THESIS

ROBERT COLLEGE GRADUATE SCHOOL

BEBEK, İSTANBUL



# ANALYSIS OF POINT-TO-POINT FLOWS
# in
# CLOSED-CIRCUIT TRANSPORTATION NETWORKS

A Gravitational Interaction Model
with special application to
Turkish Airlines' Domestic Network

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## PREFACE

In today's world, techniques of teamwork and systematic findings seem to be more fashionable than personal research. However, personal research has a challenging quality that is perhaps unequalled by any other type of work. Needless to say, a thesis of which the main requirement is to be original, provides this quality of personal research.

It will be seen that this study is quite concise and that it follows a clearly delineated pattern of composition to attain a result and to try justifying it. The judgment on whether or not it accomplishes its objective will have to belong to the reader. Therefore, let him read and decide whether "_finis coronat opus_."

The author wishes to thank all those who kindly offered their help in the course of preparation: the painstaking detection and collection of data (especially true for our country), the critical decisions of reliability of the results obtained, and the constructive criticisms much needed for a well-balanced whole.

Special thanks are due to Professors Harry G. Tobey and Sibel Tanberk without whose guidance the author's work would have been of questionable quality.

Deserving special mention is Prof. Alper Orhon who also spent invaluable time for the review and discussion of the work during the course of preparation and offered much constructive criticism.

The author would desire to extend his gratitude to all those who devoted their time and effort during the field research he conducted; especially to Mr. Mahmut Marşan, director of the Research and Planning Department of Turkish Airlines, Messrs. Cemil Çınar, Muammer Doğan, Mete Törüner, Mahir Barutçu, and Bora Gürer of the State Planning Organization, Mr. Gültekin Delice, director of the Tourism Section of the State Institute of Statistics, Mr. Burhanettin Sökmensüer, director of the Transportation Section of the same institute, the personnel of the Research and Planning Department of Turkish Airlines and the library personnel of the Civil Aviation Institute of Istanbul Technical University, and all other individuals and friends whose names he could not mention here because of space limitations, but whose help he dearly appreciated.

Istanbul
May, 1969

CONTENTS

## LIST OF TABLES

## LIST OF ILLUSTRATIONS

'Nothing has been created, unless through a technique,' has said Paul Valéry. In the order of techniques, the airplane's ~~is~~ is at the same time one of the most recent and the most likely to transform a civilization.[1]

[1] Claude Postel, L'Aéroport de Paris, trans. Hasan Akbelen (Cahiers de la Fondation Nationale des Sciences Politiques; Paris: Armand Colin, 1953), p. 7.

# INTRODUCTION

## Statement of the Problem

In any type of economic activity, planning ahead of time makes possible the use of scarce economic resources in a most profitable way. Furthermore, it saves a lot of needless effort and also reduces waste. But in order to do so, those who have the responsibility of planning must have within their reach certain working tools which would enable them to accomplish a reconstruction of the real state of affairs.

This thesis will attempt to provide such a tool for the prediction of point-to-point transport flows. Although it would be possible to apply it to any kind of transportation network, an analysis of its application to Turkish Airlines' domestic network will be undertaken in this study.

Air transport is the most modern mode of transportation that mankind has invented. Its impact on economic activity in general has been overwhelming and its implications have transformed the outlook of the world we live in. As the economy of our country develops, air transportation will gain more and more popularity, and the management of air transportation will have to resort more and more to scientific methods. It is hoped that the model developed in this thesis will be of value for practical application and that it will furthermore constitute a starting point or springboard for further research.

## Methodology

The role and significance of transport activities will be outlined and the particular implications of air travel will be emphasized. Since the model developed deals with point-to-point flows, a discussion of such flows will be given. To do so, the reasons underlying the occurrence of flows and settlements and the acquisition of importance of certain specific locations rather than others will be analyzed in a review of location theory. Based on this presentation, the relevance of a gravitational or interaction model will be discussed and concepts of connectivity related to it will be introduced.

After this preliminary establishment of a foundation for a model, the model itself will be empirically determined by the use of multiple regression techniques. In this regression analysis the volume of travel will be expressed in terms of certain socio-economic factors. After testing the significance of the said factors in a total formula yielding the potential volume of traffic, the pertinent network parameters according to the gravitational model will be established.

In conclusion, certain remarks concerning the use of the model *per se*, and also recommendations on possible ways of its development or its employment as a basis for other studies will be given.

# CHAPTER I

## ROLE OF AND DEMAND FOR TRANSPORT

### Role and significance of transport activities

As soon as we are confronted with the study of any human activity, we will be facing something that involves transportation the movement of a body from one place to another. All living creatures move. It is their activities and their contacts that make their lives valuable and meaningful. No single commodity or set of commodities is either so satisfactory or so supportable that even if we have it abundantly, we shall not look for and express a desire to have more. Our aspiration, need, predilection, and even craving for more will be an eternal truth. Since the human being has a natural tendency toward perfection whether it be in the direction of the good or the bad, everything will have to be just right or at least intended to be so. We do want our tea to be from Ceylon, our cigars from Havana, or our brandy from France. This list could of course be easily extended to cover a multitude of goods or services. All this brings us to the well-known utility of place, which by no means needs such far-fetched examples as those enumerated above. It rather implies that in order to derive satisfaction from various commodities, we actually need selected assortments of them and that these assortments will have to be collected from an arbitrarily dispersed population. The whole idea of commerce traceable back to this bare truth. In order to do these contacts with others, ardent efforts to dig up new possibilities have proved to be necessary. Thus transport produces "new utilities of location" and removes the "disutilities imposed by distance."[2]

No matter what the motivating force might be (economic advantage, necessity, pleasure, etc.) the movement of persons or goods is a vital activity in all civilizations. Along with enhanced economic activity due to approaching, albeit incrementally perhaps, perfect mobility, based on the existence of adequate transportation we notice also an invigorated social and cultural unity on the national scale and even, to some extent, on the international one. "Interregional contacts through travel and the exchange of goods promote the interchange of ideas and the breakdown of parochialism, thus encouraging an upward uniformity in tastes, health, education, and way of life in general."[3] The spread of information and ideas is stimulated through the mobility of persons. Perhaps one of the most significant achivements of increased mobility is that new value judgments are attained, and also regional differences and prejudices related to or resulting from them are alleviated. These prejudices are the result of isolation and as isolation is reduced

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[2]Michael R. Bonavia, The Economics of Transport (Cambridge Economic Handbooks; Digswell Place: Nisbet and Co., 1966), p. 2.

[3]Roy J. Sampson and Martin T. Farris, Domestic Transportation: Practice, Theory and Policy (New York: Houghton Mifflin Co. 1966), pp. 3-4.

through improved communication, people arrive at a developed level of understanding and in reducing sectionalism or regionalism, transportation allows people to achieve higher objectives and interests.

Transportation goes hand in hand with production. Whatever is produced must be distributed. A quick glance at the road maps of a sample of developed countries on the one hand and of developing ones on the other would show, without virtually any need for further analysis, how proliferated road networks can be easily associated with developed economies. The degree of inter-connectedness of transportation networks of some of the developed countries is a striking evidence of the necessity of extensive transportation facilities for sound economic development. Studies on transportation activities of various countries have resulted in the establishment of what are called mobility indices. One such study revealed the positive correlation between the mobility index and per capita gross national product index.[4]

Production requires a change of location of many items in order to bring them together in the right proportions. The same is true for distribution which enables to move products to those places where they are needed. It is for this reason that transportation is so crucial an element in the economy. The annual passenger transportation expenditures of the United States for example, have reached such a high figure as 64.7 billion dollars in 1963, which

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[4]Wilfred Owen, Strategy for Mobility ("The Brookings Institution Transport Research Program"; Washington, D.C.: The Brookings Institution, 1964), pp. 13-15.

represents roughly 20 % of the United States gross national product.[5]

Transportation also serves to achieve the objective of political unity within a nation, and in some cases, also the objective of political influence beyond the territory of that nation. The citizens of a country all deserve special attention as to their relationships within the political framework of their country, and national cohesiveness is not one of the lesser objectives. A well-known saying in Turkish summarizes this aspect of transportation so concisely:"Gidemedigin yer vatan değildir."(Where you cannot go, is not the fatherland.)

Another political aspect of transportation is reflected in the right of any independent and fairly developed country to regulate the transportation of goods and persons between its own ports: cabotage. This is also of extreme economic importance, due to the fact that the country desires not to see its economy run the risk of incapacity or paralyzation under foreign control of the means of transportation.

## Demand for Transport in General

It has been argued that transport demands between job, school, shopping, visits with relatives and friends, and other travel purposes affect a family's choice of a home location.[6]

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[5] Sampson and Farris, op. cit., p. 11.

[6] Emery Troxel, Economics of Transport (New York: Rinehart and Co., 1955), p. 145.

This is in fact a very important point to which we shall come back in the discussion of the gravitational model for transportation networks in Chapter III.

When we choose a site for a home what we are after is to select such a place that the everyday activities will be carried out at minimum dissatisfaction or maximum satisfaction or both. The food and other needs should be obtainable by travelling a reasonably low amount. Children must go to school and parents to their jobs without having to go into excessive trouble. Recreation and amusement centers should be sufficiently nearby. This list could be extended to cover all of the basic and secondary needs of the family members. In the same way, we can extend this line of thinking from the family as a human groupage form to society in general, a similar but larger human group. What society is basically trying to achieve is much the same as the family taken in a total systems context. Society is essentially a machinery that has some inputs associated with it, which through a certain set of activities result in certain outputs which ideally should be in line with society's own satisfaction and welfare objectives. Society needs many material and mental satisfactions which require an organized effort to be produced. Production is the prime function of society if it desires to sustain its existence. But production requires activity, which in turn requires transportation. We cannot eliminate the inevitabili or indispensability of transportation. All we can, and by all means should do is to minimize transport in such a way that production per unit of transport is maximized. The concept of unit of transport can be taken in any relevant meaning, e.g. ton-miles.

Transportation is associated with various types of interactions:

1. Interaction of people and people: This is the type of interaction which governs human relations, whether social or lucrative in purpose (the desire to visit with friends, or the need to go on a business trip)
2. Interaction of people and goods: This is the type of interaction which reflects our material needs (the desire to acquire a certain object)
3. Interaction of goods and goods: This is the type of interaction which is necessitated by production requirements (the need to gather a certain set of raw or semi-finished materials for assembly or processing)

All of the above-mentioned types of interactions play a lesser or greater role in the making of general transport activity.

The cost of transportation is a major determinant of the demand for transport. Persons show a different willingness to move depending on the distance to travel and also depending on different end results to be achieved by travelling. As a result, movement is realized only insofar as the comparative advantage of travel versus no-travel is at least equal or greater than the cost of transportation itself. This cost also includes the opportunity cost associated with the time spent in travelling. This is in line with our earlier statement regarding the maximization of the productivity of a unit of transport. As long as this requirement is met, all of the three interaction types enumerated above will have their say in the shaping of the general demand pattern for transport.

## Outlook of Air Transportation

The pattern of interactions outlined above taken together with the cost of transportation, including the opportunity costs incurred enhance the demand for air transport and entail the result that air transport acquires the status of one of the most important modes of travel. Needless to say, transport by air is a costly form of transportation, but the savings of air transport are reflected elsewhere. The considerable amount of time saved, which increases at a great rate with increasing stage lengths, reduces opportunity costs to a bare minimum. As for the movement of goods, time utility is reflected in such things as the reduction of inventory holding costs, of the risk of production interruptions due to raw material shortage, etc. The accomplishment of "movement from one place to another with the least possible expenditure of time and cost"[7] is more and more possible through air transportation.

The evolution of air transport has so far been rapid and profound. In a matter of two decades aircraft speeds have increased almost four times and the payloads have increased

[7] Marvin L. Fair and Ernest W. Williams, Jr., *Economics of Transportation* (New York: Harper and Brothers, 1959), p. 3.

about ten times. Although not necessarily reflecting the industry average, payload and average speed figures relating to aircraft of the same company could indicate the degree of development in time. A 1946-built Douglas DC-3 made an average speed of 220 km/hr versus 740 km/hr of the present-day DC-8 jet aircraft. The respective payloads of the two types of aircraft are 2650 kgms. and 18800 kgms.[8]

Furthermore, there has been a constant tendency of cost reduction in the operation and maintenance of aircraft which makes it possible to decrease the fares and which in turn entails the fact that air transport reaches an ever-enlarging market. Civil aviation has surpassed the forecasts of the most optimistic experts. Eight different forecasts for the 1965 traffic estimated in passenger-kilometers and a comparison of them with traffic actually performed in 1965 is given in Table I.

