid in traffic flow analysis.

In this thesis, the above described analysis has been restricted to one mode of interaction, namely air passenger transportation. It was

hypothesized that air passenger traffic volume is a function of demographic, socioeconomic, and air service characteristics. The use of the interactance equation for estimating potential airline passenger traffic between city pairs throughout the state of Alaska had not yet been sufficiently investigated. Air travel is Alaska's principal passenger transport system because of the state's size, topography, and distribution of population. The intercity trip is the fundamental unit of total air passenger traffic. Traffic volumes of only moderate or low volume are considered of vital importance when the isolation of the populations served and distances covered are weighed. Large sums are contributed annually toward traffic counts to develop estimates of potential aviation traffic serving as a basis for airport upgrading, expansion, and new facility construction. The gravitational projection of potential air passenger traffic between city pairs could thus be useful for the planning of air transportation in Alaska, providing guidance and support to planners, analysts, and local airlines in problem definition, analysis, and decision making such as the need for new airline routes and schedule preparation. By estimating the air traffic potential between two destinations, the interactance equation could evaluate

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13 J.T. Gray and J.P. Rowe utilized the gravity model to measure rural air service demand between Alaskan communities possessing 500 or less inhabitants in the arctic/western and the northern portion of the interior transport regions during the third quarter of 1979 (Gray, John T. and J. Phillip Rowe, The Economic Dimensions and Feasibility of Scheduled Air Service in Rural Alaska, Institute of Social and Economic Research, University of Alaska, Anchorage, Alaska, May, 1981). The examination employed the total observed passenger traffic via segment, as opposed to the absolute origin and destination counts utilized in this thesis as a more valid variable. The 1979 study is further detailed in Chapter II. B.
the extent to which intercommunity air passenger traffic potentials are being realized, project traffic levels resulting from service changes, propose alternative service patterns, optimize existing aircraft traffic, and forecast airline revenues under proposed operating schedules.

E. Purpose of the study

Although there exist individual idiosyncrasies pertaining to traffic estimates, informed judgment based on a sound theory is necessary to develop estimates regarding the flow of traffic between cities. If the volume of traffic between populations can be forecasted within stated limits of probability using the interactance theory, this approach could be applied as a valuable predictive device. The relative simplicity of the underlying quantitative relationships makes this method suitable to be used by individuals with limited time and resources, whose primary duty is not transport analysis. The interactance technique does not require large quantities of data, utilizes observable and accessible indices that are collected on a regular and ongoing basis, computation of the formula and quantitative testing of the results are straightforward, and the forecasting model is flexible enough to account for the factors underlying traffic volumes that may be subject to change.

It is the objective of this thesis to review the gravity and other potential parameters of interaction and the techniques employed therein. The study empirically evaluated the correlation between several predictions of the interactance formula and actual air
passenger traffic between selected city pairs in Alaska, during a
specified twelve month period.

The coefficient of correlation measured the relative relationship
between the expected interaction and the observed counts of air
passengers at origin and destination. Each of the socioeconomic
measures introduced into the interactance formula produced different
coefficients of correlation for each distance exponent examined. The
correlation coefficient increasingly approached unity and became more
meaningful as the components of interaction became well determined,
measured, and combined. A high correlation coefficient indicated a
strong association between the formulated interaction and actual
intercity air passenger traffic in Alaska. A research finding of lacking
relationship between the hypothesized variables signified the possible
presence of historical or local overlaying factors\textsuperscript{14}, that certain
pertinent factors have not been sufficiently investigated, poorly
measured variables, or the existence of random variation within the
system, thus providing valuable insights within the context of the study
matrix.

The significance of the calculated relationship between variables
was statistically tested and a scatter diagram was constructed to
graphically depict each computed correlation. Possible factors that
might explain the variance between the expected and observed air

\textsuperscript{14} Dodd, Stuart Carter. "The Interactance Hypothesis - A Gravity Model Fitting
246.
passenger movements were examined. The suitability of using an adjusted interactance equation as a method for measuring the air traffic potential between city pairs in Alaska, was assessed.
CHAPTER II

DEVELOPMENT OF THE INTERACTANCE EQUATION

A. Basic concepts and derivation

The universal law of gravitation, developed by Isaac Newton in 1665, states that "any two particles of matter attract one another with a force directly proportional to the product of their masses, and inversely proportional to the square of the distance between them." The early concepts linking gravity and human interaction, such as the P/D relationship postulated by H. C. Carey and E. G. Ravenstein that appertains to the interaction between one community and many others, and the PaPb/D concept of G. K. Zipf and J. Q. Stewart which


concerns itself with actions between many individual pairs of cities, were developed as a social counterpart to Newton's physical law of nature.

The earliest known formulation of the social gravity concept was proposed by H. C. Carey in 1858.\(^{20}\) Carey postulated that social and physical phenomena are together founded on the Newtonian law of gravitation, and stated: "The great law of Molecular Gravitation is the indispensable condition of the existence of being known as man....The greater the number collected in a given space, the greater is the attractive force that is there exerted....Gravitation is here in the direct ratio of the mass, and the inverse one of distance."\(^{21}\)

Carey's general gravitational theory of human interaction, established as the P/D relationship, comprises the most general form of the gravity model and the consequent interaction equation. The formulation refers to a ratio between the dimensions of population and distance and hypothesizes that a significant portion of societal behavior relates to these basic factors. During the latter half of the 19th century, E. G. Ravenstein and E. C. Young\(^{22}\) utilized the P/D concept

---


in their empirical examinations of migration. In 1885, Ravenstein presented data suggesting that migratory movement is directed toward cities of large population and that the amount of mobilization is curtailed with increasing distance between the origin of migration and the "center of absorption." Ravenstein expressed this notion in the following quotation: "Migrants enumerated in a certain centre of absorption will consequently grow less with the distance and proportionately to the native population which furnishes them....The process of dispersion is the inverse of that of absorption and exhibits similar features." The related mathematical relationship is indicated as:

\[ a_{Mb} = \frac{f(Pa)}{D_{ab}} \]

where:  
- \( a_{Mb} \): the migration from origin b to center of absorption a;  
- \( f(Pa) \): a function of the population of a;  
- \( D_{ab} \): the distance between origin b and center a.

---


In 1924, Young undertook similar studies in his attempt to explicate migration, and, in the course, refined the P/D principle of gravitational attraction related to social interaction. He suggested that the relative amount of farm migration from several individual origins to a particular destination is modified directly by the "force of attraction" of the destination and inversely so via the square of the intervening distance between the place of beginning and destination.\(^{24}\) The relation may be described as:

\[ aMb = k \frac{Z_a}{D_{ab}^2} \]

where:  
- \( Z_a \): the force of attraction of destination \( a \);  
- \( k \): a constant of proportionality.

In 1929, W.J. Reilly applied the theory of gravitation to the delimitation of retail areas. This formulation of the gravity concept of human interaction examined the comparative strength of attractive forces acting upon an individual with adequate access to both trade centers, rather than the interaction between the centers. Specifically, the empirical relationship embraced by Reilly's "Law of Retail

Gravitation" stated that a trade center will attract retail trade from an individual in its surrounding territory with a force that is directly comparable to the population size of the retail center and in inverse proportion to the square of the distance away from the center.

A sociological employment of the gravitational hypothesis was offered by H. S. Bossard in 1932, who empirically analyzed the function of distance as a factor in marriage selection between 5000 pairs of persons in Philadelphia, Pennsylvania. This research was concerned with the estimated force of attraction and not with the volume of trips generated. Bossard observed that the percentage of marriages decreased regularly with the increasing distance of premarriage residence of the partners, and demonstrated a linear relationship of the data plotted on a scatter diagram.

W. R. Chandler, in 1950, investigated the distance between the place of residence and the points of pedestrian accidents. The distance


between 264 pedestrian vehicle accidents and the places of residence of the victims, plotted on a scatter diagram against the frequency of accidents, exhibited a high correlation. Chandler contended an inverse proportionality between the distance of a pedestrian from his residence and the frequency of accidents.27

In the 1940s, the principle of gravitational attraction related to human interaction was generalized and shown to correspond to the ideas inherent in the original formulation proposed by Carey. In like manner, G. K. Zipf of Harvard University and J. Q. Stewart of Princeton suggested a direct analogy between observed social phenomena and physical laws of Newtonian physics. Stewart postulated that the concepts of force and energy in physics have their counterparts in social interaction. He suggested that the force of interaction between two population aggregates is proportional to the product of the size of the populations divided by the square of the distance between them, and may be mathematically expressed as:

\[ F_{ab} = \frac{(P_a)(P_b)}{D_{ab}^2} \]

where: \( F_{ab} \) : the demographic force between concentrations a and b, corresponding to Newton's gravitational force.


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Stewart subsequently developed the theory of demographic energy, and reasoned that the energy of interaction between two population units increases as the product of the two concentrations increases, and diminishes regularly with the distance separating the two centers. The equation takes the form:

\[ E_{ab} = G \frac{(Pa)(Pb)}{D_{ab}} \]

where:  
\( E_{ab} \): the energy of interaction between a and b, equivalent to Newtonian gravitational energy;  
\( G \): a constant of proportionality, comparable to the gravitational constant of physics.

Stewart empirically applied this formula to measure the energy of interaction between city pairs over a wide range of social phenomena, such as the distribution of residences from various universities, and telephoning between communities, and concluded that his examinations rendered an inverse distance law with statistical regularity. In addition, this research provided first evidence of variations in the propensity to interact among persons residing in distinct geographical locations.

Stewart augmented his physical analogy to encompass the concept of population potential as commensurate with gravitational potential. Stewart expressed that "a wide variety of observed social data are given predictability by the proposition that the influence of
people, \( P \) in number, at a distance \( D \) miles away, is proportional to the number of people divided by the distance, i.e., \( P \) divided by \( D^2 \), and formulated a quantitative index which measures the power of attraction or influence of a population:\(^{28}\)

\[
aUb = 6 \left( \frac{P_b}{D_{ab}} \right)
\]

where: \( aUb \) : the potential at location \( a \) of the population of area \( b \).

Thus, the inherent probability of interaction at a location \( a \), pertaining to an individual at \( a \), that is engendered by the population of any given area \( b \), is greater as the population of \( b \) increases and is minimized as the intervening distance between \( a \) and \( b \) increases.\(^ {29} \) The total demographic potential of location \( a \) may be estimated via summing over the total number of cities, namely:

\[
aU = 6 \sum_{b=1}^{n} \left( \frac{P_b}{D_{ab}} \right)
\]

---


Stewart argued that the demographic potentials may be mapped in order to measure the proximity of a location to all other places, or else of persons at that point, and could be utilized for descriptive purposes. The potential contour maps connect points of equal potential via isolines, thereby depicting the influence each place exercises on outlying locations, or the influence of persons at a distance.\textsuperscript{30}

G. K. Zipf observed various empirical relationships of repeated regularity in association with population and distance when the two dimensions were examined as a ratio. He determined a positive correlation between population potential and numerous social phenomena, such as wealth, death and suicide rates, and median age.\textsuperscript{31} Thus, Zipf expanded upon the potential of population concept and developed a more inclusive relationship as applied to sociological interaction. The author proposed that the potential for movement between two centers is proportional to the product of their populations and inversely equivalent to the square of the intervening distance among the aggregates, which is mathematically formulated as:

\[ M_{ab} = \frac{(Pa)(Pb)}{D_{ab}^2} \]

\textsuperscript{30} Ibid.

where: $M_{ab}$: the interaction between centers $a$ and $b$;
$P_a, P_b$: a measure of the mass of the two centers;
$D_{ab}$: a measure of the distance separating the population units.

Zipf tested his hypothesis via empirically analyzing various movements of persons, goods, and messages between selected delimited population concentrations. He claimed that the postulate was confirmed by the degree of correspondence between the predicted and observed values as indicated by the computation of the coefficients of correlation, and the rectilinearity of the plotted data illustrated on the constructed scatter diagrams.\(^3\)

Ensuing studies demonstrated the necessity of modifying the basic $P_aP_b/D$ model forwarded by Zipf and Stewart. The extended formula, hereafter expressed as the interactance equation, estimates the relative amount of group interaction within specific probability limits, given the size of the interacting populations, the distance between them, the specific or socioeconomic indices, and the total time of interaction. In notation, that is:

$$I_{ab}/T = [(W_a(P_a))(W_b(P_b))]/D_{ab}$$

where $W_a$ and $W_b$ comprise weights applied to the mass components, and $T$ represents the length of time of observed interaction. The

\(^3\) Ibid., pp. 593-401.
interactance equation has been empirically analyzed via a plethora of social interacts by, in chronological order, J. A. Cavannaugh\textsuperscript{33}, S. C. Dodd\textsuperscript{34}, G. A. P. Carrothers\textsuperscript{35}, C. Hammer and F. C. Iklé\textsuperscript{36}, D. R. Smith\textsuperscript{37}, and J. T. Gray and J. P. Rowe\textsuperscript{38} (the scope of observed phenomena that have been examined is listed in Chapter I. C., on page 12). The total demographic potential can be derived from this equation as:

\[
a^U = \sum_{b=1}^{n} \frac{(W_b)(P_b)}{D_{ab}^2}
\]

Carroll and Bevis in 1957, and Isard in 1960, maintained that the aforementioned equations could be determined via the application of

\textsuperscript{33} Cavannaugh, Joseph Aaron, 


\textsuperscript{36} Hammer, Carl and Fred Charles Iklé, "Intercity Telephone and Airline Traffic Related to Distance and the 'Propensity to Interact'." \textit{Sociometry}, volume 20, 1957, pp. 306-316.


basic probability concepts.\textsuperscript{39} T may signify the total number of interactions within an encompassing region possessing the population P. The region can be apportioned into smaller areas, indicated as a and b, in like manner retaining the populations Pa and Pb. The total interaction intensity T/P, represents the number of interactions per individual and may here be substituted via a constant k. Thus, the theoretical amount of interaction between the two homogeneous populations Pa and Pb, symbolized by Tab, may be denoted as:

\[ \text{Tab} = k \left( \frac{(Pa)(Pb)}{P} \right) \]

whereby contemplation is not given to the influence of the intervening distance between a and b.\textsuperscript{40} Carroll and Bevis, and Isard suggested that the observed interaction between the two locations be expressed by Iab, and the quotient Iab/Tab hereafter calculated. The researchers empirically observed that the relation between this quotient and the distance Dab, plotted on a two-dimensional double-logarithmic diagram for city pairs ab, generates a linear distribution of points with a negative slope. That is:

\[ \log \left( \frac{I_{ab}}{I_{ab}} \right) = a - b \log D_{ab} \]


\textsuperscript{40} Ibid., p. 47.
It is furthermore feasible to express the antilog of \( a \) via \( c \), and reformulate the equation as:\(^{41}\)

\[ \text{lab} = \frac{c(Tab)}{Dab^x} \]

The component \( Tab \) may thereupon be replaced by its previous expression, namely \( k(Pa)(Pb)/P \). The outstanding ratio of constants \( ck/P \) can be interchanged with the single constant \( k \), and the ultimate formulation written as:\(^{42}\)

\[ \text{lab} = k[(Pa)(Pb)/Dab^x] \]

B. The gravity concept of human interaction applied to air transportation

The focus of this review is now directed towards those applications of the gravity theory of social interaction involving air passenger transportation.

The first recorded utilization of the \( PaPb/D \) hypothesis with respect to air passenger transportation was undertaken by G. K. Zipf. He employed the \( PaPb/D^2 \) equation to analyze the movement of passengers via air transport between 29 randomly selected cities sufficiently scattered throughout the United States during all of 1933.

\(^{41}\) Ibid., p. 47.

\(^{42}\) Ibid., p. 48.
The mass of the concentrations was represented by their numerical populations and the distance separating the aggregates was denoted by the direct airline distances. Zipf determined an empirical relationship between the number of passengers carried, and the corresponding values of \( \frac{P_{a}P_{b}}{D^2} \). When plotted on a scatter diagram, the data exhibited a definite rectilinear distribution although some variation was indicated. Zipf speculated: "The airway data revealed a correlation even for the early year of its development. What the distribution will look like a few years hence after air travel has taken its place as a customary means of travel is an interesting question to ponder. Much will depend upon its rates and services in competition with those of other public carriers. As air travel becomes more thoroughly established, (this) variation should decrease."\(^{43}\)

In September and October, 1946, W. J. Platt presented an application of the \( \frac{P_{a}P_{b}}{D} \) formula to air passenger travel between 155 intercity pairs, involving 58 different metropoles, where service had not yet been established. Platt sought to investigate the Civil Aeronautics Board proposal to purchase a large number of aircraft and introduce direct airline service between certain major cities, by estimating the potential air traffic generation among these new city pairs. When the populations of the communities and the intercity

distances were plotted against the actual number of aviation origins and destinations appropriate to each airline terminal on a log-log graph, the results depicted an unmistakable linearity together with a visual trend line. Platt argued that a higher degree of correspondence between the empirical data and the model was obtained when calculating the square root of the product of the city populations to the first power, divided by their intervening distance, written as: $\sqrt{P_aP_b/D}$.\(^{44}\) The author thus maintained that intercommunity air passenger traffic varies directly with the square root of the product of the population of the first city multiplied by the population of the second city, and inversely with the first power of the distance, and that the aforesaid equation expresses the maximum potential of trips between two locations with respect to the population of each community and the distance separating them.\(^{45}\)

O'Arcy Harvey, of the Civil Aeronautics Administration, proceeded to inquire about the intercity exchange of air passengers with Chicago, Illinois during a four month span in 1951. Harvey employed the $P_aP_b/D$ concept to predict potential traffic volumes of Chicago and eleven interacting cities, and graphically demonstrated a significant rank correlation between the cities according to the observed traffic counts and the expected order as stipulated by the formula. By applying the $P_aP_b/D$ equation to traffic calculations, Harvey was the first to suggest


\(^{45}\) Ibid., p. 58.
a minimum distance for which intercity travel time is favorable and airline passenger travel is therefore competitive. The author observed that over 98 percent of automobile passengers and 44 percent of rail passengers tend to travel less than 100 miles, while air passenger transportation comprises a mere 5.7 percent within this distance bracket. The comparison between the theoretical computation and the actual performance produced specific insight into the air traffic pattern of Chicago. Harvey discovered that as the distance from Chicago increases, the majority of passenger exchange with Chicago is between large communities, while the traffic of the smaller cities is significantly diminished. Harvey furthermore postulated that the economic character of a population center may exert an influence upon intercity air traffic flow potentials. When each community was categorized into Marketing, Industrial, Institutional, or Balanced Centers via such indexes as amount of air mail and air cargo, and number of personal aircraft, the Marketing and Institutional groups empirically produced the larger amounts of air passenger traffic.

G. R. Mayhill substantiated the results of Harvey's study by incorporating additional communities. Mayhill concluded that this research might be used as a model for other studies of cities in the


An investigation into air service to Denver, Colorado undertaken by S. B. Richmond in 1954 set forth a new theory for predicting potential air passenger traffic between city pairs. Richmond argued that a more suitable measure of the population aggregates as modifying the propensity to interact with respect to air travel may be rendered by determining their intercity strength of attraction. Richmond analyzed various factors measuring the community of interest between Denver and its interacting city pairs, namely air freight to and from Denver, hotel registrants at Denver hotels, number of telegrams from Denver, rail passengers with Denver, and number of companies and banks with branches in Denver.\footnote{Richmond, Samuel B., "Forecasting Air Passenger Traffic by Multiple Regression Analysis." \textit{Journal of Air Law and Commerce}, volume 22, 1955, pp. 434-443.} The author selected the number of Denver hotel registrants residing in various alternate cities as the most decisive factor stimulating the generation of air travelers, and empirically employed this indicator in place of the numerical population in the PaPb/D equation. An additional parameter in the study was the restriction to a distance in excess of 200 miles between interacting city pairs for which air transport provides the dominant mode of passenger exchange. Richmond in conclusion computed a statistically significant

correlation coefficient of 0.91 in association with the expected air passenger traffic volumes and the actual observed counts. In 1950, J. A. Cavanaugh was the first to test the modified version of the gravity hypothesis of human interaction as applied to air traffic calculations. Cavanaugh's objective was the estimation of potential air passenger traffic flown from Seattle, Washington to 47 arbitrarily selected, geographically distributed cities throughout the United States from March 1, 1947 to March 1, 1948. The interactance equation introduces an index of the average propensity to interact of all individuals in each community. Cavanaugh reasoned that areas with a high per capita income would use flight transportation to a greater extent, and applied this adjusting factor for the interaction amounts affected by regional differences. The obtained coefficient of correlation between the total expected number of passengers carried according to the formula and the total observed destination counts was 0.58, which was determined to be statistically significant. In addition, the author provided a visual depiction of the data via a constructed scatter diagram. Cavanaugh suggested several explanations for the relatively poor relationship of the data. Because of resource availability, Cavanaugh utilized population figures enumerated by the 1940 census to represent the interactors at the origin and destination communities.


whereas the empirical traffic data pertained to the twelve month period during 1947. Correctly, the population figures of the entities at the time of interaction should be employed. A more detailed inspection of this research concerning the interaction hypothesis related to air travel discerned that the actual intercity traffic counts comprised origin and destination segment data and therefore may have contributed to the low correlation coefficient value. Segment data consist of the number of passengers on-line, who are traveling on the particular segment although not necessarily beginning their trip at the recorded origin or terminating travel at the destination.\footnote{Cavanaugh, Joseph Aaron, *Formulation, Analysis and Testing of the Interactance Hypothesis*. A Dissertation, University of Washington, 1950, p. 92.}

Cavanaugh moreover argued that within the specific study context airline transportation failed to represent an accessible mode of interaction to the entire population, but rather to certain economic or business groups. An alternative, cheaper mode of transport often existed, and in this manner may have influenced the correspondence between the expected and actual interaction. Cavanaugh stated conclusively: "Air travel is a newer immature culture trait which has not been diffused fully to all classes of people. Thus the laws of probability work out less smoothly for this type of interaction."\footnote{Cavanaugh, Joseph Aaron, *Formulation, Analysis and Testing of the Interactance Hypothesis*. A Dissertation, University of Washington, 1950, p. 92.}

\footnote{It should be noted that the use of absolute origin and destination air passenger traffic counts has not yet been undertaken in the estimation of air traffic via the interactance equation. This thesis therefore proposes (and forwards data for) a more appropriate means of measuring traffic flows.}
D. M. Belmont further developed the concept of interchanging the population factor with a more suitable measure of the interaction potential than the numerical counts, initially forwarded by S. B. Richmond and previously reviewed on pages 33 and 34 of this thesis. In his application of the PaPb/D relationship to airline passenger traffic between 21 airline hubs in 1956, Belmont proposed employing the total volume of air passenger traffic generated at each airport to signify the number of interactors. The standard variable used to represent the population component, the census counts pertaining to each city, does not reflect the entire market area served by an airport. The total number of enplanements at each airport more adequately indicates that population segment that may actually partake in the interaction and utilize the services and facilities provided by the respective airports. Belmont plotted the results of the study and noted that the "number of trips between any two stations depends primarily on the total traffic (recorded) at each of the stations and on the quality of service."\footnote{Belmont, Daniel M., "A Pattern of Interstation Air Travel." Transactions, American Society of Civil Engineers, Paper number 2888, 1957, p. 864. Reference quoted from Cochran, Douglas Lessel, \textit{An Evaluation of the Use of Gravitational Formulae for Estimating Potential Air Passenger Traffic Between City Pairs}. A Dissertation, University of Oregon, June, 1968, p. 35.}

In 1958, Belmont conducted a gravitational calculation of potential air passenger traffic between United States communities 400 to 2000 miles apart, in which the estimated volumes, as stipulated by the equation, were plotted against origin and destination survey data of 1955. The results of the study failed to justify the inverse linear or
the inverse square theory that previous researchers had proposed for the distance function. The author observed that a distance exponent of 0.661 for average distance routes of 400-800 miles and 0.245 for intervening distances greater than 800 miles provided a better fit between the model and the data than that predicted by an inverse linear or inverse square representation. Belmont herewith offered the first statistically significant indication of an optimum distance exponent specific for the impact of distance on the interaction examined.  

C. Hammer and F. C. Iklé recommended utilizing qualitative census data referring to each community instead of direct population data in the PaPb/D technique, in order to express the variation in the particular population compositions and peculiarities pertaining to the cities examined. Hammond and Iklé employed sociological variables such as the number of managers, officials, and proprietors as a percentage of the city populations, the annual retail sales of the communities, and the number of hotel rooms available in the metropolitan areas in their analysis of the propensity to interact via airline transportation between 27 cities in the United States. The period during which the total number of passenger trips on scheduled flights were counted was March, 1950. The intervening distance between the consequent 351 community pairs was the shortest airline distance. The authors empirically determined an invariable positive relation between the city

weights applied in the PaPb/D equation and the actual number of airline passenger trips, and ascertained that the distance exponent assumed a value between 1.3 and 1.8 with respect to the airline traffic interaction involved in the specific study.\textsuperscript{55} Hammer and Iklé concluded that: "Our city weights partly reflect the geographical location or other special situation of the city which have nothing to do with the 'interaction propensity' of the inhabitants. But in most cities more interesting differences can be found that seem because of the people and not merely to the logistics of traffic."\textsuperscript{56}

J. B. Lansing, J. Liu, and D. B. Suits hypothesized that the demand for intercity air travel increases more than that expected in proportion to the population of the aggregates. The authors proposed expressing the influence of that portion of the population involved in the "communication from one part of the economy to another" on the use of air transportation.\textsuperscript{57} Lansing, Liu, and Suits suggested that this population group may be identified via the incorporation of the percentage of annual family incomes exceeding $10,000 as a measure of the population component in the model. The PaPb/D principle was

\textsuperscript{55} Hammer, Carl and Fred Charles Iklé, "Intercity Telephone and Airline Traffic Related to Distance and the 'Propensity to Interact'." \textit{Sociometry}, volume 20, 1957, pp. 313 and 315.

\textsuperscript{56} Ibid., p. 315.

applied to investigate the variations in the air transportation flows in association with New York as compared with Chicago in 1961. Lansing, Liu, and Suits computed the relation, according to the gravity model, between the estimated potential air passenger traffic involving 35 cities and Chicago and New York, respectively, and the observed volumes. The authors produced a positive and consistent correlation between the expected and actual values, therein confirming that the utilization of family income as a representation of the population units, and the direct airline distance as a measure of the intercity friction of distance, constituted valid parameters in the projection of potential airline passenger traffic levels within a specific research context.

A University of Michigan study undertaken in 1964 further substantiated the direct relationship between income and air travel demand, as empirically determined by the PaPb/D formula. Persons of families in the high income brackets frequently engaged in intercity air transport, and the corresponding median family income of these air travelers was twice that of the average family during the survey year.58

D. L. Cochran presented a quantitatively comprehensive study of interaction involving air transportation between 53 selected city pairs in the eleven western states of the continental United States during the

period of July 1 to September 30, 1963. Cochran also postulated that
the correspondence between the estimated and observed number of
intercommunity air passengers, as stipulated by the PaPb/D equation,
may be improved by utilizing alternative sociological measures of
population that are weighted toward those individuals who constitute
the larger portion of the air transportation market.\(^5^9\) In addition to the
direct intercity airline distance in statute miles, Cochran used various
sociological indicators of mass: population counts enumerated by the
1960 census, households with family incomes in excess of $10,000 in
1963, managers, proprietors, and officials according to the 1960 census,
total passenger departures from each airport in 1963, and the number
of installed telephone headsets in 1963. The coefficient of correlation
was calculated separately for each of the population expressions at
distance exponent values of 0.5-2.5 in 0.1 increments. The resultant
correlation coefficients ranged from 74.7 to 88.2, and the empirical
data demonstrated a linear relationship between the computed
interacts and the actual air passenger traffic with respect to the
specific city pair matrix.\(^6^0\) Cochran observed that the sociological
measure 1963 total airline passenger departures for all destinations
rendered the most significant degree of correspondence, \(r = 0.88\), at the
distance exponent of 1.5.\(^6^1\) The variances between the expected and the


\(^{6^0}\) Ibid., pp. 106 and 107.
actual values were statistically significant, although the author noted that the use of 1960 population data with 1963 observed traffic counts may have introduced a substantial error in calculations.

The interactance equation was utilized by J. T. Gray and J. P. Rowe in the examination of the determinants for air passenger traffic between Alaskan communities possessing 500 or less inhabitants in the arctic/western and the northern portion of the interior transport regions during the third quarter of 1979. A multiplicative weighting was assigned to the population component to measure differences in the individual propensity to interact via intercity air transport in various geographical locations within Alaska. The attraction variables analyzed comprised the 1980 numerical populations of the interacting communities and the 1977 per capita incomes pertaining to each population concentration. The resistance variables tested encompassed the air distance between the city pairs and the per mile tariff. Gray and Rowe reported that the population and the per capita income variables produced positive correlation coefficients at the 0.01 significance level, and thus proved to be important determinants influencing the passenger traffic levels examined. The resistance factors of direct distance and per mile tariff generated the expected negative impacts on passenger traffic and illustrated an inverse relationship with the intercity interaction.62 The results obtained supported the general

61 Ibid., pp. 103, 104, and 107.

assumption incorporated in the gravity model that the potential for population movement between places is limited by distance.\textsuperscript{63} The authors concluded that the significant indicators of rural Alaskan air passenger traffic are the population and income appropriate to each center, the distance separating the communities, and the per mile fare. However, in their aforementioned research, Gray and Rowe applied non-directional observed origin and destination segment survey data. These traffic counts indicate the number of passengers who traveled on the particular segment and do not necessarily signify the true origins and destinations of the passengers, rendering it difficult to sort out local and transfer traffic from the totals recorded.

\textsuperscript{63} Ibid., p. 62.
CHAPTER III

RESEARCH DESIGN AND APPLIED METHODOLOGY

A. Selection and description of the study area

The state of Alaska was selected as the unit of observation for this study considering its unique transportation system and the vital role of aviation within the network.

The interaction of social, economic, physical, environmental, and energy factors have conjointly influenced the development of Alaska's transportation system. The initial dependence of the state's economic activity on available natural resources resulted in a distribution of small population concentrations in locations that accommodated water-borne transportation, acceptable distance to market, and efficient provision. These development centers were principally aggregated along the 5,580 miles of coastline and the Yukon River, often separated by vast distances lacking highway or alternative overland transportation connections. Alaska's half of a million residents (that is, approximately one person per square mile) are currently concentrated in or proximal to urban locations, and in small isolated communities dispersed throughout an expansive area.

Alaska's diverse terrain, elevation, and climate have affected the type and extent of transportation within the country's largest and chiefly undeveloped and unsettled state (Map 1 provides a general overview of Alaska's landforms). The land mass of Alaska encompasses 586,400 square miles, equivalent to one-fifth of the total area of the United States, and contains geographic features such as the nation's two largest national forests, eleven of the twenty highest mountains on the continent, 2000 miles of the Yukon River, the Kuskokwim River (800 miles long), and 20,000 square miles of smaller waterways and lakes, which together with the offshore continental shelf, constitute one of the world's most profitable fisheries. The 550,000 square miles of ocean shelf is furthermore a source of oil, gas, gold, and additional hard minerals. An additional mainspring of fossil fuels and hard minerals exists in the suitable geological characteristics dispersed throughout the state.