From the speed viewpoint, air transport has an unmatchable record, due both to its intrinsic speed and also to its ability to surmount geographical barriers.

As far as safety considerations are concerned, one may say that air transport today is probably the safest kind of transport, although the public image of air transport still undervalues its safety standards. But under the influence of time limitations

[8] For a more detailed comparison, refer to:

Jean-Georges Marais et Frédéric Simi, L'Aviation Commerciale ("Collection 'Que Sais-Je?'," No. 359; Paris: Presses Universitaires de France, 1964), pp. 26-27.

Frédéric Simi et Jacques Bankir, Avant et après Concorde ("Collection 'Société'," No. 25; Bourges: Éditions du Seuil, 1968), p. 135.

on the general public on one hand, and of greater speeds achieved by aircraft designers and producers on the other, air transport becomes manifold attractive even to the reticent prospective customer. Thus more and more people become of the flying crowd, because of this effect of aircraft improvement and the increase in the value of time for the general public. Due to the importance of time utility, more and more people are brought more and more often in contact with air transport and feelings of reticence are progressively dissipated.

TABLE 1

COMPARISON OF WORLD AIR TRAFFIC ESTIMATES AND ACTUAL PERFORMANCE FOR 1965

| Origin and date of study | Forecast (in billions of passenger-km) | Percentage of estimated to actual traffic[a] |
|---|---|---|
| Boeing (1961) | 188.0 | 94 % |
| T.P. Wright (1956) | 185.0 | 93 |
| ITA[b] (1962) | 179.0 | 90 |
| Douglas (1960) | 178.0 | 89 |
| Convair (1960) | 177.0 | 89 |
| Canadair (1956) | 169.0 | 85 |
| Projet Horizon (1961) | 161.0 | 81 |
| A.T.S.[c] (1960) | 156.4 | 79 |

[a] Actual traffic for 1965: 199 billion passenger-km.

[b] Institut du Transport Aérien.

[c] Research consultants for Hawker-Siddeley.

Source: G. Besse et G. Desmas, Les Prévisions dans le Transport Aérien: Méthodes et Résultats ("Etudes ITA," No. 66/7-F;

The airplane has been of great value by opening up isolated countries into the world economy. The economies of other than isolated areas have been helped significantly by air transport which provided a further and tremendous step toward a more perfect economy due to enhanced mobility of goods, services and persons. Air transport makes possible the introduction of men, their ideas and techniques into backward areas of the world and becomes the vehicle of such means of expression and thinking as books, newspapers, films, etc. It provides accelerated exchanges, and is in fact, an accelerator of exchanges. This is carried to such an extent that the airplane has become a tool of prestige and political influence.

> Using available forces, a nation penetrates and tries to fix relationships in the area beyond its specific boundaries. Any political unit is a possible example of spatial penetration . . . . Military, political, cultural, or economic forces, or combinations of these . . . can be used. . . . Operated in these contexts, transport techniques are means to extension, preservation, or minimum contraction of a political area.[9]

The airplane transports everything, everywhere. It carries far, quickly, and safely. These are the main strong points of air transport. Today, it takes about twelve hours to get from Istanbul to New York. Tomorrow, with the advent of supersonic transport, shortly referred to as SST, the same distance will be covered in about five hours, perhaps even less. This means that it will take roughly the same amount of time to fly to New York as to drive to Ankara.

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Paris: Institut du Transport Aérien, 1966), p. 19.

[9] Troxel, op. cit., p. 31.

Speed is only one feature of importance in air transport. More important perhaps is the independence of the airplanes with respect to natural geographic obstacles. It is especially on this point that airplanes surpass other kinds of transport. As airplanes acquired speed, they also acquired altitude and endurance. The range of today's commercial aircraft reaches far beyond the transatlantic distance, and even the transpacific one. The north pole which took so many years and so many human lives to be conquered, is flown over several times a day now. The highest mountain ranges constitute no challenge either.

This improvement in aircraft performance and security is also accompanied by a constant decline in the cost of the transportation unit: the passenger-kilometer. "The cost of the seat-kilometer in today's airplanes has always decreased. In fact it is lower now than the cost of the seat-kilometer for stagecoaches of the last century."[10]

The constant decline of airline fares, the easiness and comfort of air travel, and the universalization of the air transport organization through such institutions as the International Civil Aviation Organization(ICAO) and the International Air Transport Association(IATA) make air transport all the more powerful.

[10] Simi et Bankir, op. cit., p. 6.

# CHAPTER II

## A PRESENTATION OF THE GENERAL TRAITS OF LOCATION THEORY

Before entering the presentation of location theory or various models of locational pattern development, let us warn the reader that what we are trying to achieve is not to offer a full-fledged description or formalization of the theory, but rather to elaborate a consistent approach to the determinants of transportation activity, and only those elements of the theory that shall be deemed beneficial to the development of a certain line of thinking will be included in the presentation.

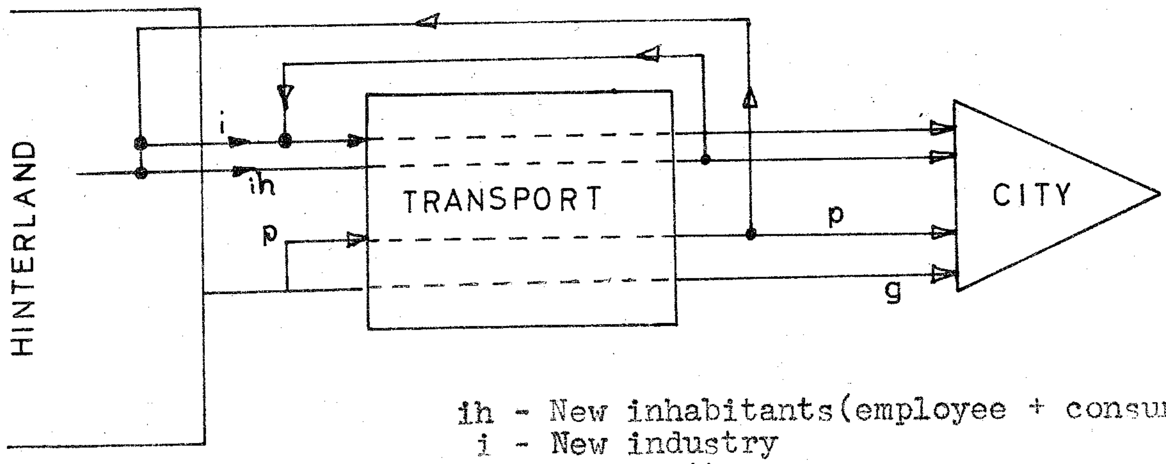
> Except in those resort and retirement areas where cities grow up because of such attractions as unusual scenery, climate, or similar manifestations of nature, or legalized gambling or quickie divorces, cities have been founded, have grown up and exist primarily to serve the needs of commerce.[11]

Cities provide a conglomeration of people which function both as the elements of production and of consumption in the economy. Large-scale manufacturing, distribution and storage, as well as financing is thus possible. Together with this, a concentrated market is available for the goods and services produced.

With this framework in mind, city location and growth can

[11] Sampson and Farris, op. cit., p.226

be traced down to some elements of transportation. Cities originally are established at locations where the exchange of goods and services is most facilitated. They grow more prosperous together with the prosperity of these exchanges. As they grow in this way, more people are attracted to them, because of increased and better-paid employment opportunities which arise. Since enough people are available both as a labor force and as a consumer body, further industry is attracted. Existing transport possibilities enhance this attraction. There is another side to this evolution, which through what we may call a feed-back process, stimulates the development of still more improved transport services and the establishment of new routes. Therefore it can be admitted that transportation and the city are influencing one another or feeding back on one another for their simultaneous and balanced growth. This process is schematically outlined in Fig. 1.




ih - New inhabitants(employee + consumer)
i - New industry
p - prosperity
g - goods and services to be marketed

Fig. 1--Feedback process between city and transport.

What location theory is primarily concerned with can be summarized in two types of problem. The first of these is trying to determine where economic activity locates itself for the maximization of returns or why specific patterns of location come into being. The second type of problem is trying to determine the optimal location for an economic entity with respect to an already existing locational framework.

There are various theoreticians who have engaged in location theory work and perfected it to a considerable extent. It will be worthwhile to review the general features of the theory within the frame of this thesis. Classics such as von Thunen and Weber cannot be omitted. However not to go into the work of authors such as Hoover, Greenhut, Isard, Losch et al. would not be detrimental to the development of the fundamental line of thinking of this study. We may further assert that they lie beyond the scope of this text.

## Von Thunen's Model

Von Thunen's theoretical work relates systematically transport costs to specific locational patterns within an agricultural context. It is a highly abstract and simplified theory which is based on utterly simplified assumptions. Von Thunen assumed an isolated state of affairs where there was a city established at the center of a large plain. The plain was used for agricultural purposes and showed equal properties throughout its area regarding climate, fertility and surface characteristics. The city received all its agricultural products from the plain considered and was the only market available to the farmers on the plain. There was but one type of transportation available to everyone at all points on the plain moving on a straight line to the city and transportation costs showed a linear relationship with respect to distance.

Depending on the nature of the product, von Thunen's model results in an array of concentric cercles, the center being the city itself, which delineate the zones where certain crops proved to be more profitable than others to cultivate.

Items that are predominantly perishable or are less valuable per unit of weight will have to be produced near the city, whereas those that are less perishable or more valuable per unit of weight will tend to be produced further away from the city.

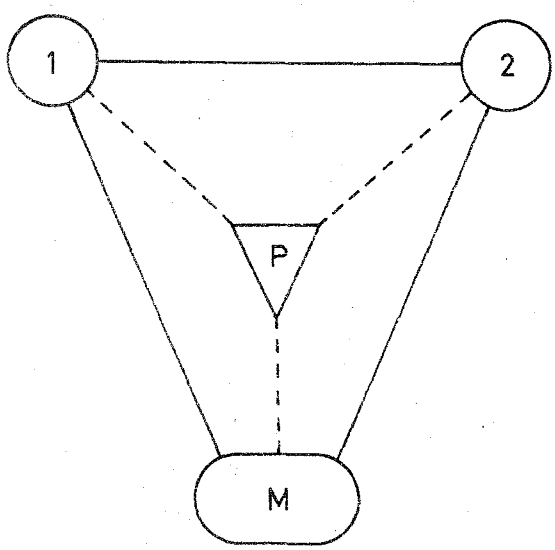
Although his model was extremely abstract, and his assumptions were highly restrictive, von Thunen's model has proven to be an important contribution to the philosophy of transportation economics. By virtue of the fact that his assumptions were indeed highly restrictive, the theory highlights impeccably the effect of distance in the development of locational patterns and does so in a systematic fashion, by letting all other things remain equal.

## Weber's Model

As indicated at the beginning of the chapter, only a special case of Weber's model will be discussed for reasons previously mentioned.

Although what we are going to review is only a special case of the Weberian model, it is nevertheless perhaps the one that is the most comparable to the majority of real world industrial location problems. Let us suppose a production process which requires two different types of raw material situated and obtainable at two different locations. Assume that the market area for the final product is neither at any of the locations of the two raw materials, nor on the prolongation of the straight line connecting them. The two raw materials will lose weight in processing or manufacture, i.e. they will both yield some scrap. Assume furthermore that labor costs are the same regardless of the location, at least for the purposes of this analysis. The transportation costs, as in von Thunen's model, are linearly dependent on distance.

Under the circumstances just described, a triangle will be formed when the three points representing the two raw material locations and the market are connected to one another. It is easily noticeable that production will not occur at any point outside the triangle, since this would entail more transportation than necessary. It must occur then, either on one of the sides or one of the corners of the triangle or at some point within the inner area. It can be shown that since both of the raw materials lose weight during the production process, the final product should be produced at a certain point within the inner area of the triangle where the two raw materials will be brought and from where the final product will be shipped to the market location at a minimum total cost of transportation. Such a Weberian industrial location triangle is pictured in Fig. 2 below.




1-Raw material source

2-Raw material source

P-Production point

M-Market

Fig. 2.--Schematic representation of the Weberian industrial location model.