The four climatic zones in Alaska comprise 1) the arctic, that extends from the Arctic Ocean to the Brooks Mountain Range, 2) the continental zone, which continues throughout most of the state with the exclusion of the coastal areas, 3) the transition between the maritime and continental zones, that includes the western coast and all of the Alaskan Penninsula aside from the southern coast, and 4) the maritime zone, which covers the southern coast, the Aleutian Islands,

65 Ibid., p. 7-12.
66 Ibid.
and the panhandle of southeastern Alaska. These severe climates and rugged topography contribute to the ineffective utilization of overland transport within the state.

The transportation system in Alaska is differentiated by its utmost reliance on non-overland modes. Alaska's remoteness from the United States, the cost of transporting commodities via the state highway system, and the absence of a connection to the North American Railroad network are factors that make marine transportation the state's foremost means of moving consumer goods. However, the transport routes serving many outlying locations are inoperable during the winter season, along with the state's river system. Inhabitants of these remote communities and of isolated interior points must therefore rely on air service for the shipment of supplies, as well as for the transport of persons throughout the state.

Air travel is Alaska's principal passenger transport system and serves an essential function in the intra-Alaska transportation network due to the state's large and sparsely populated land mass, its topography, the distribution of population, and the lack of direct surface transport in many of its regions (please refer to Map 2). The demand for air service is a function of the competition between components of the transportation system. The commercial air system

67 Ibid., pp. 7-12 and 7-13.

furnishes passenger travel and freight shipments where alternative transportation modes are either insufficient or nonexistent. The railbelt corridor is the sole transport sector in which a diversity of modes and services are competitive. For the remaining inhabited areas in Alaska, air service is the only regularly scheduled, year-round transportation mode and is thus the chief method of inter- and intra-regional transport throughout the state.

Alaska's transport network may be described on a regional basis, each area identified with the population and resource requirements, and its geographic limitations. The transport regions identified by the University of Alaska, Institute of Social and Economic Research, are indicated in Map 2. The arctic/southwest transport system is largest in size and smallest in population density. This area produces the greatest amount of seafood within the state, and the fisheries industry has strongly affected the development of the transportation network, which does not possess any overland modes aside from seasonal, small capacity access roadways. The Marine Highway system operates to the port located in Kodiak, one of two stations that support commodity flows exceeding 100,000 tons annually. Marine transport is less economical in this region than in areas that are more populated and convenient. Passenger service is infrequent and is utilized mainly to transport vehicles for recreational purposes. Air travel is the predominant method of passenger and freight transport due to the long distances between population aggregations and the lack of a regularly
scheduled year-round traffic option in many locations. The airports of King Salmon, Kodiak, St. Mary's, Dillingham, Barrow, Galena, Bethel, Kotzebue, Nome, Unalakleet, and Aniak are the principal activity centers of the region, providing scheduled jet services and widespread commuter service.

In the southeast region the foremost commodity influencing the transport structure is the timber industry, resulting in a number of population centers of moderate size that are not connected via overland transport. Roads in this area exclusively constitute local service streets or logging routes. The region maintains several significant sea ports in Ketchikan, Juneau, Sitka, Skagway, Wrangell, and Haines, all served by the Alaska Marine Highway system. Ferry service is primarily used to transport bulk goods into and out of the state, while passenger activity is infrequent and seasonal. The air mode is the principal means of transporting passengers from this region to the remainder of the state. Compared to the rest of the state, air service in the southeast area is distinguished by more extensive jet service and greater regularity between air service hubs and nonregional center locations. The substantial intercommunity air

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passenger traffic is the consequence of the larger rural settlements and shorter intervening distances within the region. Juneau, the population centroid of the area, as well as the state capital, functions as the hub for scheduled air carrier and commuter service. Additionally, the airports located in Ketchikan, Sitka, and Petersburg serve as major transportation, transfer, and distribution centers.

Finally, the interior/southcentral region is characterized by the largest part of the state's population and economic activity. The area, also indicated as the railbelt corridor, includes approximately 75 percent of Alaska's residents, exports chemicals, crude petroleum and its products, and provides various service sectors. The variant economy and adequate population density support an expanded transportation system including substantial overland modes. The region contains the only developed road and highway network within Alaska, encompassing nearly all of the Alaska Highway system except for local, small capacity routes and limited regional highways. Highway traffic is composed of both commodity and passenger transport, the latter predominantly tourist and recreational movements. However, traffic volumes are moderate, aside from locations at which the system borders urban areas and on the Kenai Peninsula, and exhibit extreme seasonal


Demand on several segments is therefore inadequate to justify winter maintenance and roads are only open during the summer season. The secondary roads suit local community needs and grant recreational access, and are passable solely during the summer months. The area is additionally served by the Alaska Railroad, although the market offered is limited by the capability and number of railcar barges included in its interline service. The state railroad system is primarily used to handle general cargo between a few origins and destinations, and traffic on the two segments accommodating daily passenger service during the summer and thrice per week in the winter is minimal. Also included in this transport region is the Marine Highway system that utilizes six seaports—Seward, Valdez, Homer, Whittier, Seldovia, and Cordova—which individually manage substantial traffic volumes, and an active river port. Both passenger and freight service is offered several times per week on most segments, accessible all year. Although most passenger traffic moves by air, air service is not as prevailing as in other regions of Alaska because the highway and rail networks exist. Air service is extensive, and connects the major population centers in the area. Anchorage is the hub of the interior/southcentral region as well as the state, and together with Fairbanks, provide international

73 Ibid., pp. 17 and 18.

and interstate access points to Alaska and major urban centers with scheduled jet service.

Another contributing factor in the geographical limitation of the present study was that air transportation in Alaska reflects a very representative type of interaction because it extends beyond the traditional air service markets and is used by a large portion of the population. Substitution with road, rail, or marine transport is mostly unavailable to the prospective traveler, or is often insufficient in locations where these alternative modes supplement air service. The total volume of passenger travel is essentially confined to scheduled and non-scheduled air carrier and commuter air transport. Of the transportation modes available within the state system, the airplane directly serves the most persons, and Alaska therein surpasses the rest of the United States per capita in the amount of air mileage traveled, number of aircraft, and air freight and air mail volumes.75

Air travel is a thoroughly established, primary means by which intense community interest is developed between cities, even in the regions providing alternative modes of transportation, and thus represents a vital element of Alaska's economy. The intercity trip is the fundamental unit of total air passenger traffic within the state, and any changes in volume of flow or facility additions may potentially impact numerous sectors of the network. The development of effective, dependable, and efficient air service in the state is therefore essential

75 Ibid., pp. III and 2.
and brings this component of the transportation system in focus of constant interest.

Social and economic activity are the primary modifiers of the demand for air passenger transportation in Alaska, and changes in population, employment, and economic conditions, therefore, impact the movement of persons within the network. (In the reverse order, the expansion of transportation services or facilities affect the state's social and economic structure.) Between 1959 and 1990, the population of Alaska grew by approximately 150 percent, and the 1980's average annual growth rate was 2.75 percent. Under a moderate growth scenario, the state's population will continue to increase from 553,600 persons in 1990, the base year examined in this thesis, to 716,500 by the year 2000 and 868,300 by 2010. Proportionally, the demands on the air transportation system will be extended. This rate of population growth for the near future constitutes the most valid forecast for Alaska, as dictated by its history since statehood. The projections consider a natural population growth, migration, and incorporate the effects of the oil, timber, fisheries, and hardrock mining industries, as well as tourism activity, federal spending (largely military), and state and local government employment appropriate to Alaska's developing economy. Future levels of aviation activity in Alaska are anticipated to

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increase, and the state will continue to support the greatest amount of air service per capita in the nation.\textsuperscript{27}

B. Selection of city pairs

The framework of this study was defined by a selection of interacting city pairs for which scheduled air service counts and adequate demographic and economic data were available for 1990, the base year elected. The air passenger traffic data comprised true origin and destination counts, considering all fare classes, for 1990 scheduled air carrier and commuter service, and the number of enplanements at each city airport pertaining to scheduled and non-scheduled U. S. certified route air carrier service and scheduled U. S. commuter service.\textsuperscript{28} City pairs for which these figures were not available, were eliminated. The demographic data constituted population counts enumerated by the 1990 census. The economic data that were utilized in the analysis included 1990 census per capita incomes, and the total number of persons actively employed in the labor force, armed forces and civilian force, in 1990.\textsuperscript{29}

\textsuperscript{27} State of Alaska Department of Transportation and Public Facilities, \textit{Alaska Aviation System Plan, Phase 1 Report: Alternatives}. Published by TRA/Farr, Anchorage, Alaska, August, 1982, pp. 1 and 15.

\textsuperscript{28} The total number of enplaned passengers, air carrier and commuter service, at each of the study area airports, was available from the \textit{Airport Activity Statistics of Certified Route Air Carriers, Calendar Year 1990}, published by the U. S. Government Printing Office, Washington, D. C.
The selection criteria for the group of representative city pairs were: Alaskan communities with a permanent population, in 1990, of 400 or greater; population centers that are not military bases; a distance exceeding 150 great circle miles between city pairs where alternate modes of transportation are available; airline points that directly serve their community and where service is likely to continue; and reliable and regularly scheduled air service between the city pairs. The requirement for a population minimum resulted in a sufficient geographical distribution throughout the state, traversing the transportation system's three regions, arctic/southwest, southeast, and interior/southcentral, in order to constitute a fair sample. Alaskan cities with a population equal to or exceeding 400 in addition are characterized as "first class" by the Alaska Department of Community and Regional Affairs. Airline stops that are civilian or military airports serving primarily a military base were excluded from this investigation because the format of recorded air passenger counts fails to account for traffic via military aircraft.

Within the 0-150 mileage bracket, available automobile, marine, or rail service tend to provide the dominant modes of passenger exchange and aviation management interest is insignificant. The implemented restriction in distance for intercity air passenger travel

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79 The 1990 census populations, and the 1990 per capita incomes and employment statistics, pertaining to the selected Alaskan cities, were furnished by Greg Williams and Bob Elliott of the Alaska Department of Labor, Research and Analysis, respectively. The great circle mileages between city pairs were computed via the software program "Distcalc", prepared by the U. S. Department of Transportation, and provided by Dianna Strain, transportation analyst at the U. S. Department of Transportation, Alaska Aviation Field Office.
considered in this study was decided upon as the minimum distance for which intercommunity air travel time is favorable and thus competitive to passenger transport. This limitation of intervening distance moreover addressed the existence of the nearby airport problem affecting the interactance equation within the framework of this study. Several studies have suggested that an airport serving a smaller community situated less than 75 miles from a well developed, centrally located air facility, will suffer a loss of passenger traffic to the nearby major airport. The option of reaching a larger air terminal that may provide cheaper fares, frequent schedules and more convenient air service routes, more modern aircraft and better facilities, however, is not available to many Alaskans, especially rural inhabitants, due to the lack of overland transportation and the time involved in traveling the long distances between population points. In this thesis, the number of trips taken was consequently postulated to be roughly proportional to the amount of person to person interactions.

The communities involved in this study are listed in Table 1 by transport region, along with their populations, city airport enplanements, and per capita incomes and employment volumes, all for 1990. The analysis has been limited to two sample subsets. One subset contains 35 cities, involving 44 interacting pairs. In order to improve the statistical accuracy by employing larger traffic volumes, the second

### Table 1

Cities Pertaining to the Study Area, Their 1990 Census Populations, Number of City Airport Enplanements, and Per Capita Incomes and Employment Volumes, by Transport Region

<table>
<thead>
<tr>
<th>City</th>
<th>Population</th>
<th>Enplanements*</th>
<th>Income ($)</th>
<th>Employment**</th>
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<td>841</td>
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\textbf{TABLE I. continued:}

<table>
<thead>
<tr>
<th></th>
<th>Population</th>
<th>Enplanements*</th>
<th>Income ($)</th>
<th>Employment**</th>
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<td>16962</td>
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<tr>
<td>Yakutat</td>
<td>534</td>
<td>8912</td>
<td>14396</td>
<td>254</td>
</tr>
</tbody>
</table>

| Interior/ |            |               |            |              |
| S. Central|            |               |            |              |
| Anchorage| 226338     | 1525455       | 19620      | 121866       |
| Cordova  | 2110       | 21176         | 23408      | 1195         |
| Fairbanks| 30843      | 262170        | 14665      | 15853        |

* from large and commuter air carriers.

** indicates total employed in labor force, armed forces, and civilian force.

\textbf{Sources:} 1990 United States Census; and 1990 Airport Activity Statistics of Certificated Route Air Carriers and 1990 Commuter Air Carrier Activity, Table D1.
subset consists of sixteen of Alaska's seventeen air service hubs and 22 interacting city pairs, all of which comprised communities in the first subset. In his examination of the interactance hypothesis, J. A. Covanaugh recognized the need to test the equation on both reliable and large quantities of data. Covanaugh determined the degree of association between estimated and actual values to be higher when the traffic data included numerous observed individual interacts.81

Service to rural Alaska is facilitated through the seventeen air service hubs indicated by the Alaska Department of Transportation and Public Facilities. The hubs serve as primary or secondary intrastate access points to or within a region of Alaska and to a medium, large, or regional population center, and often comprise the service centers for a region, possessing facilities such as government agencies, hospitals, and specialized commercial activity.82 The major movements of people and goods are concentrated within the travel corridors connecting these principal activity centers. The determination of a community as an air service hub is a result of the evolution of air service in Alaska. The air service hubs were designated as transportation centers for bush villages and distribution centers for surrounding communities at the time the state's three primary airlines started functioning: Wien Air


Alaska (serving the arctic and central regions), Reeve-Aleutian (accommodating the Aleutian Islands), and Alaska Airlines (supplying the southeast region). These air carriers selected the hubs based on their geographical locations and operational requirements; that is, the proximity of the center to outlying communities necessitating air service and the existence of airport facilities that could support transfer and distribution activities. The air service hub of Petersburg, Alaska was not included in this study because of the unavailability of relevant air service data.

The distribution of the cities and the corresponding interacting pairs pertaining to each sample subset are depicted on Maps 3 and 4.

C. Selection of various testable formulations of the interactance equation

"The success of any model depends upon the correct selection and evaluation of the facts it is constructed to represent."\(^3\) The basic gravitational theory was modified in order to ultimately achieve a basis for comparison and spatial prediction. Model specifications were altered via testing different combinations of variables that may result in functional forms of the equation. In the present study, the formulation of several testable versions of the interactance equation,

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**Sample Subset #2**

City Pairs (22)

- Bethel
- Kotzebue
- Nome
- Galena
- Fairbanks
- Anchorage
- Unalakleet
- St. Marys
- King Salmon
- Kodiak
- Juneau
- Sitka
- Ketchikan
- Dillingham

**Actual Observed Air Passengers 1990**

- Less than 5000
- 5000 to 25000
- 25000 to 75000
- Greater than 75000

**Map 4**

**Alaska Air Service Hubs & Interacting City Pairs**

Source: Reuters Information Services

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applied to potential airline passenger travel between Alaskan cities, entailed selecting and manipulating various usable socioeconomic parameters that (a) possessed long-term stability, (b) were considered to have modulating effects upon the propensity to interact, and (c) constituted meaningful measures of that portion of total social interaction between the population centers which is represented by scheduled air carrier and commuter transportation. The selected determinants affecting passenger traffic, in combination with an optimized value of the distance maximizing exponent, should thereupon result in the highest degree of correspondence between the estimated and observed airline passenger traffic among the selected community pairs.

Overall, the variables which were applied in the interactance equation substantiated the assumption that the indicators of air travel consumption within the intra-Alaska market are the presence of people, levels of income, and the number of jobs, and that a friction against this interaction is caused by the direct airline distance between city pairs. The relationship of the components of interaction in the model is indicated as:

\[ \frac{1}{{e}}T = \frac{[(11) P1] [(12) P2]}{D^x} \]
The populations, P1 and P2

The sociological measure of mass at each origin and destination was tested via two alternative variables. Data set A comprised the standard representation of the population component: the number of people of the urbanized area in which each airport is located, as enumerated by the 1990 census. Previous research has demonstrated that the variations of origin and destination traffic volumes are proportional to the relevant numerical populations to the first power, and that this measure may be applied in the interactance relationship to assist the projection of potential future intercommunity air passenger traffic regardless of whether the city pairs have previously had air service.84

The direct population counts appropriate to each community, however, may not reflect the entire market area served by a particular airport and those subgroups of a population that take part in the interaction. D. M. Belmont was the first to propose an alternative sociological reference measurement of the mass quantity in the gravity formula as a means of reducing disproportions in population allocation, and contended that the total volume of air passenger traffic generated at each airport more suitably reflected the number of interactors and the effective size of the centers.85 An ensuing investigation into


potential air passenger traffic between selected city pairs in the eleven western states of the continental United States during a specified three month period, endeavored by D. L. Cochran, rendered the highest association between the expected and actual interaction when the total passenger departures from each airport were applied as the sociological measure of mass at the origins and destinations in the gravity equation in place of the entire population. Cochran moreover found that the number of individuals who traveled between each specific community pair comprised an insignificant portion of the total passengers enplaning at the city airports.

Data set B included the number of enplaned passengers, referring to scheduled and non-scheduled U. S. certified route air carrier and scheduled U. S. commuter service, departing from each airline terminal for all destinations during calendar year 1990. The insertion of the number of enplanements into the equation as a base variable provided a more accurate indication of that population segment that actually participated in the interaction and utilized the services and facilities furnished by the respective airports, via considering the comprehensive geographical area accommodated by each of the terminals.


Ibid., pp. 79 and 80.
Employing traffic generation statistic as an index in the interactance equation to forecast traffic generation potentials and produce useful management data, presupposes that reliable and regularly scheduled air connection between the interacting city pairs has already been established. The use of airline passenger departures at a specific airport for all destinations as a sociological measure of population in the gravitational analysis technique offers a means for evaluating the extent to which present intercommunity air passenger traffic potentials are being realized. The variable is not applicable for proposing service between locations that thus far have not supported reasonably sufficient air activity, and may be misrepresentative when investigating probable traffic between points at which one or both of the airports have not been servicable for long periods due to traffic restrictions or determents.

The specific levels of interaction, 11 and 12

S. C. Dodd and J. A. Cavanaugh suggested that the socioeconomic intensity particular to population groups may be indicated by weighting the masses with influences such as sex, age, income, occupation, and education, and that an index of specific activity may be the product of several of these candidate subfactors. However, the manipulation of

88 Ibid., p. 54.
89 Ibid., pp. 108 and 109.
numerous variables substantially complicates the formula and the computation of interaction potentials, and may be avoided by introducing a single factor that most satisfactorily represents the attraction components in the gravity model.\textsuperscript{91}

Several analyses have ascertained that the propensity for passenger travel is affected by economic considerations, such as occupational responsibilities and the feasibility of an individual to incur the cost of transport. Various above-cited applications of the interactance equation (discussed in Chapter II. B.) have indicated the economic character of a population center to exert an influence upon intercity air passenger traffic levels. Greater levels of employment provide individuals the opportunity to purchase air travel, and thus increase the demand for air transportation.

A study undertaken by G. A. Mayhill suggested that while employment may indeed serve as an index of the economic composition of the population groups, those individuals who constitute a larger portion of the intercommunity air travel market may be identified by the incorporation of a money income variable into the specific interactance formulation.\textsuperscript{92} A number of studies have confirmed the

\textsuperscript{91} Olsson, Gunnar, \textit{Distance and Human Interaction}. Bibliography Series, number 2, Regional Science Research Institute, Philadelphia, Pennsylvania, 1965, p. 55.

relationship between income and the level of demand for air transportation, and shown the appropriateness of utilizing the income potential of each place in the gravity equation as an index of the average propensity to travel by airway between cities of all individuals in the community. In his empirical estimation of air passenger traffic from Seattle, Washington to 47 randomly selected cities throughout the United States from March 1, 1947 to March 1, 1948, Cavanaugh applied per capita income as an adjusting factor in the gravity model of human interaction to study the regional differences which influence the amount of interaction, and determined its significance within the specific research context. The author observed that inasmuch as interaction entails economic regard, areas with a higher average wage level would accordingly use a greater amount of flight transport than would be predicted by a simplified version of the equation which failed to incorporate this attraction factor into its interactance index. The variability of per capita income likewise produced a positive coefficient, significant at the 0.01 level, in the examination of scheduled air service in rural Alaska by J. T. Gray and J. P. Rowe in 1981. The authors concluded that income was a primary determinant of the demand for air transportation between two places.

93 Please refer to Chapter II. B., pages 38-42.

In the present study, the specific indicators of each population aggregate that were postulated to affect the amounts and intensities of the intercommunity air passenger traffic flows examined, were determined considering interregional distinctions in employment and income levels. These indices were introduced into the interactance equation to measure the differences in the individual propensity to interact via intercommunity air transport between the set of the groups studied in various geographical locations within Alaska. The socioeconomic weights encompassed the 1990 census per capita incomes and employment volumes, number of actively employed in the labor force, armed forces and civilian force, pertaining to each city listed in Table 1. The indicators of interaction were tested separately and in combination with each other in both data sets A and B, in order to reliably evaluate the air traffic potentials.

The space dimension, $D^2$

The effect of distance on the interaction potential of intercity air passengers in Alaska was assessed by considering the great circle mileage between each interacting community pair, shown in Table 2. The linear treatment of distance was selected as the resistance variable in order to maintain the Euclidean properties of space incorporated in the gravity model, to maintain the simplicity of computation provided by

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<td>Sitka*</td>
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<td>HPB</td>
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<tr>
<td>Ketchikan*</td>
<td>KTN</td>
<td>Yakutat</td>
<td>YAK</td>
</tr>
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</table>

Distances are in great circle miles.
**Source:** Distcalc, U.S. Department of Transportation.

* indicates an Alaska Department of Transportation and Public Facilities (DOT & PF) air service hub.
**Source:** Alaska DOT & PF.
the equation, because the shortest airline distance is used by air carriers as the basis for fare calculations, and since the data were readily accessible.

The distance between city pairs inevitably affects traffic volumes because of the greater expenditures involved in undertaking lengthy journeys. The friction of distance in Alaskan intercity air passenger traffic may be more proportional to the linear distance separating the communities than to travel time, transport cost, or other social measurements due to the relative ease and convenience of movement from location to location via air transportation. Air travel is Alaska's principal passenger transport system due to the lack of overland modes and the time involved in traveling the long distances between population points. Substitution with road, rail, and marine transport is largely unavailable to the prospective traveler, and is often insufficient in locations where these alternative modes supplement air service.

The demand for air passenger service is not coupled to fluctuations in the Alaskan economy as tightly as in states with various modes of competitive transportation, and the price of air transportation relative to other components within the network is therefore not as imperative in the analysis of Alaskan aviation. Moreover, the utilization of transport cost as a transformation of the distance variable in applying the interactance equation to air passenger traffic potentials has produced unsatisfactory results, because air fares tend to increase in a few, large steps in various directions, rather than gradually and continuously with per mile distance. The linear
measurement of intervening distance provided a competitive measure for scheduled air carrier and commuter activity, the types of service that amount to virtually the entire volume of passenger traffic in Alaska, and were included in the observed passenger counts (10) examined in this study.

The correlation between the theoretical and actual volumes of airline traffic was further refined via adjusting the distance exponent in the interactance formula. An optimal exponent of the distance factor specific to the impact of distance on intra-Alaska air passenger travel between the selected cities was empirically determined by way of an analysis for each interactance formulation in 0.5 increments from 0.5 - 2.5, the range previously determined to maximize the correspondence between the estimated and observed values with respect to scheduled commercial air transportation.

The time dimension, T

The length of time of the observed interactions in this study spanned the calendar year 1990. For convenient analysis and pertinent results, both the above-mentioned hypothesized variables and the origin and destination air passenger traffic counts were recorded annually and were all available for 1990. These comparable periods provided a preferred basis for assessing the stability characteristics of airline traffic within the intra-Alaska market. 1990 was the most recent year for which the United States census data on population, income, and employment were available, and the focus on this period ensured that
the research results would relate to current conditions within the study area. By confining the study to a fixed time period, the duration of interaction was held constant and was therefore eliminated as a factor in the interactance equation.

Examining the demand for year-round air transportation negated the effects of seasonal variation upon traffic flows encountered in previous investigations for which the period of actual interaction ranged from one to four months. The seasonal fluctuations within this context may include the availability and accessibility of alternative modes of transport in areas where the sectors exist, passenger recreation and tourist movements, or air fares that are adjusted upward during peak seasonal demands to allow for tourist traffic and discounted when business is lagging.

D. Statistical analysis of the interaction data

The forecasting potential of each formulation of the interactance equation as applied to air passenger transportation between the selected intra-Alaska city pairs, was evaluated by several statistical procedures that described the data and portrayed the relative relationship between the expected and observed values. The four

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97 The statistical investigation of the interaction data was performed via the statistical and information analysis system, SPSS, version 4. 0. 2, copyright by SPSS Inc., Chicago. Illinois, 1990.

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socioeconomic characteristics of the communities, introduced into the interactance equation as presumable measures of the propensity for interactional behavior involving intercity air passenger traffic within the research context, generated eight combinations of variables that produced different interaction indexes for every distance exponent examined. The statistical examination of the obtained data began with a correlation analysis for all of the possible pairs of the variables. After adjusting for the socioeconomic factors, this resulted in a total of forty estimated interactions (Ie), each of which was compared with the total actual intercity air passenger movements (Io). All of the coefficients of correlation were based on two sets of observed interacts: a) 1990 origin and destination air passenger counts for 35 cities and 44 interacting pairs, and b) 1990 origin and destination air passenger counts for sixteen of Alaska’s seventeen air service hubs, involving 22 interacting community pairs.

The number of passengers traveling by airway is a measurable index of interaction for which distance constitutes an effective variable, the pertinent data are obtainable for research, and was shown to follow the P1P2/D relationship. However, the utilization of true origin and destination air passenger counts has not yet been undertaken to estimate aviation traffic via the interactance equation. Air traffic may be classified as local or transfer movement, the former of which comprises passenger travel that is either embarked upon or

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98 The gravity formula and the interactance equation as applied to air transportation are discussed in Chapter 11. B.
terminated at the population point designated as the respective origin or destination. For air service hubs it represents traffic that would exist if the community was not a principal activity center. Transfer traffic, on the other hand, includes passenger traffic that has shifted to another aircraft or carrier for further movement. It is not feasible to differentiate between local and transfer traffic from the totals disclosed because of the tabulation methods. Air traffic volumes are annually recorded as on-line, indicating the number of persons who traveled on a specific segment but not necessarily stating the actual origins and ultimate destinations of the passengers. For example, the transfer point would be reported as the destination of the air traveler if the passenger flew one portion of the entire trip via the line of one carrier, and continued the journey on a competing airline.

As a thorough means of measuring aviation traffic flows, the data for airline traffic utilized in the present analysis comprised intra-Alaska absolute origin and destination passenger counts, all fare classes, for 1990 scheduled air carrier and commuter service. The true origin and destination traffic counts indicate the initial and terminal points of interaction, and furthermore correspond to the population, income, and employment indices applied in the interactance equation as the socioeconomic characteristics particular to each community. The passenger flows were determined via a) a ten percent sample of

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ticketed passengers recorded traveling from a location within Alaska to an intrastate destination on scheduled U. S. air carriers and commuter airlines between January 1, 1990 and December 31, 1990, and b) specially acquired activity reports requested directly from the air carriers serving the intra-Alaska market. For the purposes of the present analysis, the format of air traffic counts was non-directional. That is, the tabulated totals included the number of passengers traveling in both directions between each city pair. Within this context, the total number of passengers flown between the selected intrastate communities during the year examined was 559,320. The observed intercity interacts ranged from 140 to 153,750 passengers in sample subset #1, and spanned 330 - 153,750 in subset #2, as depicted by several intervals of passenger traffic on Maps 3 and 4.

The computed coefficient of correlation assessed the statistical correspondence between the predictions of the interactance theory and the observed interacting. This approach represents an objective method by which the relationship between the pairs of variables is measured, quantitatively described, and rendered comparable. The calculation of the correlation coefficient was accomplished by the Pearson method, a useful, symmetric index that summarizes the observed strength of
the linear association between variables. Pearson's coefficient is abbreviated as r, and its values range from -1 (a perfectly negative relation) to +1 (a perfectly positive linear correlation). The sign designates the direction of the interrelationship from positive to negative correlation. Variables are positively correlated if high values for one cause similar changes in the other or if two sets of variables with low values are in direct proportion to each other, and negatively associated if the variables illustrate an inverse relationship. The numerical value of the coefficient expresses the strength of correlation and was used as a vital test of the interactance hypothesis. An r value of 1 denotes an exact correlation between the interactance theory and the observation, and thus a perfect prediction of interaction among the populations involved. A low coefficient, close to zero, indicates a weak correlation and may signify the invalidity of the interactance hypothesis within the research parameters, the presence of historical or overlying factors, or errors. A random, nonlinear correspondence between variables is represented by an r value approaching zero. A prediction between variables via the Pearson technique is more precise


among components that are strongly related, because of a minimization of the degree of error involved in the estimation.\textsuperscript{105}

The correlation index between the expected behavior predicted by the equation (1e) with the actual interactional behavior increasingly approached unity and signified a strong association between the hypothesized factors of interaction and observed intercity air passenger traffic in Alaska, as the components of interaction became well determined, measured, and considered.\textsuperscript{106} If the predictance correlation, \( r \), was raised by the employment of a hypothesized measure of interaction potential or a specific differential characteristic pertaining to a population unit, singly or in combination, the candidate indicator could be recognized as a factor in the interactance equation.\textsuperscript{107} J. A. Cavanaugh observed a correlation of \( r = 0.80 \) at the 0.05 level of significance between predicted interaction and the actual amounts of observed interaction, in his analysis of the interactance equation as applied to passenger flows by airlines between Seattle, Washington and various United States cities in 1948.\textsuperscript{108}

In this thesis, the significance of the calculated interrelationship between variables was then statistically tested. This test evaluates the

\begin{footnotesize}
\begin{enumerate}
\item Linton, Marigold, Phillip S. Gallaw Jr., and Cheryl A. Logon, \textit{The Practical Statistician}. Published by Brooks/Cole Publishing Company, Monterey, California, 1975, p. 344.
\item ibid., p. 245.
\item ibid., p. 248.
\end{enumerate}
\end{footnotesize}
probability that the association between variables may be due to random variation, and complements the coefficient of correlation. While a descriptive statistic such as Pearson's coefficient, r, measures the extent of agreement between two sets of paired values, the significance level indicates the chance of correlation when no linear relationship exists in the population among the variables examined. If the r obtained exceeded the critical value specific to the number of paired scores involved in the study, it could be deduced that the correspondence in the sample was representative of an existing relation in the population from which the observations were obtained. A two-tailed significance test was utilized to determine the percent probability of chance variation in two directions, because the pairs of variables may potentially have been positively or negatively correlated. The critical value of the correlation index, r, required for sample subset #1, involving 44 interacting city pairs, was 0.288 for the 0.05 level of statistical significance and 0.372 for the 0.01 level. The difference between sample subset #2, containing 22 pairs of communities, and the observed interaction, was determined


111 Ibid., p. 375.
statistically significant at the 0.05 level with a value of $r = 0.428$, and $r = 0.562$ at the 0.01 level.\textsuperscript{112}

The values of the variables for all of the cases were plotted on a scatter diagram, constructed for each computed correlation. The graphic representation depicts the degree of correspondence between the estimated amounts of interaction and the actual counts of air passengers at origin and destination, from which previously undiscovered relationships among certain city pairs can be detected, conclusions may efficiently be realized, explanations for observed behavior attempted, and ultimately, limitations of the research revealed.