The exact determination of the production point that will yield the minimum total transportation expenditure will depend on the relative quantities of the raw materials used, and their weight-losing properties.

As it may be observed, this model is in close parallel with the center of gravity concept in physics resulting from the relative attraction forces acting on a system, whereupon the system comes to an equilibrium at its center of gravity.

# CHAPTER III

## TOWARD A JUSTIFICATION OF GRAVITATIONAL OR INTERACTION MODELS

> Various models have been especially designed for analyzing . . . , or for measuring or predicting the interaction between areas. . . .
>
> In general, this latter group of models postulates that size of an area or city exerts a demand "pull" and that distance brings a supply "drag." Trade or other interaction between two communities varies positively according to their sizes and negatively according to distance. In the simple size-distance formulation of such models, there is an implicit assumption that other factors are equal. On the demand side, this means similar cultural, social, and physical environments, and income levels; for supply, it means that distance, usually under a straight-distance formula, is the only pertinent cost difference to be overcome. . . .
>
> Various . . . gravitational models . . . have been developed for specific purposes. If viewed simply as first-approximation explanatory devices, these models may be useful. Despite the sometimes extravagant claims of some of their builders and users . . . , their success in actual prediction has not been spectacular.
>
> . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
>
> In addition, no one has conclusively demonstrated that population size alone generally determines the attraction between different communities in a Newtonian sense. Gravity models which exclude by assumption numerous physical, social, cultural, and income factors, and institutional ties, are likely to exclude thereby the major forces of gravitational attraction.[12]

The above quotation has been incorporated in this text despite its length, because by its denial of the predictive abilities of gravitational interaction models, it puts the reader on

[12] Sampson and Farris, *op. cit.*, pp. 232-33.

the defensive and would therefore (hopefully) make him more convinced of the virtues of such models as a result of an attempt for persuasion with this initial defensive attitude than without it. Furthermore, and paradoxical as it may seem, it gives clues for possible means of improvement of gravitational interaction models, by virtue of the fact that it points out common deficiencies of such models.

We have seen that demand for transport is generated by the channeling of economic activity and is an integral part of it. We have also argued that transport was inevitable and even indispensable, lest we resign to the cessation of activity in general.

Since we cannot eliminate transportation altogether, we must minimize transport in such a way that production per unit of transport is maximized. This leads us to the concept of center of gravity which, as we have seen, is reflected in the general outline of location theory, namely in the Weberian industrial location model.

As long as there is economic activity going on at various locations, there is bound to be some form of interaction between the different sets of activity. But the crucial question is how to measure this interaction in a relevant, reliable and furthermore practical way so as to attain workable results. Of course it is understood that economic, social or generally human interaction could not possibly be measured in such clear-cut fashion as actual gravitational attraction is measured, i.e. simply by measuring the size or weight of the respectively interacting masses in common weight units. However a certain analogy can be depicted and hopefully through an inductive process, certain relationships can be brought to light.

Some form of weight measure can be devised to accurately define the importance of various locations with respect to one another and in terms of certain indicators of which the relevance could have been determined beforehand. One can do nothing but agree with Sampson and Farris in that population size alone cannot possibly be one such measure. But why set forth this criticism and stop going any further, discarding the whole idea altogether? Why condemn a concept simply because "no one has yet (italics mine) conclusively demonstrated . . . the attraction between different communities in a Newtonian sense"?[13] Certainly population size is not the sole determinant of inter-community attraction, but it is a component force in the whole complex of forces that determine attraction as a whole. There is no doubt that transportation activity is related to certain attraction forces, and where forces occur, some form of a gravitational concept can be of relevance, because the existence of forces readily implies the existence of either attraction or repulsion or both.

What we are after is a general definition of a measure relating to a certain index of mobility potential. The index values will then be used to determine the extent of point-to-point attraction within a certain system. The total system concept is of extreme importance here. By virtue of the fact that

[13]Sampson and Farris, loc. cit.

we are dealing with gravitation, we ipso facto are dealing with a resulting equilibrium therefrom, and assuming this end result of equilibrium, we have to define the system totally and include all relevant forces and their effects in reaching this very equilibrium. Therefore, unless we can legitimately and fairly accurately approximate the effects of any extraneous forces by introducing an extra point representing the outer system under some such heading as "rest of the world", gravitational models will have to be applicable only to closed circuit systems and the analysis will be in terms of the parameters of this closed circuit.

### Factors Affecting the Volume of Travel

In assessing the volume of travel, we have to first determine the important factors affecting the volume of travel, and to do this, we can proceed through a rigorous study of the travel centers, i.e. departure and destination points. We can classify these factors in the following fashion:

1. Economic and social characteristics of travel centers.
   a) Commercial cities, where the dominating activity is trade.
   b) Industrial cities, where production activity is the prime factor.
   c) Institutional centers, where commercial and industrial activities are not very important but other activities such as those related to existing governmental organizations, educational institutions, or touristic facilities are witnessed.

2. Geographic situation of travel centers with respect to one another.
   a) Distance with respect to other centers.
   b) Presence of natural ground hindrances (mountains, lakes, straits, etc.) along the travel span.[14]

Additive versus Multiplicative Indices

An index used by the Civil Aeronautics Board of the United States in order to estimate the relative importance of traffic between a city A and cities B,C,D,etc. is the <u>passenger traffic ratio</u> p defined as:

$$p = \frac{P \cdot P'}{d}$$

where:

P: Population of A

P': Population of B,C,D,etc.

d : Distance between them

The result thus obtained is used as a ranking index between the various air connections. It is to be noted that the demographic product rather than the demographic sum is used in the formulation of the index. A numerical example will suffice to justify the adoption of multiplicative indices rather than additive ones. Let there be four cities A,B,C, and D. Let their populations be 500,000; 500,000; 999,000; and 1,000 respectively. Using an additive index, we would have

$$A + B = C + D \quad 1,000,000$$

Supposing the distance between A and B to be equal to

[14]The factors thus enumerated will be explained in detail and their relevance discussed later in the text.

that between C and D, an additive index would indicate the same amount of interaction between the cities of each set. However, it is self-evident that A and B will have a much larger traffic between them than that between C and D, since the latter is such a negligibly small town. But the multiplicative index would give a much clearer picture of the real-life situation as the following figures indicate.

$$A \times B = 2{,}500 \times 10^8$$

$$C \times D = 9.99 \times 10^8$$

Presentation of Various Models already in Use

G. Desmas has compiled various methods of traffic estimation in air transport.[15] The following is taken in summary form from his study.

1. Study by S.B. Richmond: "Forecasting Air Passenger Traffic by Multiple Regression Analysis" (1956)[16]

After an analysis of existing traffic, a search is made for a relationship between this traffic and "common interests," distance and quality of existing services between the two points being studied. A number of characteristics of urban centers, such as economic, social, cultural, and demographic factors are considered. Especially the population and the distance have been par-

[15] G. Desmas, Méthodes d'Etude du Marché dans le Transport Aérien ("Etudes ITA," No. 64/11-F; Paris: Institut du Transport Aérien, 1964), pp. 23-32.

[16] Information regarding the individual studies considered are reproduced as they are related in Desmas' study. It will be noticed that they are unfortunately incomplete as to the facts of publication.

ticularly examined in the quest of an applicable formula. The number of travelers registered in hotels according to their permanent residences has been used as a criterion in developing the model. The general shape of Richmond's model is reflected by the following formula:

$$T_{ij} = K \cdot \frac{P_i \cdot P_j}{D_{ij}}$$

which expresses the traffic $T_{ij}$ between two towns of populations $P_i$ and $P_j$ separated by a distance $D_{ij}$.

2. Study by Daniel M. Belmont (University of California): "A Study of Airline Inter-Station Traffic" (1958)

Belmont's model is of the form

$$T_{ij} = K \cdot \frac{(T_i \cdot T_j)^p}{D^q} .$$

He interpreted the minor influence of distance on long routes, because q is calculated to be less than one. Desmas asserts that this model can be used to estimate potential air traffic between two towns which have no air service.

3. Study by W.J. Platt (Consolidated Vultee): "Evaluating Intercity Air Traffic" (1946)

This study is based on the relationship to be found on the following page.

$$t = k\frac{\sqrt{P_1 \cdot P_2}}{d}$$

where $t$ is the traffic between two towns of populations $P_1$ and $P_2$ at a distance $d$ from one another.

4. Study by S. Tomasino: "Contributo per il calcolo di un indice della distribuzione territoriale della clientela potenziale dei servizi aerei in Italia" (1961)

Tomasino tries to establish an index of local activity of regions of Italy by a calculation based on fourteen economic parameters (number of bank accounts, use of telephone, wages, hotels, etc.) The value for the regional index is then expressed in percentage value for Italy as a whole. Recorded traffic at Rome airports is used to estimate the theoretical traffic for each regional town.

5. Study by Dr. Ing. H. P. Piper: "Die Netzanalyze als Grundlage für Luftverkehrsplanungen" (1957)

Dr. Piper suggests a formula of the form

$$Y = \frac{R_1 \cdot R_2}{D^n} \cdot C$$

where $R_1$ and $R_2$ are representative of the air traffic potential of the respective cities and notes that according to American studies, it would seem that wholesale turnover or the number of employees in industry can be used for $R$.

Piper's model contains certain interesting refinements such as the inclusion of the time-saving factor in air travel and the price per unit of time saved, which are supposed to be included in the factor C which should not be accepted as a constant. The time-saving factor is expressed as

$$Z_{AB} = 1 - \frac{T_{air}}{T_{ground}}$$

The price per unit of time saved is expressed as

$$W = \frac{P_{air} - P_{ground}}{T_{air} - T_{ground}}$$

where P represents the price and T the duration of travel. The subscripts are self-explanatory.

All of the models reviewed above present certain common points. No matter what the details of the various formulae may be, one notes right away that the town sizes are in direct proportion to the volume of traffic, whereas distance between the towns exhibits an inverse proportionality, which is very interesting information for builders of other such models.

# CHAPTER IV

## APPLICATION OF THE GRAVITATIONAL FLOW CONCEPT TO CLOSED-CIRCUIT AIR TRANSPORT NETWORKS

### A Formalization of Point-to-point Network Flows in an n-point Closed-circuit

Presentation.--Let us define a closed system in which there are various airports located at $n$ different points. Airline services are operated between a number of these airports. Certain airports may be connected to all of the other airports,[17] certain others may be not. If we use two counters or subscripts $i$ and $j$ denoting the origin and destination of travel and $P$ denoting the number of passengers, $P_{ij}$ will represent the number of passengers carried from $i$ to $j$ within a certain period of time. By the use of this notation, we will obtain a matrix where the $i^{th}$ row will contain figures representing the number of passengers departing from $i$ to the destinations 1, 2, 3, . . . , $j$, . . . , $n$; and the $j^{th}$ column will be constituted by figures representing the number of passengers arriving to $j$ from the origins 1, 2, 3, . . . , $i$, . . . , $n$; subject to the limitation that the terms along the diagonal, namely $P_{11}$, $P_{22}$,

[17] The said connections need not be non-stop connections. However, transfer connections are not acceptable within the scope of this definition; whereas all direct connections are.

$$
\begin{array}{c|cccccccccc|c}
 & 1 & 2 & 3 & \cdots & j & \cdots & n & \\
\hline
1 & P_{11} & P_{12} & P_{13} & \cdots & P_{1j} & \cdots & P_{1n} & D_1 \\
2 & P_{21} & P_{22} & P_{23} & \cdots & P_{2j} & \cdots & P_{2n} & D_2 \\
3 & P_{31} & P_{32} & P_{33} & \cdots & \cdots & \cdots & \cdot & \cdot \\
\vdots & \vdots & \vdots & \vdots & & \vdots & & \vdots & \vdots \\
i & P_{i1} & P_{i2} & \cdots & \cdots & P_{ij} & \cdots & P_{in} & D_i \\
\vdots & \vdots & \vdots & \vdots & & \vdots & & \vdots & \vdots \\
n & P_{n1} & P_{n2} & \cdots & \cdots & P_{nj} & \cdots & P_{nn} & D_n \\
\hline
 & A_1 & A_2 & \cdot & \cdots & A_j & \cdots & A_n & S
\end{array}
$$

Fig. 3.--Point-to-point passenger transport matrix (General form.)