The expected interaction (Ie) according to several predictions of the interactance equation was plotted in various magnitudes on the ordinate, while the original observed interaction values by city pair (Io) were placed along the abscissa at evenly spaced intervals. The calculated relative values of interaction were not depicted on the y-axis as a standardized, measurable unit system because of their dependence on the various measures utilized to represent the population, socioeconomic indicator, and distance components in the interactance formulations. The values for each case on the estimated and the actual interaction are presented via a symbol 1 on the scatter diagram. Due to the plotting capacity, cases with similar values for the

two variables are exhibited on the same point and are hence indistinct. Multiple cases at the same position may represent close but not identical values, and are signified by the actual number of overlapping points or via different symbols included in an attached key, which represent the number of coincident cases on the plot. Accordingly, an aggregation of points may be displayed on the plot upon the inclusion of cases possessing remote values.

A line most closely fitting the observed points was superimposed on the scatter diagram as a summary expression of the linear relationship in the data, indicated by the patterns of the plotted symbols. A linear data distribution is one in which the points representing the variates cluster around a straight line running through the plot, and implies a substantial correlation between exponentially related variables. Because both a linear and a nonlinear correspondence may generate similar values of r, the trend of the plot provides a valuable supplement to the correlation coefficient in verifying the interactance equation via its description of the relationship between variables, especially among significantly associated ones that have been confirmed at a 95% or 99% confidence interval.

The line of best fit was computed via the method of least squares, which incorporates the smallest sum of squared vertical distances from the observed data points to the line, and its intercepts were indicated


114 Ibid.
by the letter R placed at two positions in the margins of the plot.\textsuperscript{115} The trend line designated regularities and thus identified city pairs that significantly deviated from the hypothesized relationship between the expected and actual interaction, for which additional or alternative factors must be considered in order to increase the predictance.

\textsuperscript{115} Ibid., pp. 187 and 247; and Ibid., SPSS/PC+ Studentware. Copyright by SPSS Inc., Chicago, Illinois, 1988, p. 329.
CHAPTER IV

RESEARCH FINDINGS

R. Results of computation analysis

Figures 1 through 20 depict the results of the computations of the obtained data on the volume of intercity airline passenger traffic, intercommunity mileage, city populations, an alternative sociological measure of population, and socioeconomic indicators of interaction, utilized in analyzing and evaluating the interactance equation within the parameters of this research as detailed in the previous chapter and summarized in Table I. The outcomes shown in Figures 1 to 12 reflect the various formulations of the equation as applied to the selected intra-Alaska city pairs (sample subset #1), whereas Figures 13 through 20 describe the findings appertaining to the air service hubs within the state (sample subset #2).

In Figures 1-5 are presented the statistical results concerning the formulations in which the numerical populations (data set A) were introduced as the sociological measure of mass at each of the selected pairs of cities in sample subset #1. Along the abscissa of the scatter diagrams are plotted the number of passengers moving via airway between the above-mentioned community pairs whose interaction values, as estimated by the interactance equation, are depicted on the
**FIGURE 1**

Correlation Coefficient and Scatter Diagram Between Observed Airline Passenger Traffic and the Interactance Index, Utilizing Variables Population, Distance, and the Distance Exponent 0.5, for Sample Subset 1, Data Set A

```
include file=data1a.plot.
1 data list file=data1a.dat/ pair 1-2 income1 3-9 emp1 10-16 enplane1 17-23
2 income2 24-30 emp2 31-37 enplane2 38-44 pop1 45-51
3 pop2 52-58 dist 59-62 observea 63-68.
```

This command will read 1 records from data1a.dat

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```
4 compute 11=income1*emp1*enplane1.
5 compute 12=income2*emp2*enplane2.
6 compute exp1a=(pop1)*(pop2)/dist**.5.
7 corr variables=exp1a observe1a/statistics=all.
```

--- Correlation Coefficients ---

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<td>1.0000</td>
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* - Signif. LE .05  ** - Signif. LE .01  (2-tailed)
FIGURE 1, continued:

PLOT OF EXPECTED DATA SET1A WITH OBSERVED DATA SET1A
For key see Appendix
Figure 2

Correlation Coefficient and Scatter Diagram Between Observed Airline Passenger Traffic and the Interactance Index, Utilizing Variables Population, Distance, and the Distance Exponent 1.0, for Sample Subset 1, Data Set A

```
include file=data1a.plot.
data list file=data1a.dat/ pair 1-2 income1 3-9 emp1 10-16 enplane1 17-23 income2 24-30 emp2 31-37 enplane2 38-44 pop1 45-51 pop2 52-58 dist 59-62 observe1 63-68.
```

This command will read 1 records from data1a.dat

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<td>F6.0</td>
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</table>

```
4 compute l1=income1*emp1*enplane1.
5 compute l2=income2*emp2*enplane2.
6 compute exp1a=(pop1)*(pop2)/dist**1.
7 corr variables=exp1a observe1/statistics=all.
```

--- Correlation Coefficients ---

<table>
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* - Signif. LE .05  ** - Signif. LE .01  (2-tailed)
FIGURE 2, continued:

PLOT OF EXPECTED DATA SET1A WITH OBSERVED DATA SET1A
For key see Appendix
Correlation Coefficient and Scatter Diagram Between Observed Airline Passenger Traffic and the Interactance Index, Utilizing Variables Population, Distance, and the Distance Exponent 1.5, for Sample Subset 1, Data Set A

include file=data1a.plot.
1 data list file=data1a.dat/ pair 1-2 income1 3-9 emp1 10-16 enplane1 17-23
2 income2 24-30 emp2 31-37 enplane2 38-44 pop1 45-51
3 pop2 52-58 dist 59-62 observea 63-68.

This command will read 1 records from data1a.dat

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</table>

4 compute 11=income1*emp1*enplane1.
5 compute 12=income2*emp2*enplane2.
6 compute exp1a=(pop1)*(pop2)/dist**1.5.
7 corr variables=exp1a observea/statistics=all.

-- Correlation Coefficients --

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* - Signif. LE .05    ** - Signif. LE .01 (2-tailed)
FIGURE 3, continued:

PLOT OF EXPECTED DATA SET1A WITH OBSERVED DATA SET1A
For key see Appendix

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Correlation Coefficient and Scatter Diagram Between Observed Airline Passenger Traffic and the Interactance Index, Utilizing Variables Population, Distance, and the Distance Exponent 2.0, for Sample Subset 1, Data Set A

```
- include file=data1a.plot.
  1 data list file=data1a.dat/ pair 1-2 income1 3-9 emp1 10-16 enplane1 17-23
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  3          pop2 52-58 dist 59-62 observe1 63-68.

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</table>

4 compute l1=income1*emp1*enplane1.
5 compute l2=income2*emp2*enplane2.
6 compute expla=(pop1)*(pop2)/dist**2.
7 corr variables=expla observe1a/statistics=all.

```
-- Correlation Coefficients --

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* - Signif. LE .05    ** - Signif. LE .01 (2-tailed)
```
Figure 4, continued:

Plot of Expected Data Set 1A with Observed Data Set 1A
For key see Appendix
FIGURE 5

Correlation Coefficient and Scatter Diagram Between Observed Airline Passenger Traffic and the Interaction Index, Utilizing Variables Population, Distance, and the Distance Exponent 2.5, for Sample Subset 1, Data Set A

-> include file=data1a.plot.
1 data list file=data1a.dat/pair 1-2 income1 3-9 emp1 10-15 enplane1 17-23
2 income2 24-30 emp2 31-37 enplane2 38-44 pop1 45-51
3 pop2 52-58 dist 59-62 observe1a 63-68.

This command will read 1 records from data1a.dat

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</tr>
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</table>

4 compute 11=income1*emp1*enplane1.
5 compute 12=income2*emp2*enplane2.
6 compute exp1a=(pop1)*(pop2)/dist**2.5.
7 corr variables=exp1a observe1a/statistics=all.

-- Correlation Coefficients --

EXP1A   OBSERVE1A
EXP1A    1.0000  .6970**
OBSERVE1A .6970**  1.0000

* = Signif. LE .05   ** = Signif. LE .01 (2-tailed)
Figure 5, continued:

Plot of Expected Data Set 1A with Observed Data Set 1A
For key see Appendix
ordinate. For the sake of brevity, the calculated coefficients of correlation and the scatter diagrams that were constructed for each value of intercity distance between 0.5 and 2.5 in 0.5 increments of the exponent, were cited only for sample subset #1, Figures 1 through 5, when the direct population counts were incorporated as the sole attraction variable in the model. Throughout the study, the relationship between intercommunity distance and the passenger counts at origin and destination was shown to be an inverse linear one. As summarized in Figure 2, a distance maximizing exponent of 1.0 provided the highest association between the interactance equation and aviation traffic among the selected cities in 1990, and hence was chosen as the base value to determine the outcomes of the formulations that were analyzed in Figures 6-20.

In sample subset #1, the identical demographic variable, combined with per capita income, was utilized in the gravity equation and the computed correlation index and scatter diagram for these values are given in Figure 6. Figure 7 shows the findings generated by using the number of individuals actively employed in the labor force, armed forces, and civilian force in conjunction with the population expression. Figure 8 illustrates the correspondence between le and lo stipulated by the interactance equation upon the introduction of the direct population counts, per capita income, and employment volumes.

The data for scheduled intra-state air passengers between the selected community pairs in sample subset #1 using the formulations that introduced the number of enplaned passengers departing from
FIGURE 6

Correlation Coefficient and Scatter Diagram Between Observed Airline Passenger Traffic and the Intercorrelation Index, Utilizing Variables Population, Income, Distance, and the Distance Exponent 1.0, for Sample Subset 1, Data Set A

> include file=data1a.plot.
1 data list file=data1a.dat/pair 1-2 income1 3-9 emp1 10-16 enplane1 17-23
2 income2 24-30 emp2 31-37 enplane2 38-44 pop1 45-51
3 pop2 52-58 dist 59-62 observe1a 63-68.

This command will read 1 records from data1a.dat

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</table>

4 compute 11=income1*emp1*enplane1.
5 compute 12=income2*emp2*enplane2.
6 compute exp1a=(income1*pop1)*(income2*pop2)/dist**1.
7 corr variables=exp1a observe1a/statistics=all.

--- Correlation Coefficients ---

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* - Signif. LE .05  ** - Signif. LE .01  (2-tailed)
FIGURE 6, continued:

PLOT OF EXPECTED DATA SET 1A WITH OBSERVED DATA SET 1A
For key see Appendix
FIGURE 7

Correlation Coefficient and Scatter Diagram Between Observed Airline Passenger Traffic and the Interactance Index, Utilizing Variables Population, Employment, Distance, and the Distance Exponent 1.0, for Sample Subset 1, Data Set A

> include file=data1a.plot.
  1 data list file=data1a.dat/ pair 1-2 income1 3-9 emp1 10-16 enplane1 17-23
  2 income2 24-30 emp2 31-37 enplane2 38-44 pop1 45-51
  3 pop2 52-58 dist 59-62 observe1a 63-68.

This command will read 1 records from data1a.dat

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4 compute I1=income1*emp1*enplane1.
5 compute I2=income2*emp2*enplane2.
6 compute exp1a=(emp1*pop1)*(emp2*pop2)/dist**1.
7 corr variables=exp1a observe1a/statistics=all.

--- Correlation Coefficients ---

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* - Signif. LE .05 ** - Signif. LE .01 (2-tailed)
FIGURE 7, continued:

PLOT OF EXPECTED DATA SET 1A WITH OBSERVED DATA SET 1A
For key see Appendix
FIGURE 8

Correlation Coefficient and Scatter Diagram Between Observed Aircraft Passenger Traffic and the Interaction Index, Utilizing Variables Population, Income, Employment, Distance, and the Distance Exponent 1.0, for Sample Subset 1, Data Set A

include file=data1a.plot.
data list file=data1a.dat/ pair 1-2 income1 3-9 emp1 10-16 enplane1 17-23
          income2 24-30 emp2 31-37 enplane2 38-44 pop1 45-51
          pop2 52-58 dist 59-62 observe1a 63-68.
This command will read 1 records from data1a.dat

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<td>63</td>
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<td>F6.0</td>
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</table>

compute l1=income1*emp1*enplane1.
compute l2=income2*emp2*enplane2.
compute exp1a=(income1*emp1*pop1)*(income2*emp2*pop2)/dist**1.
corr variables=exp1a observe1a/statistics=all.

--- Correlation Coefficients ---

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* - Signif. LE .05  ** - Signif. LE .01  (2-tailed)
FIGURE 8, continued:

PLOT OF EXPECTED DATA SET1A WITH OBSERVED DATA SET1A
For key see Appendix

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each airline terminal for all destinations (data set B) in place of city population to represent the airline segments for each value of distance, are indicated and plotted in Figure 9. The same demographic variable, applied along with money income, is illustrated in Figure 10. Figure 11 signifies the number of enplanements entered into the interactance equation in conjunction with the amount of employed persons in each place. The results produced by the formulations which incorporated all three of the previously mentioned variables are depicted in Figure 12.

An equivalent treatment of the data was adhered to in Figures 13 through 16, which specify and graphically summarize the association between the estimated and actual values when the population counts of each incorporated community, as enumerated by the census, were included in the gravitational formula to forecast passenger traffic levels within sample subset #2. In Figures 17 to 20 the number of enplaned passengers represented the populations of the air service hubs and interacting city pairs in the model.

The obtained results conclusively indicate a positive correlation, ranging from $r = 0.70$ to $0.97$ and significant at the 0.01 two-tailed level, between the expected interaction according to the predictions of the interactance formulations (1e) and the samples of actual observed aviation traffic (1o). The closeness of fits in both sample subsets 1 and 2, depicted by the scatter diagrams, is high with those sets of data in which either the 1990 census populations of each community or the number of enplaned passengers at each airline terminal departing for all destinations, were entered into the interactance equation as the
FIGURE 9

Correlation Coefficient and Scatter Diagram Between Observed Airline Passenger Traffic and the Interactance Index, Utilizing Variables Population, Distance, and the Distance Exponent 1.0, for Sample Subset 1, Data Set B

```
include file=data1b.plot.
data list file=data1b.dat/ pair 1-2 income1 3-9 emp1 10-16 income2 17-23
emp2 24-30 pop1 31-37 pop2 38-44 dist 45-46 observe1b 49-54.
```

This command will read 1 records from data1b.dat

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</table>

```
3 compute 11=income1*emp1.
4 compute 12=income2*emp2.
5 compute exp1b=(pop1)*(pop2)/dist**1.
6 corr variables=exp1b observe1b/statistics=all.
```

```
+-- Correlation Coefficients --+

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* - Signif. LE .05  ** - Signif. LE .01  (2-tailed)
```

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FIGURE 9, continued:

PLOT OF EXPECTED DATA SET 1B WITH OBSERVED DATA SET 1B
For key see Appendix

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FIGURE 10

Correlation Coefficient and Scatter Diagram Between Observed Airline Passenger Traffic and the Interaction Index, Utilizing Variables Population, Income, Distance, and the Distance Exponent 1.0, for Sample Subset 1, Data Set B

-> include file=data1b.plot.
1 data list file=data1b.dat/ pair 1-2 income1 3-9 emp1 10-16 income2 17-23
2 emp2 24-30 pop1 31-37 pop2 38-44 dist 45-48 observe1b 49-54.

This command will read 1 records from data1b.dat

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</table>

4 compute l1=income1*emp1.
5 compute l2=income2*emp2.
6 compute exp1b=(income1*pop1)*(income2*pop2)/dist**1.
7 corr variables=exp1b observe1b/statistics=all.

--- Correlation Coefficients ---

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* - Signif. LE .05  ** - Signif. LE .01  (2-tailed)

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FIGURE 10, continued:

PLOT OF EXPECTED DATA SET 1B WITH OBSERVED DATA SET 1B
For key see Appendix
FIGURE 11

Correlation Coefficient and Scatter Diagram Between Observed Airline Passenger Traffic and the Interactance Index, Utilizing Variables Population, Employment, Distance, and the Distance Exponent 1.0, for Sample Subset 1, Data Set B

include file=data1b.plot.
1 data list file=data1b.dat/ pair 1-2 income1 3-9 emp1 10-16 income2 17-23 emp2 24-30 pop1 31-37 pop2 38-44 dist 45-48 observe1b 49-54.

This command will read 1 records from data1b.dat

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</tr>
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<tr>
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<td>DIST</td>
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<tr>
<td>OBSERVE2</td>
<td>1</td>
<td>49</td>
<td>54</td>
<td>F6.0</td>
</tr>
</tbody>
</table>

3 compute 11=income1*emp1.
4 compute 12=income2*emp2.
5 compute exp1b=(emp1*pop1)*(emp2*pop2)/dist**1.
6 corr variables=exp1b observe1b/statistics=all.

-- Correlation Coefficients --

<table>
<thead>
<tr>
<th>EXP1B</th>
<th>OBSERVE1B</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXP1B</td>
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</tr>
<tr>
<td>OBSERVE1B</td>
<td>.9177**</td>
</tr>
</tbody>
</table>

* - Signif. LE .05  ** - Signif. LE .01  (2-tailed)
FIGURE 11, continued:

PLOT OF EXPECTED DATA SET1B WITH OBSERVED DATA SET1B
For key see Appendix
FIGURE 12

Correlation Coefficient and Scatter Diagram Between Observed Airline Passenger Traffic and the Interaction Index, Utilizing Variables Population, Income, Employment, Distance, and the Distance Exponent 1.0, for Sample Subset 1, Data Set B

```plaintext
-> include file=data1b.plot.
  1 data list file=data1b.dat/ pair 1-2 income1 3-9 emp1 10-16 income2 17-23
  2 emp2 24-30 pop1 31-37 pop2 38-44 dist 45-48 observe1b 49-54.

This command will read 1 records from data1b.dat

<table>
<thead>
<tr>
<th>Variable</th>
<th>Rec</th>
<th>Start</th>
<th>End</th>
<th>Format</th>
</tr>
</thead>
<tbody>
<tr>
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<td>1</td>
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</tr>
<tr>
<td>INCOME1</td>
<td>1</td>
<td>3</td>
<td>9</td>
<td>F7.0</td>
</tr>
<tr>
<td>EMP1</td>
<td>1</td>
<td>10</td>
<td>16</td>
<td>F7.0</td>
</tr>
<tr>
<td>INCOME2</td>
<td>1</td>
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<td>23</td>
<td>F7.0</td>
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<tr>
<td>EMP2</td>
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<tr>
<td>POP1</td>
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<td>37</td>
<td>F7.0</td>
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<tr>
<td>POP2</td>
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<td>38</td>
<td>44</td>
<td>F7.0</td>
</tr>
<tr>
<td>DIST</td>
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<td>45</td>
<td>48</td>
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<tr>
<td>OBSERVE2</td>
<td>1</td>
<td>49</td>
<td>54</td>
<td>F6.0</td>
</tr>
</tbody>
</table>

3 compute 11=income1*emp1.
4 compute 12=income2*emp2.
5 compute exp1b=11*pop1*12*pop2/dist**1.
6 corr variables=exp1b observe1b/statistics=all.

--- Correlation Coefficients ---

<table>
<thead>
<tr>
<th></th>
<th>EXP1B</th>
<th>OBSERVE1B</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXP1B</td>
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<td>.9223**</td>
</tr>
<tr>
<td>OBSERVE1B</td>
<td>.9223**</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

* - Signif. LE .05   ** - Signif. LE .01 (2-tailed)
```

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FIGURE 12, continued:

PLTV OF EXPECTED DATA SET1B WITH OBSERVED DATA SET1B
For key see Appendix
Correlation Coefficient and Scatter Diagram Between Observed Airline Passenger Traffic and the Interactance Index, Utilizing Variables Population, Distance, and the Distance Exponent 1.0, for Sample Subset 2, Data Set A

include file=data2a.plot.
data list file=data2a.dat/ pair 1-2 income1 3-9 emp1 10-15 enplane1 17-23
          income2 24-30 emp2 31-37 enplane2 38-44 pop1 45-51
          pop2 52-58 dist 59-62 observe2a 63-68.

This command will read 1 records from data2a.dat

Variable Rec Start End Format
PAIR 1 1 2 F2.0
INCOME1 1 3 9 F7.0
EMP1 1 10 16 F7.0
ENPLANE1 1 17 23 F7.0
INCOME2 1 24 30 F7.0
EMP2 1 31 37 F7.0
ENPLANE2 1 38 44 F7.0
POP1 1 45 51 F7.0
POP2 1 52 58 F7.0
DIST 1 59 62 F4.0
OBSERVE5 1 63 68 F6.0

4 compute 11=income1*emp1*enplane1.
5 compute 12=income2*emp2*enplane2.
6 compute exp2a=(pop1)*(pop2)/dist**1.
7 corr variables=exp2a observe2a/statistics=all.

-- Correlation Coefficients --

EXP2A          OBSERVE2A
EXP2A  1.0000  .9722**
OBSERVE2A  .9722**  1.0000

* - Signif. LE .05  ** - Signif. LE .01  (2-tailed)
FIGURE 13, continued:

PLOT OF EXPECTED DATA SET2A WITH OBSERVED DATA SET2A
For key see Appendix

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Correlation Coefficient and Scatter Diagram Between Observed Airline Passenger Traffic and the Interaction Index, Utilizing Variables Population, Income, Distance, and the Distance Exponent 1.0, for Sample Subset 2, Data Set A

-> include file=data2a.plot.
1 data list file=data2a.dat/ pair 1-2 income1 3-9 emp1 10-16 enplane1 17-23
2 income2 24-30 emp2 31-37 enplane2 38-44 pop1 45-51
3 pop2 52-58 dist 59-62 observe2a 63-68.

This command will read 1 records from data2a.dat

<table>
<thead>
<tr>
<th>Variable</th>
<th>Rec</th>
<th>Start</th>
<th>End</th>
<th>Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAIR</td>
<td>1</td>
<td>1</td>
<td>2</td>
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</tr>
<tr>
<td>INCOME1</td>
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<td>3</td>
<td>9</td>
<td>F7.0</td>
</tr>
<tr>
<td>EMP1</td>
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<td>ENPLAN1</td>
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<td>17</td>
<td>23</td>
<td>F7.0</td>
</tr>
<tr>
<td>INCOME2</td>
<td>1</td>
<td>24</td>
<td>30</td>
<td>F7.0</td>
</tr>
<tr>
<td>EMP2</td>
<td>1</td>
<td>31</td>
<td>37</td>
<td>F7.0</td>
</tr>
<tr>
<td>ENPLAN2</td>
<td>1</td>
<td>38</td>
<td>44</td>
<td>F7.0</td>
</tr>
<tr>
<td>POP1</td>
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<tr>
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<td>63</td>
<td>68</td>
<td>F6.0</td>
</tr>
</tbody>
</table>

4 compute I1=income1*emp1*enplane1.
5 compute I2=income2*emp2*enplane2.
6 compute exp2a=(income1*pop1)*(income2*pop2)/dist**1.
7 corr variables=exp2a observe2a/statistics=all.

--- Correlation Coefficients ---

<table>
<thead>
<tr>
<th>EXP2A</th>
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* - Signif. LE .05  ** - Signif. LE .01 (2-tailed)
FIGURE 14, continued:

PLOT OF EXPECTED DATA SET2A WITH OBSERVED DATA SET2A
For key see Appendix
FIGURE 15

Correlation Coefficient and Scatter Diagram Between Observed Airline Passenger Traffic and the Interaction Index, Utilizing Variables Population, Employment, Distance, and the Distance Exponent 1.0, for Sample Subset 2, Data Set A

include file=data2a.plot.
1 data list file=data2a.dat/ pair 1-2 income1 3-9 emp1 10-16 enplane1 17-23
2 income2 24-30 emp2 31-37 enplane2 38-44 pop1 45-51
3 pop2 52-58 dist 59-62 observe2a 63-66.

This command will read 1 records from data2a.dat

<table>
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<td>EMP1</td>
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<td>F7.0</td>
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<tr>
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<tr>
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<tr>
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<td>68</td>
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</table>

4 compute 11=income1*emp1*enplane1.
5 compute 12=income2*emp2*enplane2.
6 compute exp2a=(emp1*pop1)*(emp2*pop2)/dist**1.
7 corr variables=exp2a observe2a/statistics=all.

-- Correlation Coefficients --

<table>
<thead>
<tr>
<th></th>
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* - Signif. LE .05 ** - Signif. LE .01 (2-tailed)
FIGURE 15, continued:

PLOT OF EXPECTED DATA SET2A WITH OBSERVED DATA SET2A
For key see Appendix
FIGURE 16

Correlation Coefficient and Scatter Diagram Between Observed Airline Passenger Traffic and the Interactance Index, Utilizing Variables Population, Income, Employment, Distance, and the Distance Exponent 1.0, for Sample Subset 2, Data Set A

-> include file=data2a.plot.
1 data list file=data2a.dat/ pair 1-2 income1 3-9 emp1 10-16 enplane1 17-23
2 income2 24-30 emp2 31-37 enplane2 38-44 pop1 45-51
3 pop2 52-58 dist 59-62 observe2a 63-68.

This command will read 1 records from data2a.dat

<table>
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<td>9</td>
<td>F7.0</td>
</tr>
<tr>
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<td>16</td>
<td>F7.0</td>
</tr>
<tr>
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<td>17</td>
<td>23</td>
<td>F7.0</td>
</tr>
<tr>
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<td>30</td>
<td>F7.0</td>
</tr>
<tr>
<td>EMP2</td>
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<td>37</td>
<td>F7.0</td>
</tr>
<tr>
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<td>44</td>
<td>F7.0</td>
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<td>POP1</td>
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<tr>
<td>DIST</td>
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<td>59</td>
<td>62</td>
<td>F4.0</td>
</tr>
<tr>
<td>OBSERVE5</td>
<td>1</td>
<td>63</td>
<td>68</td>
<td>F6.0</td>
</tr>
</tbody>
</table>

4 compute 11=income1*emp1*enplane1.
5 compute 12=income2*emp2*enplane2.
6 compute exp2a=(income1*emp1*pop1)*(income2*emp2*pop2)/dist**1.
7 corr variables=exp2a observe2a/statistics=all.

--- Correlation Coefficients ---

<table>
<thead>
<tr>
<th>EXP2A</th>
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</thead>
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<td>.9275**</td>
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* - Signif. LE .05 ** - Signif. LE .01 (2-tailed)
FIGURE 16, continued:

PLOT OF EXPECTED DATA SET2A WITH OBSERVED DATA SET2A
For key see Appendix
FIGURE 17

Correlation Coefficient and Scatter Diagram Between Observed Airline Passenger Traffic and the Interactance Index, Utilizing Variables Population, Distance, and the Distance Exponent 1.0, for Sample Subset 2, Data Set B

-> include file=data2b.plot.
1 data list file=data2b.dat/ pair 1-2 income1 3-9 emp1 10-15 income2 17-23
2 emp2 24-30 pop1 31-37 pop2 38-44 dist 45-48 observe2b 49-54.

This command will read 1 records from data2b.dat

<table>
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<tr>
<th>Variable</th>
<th>Rec</th>
<th>Start</th>
<th>End</th>
<th>Format</th>
</tr>
</thead>
<tbody>
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</tr>
<tr>
<td>INCOME1</td>
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<td>3</td>
<td>9</td>
<td>F7.0</td>
</tr>
<tr>
<td>EMP1</td>
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<td>10</td>
<td>16</td>
<td>F7.0</td>
</tr>
<tr>
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<td>23</td>
<td>F7.0</td>
</tr>
<tr>
<td>EMP2</td>
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<td>24</td>
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<tr>
<td>POP2</td>
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<td>F7.0</td>
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<td>DIST</td>
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<tr>
<td>OBSERVE2</td>
<td>1</td>
<td>49</td>
<td>54</td>
<td>F6.0</td>
</tr>
</tbody>
</table>

3 compute l1=income1*emp1.
4 compute l2=income2*emp2.
5 compute exp2b=(pop1)*(pop2)/dist**1.
6 corr variables=exp2b observe2b/statistics=all.

--- Correlation Coefficients ---

<table>
<thead>
<tr>
<th></th>
<th>EXP2B</th>
<th>OBSERVE2B</th>
</tr>
</thead>
<tbody>
<tr>
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<td>.8497**</td>
</tr>
<tr>
<td>OBSERVE2B</td>
<td>.8497**</td>
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</tbody>
</table>

* - Signif. LE .05  ** - Signif. LE .01 (2-tailed)
FIGURE 17, continued:

PLOT OF EXPECTED DATA SET28 WITH OBSERVED DATA SET28
For key see Appendix
FIGURE 18

Correlation Coefficient and Scatter Diagram Between Observed Airline Passenger Traffic and the Interaction Index, Utilizing Variables Population, Income, Distance, and the Distance Exponent 1.0, for Sample Subset 2, Data Set B

```
include file=data2b.plot.
1 data list file=data2b.dat/ pair 1-2 income1 3-9 emp1 10-16 income2 17-23
2 emp2 24-30 pop1 31-37 pop2 38-44 dist 45-48 observe2b 49-54.

This command will read 1 records from data2b.dat

<table>
<thead>
<tr>
<th>Variable</th>
<th>Rec</th>
<th>Start</th>
<th>End</th>
<th>Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAIR</td>
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<td>F2.0</td>
</tr>
<tr>
<td>INCOME1</td>
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<td>3</td>
<td>9</td>
<td>F7.0</td>
</tr>
<tr>
<td>EMP1</td>
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<td>10</td>
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<td>F7.0</td>
</tr>
<tr>
<td>INCOME2</td>
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<td>23</td>
<td>F7.0</td>
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<tr>
<td>EMP2</td>
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<tr>
<td>POP2</td>
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<td>F7.0</td>
</tr>
<tr>
<td>DIST</td>
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<td>F4.0</td>
</tr>
<tr>
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<td>1</td>
<td>49</td>
<td>54</td>
<td>F6.0</td>
</tr>
</tbody>
</table>

3 compute I1=income1*emp1.
4 compute I2=income2*emp2.
5 compute exp2b=(income1*pop1)*(income2*pop2)/dist**1.
6 corr variables=exp2b observe2b/statistics=all.

--- Correlation Coefficients ---

<table>
<thead>
<tr>
<th>EXP2B</th>
<th>OBSERVE2B</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXP2B</td>
<td>1.0000</td>
</tr>
<tr>
<td>OBSERVE2B</td>
<td>.9022**</td>
</tr>
</tbody>
</table>

* - Signif. LE .05    ** - Signif. LE .01   (2-tailed)
```

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FIGURE 19, continued:

PLOT OF EXPECTED DATA SET2B WITH OBSERVED DATA SET2B
For key see Appendix

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Correlation Coefficient and Scatter Diagram Between Observed Airline Passenger Traffic and the Interaction Index, Utilizing Variables Population, Employment, Distance, and the Distance Exponent 1.0, for Sample Subset 2, Data Set B

/* include file=data2b.plot.
1 data list file=data2b.dat/ pair 1-2 income1 3-9 emp1 10-16 income2 17-23
2 emp2 24-30 pop1 31-37 pop2 38-44 dist 45-48 observe2b 49-54.
This command will read 1 records from data2b.dat

Variable Rec Start End Format
PAIR    1  1  2  F2.0
INCOME1 1  3  9  F7.0
EMP1    1 10 16  F7.0
INCOME2 1  17 23  F7.0
EMP2    1  24 30  F7.0
POP1    1  31 37  F7.0
POP2    1  38 44  F7.0
DIST    1  45 48  F4.0
OBSERVE6 1  49 54  F6.0

3 compute 11=income1*emp1.
4 compute 12=income2*emp2.
5 compute exp2b=(emp1*pop1)*(emp2*pop2)/dist**1.
6 corr variables=exp2b observe2b/statistics=all.