$P_{33}, \ldots, P_{nn}$, will all be equal to zero. Using a shorter notation, this becomes:

$$P_{kk} = 0 \qquad \text{for } k = 1, 2, 3, \ldots, n$$

In this fashion we obtain a point-to-point passenger transport matrix, shown in Fig. 3 above. On the right hand side of the matrix, we find the total number of departures from each airport regardless of destinations. These are $D_1, D_2, \ldots, D_i, \ldots, D_n$. Just in the same way, at the bottom the total number of arrivals at each airport regardless of origins are tabulated: $A_1, A_2, \ldots, A_j, \ldots, A_n$.

Let us assume that we know only the $D_i$'s and $A_j$'s and we would like to apportion (paylaştırmak) them to the various cells of the matrix in a consistent manner. Let us furthermore adopt the principle of proportional allocation (tahsisat) of row totals according to column totals and of column totals according to row totals.

The resulting relationship that would yield the individual cell values will be then:

$$P'_{ij} = \frac{D_i \; A_j}{D_1 + D_2 \; . \; . \; . + D_i \; . \; . \; . + D_n} = \frac{D_i \; A_j}{\sum_{i=1}^{n} D_i}$$

or $$P'_{ij} = \frac{D_i \; A_j}{A_1 + A_2 \; . \; . \; . + A_j \; . \; . \; . + A_n} \quad \frac{D_i \; A_j}{\sum_{j=1}^{n} A_j}$$

Since all departing planes will have to arrive some place, by definition we have:

$$\sum_{i=1}^{n} D_i = \sum_{j=1}^{n} A_j = S$$

Then $P'_{ij}$ is conveniently expressed as:

$$\boxed{P'_{ij} = \frac{D_i \; A_j}{S}}$$

But this relationship does not satisfy the constraint (sınırlamak)

$$P_{kk} = 0 \qquad \text{for} \quad k = 1, 2, \; . \; . \; . \; , n$$

In fact, this is the reason that we use the $P'_{ij}$ notation rather than simply $P_{ij}$.

In order to eliminate this inconsistency, let us further proceed to a second proportional allocation, whereby each $P'_{kk}$ term will be considered as made up of two parts, one of which will be allocated to the (n-1) terms of the $k^{th}$ row, and by the same token, the other to the (n-1) terms of the $k^{th}$ column.

$$P'_{kk} = P'_{kk\text{-row}} + P'_{kk\text{-column}}$$

$$\text{or} \quad P'_{kk} = \frac{D_k - P'_{kk}}{D_k + A_k - 2\,P'_{kk}} \cdot P'_{kk} + \frac{A_k - P'_{kk}}{D_k + A_k - 2\,P'_{kk}} \cdot P'_{kk}$$

The first term of the above equation represents that part of the cell value at the intersection of the $k^{th}$ row and the $k^{th}$ column (therefore a diagonal cell) which is to be apportioned to all the other cells of the $k^{th}$ row, and similarly the second term of the equation represents that part of it to be apportioned to all other cells of the $k^{th}$ column, as the subscripts indicate. This apportionment will be proportional with respect to all terms of the row (or column), except of course to the diagonal one. By doing so, we obtain an adjusted value for $P'_{ij}$ which we will denote by $P^*_{ij}$.

düzeltmek

$$\boxed{P^*_{ij} = P'_{ij}\left(1 + \frac{P'_{ii}}{D_i + A_i - 2\,P'_{ii}} + \frac{P'_{jj}}{D_j + A_j - 2\,P'_{jj}}\right)}$$

We have thus obtained a formula by the use of which we can apportion total figures to the appropriate cells always in

Tahsis etmek

compliance with the requirement of having zero-value cells along the diagonal of the point-to-point passenger transport matrix.

The derivation procedure above and the relationship arrived at itself could perhaps be viewed as an absurd mathematical artificiality which serves no constructive purpose. However, when regarded as the first phase of an effort to obtain a workable formula relating gravitational flows in a closed system, we see that except for a term representing distance, there is nothing missing in the $P_{ij}$ relationship, which in effect is starred simply because the final relationship has not yet been attained.

In order to include the dimension of distance, we propose the following adjustment:

$$P_{ij} = e^{\alpha} \frac{\left(P^{*}_{ij}\right)^{\beta}}{d^{\gamma}_{ij}}$$

where $d_{ij}$ : distance between points $i$ and $j$.

$\alpha, \beta, \gamma$ : constants (parameters of the system)

The term $e^{\alpha}$ is a constant introduced for purposes of correction of units. It has been taken in exponential form in order to facilitate the application of linear multiple regression on a logarithmic scale by the application of the formula

$$\boxed{\ln_e P_{ij} = \alpha + \beta \ln_e P^{*}_{ij} + \gamma \ln_e d_{ij}}$$

Concept and measures of connectivity.--In order to get a general appreciation of flows in closed-circuit networks, let us review the properties of connectivity associated with such networks.

> The word connectivity expresses the existence of linkages between elements, and the possibility for these elements to communicate among them. . . .
> All problems involved with the circulation of economic "objects" (persons, goods, credits, debts, information) between economic "locations" (countries, regions, urban or rural centers, industrial locations, loading and unloading points, machines of a chain, persons of an economic organization or establishment, groups of a complex economic set, etc.) can be represented by what is called a graph.[18]
> . . . . . . . . . . . . . . . . . . . . . . . . . . .
> The most general property [of a graph or network] is that of the quantitative existence of linkages in a network, i.e. of connections between the various types of economic "locations" that one could visualize, or graph "nodes" (quantitative measure of connectivity.)[19]

We will say that there is connectivity between two locations as long as exchanges are present between them. These exchanges could be performed either directly or indirectly, i.e. through intermediate stops between origin and destination points. The concept of connectivity also brings forth the concept of degree of connectivity. When there is direct connectivity, we speak of first-degree connectivity, and when connection exists but indirectly, we speak of $n^{th}$-degree connectivity, n being the number

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[18] Erbès states that "for abstract definitions of connectivity notions" the reader can refer to:

C. Berge, Théorie des Graphes et ses Applications (Paris: Dunod, 1958)

A. Kaufmann, Méthodes et Modèles de la Recherche Opérationnelle (Paris: Dunod, 1959), Tome II.

[19] Robert Erbès, L'Intégration Economique Internationale, trans. Hasan Akbelen ("Etudes Economiques Internationales"; Paris: Presses Universitaires de France, 1966), pp. 107-08.

of intermediate points minus one.

a) Connectivity number.--This number is taken as the number of linkages between the nodes of a network, without reference to the direction of flow. So in an n-point network, the minimum connectivity number will be

$$N_{min} = n - 1$$

The maximum number of connectivity will be then

$$N_{max} = \frac{n\ (n - 1)}{2}$$

In this type of a network we obtain a triangular matrix of which the diagonal contains zeros only and all the other cells are either one, expressing merely that connectivity exists for the connection represented by that cell, or a figure relating the quantity of the economic object taking part in that flow as a result of the existing state of connectivity. (See Table 2.)

We note here that in any connected network, it is always possible to proceed from one node to another, but for the case of the minimally connected network, the number of possible route options is only one.

b) Actual connectivity ratio.--If we denote by N the actual number of existing connections (direct or indirect), the actual connectivity ratio is defined as

$$C.R. = \frac{N_{max}}{N}$$

c) Connectivity index.--The actual connectivity ratio is

TABLE 2

POINT-TO-POINT PASSENGER TRAFFIC ON TURKISH AIRLINES DOMESTIC NETWORK (Summer 1968)

| From \ To | ADA | AFY | ANK | AYT | BDM | BTZ | BZI | DIY[a] | ERC | ERZ | EZS | IST | IZM | KYZ | MLX | SSX | TZX | VAN | VAS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ADA | | | 5682 | | | | | | | | | 7440 | | | | | | | |
| AFY | | | 21[b] | 21[b] | | | | | | | | 185 | | | | | | | |
| ANK | 6354 | 63[b] | | 798[b] | | | | 4509 | 445 | 3047 | 1564 | 46335 | 10426 | 401 | 710[b] | 2886 | 3681 | 1189 | 429 |
| AYT | | 36[b] | 784[b] | | | | | | | | | 5791 | | | | | | | |
| BDM | | | | | | | 58[b] | | | | | 6705 | | | | | | | |
| BTZ | | | | | | | | | | | | 18956 | | | | | | | |
| BZI | | | | | 58[b] | | | | | | | 847[b] | | | | | | | |
| DIY[a] | | | 5088 | | | | | | | | | 2221 | | | 329[b] | | | 1781 | |
| ERC | | | 586 | | | | | | | 39[b] | | 511[b] | | | | | | | 147[b] |
| ERZ | | | 3143 | | | | | | 23 | | | 2173 | | | | | | | 226 |
| EZS | | | 1429 | | | | | | | | | 904 | | 154 | | | | | |
| IST | 6827 | 207 | 46108 | 5541 | 6853 | 18393 | 875[b] | 1920 | 468 | 2272 | 775 | | 45711 | 844 | 731[b] | 2676 | 3522 | 507 | 669 |
| IZM | | | 9807 | | | | | | | | | 43842 | | | | | | | |
| KYZ | | | 486 | | | | | | | | 85 | 658 | | | | | | | |
| MLX | | | 1078 | | | | | 217[b] | | | | 791[b] | | | | | | 95[b] | |
| SSX | | | 3119 | | | | | | | | | 2280 | | | | | 427[b] | | |
| TZX | | | 3696 | | | | | | | | | 2777 | | | | 420[b] | | | |
| VAN | | | 1246 | | | | | 1931 | | | | 470 | | | 95[b] | | | | |
| VAS | | | 510 | | | | | | 77 | 170 | | 517 | | | | | | | |

[a] Figures for Batman are included in those of Diyarbakır.

unfortunately not a good indicator of the state of the network. It does not tell us whether new linkages should be added or existing ones should be deleted in case there are redundancies in the network connections.

So, we define the connectivity index as

$$C.I. = N - (n - 1) = N - N_{min}$$

where N denotes the number of existing linkages as before.

So, for a connected network we have

$$N \geqslant n - 1$$

Then, if $C.I. < 0$, we say that the network is not connected, and if $C.I. > N_{max} - N_{min}$, we speak of redundancies in the network.

Applying these concepts to the Turkish Airlines domestic network, we obtain the following results:

$$N = 42$$

$$n = 19$$

$$N_{min} = 19 - 1 = 18$$

$$N_{max} = \frac{19 \times 18}{2} = 171$$

$$C.R. = \frac{171}{42} = 4.07$$

$$C.I. = 42 - 18 = 24$$

what is an acceptable value for C.R., C.I.

## Determination and Use of the Empirical Point-to-point Network Flow Model

General properties of the model.--The model which we are trying to determine will be based on interaction forces existing between Turkish cities and will attempt to determine quantitatively the degree of exchanges of persons between them in terms of airline passenger figures.

As we have tried to develop the idea of a total system so far, and based on it we introduced the concept of connectivity, in order to determine the equilibrium plane of the system on which the results sought will be found, we have to correct the presently available data to fit perfect connectivity conditions. Then and only then, gravitational interaction forces can be legitimately used. This is necessary in order not to sacrifice consistency.

Our main assumption will be that the <u>weight</u> of a certain city for the purpose of determining gravitational attraction, can be defined as made up of a combination of various relevant socio-economic variables, each playing a determined role to a determined extent. This weight can be said to represent an index of mobility potential for the city considered and rather than using any arbitrary scale of measurement units, we shall arrange the model so as to reflect by this index the number of potential arrivals or departures (<u>not their sum</u>) to the airport of that city. Furthermore, it is logical to assume that the number of air travelers using the airport of a given city is a good surrogate of the <u>weight</u> of that city in terms of air traffic potential.

Secondly we are going to assume that the general gravitational formula developed earlier (see p. 34) will hold for the total system, which is in our case the domestic network of Turkish Airlines. This assumption merely states that the parameters $\alpha$, $\beta$, and $\gamma$ will be applicable to the totality of Turkish cities.

Thirdly, we will state that the estimates derived from the model shall be deemed reliable, with the understanding that they will of course be subject to a margin of statistical error, for those airline connections that already were in operation and whose air travel data has been used for the building of the model. However, the estimates for those connections that are presently non-existent should cautiously be taken as merely an indication of the order of magnitude or importance of any specific connection, had there actually been such a connection.

The next chapter therefore will deal with the application of this model to the Turkish Airlines domestic network.