--- Correlation Coefficients ---

<table>
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<th>EXP2B</th>
<th>OBSERVE2B</th>
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<tbody>
<tr>
<td>EXP2B</td>
<td>1.0000</td>
<td>.9349**</td>
</tr>
<tr>
<td>OBSERVE2B</td>
<td>.9349**</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

* - Signif. LE .05    ** - Signif. LE .01  (2-tailed)
FIGURE 19, continued:

PLOT OF EXPECTED DATA SET2B WITH OBSERVED DATA SET2B
For key see Appendix
FIGURE 20

Correlation Coefficient and Scatter Diagram Between Observed Airline Passenger Traffic and the Interactance Index, Utilizing Variables Population, Income, Employment, Distance, and the Distance Exponent 1.0, for Sample Subset 2, Data Set B

```
include file=data2b.plot.
data list file=data2b.dat/ pair 1-2 income1 3-9 emp1 10-16 income2 17-23 emp2 24-30 pop1 31-37 pop2 38-44 dist 45-48 observe2b 49-54.
This command will read 1 records from data2b.dat

Variable Rec Start End Format
PAIR 1 1 2 F2.0
INCOME1 1 3 9 F7.0
EMP1 1 10 16 F7.0
INCOME2 1 17 23 F7.0
EMP2 1 24 30 F7.0
POP1 1 31 37 F7.0
POP2 1 38 44 F7.0
DIST 1 45 48 F4.0
OBSERVE6 1 49 54 F6.0
3 compute l1=income1*emp1.
4 compute l2=income2*emp2.
5 compute exp2b=(l1*pop1)*(l2*pop2)/dist**1.
6 corr variables=exp2b observe2b/statistics=all.
```

--- Correlation Coefficients ---

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<tr>
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<tr>
<td>OBSERVE2B</td>
<td>.9366**</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

* - Signif. LE .05  ** - Signif. LE .01  (2-tailed)
FIGURE 20, continued:

PLOT OF EXPECTED DATA SET2B WITH OBSERVED DATA SET2B
For key see Appendix
reference measurement of the mass quantity, singly or in conjunction with per capita income as a socioeconomic determinant of the potential for intercity air passenger travel.

The results shown in Figures 2, 9, 13, and 17 support a positive correlation between the interactance index and the airline passenger counts in 1990, when population was employed in the equation as the sole attraction variable. Both of the sociological measures of the mass component that were analyzed, yielded a high degree of association between the theoretical airline traffic among each community pair and the actual amount of interaction. The obtained $r$ between the predicted potential number of passengers carried and the observed number was 0.9662 (Figure 2), and 0.9722 (Figure 13), determined significant at the 0.01 level, when the census counts for direct population were incorporated into the formula for each of the 44 city pairs in sample subset #1 and 22 pairs within sample subset #2, respectively. The correlation values are listed in a symmetric table for the reason that the associations between $le$ and $lo$ is identical to the relation among $lo$ and $le$. There exist values of 1.0000 on the diagonal because a variable corresponds perfectly with itself. When the number of enplanements at each airport departing for all destinations was used in the gravitational formula instead of the entire city population, the calculated $r$ was 0.8748 for sample subset #1 (Figure 9), and 0.8497 involving sample subset #2 (Figure 17), at the 0.01 level of significance.

The data suggest that the amount of air passenger traffic increases proportionately with the number of persons residing in the specific centers.

According to the theoretical expectations, the scatter diagrams for the data graphically depict a rectilinear relationship between population and the observed traffic. Although the points representing the data on the plots do not form a perfectly straight line, and thereby indicate that the two sets of variates are not ideally correlated, the majority of cases are not far removed from the constructed trend lines and unmistakably illustrate linear data distributions.

The propensity for intra-Alaska airline passenger travel between the geographically distributed pairs of communities was positively influenced by the inclusion of per capita income in the interactance equation. As illustrated in Figures 6, 10, 14, and 18, the validity of the interactance theory was confirmed by comparing the data generated through formulations of the equation in which the population component was weighted with this socioeconomic indicator, and the observed 1990 aviation traffic. The coefficient of correlation between the forecasted and actual traffic levels was determined to be 0.9642 when per capita income was applied in conjunction with census population counts in the model within sample subset #1, and 0.9171 when the population dimension was measured via the number of enplaned passengers departing from each airline terminal for all destinations, both values of r being significant at the 0.01 level. A value of 0.9683 at the 0.01 level of significance was calculated between the
interactance index, utilizing the income variable as well as direct population, and the sample of observed airline passenger traffic between city pairs in subset #2, and an $r$ of 0.9022 was rendered upon the inclusion of income and the alternative sociological expression of mass when applied to the sixteen Alaskan air service hubs and their intrastate interacting communities. These high values of $r$ were anticipated, since the probability for interaction is greater for those individuals possessing the financial resources to purchase air travel than it is for the total population.\textsuperscript{117}

The strong linear relation among the two variables, the expected number of passengers carried as predicted via the hypothesis of interaction and the actual number, is substantiated by the linear distribution of the points on the constructed scatter diagrams. As the interaction indexes increase for the formulations that were modified to include the attraction variables of per capita income as well as population, so did the observed intercommunity airline passenger movements, resulting in a positive correspondence. Although the association is not perfect, and the plots depict some variability surrounding the generated lines of best fit, the points cluster around a straight line.

The presence of an empirical relationship between the above-cited factors within the investigative parameters is quite evident. The formulations of the interactance equation that most accurately

estimated the actual air passenger traffic potentials between the selected city pairs (in both sample subsets 1 and 2) were those which incorporated either the population counts of each community as enumerated by the census, or the number of passengers at each airport departing for all destinations, solely or in association with the per capita income appropriate to each center, the two specific indicators of the population aggregates postulated to affect the amounts and intensities of the intercommunity air passenger traffic flows. The distribution of the selected intra-Alaska aviation traffic during 1990, plotted on the abscissa of the scatter diagrams, depicts the close relationship between the theoretical calculation and actual performance. Regardless of some divergency in the distribution of points, there is an obvious positive correlation between the amount of passengers who traveled via airway and the accordant values expected from the interactance equation.

The linear trend of the data shows that the predictions between le and lo become more successful with increasing volume of observed passenger counts. The threshold level at which the model begins to successfully forecast the amount of intercity airline passenger traffic within the research context is approximately 20,000 scheduled air carrier and commuter passenger movements. The degree of correlation between the potential and observed intercommunity interaction was somewhat lower when the number of enplaned passengers departing from each airport for all destinations was applied in the equation as the sociological measure of mass in place of direct population. In addition,
the application of this variable caused one airline segment among the
44 and 22 pairs of cities examined in sample subsets 1 and 2,
respectively, to deviate considerably in the graphic comparison of
theoretical versus actual distribution of intra-Alaska airline passenger
traffic (Figures 9, 10, 17, and 18). The volumes of traffic on airline
routes of which Anchorage or Fairbanks was either the initial or
terminal point of passenger travel are compounded by international
traffic that comprises roughly 25 percent of the total commercial
activity at Anchorage International Airport, by increasing international
activity at Fairbanks International Airport, and by interstate service
prevalent at both gateway terminals. Although this study exclusively
evaluated intrastate service, the insertion of enplanements as a
sociological measure of mass into the model could have included traffic
counts pertaining to passengers who may have used the major hubs
while traveling on the routes of international and interstate air
carriers, and could have resulted in the point far removed.

The outlying case, apparent from all of the data distributions,
represents the Anchorage-Fairbanks city pair which appears on the
abscissa as the highest volume segment extrapolated from the 1990
origin and destination passenger traffic between the pairs of
communities that were examined (please refer also to Maps 3 and 4). In
addition to possessing the largest traffic volumes, the Anchorage-
Fairbanks airline segment included the highest population counts,
number of enplaned passengers, and employment levels appropriate to
each sample subset (Table 1). These extreme values, relative to the
remaining city pairs involved in the study, clearly enhanced the relationship between the estimated and actual interaction according to the gravity equation. An adjustment in the observed traffic levels of subsets 1 and 2 was made by deleting the Anchorage-Fairbanks airline segment that generated large and atypical activity within the intra-Alaska air transportation market. The coefficients of correlation resulting from this calculation did not fall below 0.8100 at the 0.01 level of significance, and the graphical depiction of the data remained a linear trend.

The experimental subfactor of employment when introduced into the index of activity failed to become a positive indicator of intercity air passenger traffic within both of the sample subsets. Furthermore, the utilization of the number of persons actively employed in the labor force, armed forces, and civilian force in the interactance equation as a socioeconomic index of the population centers, combined with either alternative measure of the mass quantity, did not produce a discernible modulating effect upon passenger movements between the intra-Alaska origins and destinations investigated. The obtained correlation coefficients for this data appear in Figures 7, 11, 15, and 19, and range from 0.9115 pertaining to sample subset #1, data set A, to 0.9349 when subset #2, data set B, were analyzed, both of which being significant at the 0.01 level. Although these values are consistent with those generated by formulations in which income and both of the population expressions were incorporated, singly and in combination, the scatter diagrams for the data illustrate poor linear distributions of the majority
of the pairs of communities. The non-linear trends involve those airline segments for which lower traffic volumes were recorded in 1990, and the substantial clustering of these cases may have been largely responsible for the high overall degree of correlation.

As expected, the interactance equation generated similar results when the employment data were inserted into the formula along with either of the alternative population variables and per capita income, the specific index of activity. The correlation indexes evident in Figures 8, 12, 16, and 20, ranged from 0.9124 to 0.9366 at the 0.01 level of significance. The formulations that were analyzed with all of the experimental indicators of origin and destination aviation traffic introduced in this thesis, depicted similar non-linear data distributions to those indicated above and an aggregation of airline segments which in 1990 experienced less than 40,000 passengers.

B. Evaluation of the interactance formula

This thesis has 1) presented the basis for postulating that the potential for intercity airline passenger traffic in Alaska, within a given interval of time, would vary directly with the product of some measure of the populations of the pair of communities, and with the socioeconomic homogeneity between each group, and inversely with some function and power of the intervening distance between the two aggregates; 2) provided empirical data for the extent of estimated interaction occurring between two areas as stipulated by the
gravitational equation, compared with the actual observed number of passengers carried by flight transportation; and 3) demonstrated the presence of the interactance principle within the study area. The number of passengers traveling by airway is a measurable index of interaction that in other studies has been shown to follow the $P_1P_2/D$ relationship, including an investigation by Gray and Rowe of the determinants for aviation demand between rural Alaskan communities within two specific transport regions during a four month span in 1979. However, the true origin and destination passenger counts had not previously been applied in the estimation of airline traffic via the interactance equation. The observed data for aviation traffic that were utilized in the present analysis comprised intra-Alaska, non-directional, absolute origin and destination passenger counts (all fare classes) for 1990 scheduled air carrier and commuter service, as a more thorough means of measuring airline traffic flows. The true origin and destination traffic counts indicated the initial and terminal points of interaction, and furthermore corresponded to the population, income, and employment indices that were tested in the model as the socioeconomic characteristics particular to each community. The selection and application of this methodological approach for the conducted research seems to have contributed to the higher degree of correlation between the theoretical calculation of air passenger traffic via the interactance equation and the actual aviation transport.

118 Please refer to pages 41 and 42 of this thesis.
The origin and destination traffic data analyzed by several particular formulations of the interactance equation produced a consistent pattern, despite the degree of random variation inherent in even a perfectly specified predictive model. There was no apparent relationship between the number of individual interacts included in the traffic data, in this case intercity airline passengers, and the value of the correlation coefficients in the examination of sample subsets 1 and 2. The difference in traffic volumes among the 35 selected intra-Alaska cities and 44 interacting pairs, and those pertaining to sixteen of the state's seventeen air service hubs and 22 pairs of communities, did not appear to be extensive enough to produce a statistical distinction in the application of the equation. Furthermore, the data on origin and destination included in sample subset #1 formed a pattern on the scatter diagrams comparable to that of subset #2.

The validity of the gravitational analysis of potential intercity interaction, as well as the reliability of research findings is heavily dependent upon the correct selection of variables regarding the type of activity that the model is required to represent. The 1990 origin and destination airline passenger traffic among the selected intra-Alaska community pairs appeared to be accurately expressed by the interactance equation when either the direct population counts of each center, or the number of enplaned passengers departing from each center, or the number of enplaned passengers departing from each

airline terminal for all destinations, were incorporated into the formula to represent the population of the cities, singly or in conjunction with per capita income applied as a socioeconomic adjusting factor for the regional differences affecting the extent of interaction. In addition, the potential for population movement via flight transport between places in Alaska was limited by an inverse linear distance entered into the model.

The successful experimental subfactors of the interaction potential that were applied to the interactance equation in this analysis were shown to be significant indicators of the demand for airline passenger transportation between the selected Alaskan communities. The population and money income appropriate to each center, and the direct linear distance separating the places competently determined the variations in the intercity aviation traffic flows during the calendar year 1990. The most appropriate and successful measure of the population aggregates in modifying the propensity to interact with respect to airline travel was the entry of direct numerical counts into the formula, solely or in addition to the income potential of each origin and destination community. It may be observed from an examination of Figure 13, that the coefficient of correlation between the forecasted and actual intercity air passenger movements obtained by the inclusion of the census population counts as the sociological measure in the interactance equation, was 0.9722 involving sample subset #1. This value represents the single highest association between the calculated and actual aviation traffic produced by the various gravitational
formulations, and is commensurate with an $r$ of 0.9662 when the same variable was applied to subset #2 in Figure 2. Comparable high correlation coefficients of 0.9642 (Figure 6) and 0.9683 (Figure 14) were obtained for the city pair matrix in sample subsets 1 and 2 and the model upon the introduction of per capita income as a socioeconomic indicator in connection with the direct populations of the centers. The number of persons of the urbanized area in which each airport is located, tested in the gravity equation as the sociological representation of mass at the origins and destinations, singly or combined with the income potential of each place, represents an index of the average propensity to travel by airway between cities of all individuals in the community. This measure may be applied in the formula to enhance the projection of potential future passenger traffic regardless of whether the pairs of communities have previously had air service.

The coefficients of correlation, ranging from 0.8487 to 0.9171 as indicated in Figures 9, 10, 17, and 18, that were generated by the interactance relationships which included the number of enplanements at each airline terminal departing for all destinations, support the applicability of this alternative demographic variable in the equation for predicting potential air passenger traffic between pairs of cities in Alaska. However, as noted in Chapter III. C., certain conditions regarding the use of this variable should be recognized. Employing a statistical measure of traffic generation as an index in the interactance equation to forecast potentials of air traffic flow and produce useful
management data, presupposes that reliable and regularly scheduled air connection between the interacting city pairs has already been established. The use of airline passenger departures at a specific airport for all destinations as a sociological expression of population in the gravitational analysis technique offers a means for evaluating the extent to which present intercommunity aviation traffic potentials are being realized. The variable is not applicable for proposing service between locations that so far have not supported reasonable air activity, and may be misrepresentative when investigating probable traffic between points at which one or both of the airports have not been serviceable for long periods due to traffic restrictions or determents.

The research results obtained in this study provide evidence that the demand for intercommunity air travel in Alaska may increase more than expected from its proportion to the population of the relevant centers. The correlation between the estimated and observed number of intercity airline passengers as stipulated by the interactance equation was improved by the introduction of per capita income, assigned as a multiplicative weight to the population component to measure differences in the individual propensity to interact via aviation transport in various geographical locations within Alaska.