# CHAPTER V

## CROSS-SECTIONAL ANALYSIS OF THE DOMESTIC NETWORK OF TURKISH AIRLINES

### Setting the Basis for the Model

As we have made clear earlier, one of the essentials of gravitational models is the determination of the relative weights of the communities considered. We have said aso that these will be assumed to bear a relationship to certain socio-economic factors which will form the basis of the analysis. Let us now review what these socio-economic factors will be and why they have been chosen rather than others.

A. Socio-economic factors influencing air travel.

1. Urban population.--The city's economic activity is largely determined by the size of its population (cf. location theory, Chapter II.) The very fact that any activity will be due to the people originating it makes population a sine qua non requirement in a list of socio-economic factors. But what type of population? Certainly, since we are considering a special kind of transport, namely that which is done by air, we would be entitled to choose urban population rather than population in toto,

at least for the case of Turkey, where the population in higher income brackets is largely accounted by urban population.

2. Literate population.--For the specific case of Turkey where the degree of illiteracy is considerably high, the significance of literate population rather than population per se was thought to be worthwhile to investigate in the context of the regression analysis.

3. Bank deposits.--The volume of bank deposits reflects the prosperity of the urban community, considering that most of the banks are located at urban centers in the first place and that the rural population's savings can be assumed to be small in comparison to those of the urban one. Private and commercial deposits have been included in the figures and official government deposits are excluded. It is clear that air travel requires a certain minimum level of prosperity. Bank deposits rather than income tax revenues have been accepted as a better indicator of prosperity, because of the notorious unreliability of income tax figures reported by taxpayers.

4. Number of firms.--When considering the number of firms, two basic categories have been accepted as reflecting properly the general commercial activity of the towns considered. These were the joint-stock and limited responsibility companies. It is generally accepted that business accounts for a large part of air travel. The percentage of business travel in the United States is 50 per cent. "The United States is the leading 'consumer society' and yet . . . [this figure shows] that, as yet, really

quite a small proportion buy air travel out of personal income."[20]

5. Quantity of electrical energy used for illumination.--The consumption of electrical energy is a good sign of prosperity and of consumption expenditures in general. Since what we are looking for here is an indication of consumption expenditures of individuals, industrial consumption was not included in the figures.

6. Number of transient facilities.--

a) Overnight accommodation: The number of beds offered by hotels, motels, pensions, etc. has been taken in order to have a measure of the town's attraction power.

b) Restaurant capacity: The number of restaurant seats has been included in the analysis for the same reason as overnight accommodation capacity.

The analysis is assumed to show subsequently whether either one or both are significant in the determination of air traffic potential.

7. Number of private automobiles.--The ownership of an automobile is a good indication of prosperity, especially in Turkey. Therefore, the number of automobiles can be expected to show a high correlation with air traffic.

8. Number of registered radios.--The number of registered radios is quite a reliable figure in Turkey and is perhaps the only reliable figure available for anything in the category of household appliances. This also was expected to be, to a certain extent, an indication of the degree of prosperity.

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[20] Jack L. Grumbridge, Marketing Management in Air Transport ("Business Management in Transport"; London: George Allen and Unwin, 1966), p. 44.

9. Number of telephone subscriptions.--Telephone subscriptions are scarce utilities in Turkey and constitute even a commercial commodity, since they can be disposed of by way of trade. Therefore, they can be expected to be a very good sign of the availability of disposable income.

10. Measures of outside connections.--

a) Number of letters exchanged,

b) Number of telegrams sent and/or received,

c) Number of completed long-distance calls.

All of the above are by themselves measures of interaction with other communities. Since they reflect a tendency toward long-distance interests, they can be expected to bear a relationship to the extent of air travel.

11. Number of associations.--The weight of a city is also accounted for by its degree of institutionalization. The number of associations presently active in a city can be accepted as a measure of the degree of institutionalization, if nothing better is available.[21]

12. Number of passengers transported on the highways.--Although air transportation is in many ways different than ground transportation, an already existing ground traffic can be investigated as to whether it bears a relationship to potential air traffic. At any rate, as a *prima facie* assumption, we can say it would be relevant to include it in the formulation of a mobility

[21] The government employees would have been a very good measure of the degree of institutionalization, especially to account for Ankara's air traffic. However, this precious data could not be obtained.

index.

All of the above-enumerated variables are to be found in Appendix A. The data is given for each of the sixty seven provinces of Turkey. Since there are not sixty seven airports in Turkey, but nineteen, we are going to assume that the nineteen airports of Turkey will constitute nineteen different regions to which one or more provinces or part of them will be attributed.

B. Determination of the hinterlands of Turkish airports.

It must unfortunately be admitted that no study relating the passenger profiles of each airport broken down with respect to the provinces of their permanent residence has been found by the writer of this text. It would have been very beneficial for the results of this work, if we had this information (e.g. of the air travelers departing from or arriving to Ankara, x per cent are from Ankara, y per cent from Eskişehir, z per cent from Çankırı, etc.) Since this is not the case, our only possibility is resorting to common sense and associating provinces or portions of them with individual airports by more or less educated guesses, i.e. by putting ourselves in the place of a resident of a particular province and taking into account the relative proximity of nearby airports and the most probable directions of travel.

This allocation will be as follows:

Adana (ADA)[22]: Adana + 2/5 Konya + İçel + Hatay + 1/3 Maraş
+ 1/3 Niğde + Gaziantep + 1/2 Urfa

[22] The abbreviations in parentheses are international airport name codes, and these will be used throughout for the various tables.

Afyon(AFY) : Afyon + 1/5 Konya + 1/2 Isparta + 2/3 Kütahya + Uşak + 1/3 Eskişehir + 1/4 Denizli

Ankara(ANK) : Ankara + 2/3 Eskişehir + Çankırı + Bolu + Çorum + 2/5 Konya + 3/5 Yozgat + 1/2 Kırşehir + Kastamonu + Zonguldak

Antalya(AYT) : Antalya + Burdur + 1/2 Isparta

Bandırma(BDM) : 2/3 Çanakkale

Bursa(BTZ) : Bursa + Bilecik + 1/3 Kütahya

Balıkesir(BZI) : Balıkesir + 1/3 Çanakkale

Diyarbakır(DIY) : Diyarbakır + 1/2 Urfa + Mardin + Siirt

Erzincan(ERC) : Erzincan

Erzurum(ERZ) : Erzurum + Kars + Ağrı + 1/2 Muş

Elâzığ(EZS) : Elâzığ + Tunceli + Bingöl + 1/2 Muş

İstanbul(IST) : İstanbul + Tekirdağ + Edirne + Kırklareli + Sakarya + Kocaeli

İzmir(IZM) : İzmir + Manisa + Aydın + Muğla + 3/4 Denizli

Kayseri(KYZ) : Kayseri + Nevşehir + 1/5 Yozgat + 1/3 Maraş + 1/2 Kırşehir + 2/3 Niğde

Malatya(MLX) : Malatya + Adıyaman + 1/3 Maraş

Samsun(SSX) : Samsun + Sinop + Amasya + Ordu + 1/3 Tokat

Trabzon(TZX) : Trabzon + Giresun + Gümüşhane + Rize + Artvin

Van(VAN) : Van + Bitlis + Hakkâri

Sivas(VAS) : Sivas + 2/3 Tokat + 1/5 Yozgat

After having assumed the above distribution of hinterlands according to airports, we shall determine all socio-economic variables for the region after the specified pattern.

A Reconstruction Toward the Establishment of Perfect Connectivity Conditions

As a prerequisite of the gravitational model we have to assume perfect connectivity conditions. If they do not exist, we must find a way to establish them, mutatis mutandis. To this end we propose the following.

The existing lines of Turkish Airlines will be investigated as to the number of passengers being carried. Since the summer season is most active, the data used for the analysis will be that for summer 1968. Denoting by $X_k$ the various socio-economic variables at hand, we will try to establish a relationship of the form[23]

$$P_{ij} = f( X_{1i}\, X_{1j},\ X_{2i}\, X_{2j},\ .\ .\ .\ ,\ X_{ki}\, X_{kj},\ .\ .\ .\ .\ ,\ X_{ni}\, X_{nj} )$$

where $n$ is the total number of variables.

To do so, we shall try various ways such as the use of the cross-products of the variables as shown above in their original form, then of their logarithms as the variables. We will then include the distance between i and j as a variable and in these different forms of the equation, we will try to obtain the best relationship for $P_{ij}$ by multiple regression analysis.

After thus having established a formula which will make it possible to estimate the traffic between any city $i$ and $j$, we will calculate $P_{ij}$ for all possible connections. Summing these

[23]For an interesting type of airline activity analysis which suggested various refinements refer to:

Nevins D. Baxter and E. Philip Howrey, "The Determinants of General Aviation Activity," Transportation Research, Vol. II, No. 1 (March, 1968), pp. 73-81.

values up, we can obtain a total figure for the departures and arrivals of passengers for each airport.[24] We will use the estimated values for connections that are presently non-existent, but we will replace actual values for connections that are in operation, unless they are clearly under-utilized due to insufficient frequencies or other pertinent reasons. In this way, the figures obtained for departures (arrivals) will give us an index of mobility for conditions of perfect connectivity.

A. Derivation of the mobility index or potential traffic formula.

Using the mobility index (or potential traffic) figures for each airport obtained as a result of the aforesaid multiple regression analysis, we can then try to establish a relationship between these and the socio-economic factors associated with the airport regions considered. Each of these will have a certain contribution to the making of the total demand and so a linear relationship will be sought. This relationship will be of the form

$$D_i = b_o + \sum_{k=1}^{n} b_k \cdot X_{ki}$$

This type of an analysis will give us an idea about the extent of the contribution of each variable considered to the total potential traffic, and rather than an arbitrary assignment of weighting factors, a more reasonable and justified determination

[24] Since the relationship used for $P_{ij}$ will not take into consideration the direction of flow, the departures at any airport will equal arrivals. So this means: $D_i = A_i$

of coefficients will be possible.

B. Determination of the gravitational parameters $\alpha, \beta, \gamma$.

The $D_i$ values thus obtained will be used to determine $P^*_{ij}$ values for all existing connections. These values together with the ground distance data between points i and j will constitute the inputs to the gravitational formula.[25]

A new multiple regression analysis will be performed at this stage in order to determine the gravitational parameters $\alpha$, $\beta$, and $\gamma$.

The relationship giving the traffic potential on the one hand, and that giving the point-to-point passenger figures in terms of the network parameters $\alpha, \beta$, and $\gamma$ on the other can be used anytime in order to forecast potential point-to-point traffic for other years by the use of other similar data as a new input.

Application of the Model

In the course of the investigation in quest of relevant relationships, the IBM computer library program 1620/ 06.0.184 for linear multiple regression has been used. This program gives quite a detailed output. Other than the usual output of partial regression coefficients and the coefficients of multiple determination and correlation, one can avail himself by the variable means and standard deviations, the standard errors of the regression coefficients, the beta coefficients, the standard error of

[25]Ground distance rather than straight-line air distance is used, because this is de facto the distance that affects the prospective traveler's decision of whether or not to fly.

the estimate, the partial correlation coefficients. The program is designed in such fashion as to allow for tests of significance and both the F-test and the T-test are used. Furthermore, after each such test the least significant variable is eliminated and the process starts over again. This iterative process continues until all of the remaining variables are significant. The results of the analyses performed will be found in the Appendix B, each result being clearly captioned as to its particular conditions. All of them were started out with all of the variables mentioned as their input. The significant variables remaining in the solution are indicated by abbreviated names in a format required by the computer program, but this abbreviation is clear to understand. Since it would take a large space in the body of the text or even in the appendix, not all of the iterations but only the last and significant one of each run has been incorporated into the thesis.

## Explanation of Computations

As the passenger traffic figures for the regression analysis were considered, the figure adopted as dependent variable was the highest of the two figures for both directions of flow for the same point-to-point connection. These figures were given earlier on Table 2.

The first relationship pattern analyzed was that of the point-to-point traffic to the cross-products of socio-economic variables. This resulted in the elimination of all variables but one, and not even the last one that remained was any significant. The statistic $t$ was equal to 0.62935 and the coefficient of multiple correlation was only 0.099, which clearly indicated that simple cross-products function was not the pattern by which the traffic flows abode.