121 Ibid., pp. 108 and 109.
The aggregation of the cases that resulted from the correlation between the expected and actual interaction data when the formulations of the equation were used that included the number of persons actively employed in the labor force, armed forces, and civilian force, may indicate a variety of pertinent circumstances. The findings suggest that occupation may not be a primary determinant of intercity air travel by individuals within Alaska, and that this attraction variable is ineffective in influencing traffic potentials when utilized in the model as a socioeconomic characteristic of the communities. Conversely, the employment index may represent a complementary difference between places that do indeed contribute to potential aviation traffic, but where interaction is curbed because of the presence of additional factors which need to be further examined.

The observation that the interactance theory bodes well and is efficient for evaluating origin and destination airline passenger traffic between pairs of cities in Alaska, implies that there exists a uniform per capita pattern of travel consumption by air passengers which is modified with income, and that aviation service is of equitable significance to inhabitants within the state notwithstanding the demographic characteristics or geographic situation of their places of residence.

The correlation between the estimated and actual intercommunity passenger traffic data may be close in part because transport via airway within the state reflects a thoroughly established, very representative type of interaction, for which the laws of probability are
applicable. The low value of the distance maximizing exponent signifies wide and easy fields of movement, thus indicating the transferability of air passenger traffic in Alaska and the efficiency of the aviation network in its intercommunity movement of persons. As mentioned previously in Chapter III, sections A and C, of this thesis, interaction by airway transportation extends beyond the traditional air service markets, and this mode of travel is engaged in by a large portion of the population. Substitution with road, rail, and marine transport is mostly unavailable to the prospective traveler, and is often insufficient in locations where these alternative modes supplement air service. The demand for airline service therefore does not fluctuate with vacillations in the Alaskan economy as determinedly as in states throughout which variant traffic modes are competitive. The total volume of passenger travel is essentially confined to scheduled and non-scheduled air carrier and commuter transport. Of the transportation modes available within the state system, the airplane directly serves the most persons, and Alaska therein surpasses the rest of the country per capita in the amount of air mileage traveled, number of aircraft, and air freight and air mail volumes.

The experimental factors, investigated as indices of traffic activity, that demonstrated accurate predictive power confirm the postulate that intercity airline passenger volumes in Alaska are modified by gravitational forces. The computational results suggest

that air passenger traffic demand is directly proportional to the population density of each place, that aviation traffic varies with the intervening straight line distance between the pair of interacting centers, and that the distance-related decay in passenger movements via intercommunity flight transportation occurs continuously and evenly in each direction in proportion to the distance from the origin of travel. In addition, the interaction is to some extent affected by the complementarity of the populations of the city pairs, which was accommodated by the interactance equation via measuring the spending power of the interacting populations.
CHAPTER V

CONCLUSIONS AND FUTURE RESEARCH DIRECTIONS

A. General evaluation of the study

The findings of this study support the utility of the interactance model as a versatile method to project intercity movements in traffic studies. The approach offered efficient computation and effective quantitative testing of the obtained results. Furthermore, the observed association between interaction, community attributes, and spatial distance provided insight into the interrelation among the incorporated components and the variables that were utilized to represent them. The model revealed the extent to which the postulated factors modulate interaction between individuals and their degree of constancy under the research conditions\(^{123}\), and permitted an examination of divergent cases. Based on its versatility, it is plausible to predict applicability of the model to analyze various specific types of interactions for which the appropriate indices have been determined. It should be noted, however, that informed judgments are required throughout the evaluation process as seen in the present study with a city pair that

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\(^{123}\) Hammer, Carl and Fred Charles Iké, "Intercity Telephone and Airline Traffic Related to Distance and the 'Propensity to Interact'." *Sociometry*, volume 20, 1957, pp. 315 and 316.
possesses comparable population density and socioeconomic qualifications, as well as provides similar airline service and terminal facilities, but nevertheless may produce variant air passenger traffic volumes.$^{124}$

The interactance formula provides a basis with which absolute origin and destination data may be applied to aid in traffic flow analysis. There is now sufficient evidence verifying the suitability of the hypothesis of interaction to study the management of passenger transportation via scheduled air service in Alaska. Such gravitational analysis of intercommunity airline traffic levels could facilitate the evaluation and control of passenger movements within a state so dependent upon effective and reliable air transportation and, consequently, increase the generation of aviation traffic. Moreover, the interactance equation could be applied in conjunction with what is widely recognized as the most precise and extensive econometric projection model of Alaska, the "Man in the Arctic Program" (MAP) technique formulated by the Institute for Social and Economic Research in Anchorage.$^{125}$ By simulating the evolution of the Alaskan economy, this model is currently being used to generate forecasts regarding economic variables that presumably affect income and employment


levels, and, therefore, aviation traffic volumes.\textsuperscript{126} Estimations of the demand for airline service made by traffic analysts are founded on econometric projections and the past and present relationships between the economic indicators and intrastate air passenger traffic data. The interactance formula could thereby be utilized as a theoretical predictive device by planners, local airlines, financial analysts, and/or regulators to estimate the passenger traffic demand between cities in Alaska, evaluate the extent to which intercommunity aviation traffic potentials are being realized, forecast traffic levels resulting from service changes, and propose alternative service patterns, airline routes, and schedules.

Acknowledgment should be given to the fact that the hypothesis of interaction calculates and compares the relative potential interaction between population groups, and is not expected to indicate the exact amount of traffic. In the present study, the model has analyzed the airline traffic potentials of the selected centers regardless of the type or purpose of trip undertaken by each traveling passenger (inasmuch as this information is not recorded in airway service counts). Because the motivations for passenger movement are not documented, the representation of aviation interaction by the gravity equation is established via historical statistical data concerning the mobility rates of individuals in subgroups of a population, and by

\textsuperscript{126} Ibid..
the theorization of a perpetuity in travel behavior within the specific environment.\textsuperscript{127}

Studies of aviation traffic have demonstrated that the number of passengers carried between two locales is modified by the density of communities within the geographic vicinity.\textsuperscript{128} Observed intercity traffic among airline terminals about twenty-five minutes apart has shown to be lower than would be expected on the basis of population and intervening distance. As the size of a market area is altered by the introduction of additional service stations, one community may fall into the market area surrounding the other, thus perturbing the analysis.\textsuperscript{129} However, the limitation of the present study to intra-Alaska flight transportation largely eliminated the "nearby airport problem" and the complexities involved in allocating the appropriate extent of the market area of each air terminal, a task requiring an elaborate analysis of the traffic generated at the respective airports. When utilizing the interactance equation to estimate potential aviation traffic between city pairs in which several airports compete for passenger service, the employment of direct numerical population counts in the formula, as an expression of the mass quantities, may not be the most representative

\textsuperscript{127} Berry, Brian J. L. and Duane F. Marble, \textit{Spatial Analysis}. Published by Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1968, p. 56.


\textsuperscript{129} Ibid., pp. 160 and 164.
measure, because it would be difficult to identify that population segment which uses flight transport at the various air carrier terminals. This research was confined to scheduled passenger activity between cities in Alaska. The inclusion of interstate and international passenger traffic in the study would have additionally affected the flows within the aviation network, particularly the volumes of exchange at Anchorage, Fairbanks, and Juneau airports, considered in this study by the insertion of the total number of enplaned individuals at each terminal as a variable in the equation. Significant volumes of passenger traffic in Alaska are also generated by unscheduled commuter flights that frequently service rural communities throughout the state. Passenger counts referring to these airline operations are however not recorded in the scheduled origin and destination data, and were consequently absent from the totals applied in this work. Analysis and interpretation of the data obtained in the thesis are therefore restricted to the research parameters incorporated into the specific formulations of the interactance model.

B. Recommendations for future research

The research carried out in this study may conceivably be utilized as a basis for furthergoing investigations into aspects of aviation interaction and state-wide travel patterns, which extend beyond the scope of this thesis and would require additional resources. By refining its components, the interactance equation could be made more
powerful to resolve the analyses of passenger airline traffic in general and in Alaska in particular. For example, the inclusion of variable measures of distance may improve the correlation between the theoretical and actual interaction. Furthermore, the demand for intercommunity airway transportation may be influenced by management factors such as the availability of aircraft at each airport. J. T. Gray and J. P. Rowe have suggested that there exists a higher level of passenger traffic in markets offering more than two scheduled air carriers, because of the inclination of local operators to judge demand and react in consonance with the competition.\footnote{Gray, John T. and J. Phillip Rowe, \textit{The Economic Dimensions and Feasibility of Scheduled Air Service In Rural Alaska}, Institute of Social and Economic Research, University of Alaska, Anchorage, Alaska, May, 1981, p. 64.} Traffic flow could also be influenced by route structure (the convenience of a direct connection between origin and destination), roundtrip fares (including a distinction among rates for business, first class, and coach classes of travel), service schedule (daily or weekly frequency), and specific terminal facilities. All of these factors were assumed to be at an average level in this thesis.

On the other hand, the temptation to modify or expand the interactance formula has its own shortcomings. Although a transformation of the distance variable in the application of the interactance formula to project aviation traffic potentials may assist in the identification of distinct spatial patterns, the nature and form of nonlinear treatments are both laborious and cumbersome to
incorporate. Moreover, the modification of linear measures by many of these alternative views of intervening distance may not be effective in examining airline passenger travel consumption in Alaska, due to the noncompetitive nature of the state transportation system and the unique role of aviation within the network that result from the lack of overland modes throughout most regions, and the relative ease and convenience of movement from location to location via air transport.

Travel cost, when entered into the interactance equation as the distance variable in place of the direct intercity airline mileage, has also produced unsatisfactory results possibly because fares tend to increase in a few large intervals and in various directions in flight transportation, rather than gradually and continuously from the origin of travel. Distance could also be interpreted sociologically, by expressing the direction of travel in the model via one-way aviation traffic data that would acknowledge the originators versus the recipients of interaction. However, as previously noted, defining distance by some social term nullifies the Euclidean properties of space embodied in the equation and introduces topological difficulties when mapping the distribution of distance between places. Thus, the


addition of numerous hypothesized indicators of interaction to the gravity formula sometimes counteracts the primary elements of the model, namely its simplicity and efficiency of calculation.

The hypothesis of interaction could be further developed by separately manipulating the dimensions proposed by the model. The population, level of socioeconomic intensity, and distance factors could be modified independently via analyzing several variables and powers while the other dimensions are held constant. Each of the formulations of the equation would generate different values of correlation between the anticipated and actual interaction, and could facilitate the determination of meaningful indices for inclusion into the hypothesis. The appropriate variables could then be tested in the interactance equation on an annual basis and over the longest time interval for which observed traffic data are available. In that respect, the most successful estimations presented in this thesis were rendered by the formulas which analyzed airline segments on which a total of at least 20,000 passengers traveled via scheduled air carriers and commuter flights. Thus, in the future, larger volumes of actual passenger traffic counts should be tested in the relation between the forecasted interaction according to the model and the observed performance, for instance 5 years of reported intercity movements, followed by a decade, etc.. A comparison of the computed associations

for each year, as well as the comprehensive time period, may specify important distinctions that should be considered in the equation.\textsuperscript{135}

Acceptable sources of values for the variables that were introduced into the interactance equation in this analysis include statewide predictions of community demographics, based on the appraisal of the socioeconomic effects of various proposed plans and programs, and the projections supplied periodically by the United States Department of Commerce, Bureau of the Census, as well as the Alaska Department of Labor, Research and Analysis. These agencies update the population, income, and employment figures from surveys and forecasting methods based on different economic and public policy scenarios.\textsuperscript{136} If growth rates are presumed to remain constant, historical growth rates may be used as forecast variables in the interactance model, and aviation officials could be consulted for input values if air service data are to be utilized to sociologically measure distance in the formula.\textsuperscript{137} It must be recognized that the gravitational projection of probable interaction nevertheless becomes increasingly less precise when applied to larger forecasting time periods due to the assumptions incorporated into forecasts, and because miscalculations intensify as limitations of the specific research design, procedure, and input data are exceeded.\textsuperscript{138}

\begin{flushright}
\textsuperscript{135} Ibid., p. 30.
\textsuperscript{137} Ibid., p. 92.
\textsuperscript{138} Ibid., p. 82.
\end{flushright}
The application of the gravity concept of human interaction has in this study been restricted to state-wide aviation travel potentials within Alaska. It would be interesting to conduct research on numerical values that could be assigned to the equation as allowances for variations in the average propensity to interact of groups of individuals residing in the three transport regions within the state, each characterized by a distinct network, and assess its correspondence with the extrapolated sample of observed traffic. The availability of overland transportation modes and the price-defined alternatives specific to each region may prove useful in the identification of suitable aviation policies and programs, as well as the generation of financial data according to the different options under consideration.

The competency of the gravitational estimation of potential airline traffic between city pairs may also be improved by analyzing the attraction of connecting cities of origin or destination and its effect on the total intra-Alaska passenger load, in addition to the initial and terminal points of travel that were examined in this investigation. This adjustment to the model could augment the practicality of the interactance technique as applied to aviation planning, since service scheduling accommodates connecting passengers as well as those originating locally.\footnote{139 Cochran, Douglas Lessel, \textit{An Evaluation of the Use of Gravitational Formulae for Estimating Potential Air Passenger Traffic Between City Pairs}. A Dissertation, University of Oregon, June, 1968, pp. 121 and 123.}
W. J. Platt has suggested that the political, economic, and recreational relationships between pairs of communities may further contribute to intercity travel demand.\textsuperscript{140} In his application of the PaPb/D formula to aviation traffic among 58 different metropoles in September and October, 1946 \textsuperscript{141}, several of the city pairs that illustrated a high degree of traffic based on the the effects of population and distance analyzed by the equation, were hubs of commercial activity. The author concluded that major centers possess an extraordinary drawing power, and that maximum traffic potentials may therefore be attained between pairs of these air traffic cities notwithstanding a significant intervening distance.\textsuperscript{142} Thus, further studies should be directed toward the development of an index for measuring the extent of community interest provided by major centers of government or business, and the introduction of an accounting factor into the projection formula for those airports situated in a resort location or immediately proximal to a major tourist attraction, such as Denali National Park and Kenai National Wildlife Refuge. These locations may incur larger volumes of passenger movements than would be expected by the population and income level appropriate to the

\textsuperscript{140} Platt, William J., "Evaluating Intercity Air Traffic, Parts 1 and 2." \textit{Air Transport}, September, 1946, and October, 1946.

\textsuperscript{141} Please refer to Chapter II. B. for a more detailed account of the research undertaken by W. J. Platt.

particular community. The obtained values may correlate more accurately with the performed interaction, whereby the traffic generation potentials could indicate whether small volumes of passenger traffic are related to a lack of community interest, or if inadequate air service eventuates in low intercity attraction.

In summary, the results of this study demonstrate the usefulness of the interactance approach to analyze and estimate airline traffic between settlements in Alaska. Concurrently, the findings reveal the adaptability of the method to specific circumstances, and indicate its potential to provide furthergoing resolution in future studies on transportation.

143 Ibid., pp. 123 and 124.
APPENDIX

Key for Figures 1-20

Frequencies and Symbols Used for Scatterdiagrams

| 1 - 1 | 11 - B | 21 - L | 31 - V |
| 2 - 2 | 12 - C | 22 - M | 32 - W |
| 3 - 3 | 13 - D | 23 - N | 33 - X |
| 4 - 4 | 14 - E | 24 - O | 34 - Y |
| 5 - 5 | 15 - F | 25 - P | 35 - Z |
| 6 - 6 | 16 - G | 26 - Q | 36 - * |
| 7 - 7 | 17 - H | 27 - R |
| 8 - 8 | 18 - I | 28 - S |
| 9 - 9 | 19 - J | 29 - T |
| 10 - A | 20 - K | 30 - U |
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