Secondly, all of the cross-products were replaced by their logarithms and a logarithmic relationship was sought. The $P_{ij}$ figures were also changed to assume the value of their logarithms, of course. As a first trial, the distance between the cities concerned was not included as a variable and for the 42 observations a coefficient of correlation of 0.755 was obtained and the standard error of the estimate was 1.52 for a mean value of 7.207. Then distance was introduced as a variable and a sharp increase in the correlation coefficient and a decrease in the standard error of the estimate were reached. These values were respectively 0.806 and 1.393. Correcting the correlation coefficient for the degrees of freedom by the use of the formula

$$\frac{1 - \overline{R}^2}{1 - R^2} = 1 + \frac{m}{DF}$$

where $\overline{R}$ is the corrected coefficient of correlation, $m$ the number of independent variables, and $DF$ the degrees of freedom, we obtain for the former case $\overline{R}^2 = 0.525$ ; $\overline{R} = 0.725$

and for the latter one $\overline{R}^2 = 0.602$ ; $\overline{R} = 0.776$ .

However, this coefficient is still not sufficiently high, despite the fact that distance has been introduced. This is most probably due to the fact that the fourty-two observations at hand are widely different, since within the same set of observations we have such insignificantly small lines as the Afyon-Antalya line carrying only 36 passengers for the whole summer, and important lines such as Istanbul-Ankara carrying 46,335 passengers. Furthermore, the city of Samsun gave very different estimates from the actual values. This might be due to the fact that Samsun is quite a developed city and has an important air traffic potential. But it is also true that Samsun is connected to other centers by sea transportation, and especially to Ankara by a good highway.[26] Therefore, in the second run, the regression analysis was based on thirty observations only, leaving out the cities of Afyon, Balıkesir, Erzincan and Samsun. This sharply increased the coefficient of correlation to a value of 0.936 which means the coefficient of multiple determination was 0.877. The standard error of the estimate dropped to 0.608 for a mean value of 7.534 . The corrected value of the coefficient of correlation can be computed as 0.920 and that of the coefficient of multiple determination as 0.845 .

A further elimination was done and the city of Elâzığ was left out of the regression analysis. This decreased the number of observations to twenty-seven. For this run, the results were obtained as follows: $R = 0.942$ and $R^2 = 0.888$ . R denotes the coefficient of multiple correlation, and $R^2$ the coefficient of multiple determination. The corrected values are:

$$\bar{R} = 0.921 \qquad \text{and} \qquad \bar{R}^2 = 0.847$$

Afterwards, a computer program was designed so that the

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[26] It might be of interest to find out by way of a survey whether the passengers boarding in Ankara exhibit a disproportionate constituency of Samsun residents, i.e. residents of provinces attributed to the Samsun airport.

$D_i$ values for each airport could be determined according to the results of the regression analyses of 27 and 30 observations. Since at the present time, Istanbul is the only airport which fulfills the perfect connectivity conditions, the result for Istanbul has been checked. The average of the total number of actual arrivals and departures for Istanbul was 144,141 and the multiple regression analysis of 30 observations gave the result of 150,124 and that of 27 observations gave the result of 144,145, both being close enough.

Then these totals for each airport have been subjected to a linear multiple regression analysis in function of the socio-economic variables. Two such runs have been performed so that the results of both the thirty and twenty-seven-observation regression analyses were used each time as dependent variable figures.

The results were found to be as follows, the subscripts denoting the number of observations in the analysis:

$R_{30} = 0.997$ $\qquad$ $R^2_{30} = 0.995$

$R_{27} = 0.998$ $\qquad$ $R^2_{27} = 0.996$

corrected values:

$\bar{R}_{30} = 0.995$ $\qquad$ $\bar{R}^2_{30} = 0.991$

$\bar{R}_{27} = 0.995$ $\qquad$ $\bar{R}^2_{27} = 0.991$

The determination of the potential traffic formula is only the first part of the determination of the model.

The second part is the determination of the parameters $\alpha$, $\beta$, and $\gamma$ of the gravitational model. To this end, we shall we shall proceed in three steps and use the data for all the observations at first, that for only thirty observations on the second run, and that for twenty-seven on the third. On each run, the $D_i$ figures used will be those obtained from the thirty and twenty-seven-observation regression analyses, i.e. each of the three steps mentioned above will again be broken down to two more steps.

The results obtained are tabulated on Table 3. As a consequence of a comparison of various results, we can infer <u>in toto</u> that the best are obtained by using the thirty-observation sample. The higher corrected correlation and the greater statistical significance attained are in support of the foregoing statement.

Therefore, the final formulae we were looking for will be adopted as follows:

1. The formula for potential traffic.

$$D_i = 579.982 - 0.08232672\ X_{1i} - 0.20225524\ X_{2i} + 4.9099674\ X_{3i} - 2.0299265\ X_{4i} + 26.746257\ X_{5i} + 0.92839569\ X_{6i} + 0.12533313\ X_{7i} - 0.06756726\ X_{8i}$$

where $X_1$ : Urban population

$X_2$ : Bank deposits (in 1000 TL)

$X_3$ : Hotel, motel, etc. beds

$X_4$ : Restaurant capacity

$X_5$ : Private automobiles

TABLE 3

RESULTS OF MULTIPLE REGRESSION ANALYSIS

FOR THE GRAVITATIONAL FORMULA

| No. of observations | | Coeff. of correlation | Coeff. of determination | Corrected values | | F-test |
|---|---|---|---|---|---|---|
| $D_i$ regression | gravitational formula | $R$ | $R^2$ | $\bar{R}$ | $\bar{R}^2$ | |
| 30 | 42 | 0.603 | 0.364 | 0.576 | 0.332 | 11.19 |
| | 30 | 0.940 | 0.884 | 0.936 | 0.876 | 103.22 |
| | 27 | 0.939 | 0.883 | 0.935 | 0.873 | 90.82 |
| 27 | 42 | 0.647 | 0.419 | 0.624 | 0.389 | 14.09 |
| | 30 | 0.927 | 0.860 | 0.921 | 0.850 | 83.08 |
| | 27 | 0.926 | 0.858 | 0.920 | 0.846 | 72.56 |

$X_6$ : Registered radios

$X_7$ : Telegrams

$X_8$ : Long-distance calls

2. The gravitational formula.[27]

$$P_{ij} = e^{6.231} \frac{\left(P_{ij}^{*}\right)^{0.958}}{d_{ij}^{\,0.933}}$$

All component terms of this formula have been explained earlier.

Discussion

The above regression formulae are associated with a high coefficient of correlation which means that their predictive abilities are quite satisfactory. They can be used reliably in order to forecast future airline operations so that timetables could be constructed in time for the services to be on sale. If projections for several years are made using relevant growth indices, the requirements of aircraft fleet, personnel, capital, etc. could be determined for planning purposes.

Moreover, by the use of this model, one could satisfactorily judge the importance of various routes. Certain routes not in operation might be pointed out by the model as potentially worthwhile to investigate specifically, while certain others in

[27] The exponents have been rounded to three decimals. For an extension of significant digits, refer to computer solution in Appendix B.

operation might suggest a much greater potential than the actual case might seem to exhibit. It would then be the task of airline research bureaux to find out whether this is accounted for simply by the unexplained variation in the model or by failure to tap on currently available potential.

However, although this model is satisfactory for forecasting purposes, it does not point out the <u>structural determinants</u> of the demand for air transport. As we have seen in the final formula for the potential traffic $D_i$ , such important factors as urban population, bank deposits and restaurant capacity assumed negative coefficients. It is impossible to admit that as population increases the volume of travel will decrease. This would be utterly illogical. Clearly, this outcome is due to the fact that the variables considered are forced to assume these negative coefficients in order for the function to fit a least-squares plane. So, if one or more of the variables are already quite highly correlated, their coefficients will be so adjusted by regression techniques to yield the highest possible multiple correlation coefficient. This is known as the <u>multicollinearity</u> effect. Therefore, one needs not worry about the reliability of the final relationship due to the <u>seemingly</u> illogical coefficients obtained.

However, let us proceed to another regression analysis where we shall rearrange somewhat the same data available to us, changing part of the variables to a per capita basis.

Let us define the new variables as follows:

1. Urban population
2. Bank deposits/urban population
3. Number of firms
4. Literate population
5. Electrical energy consumption/urban population
6. Hotel, motel, etc. beds
7. Restaurant capacity
8. Number of private automobiles/urban population
9. Number of registered radios/urban population
10. Number of telephone subscriptions/urban population
11. Number of letters exchanged/number of firms
12. Number of telegrams sent/number of firms
13. Number of long-distance calls/number of firms
14. Number of letters exchanged/urban population
15. Number of telegrams sent/urban population
16. Number of long-distance calls/urban population
17. Number of associations
18. Number of passengers carried on highways
19. Number of firms/urban population
20. Distance between the points considered

Variables 2,5,8,9,10 will thus be indices of prosperity, propensity to consume and standard of living. Variables 11 through 16 will be indices of intercity business or personal involvement. Variable 19 will be an index relating the degree of industrialization and also of employment opportunities.

This rearrangement of variables actually gave a very good correlation and the structural determinants have proven to be more in line with common sense. However, the number of associations and the number of firms per capita of urban population still assumed negative coefficients. The correlation measures are:

$R = 0.940 \qquad R^2 = 0.884$

$\bar{R} = 0.921 \qquad \bar{R}^2 = 0.847$

The variables remaining in the solution were:

$X_1$ : Urban population

$X_2$ : Restaurant capacity

$X_3$ : Number of associations

$X_4$ : Number of firms/urban population

$X_5$ : Distance between the points considered (i and j)

$X_6$ : Number of letters exchanged/urban population

$X_7$ : Number of long-distance calls/urban population

The formula for $P_{ij}$ was found to be

$$\begin{aligned}\ln P_{ij} = &- 30.372242 + 1.4411978 \ln (X_{1i}X_{1j})\\ &+ 1.32777539 \ln (X_{2i}X_{2j})\\ &- 1.9383461 \ln (X_{3i}X_{3j})\\ &- 0.89603827 \ln (X_{4i}X_{4j})\\ &- 1.25507588 \ln X_{5ij}\\ &+ 1.2838833 \ln (X_{6i}X_{6j})\\ &+ 2.7288383 \ln (X_{7i}X_{7j})\end{aligned}$$

This shows that urban population, restaurant capacity, the number of letters and long-distance calls exchanged and ground distance are important determinants of airline activity in terms of passenger demand. The lowest value obtained for the T-test was 2.87 which is above the 0.01 level of significance for 22 degrees of freedom. The F-test value is 24.09 which is well above 6.10, the required minimum for 0.01 level of significance.

CHAPTER VI

RECOMMENDATIONS

Although Turkey is essentially a developing country, air transportation which is generally accepted as an expensive and even luxurious means of travel seems to have a good potential of development. This study showed that there is at the present moment untapped potential demand and that many existing lines could profitably be better exploited and certain new lines could be inaugurated. To this end, a plotback of the final gravitational formula is given for each possible connection in Appendix B. Air traffic potentials of cities like Adana, İzmir, Samsun in general and certain specific lines such as Antalya-İzmir, Balıkesir-İzmir, Trabzon-Erzurum would perhaps be worth investigating in the context of surveys ad rem.

Furthermore, the writer of this thesis feels that there are strong reasons to assume that by the adoption of drastic measures of quality improvement in the Turkish Airlines' services, much untapped resources could be attracted to air travel. Many passenger complaints are in fact noticed, especially on matters of punctuality and treatment of passengers.[28]

[28] Metin Toker, "Bu Hesabı Biri Sormalıdır," Milliyet, Yıl XVIII, Sayı 7211, 21 Aralık 1967, s. 2.

As pointed out in the previous portions of this text, a study of passenger profiles must be made according to their permanent residences in order to enable those who apply the model developed to achieve a more true-to-life delineation of airport service areas. Once this type of a survey is undertaken, other information such as purpose of travel, age, profession, etc. could also be gathered.

The author of this study has had the privilege of communicating and getting acquainted with the research and planning personnel of THY and is happy to state that very dynamic steps are being taken toward more and more valuable research and a constant effort toward upgrading the quality of that research is present.

A rigorous proof of whether or not untapped potential exists requires many more detailed studies, investigating the effect of price elasticities, frequency of services, speeds of aircraft, design of schedules on the attraction of people to air travel. The present work should be viewed only as possibly setting a guideline toward a systematic approach to find out where to look for most probable potential gains.

In fact, the price factor is very important in this context. Since no consideration of the influence of fares on potential traffic has been included in this study, much of the unexplained variation may be due to price differentials.[29] Ceteris paribus,

[29]The factor W in Piper's model (see Ch. III) was intended to be incorporated into our model. But this required the collection of price data on alternate modes of travel which was difficult to

price is a very significant determinant of the volume of air travel. An investigation of the effect of price per kilometer of travel on potential air transport demand would be highly recommendable as a further research subject on the Turkish Airlines' domestic network.

Also of special interest are service frequencies. An effort toward the realization of optimum frequencies with respect to aircraft capacity might well prove to be extremely profitable. A study of inconvenience burden on the passengers in terms of waiting time between flights might be made through questionnaires distributed among passengers and this would greatly help the preparation of timetables. This study could further be improved by the introduction of elements of queuing theory so as to attain the optimum scheduling of flights, aircraft maintenance and engine overhaul times. This would make possible the use of time in a most profitable way and would not be one of the lesser types of profit, since time is perhaps the scarcest resource in airline operations. Higher utilization levels of the aircraft fleet would thus be realized.

Another type of study that could be recommended is the design of some system whereby the aircraft routes can be determined in order to achieve optimum load factors, given the demand on each portion. Queuing theory would again be very helpful here and one of the important operations research tools that the designer

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obtain for the whole country and all the possible connections in the first place. Secondly, since different kinds of prices would be applicable for the same connection, a method of measuring price indices had to be set up, which would by then have constituted a topic for a complete study in itself, for which reason the idea was abandoned altogether.

of such a route determination system could use would be dynamic programming.

The author would especially consider it important to warn the user of his model that although its modus operandi would hold true as time passes, the network parameters are subject to change with time. So these parameters would have to be re-established after a reasonable amount of time , perhaps every two years.

# APPENDIX A

TABLE 4

SOCIO-ECONOMIC VARIABLES RELATED TO THE MODEL

| Province | Urban popu- lation | Bank Deposits (x1000 TL) | Number of Firms | Literate popu- lation | Electricity Consumption (x1000 kWh) |
|---|---|---|---|---|---|
| 1 ADANA | 422298. | 397376. | 57. | 213178. | 53684. |
| 2 ADIYAMAN | 51463. | 11215. | 0. | 14934. | 779. |
| 3 AFYON | 377146. | 67842. | 19. | 65353. | 4914. |
| 4 AGRI | 53420. | 17949. | 1. | 22998. | 1169. |
| 5 AMASYA | 83016. | 51260. | 5. | 46028. | 3272. |
| 6 ANKARA | 1069761. | 2683690. | 779. | 688859. | 185618. |
| 7 ANTALYA | 129657. | 173599. | 18. | 73887. | 8426. |
| 8 ARTVIN | 30068. | 36894. | 0. | 17966. | 1090. |
| 9 AYDIN | 165953. | 231461. | 27. | 94981. | 13823. |
| 10 BALIKESIR | 230353. | 249720. | 42. | 139756. | 13162. |
| 11 BILECIK | 36356. | 24916. | 0. | 21675. | 1376. |
| 12 BINGOL | 20401. | 6383. | 0. | 8338. | 306. |
| 13 BITLIS | 43813. | 13227. | 3. | 15632. | 919. |
| 14 BOLU | 70459. | 121853. | 29. | 42356. | 4983. |
| 15 BURDUR | 54135. | 46016. | 5. | 29665. | 1931. |
| 16 BURSA | 335048. | 390666. | 64. | 198754. | 24749. |
| 17 CANAKKALE | 81753. | 86592. | 12. | 52972. | 4283. |
| 18 CANKIRI | 43731. | 41331. | 0. | 23049. | 5927. |
| 19 CORUM | 97032. | 59270. | 6. | 46342. | 3267. |
| 20 DENIZLI | 117739. | 143364. | 18. | 66530. | 6970. |
| 21 DIYARBAKIR | 162467. | 71249. | 19. | 62698. | 8739. |
| 22 EDIRNE | 102171. | 82121. | 7. | 59267. | 4335. |
| 23 ELAZIG | 106180. | 82896. | 16. | 50739. | 4784. |
| 24 ERZINCAN | 57397. | 58321. | 5. | 35336. | 3349. |
| 25 ERZURUM | 152183. | 111237. | 21. | 77338. | 11750. |
| 26 ESKISEHIR | 200332. | 179330. | 56. | 130837. | 29370. |
| 27 GAZIANTEP | 244215. | 128682. | 19. | 94772. | 10258. |
| 28 GIRESUN | 75069. | 97425. | 6. | 37030. | 2552. |
| 29 GUMUSHANE | 31957. | 26380. | 0. | 17300. | 877. |
| 30 HAKKARI | 14132. | 5243. | 0. | 5816. | 69. |
| 31 HATAY | 203610. | 149711. | 38. | 97184. | 10201. |
| 32 ISPARTA | 95551. | 79069. | 16. | 57413. | 6330. |
| 33 ICEL | 189362. | 205031. | 31. | 103996. | 14200. |

TABLE 4-Continued

| Province | Urban popu- lation | Bank Deposits (x1000 TL) | Number of Firms | Literate popu- lation | Electricity Consumption (1000 kWh) |
|---|---|---|---|---|---|
| 34 İSTANBUL | 1792071. | 5680765. | 3436. | 1255700. | 390536. |
| 35 İZMIR | 621555. | 1033470. | 495. | 397083. | 80270. |
| 36 KARS | 117363. | 75645. | 0. | 58861. | 4107. |
| 37 KASTAMONU | 67162. | 98853. | 7. | 36303. | 2663. |
| 38 KAYSERI | 191221. | 194571. | 50. | 97795. | 13079. |
| 39 KIRKLARELI | 85856. | 63086. | 9. | 56420. | 4031. |
| 40 KIRSEHIR | 42000. | 41451. | 0. | 21815. | 2102. |
| 41 KOCAELI | 136531. | 213409. | 23. | 68557. | 12456. |
| 42 KONYA | 354576. | 282261. | 54. | 192034. | 28085. |
| 43 KUTAHYA | 87084. | 77233. | 42. | 51543. | 6281. |
| 44 MALATYA | 147040. | 94874. | 12. | 70780. | 6074. |
| 45 MANISA | 265287. | 277939. | 35. | 149298. | 15077. |
| 46 MARAS | 105090. | 34361. | 6. | 42516. | 4084. |
| 47 MARDIN | 90093. | 23293. | 0. | 29810. | 1660. |
| 48 MUGLA | 59330. | 90841. | 3. | 36140. | 2737. |
| 49 MUS | 32503. | 13913. | 0. | 13411. | 797. |
| 50 NEVSEHIR | 46710. | 72919. | 0. | 23348. | 2535. |
| 51 NIGDE | 69956. | 63355. | 15. | 37169. | 3243. |
| 52 ORDU | 93385. | 94613. | 0. | 39196. | 2607. |
| 53 RIZE | 33554. | 104972. | 6. | 28953. | 1780. |
| 54 SAKARYA | 124936. | 145781. | 15. | 74913. | 12304. |
| 55 SAMSUN | 197103. | 196092. | 16. | 102777. | 9974. |
| 56 SIIRT | 75520. | 22020. | 0. | 24338. | 4416. |
| 57 SINOP | 38068. | 43008. | 0. | 22854. | 1748. |
| 58 SIVAS | 168685. | 115543. | 13. | 87277. | 2594. |
| 59 TEKIRDAG | 96897. | 60682. | 5. | 59883. | 4847. |
| 60 TOKAT | 123403. | 76540. | 8. | 58355. | 3215. |
| 61 TRABZON | 108492. | 186638. | 9. | 57368. | 8026. |
| 62 TUNCELI | 23240. | 17584. | 0. | 12950. | 237. |
| 63 URFA | 150363. | 44269. | 0. | 43003. | 3513. |
| 64 USAK | 57135. | 45293. | 19. | 30377. | 2654. |
| 65 VAN | 60686. | 37499. | 4. | 24797. | 1002. |
| 66 YOZGAT | 67466. | 46564. | 4. | 33372. | 1931. |
| 67 ZONGULDAK | 157463. | 369682. | 20. | 96054. | 17759. |

TABLE 4-Continued

| Province | Hotel Beds | Restau- rants | Private Autos | Regis- tered Radios | Telephone sub- scriptions |
|---|---|---|---|---|---|
| 1 ADANA | 1755. | 3867. | 4681. | 67642. | 7904. |
| 2 ADIYAMAN | 362. | 1565. | 116. | 5567. | 341. |
| 3 AFYON | 1888. | 2781. | 285. | 31162. | 1601. |
| 4 AGRI | 236. | 711. | 111. | 5155. | 467. |
| 5 AMASYA | 441. | 1170. | 243. | 20497. | 926. |
| 6 ANKARA | 6072. | 9870. | 21200. | 212976. | 45470. |
| 7 ANTALYA | 3272. | 2339. | 880. | 38231. | 2619. |
| 8 ARTVIN | 989. | 1616. | 149. | 10798. | 614. |
| 9 AYDIN | 2165. | 5398. | 1460. | 50933. | 3033. |
| 10 BALIKESIR | 6897. | 7466. | 1066. | 59990. | 3589. |
| 11 BILECIK | 511. | 1170. | 143. | 12672. | 432. |
| 12 BINGOL | 439. | 438. | 56. | 3681. | 172. |
| 13 BITLIS | 176. | 450. | 122. | 3958. | 380. |
| 14 BOLU | 1416. | 5439. | 556. | 31434. | 1576. |
| 15 BURDUR | 470. | 2410. | 250. | 14522. | 664. |
| 16 BURSA | 8747. | 7294. | 3044. | 76489. | 7337. |
| 17 CANAKKALE | 1825. | 1843. | 281. | 32769. | 1443. |
| 18 CANKIRI | 349. | 971. | 138. | 17920. | 543. |
| 19 CORUM | 1367. | 1584. | 257. | 26119. | 968. |
| 20 DENIZLI | 1728. | 4676. | 596. | 35206. | 1621. |
| 21 DIYARBAKIR | 1386. | 1475. | 544. | 16413. | 2178. |
| 22 EDIRNE | 1053. | 2186. | 356. | 25689. | 1181. |
| 23 ELAZIG | 1130. | 1171. | 423. | 18985. | 1119. |
| 24 ERZINCAN | 1074. | 930. | 164. | 17339. | 786. |
| 25 ERZURUM | 1234. | 1510. | 455. | 24955. | 2319. |
| 26 ESKISEHIR | 3055. | 7633. | 1600. | 54015. | 2761. |
| 27 GAZIANTEP | 2174. | 2583. | 822. | 35449. | 3290. |
| 28 GIRESUN | 1013. | 2024. | 286. | 23434. | 1287. |
| 29 GUMUSHANE | 473. | 630. | 71. | 10388. | 457. |
| 30 HAKKARI | 122. | 0. | 39. | 2049. | 185. |
| 31 HATAY | 1922. | 3813. | 1127. | 32390. | 3733. |
| 32 ISPARTA | 1586. | 2404. | 277. | 22737. | 647. |
| 33 ICEL | 3098. | 4904. | 1030. | 42272. | 4516. |

TABLE 4-Continued

| Province | Hotel Beds | Restaurants | Private Autos | Registered Radios | Telephone subscriptions |
|---|---|---|---|---|---|
| 34 ISTANBUL | 27810. | 93245. | 39693. | 511697. | 86149. |
| 35 IZMIR | 2356. | 18742. | 9220. | 178444. | 21786. |
| 36 KARS | 950. | 1575. | 238. | 17648. | 1068. |
| 37 KASTAMONU | 2366. | 4451. | 365. | 34320. | 1186. |
| 38 KAYSERI | 2607. | 2125. | 715. | 26580. | 1287. |
| 39 KIRKLARELI | 699. | 3142. | 313. | 24596. | 874. |
| 40 KIRSEHIR | 434. | 798. | 154. | 11668. | 420. |
| 41 KOCAELI | 1032. | 4766. | 1259. | 34830. | 1692. |
| 42 KONYA | 6071. | 5344. | 1415. | 85511. | 4553. |
| 43 KUTAHYA | 1452. | 2463. | 454. | 28420. | 1492. |
| 44 MALATYA | 1370. | 1150. | 336. | 26606. | 2100. |
| 45 MANISA | 2679. | 3481. | 938. | 76548. | 3637. |
| 46 MARAS | 612. | 1299. | 407. | 15559. | 1348. |
| 47 MARDIN | 393. | 1070. | 366. | 10025. | 672. |
| 48 MUGLA | 1760. | 1760. | 723. | 29021. | 1325. |
| 49 MUS | 549. | 633. | 102. | 3884. | 253. |
| 50 NEVSEHIR | 766. | 810. | 123. | 15773. | 612. |
| 51 NIGDE | 2712. | 1716. | 201. | 18132. | 908. |
| 52 ORDU | 1677. | 3524. | 302. | 24228. | 1279. |
| 53 RIZE | 686. | 2150. | 310. | 14849. | 887. |
| 54 SAKARYA | 1918. | 4035. | 532. | 34395. | 2519. |
| 55 SAMSUN | 2088. | 8902. | 1047. | 48027. | 4236. |
| 56 SIIRT | 1006. | 270. | 151. | 6068. | 522. |
| 57 SINOP | 1102. | 593. | 128. | 14971. | 539. |
| 58 SIVAS | 639. | 1366. | 270. | 36448. | 1632. |
| 59 TEKIRDAG | 802. | 1347. | 336. | 26839. | 1054. |
| 60 TOKAT | 1194. | 1792. | 249. | 26981. | 1277. |
| 61 TRABZON | 904. | 1140. | 584. | 26315. | 2670. |
| 62 TUNCELI | 86. | 375. | 68. | 6078. | 222. |
| 63 URFA | 755. | 1690. | 555. | 13604. | 1412. |
| 64 USAK | 621. | 394. | 179. | 14262. | 594. |
| 65 VAN | 830. | 460. | 191. | 8338. | 909. |
| 66 YOZGAT | 640. | 1455. | 155. | 17390. | 661. |
| 67 ZONGULDAK | 3053. | 7717. | 957. | 61947. | 3794. |

TABLE 4-Continued

| Province | Number of Letters | Number of Telegrams | Long-Distance Calls | Associations | Highway passengers per day |
|---|---|---|---|---|---|
| 1 ADANA | 6435644. | 235512. | 1074185. | 847. | 4200. |
| 2 ADIYAMAN | 930362. | 23902. | 54812. | 80. | 940. |
| 3 AFYON | 2418443. | 51713. | 238877. | 525. | 1600. |
| 4 AGRI | 2502521. | 80665. | 118722. | 142. | 790. |
| 5 AMASYA | 3174786. | 64709. | 185209. | 213. | 1500. |
| 6 ANKARA | 65252070. | 964517. | 3029021. | 1775. | 4900. |
| 7 ANTALYA | 2477045. | 129802. | 480945. | 405. | 780. |
| 8 ARTVIN | 1111562. | 90943. | 99212. | 246. | 520. |
| 9 AYDIN | 3452479. | 87818. | 512945. | 569. | 3800. |
| 10 BALIKESIR | 8257908. | 187749. | 813679. | 966. | 2600. |
| 11 BILECIK | 607189. | 20124. | 84447. | 188. | 1600. |
| 12 BINGOL | 402956. | 25712. | 42722. | 42. | 510. |
| 13 BITLIS | 590096. | 44849. | 88798. | 109. | 600. |
| 14 BOLU | 1939152. | 68499. | 272639. | 374. | 3800. |
| 15 BURDUR | 978544. | 29722. | 108886. | 225. | 2140. |
| 16 BURSA | 5183427. | 161148. | 1023939. | 943. | 3500. |
| 17 CANAKKALE | 2990832. | 111594. | 317980. | 412. | 1800. |
| 18 CANKIRI | 1807890. | 36447. | 76568. | 307. | 780. |
| 19 CORUM | 1374611. | 57264. | 154929. | 309. | 1500. |
| 20 DENIZLI | 4656632. | 77982. | 308219. | 649. | 2200. |
| 21 DIYARBAKIR | 4457179. | 125221. | 299580. | 178. | 1500. |
| 22 EDIRNE | 4316346. | 59992. | 224114. | 340. | 2300. |
| 23 ELAZIG | 2455416. | 90157. | 216770. | 166. | 1800. |
| 24 ERZINCAN | 2300146. | 72040. | 108733. | 184. | 650. |
| 25 ERZURUM | 5518390. | 225459. | 341956. | 400. | 690. |
| 26 ESKISEHIR | 5191721. | 95306. | 406173. | 383. | 3400. |
| 27 GAZIANTEP | 2597650. | 130696. | 421438. | 269. | 2700. |
| 28 GIRESUN | 1649476. | 112750. | 195247. | 247. | 2100. |
| 29 GUMUSHANE | 969556. | 54101. | 95913. | 187. | 740. |
| 30 HAKKARI | 450792. | 41947. | 35825. | 20. | 160. |
| 31 HATAY | 4611507. | 151422. | 594693. | 332. | 3700. |
| 32 ISPARTA | 3824458. | 62980. | 186800. | 350. | 1100. |
| 33 ICEL | 4054686. | 159627. | 683191. | 414. | 2900. |

TABLE 4-Continued

| | Number of Letters | Number of Telegrams | Long-Distance Calls | Asso-ciations | Highway passengers per day |
|---|---|---|---|---|---|
| 34 ISTANBUL | 107292610. | 1656237. | 3494994. | 1937. | 6200. |
| 35 IZMIR | 23677223. | 440094. | 1807133. | 1168. | 6200. |
| 36 KARS | 4677779. | 182323. | 206078. | 253. | 420. |
| 37 KASTAMONU | 1515756. | 91912. | 228998. | 431. | 1100. |
| 38 KAYSERI | 3944880. | 107457. | 308566. | 580. | 1300. |
| 39 KIRKLARELI | 3805666. | 50968. | 169062. | 320. | 1700. |
| 40 KIRSEHIR | 950291. | 26004. | 62613. | 135. | 1670. |
| 41 KOCAELI | 3607533. | 108672. | 495303. | 536. | 6000. |
| 42 KONYA | 5957041. | 265525. | 827636. | 1559. | 1500. |
| 43 KUTAHYA | 2804258. | 50679. | 232824. | 367. | 960. |
| 44 MALATYA | 3473219. | 92663. | 210063. | 358. | 1000. |
| 45 MANISA | 2855566. | 128522. | 640232. | 717. | 3500. |
| 46 MARAS | 1551138. | 51617. | 130956. | 239. | 1200. |
| 47 MARDIN | 1466461. | 77284. | 110170. | 82. | 560. |
| 48 MUGLA | 1747108. | 78015. | 248543. | 274. | 600. |
| 49 MUS | 779237. | 67133. | 60050. | 59. | 320. |
| 50 NEVSEHIR | 673488. | 40622. | 143342. | 279. | 1000. |
| 51 NIGDE | 1423157. | 72373. | 265148. | 406. | 2400. |
| 52 ORDU | 1640207. | 117644. | 245169. | 285. | 2800. |
| 53 RIZE | 1402736. | 150275. | 174605. | 414. | 2[illegible]00. |
| 54 SAKARYA | 2959823. | 98831. | 357699. | 424. | 4440. |
| 55 SAMSUN | 4765090. | 205758. | 564280. | 537. | 4300. |
| 56 SIIRT | 1257306. | 79335. | 111555. | 90. | 580. |
| 57 SINOP | 1062230. | 73364. | 101273. | 145. | 560. |
| 58 SIVAS | 3589402. | 113657. | 252988. | 371. | 700. |
| 59 TEKIRDAG | 2649560. | 52525. | 206293. | 237. | 2200. |
| 60 TOKAT | 1798115. | 78338. | 214009. | 267. | 690. |
| 61 TRABZON | 27[illegible]7060. | 203330. | 376217. | 672. | 3900. |
| 62 TUNCELI | 746581. | 32217. | 84817. | 101. | 530. |
| 63 URFA | 1534606. | 84005. | 192952. | 169. | 1400. |
| 64 USAK | 814940. | 32330. | 103518. | 219. | 1700. |
| 65 VAN | 1228614. | 104595. | 159855. | 79. | 400. |
| 66 YOZGAT | 1268329. | 51745. | 130182. | 328. | 1200. |
| 67 ZONGULDAK | 5482563. | 199971. | 733807. | 734. | 1100. |

Source: Personal collection of data from the following: State Institute of Statistics, Directorate of Highways, Directorate of PTT, Turkish Association of Banks.

# APPENDIX B

**Simple cross-product model:**

MULTIPLE REGRESSION ANALYSIS RESULTS

THE VARIABLE MEANS AND STANDARD DEVIATIONS.

```
YBAR = 148690.38000          SIGMA(Y) =  922741.710000    PAX BETW IU
XBAR(  1)=    771745.920      SIGMA(  1)=    926028.010    URBAN POP
```

THE PARTIAL REGRESSION COEFFICIENTS.

B(  1)= -.09866775

THE Y-INTERCEPT.

ALPHA= 224836.81000000

THE STANDARD ERRORS OF THE REGRESSION COEFS.

SB(  1)= .15677689

THE BETA COEFFICIENTS.

BETA(  1)= -.099

THE COEFFICIENT OF MULTIPLE DETERMINATION.

RHO= .009

THE COEFFICIENT OF MULTIPLE CORRELATION.

R= .099

THE STANDARD ERROR OF ESTIMATE.

S(1.23...M)= 940882.260

THE PARTIAL CORRELATION COEFFICIENTS.

R(  1)= .09902014

THE F-TEST.

F= .3960

THE T-TEST.

T(  1)= .62935137

THE DEGREES OF FREEDOM

N-M-1= 40.

**Logarithmic cross-product model:**

MULTIPLE REGRESSION ANALYSIS RESULTS

DISTANCE BETWEEN I AND J NOT CONSIDERED

THE VARIABLE MEANS AND STANDARD DEVIATIONS.

| | | | | |
|---|---|---|---|---|
| YBAR = | 7207.92850 | SIGMA(Y) = | 2180.746300 | PAX BETW IJ |
| XBAR( 1)= | 26921.428 | SIGMA( 1)= | 2023.251 | BANK DEPOSIT |
| XBAR( 2)= | 9771.785 | SIGMA( 2)= | 2747.274 | NO. FIRMS |
| XBAR( 3)= | 28226.952 | SIGMA( 3)= | 1537.816 | LONGDIS CALL |
| XBAR( 4)= | 14527.500 | SIGMA( 4)= | 1410.939 | NO. ASSNS |

THE PARTIAL REGRESSION COEFFICIENTS.

B( 1)= 3.41687520
B( 2)= -1.94496850
B( 3)= 1.57284750
B( 4)= -2.17430900

THE Y-INTERCEPT.

ALPHA= -78582.83200000

THE STANDARD ERRORS OF THE REGRESSION COEFS.

SB( 1)= .89343657
SB( 2)= .41678391
SB( 3)= .75414041
SB( 4)= .72620336

THE BETA COEFFICIENTS.

BETA( 1)= 3.170
BETA( 2)= -2.450
BETA( 3)= 1.109
BETA( 4)= -1.406

THE COEFFICIENT OF MULTIPLE DETERMINATION.

RHO= .571

THE COEFFICIENT OF MULTIPLE CORRELATION.

R= .755

THE STANDARD ERROR OF ESTIMATE.

S(1.23...M)= 1520.940

```
THE PARTIAL CORRELATION COEFFICIENTS.

R(  1)=          .53226806
R(  2)=          .60869111
R(  3)=          .32433792
R(  4)=          .44162306

THE F-TEST.

F=      12.3361

THE T-TEST.

T(  1)=         3.82441830
T(  2)=         4.66661120
T(  3)=         2.08561620
T(  4)=         2.99407730

THE DEGREES OF FREEDOM

N-M-1=        37.

======================================================================

MULTIPLE REGRESSION ANALYSIS RESULTS

ALL 42 OBSERVATIONS INCLUDED

THE VARIABLE MEANS AND STANDARD DEVIATIONS.
YBAR =   7207.92850          SIGMA(Y) =    2180.745300    PAX BETW IJ
XBAR(  1)=    26921.428       SIGMA(  1)=      2023.251     BANK DEPOSIT
XBAR(  2)=     9771.785       SIGMA(  2)=      2747.274     NO. FIRMS
XBAR(  3)=    14527.500       SIGMA(  3)=      1410.939     NO. ASSNS
XBAR(  4)=    17560.119       SIGMA(  4)=      1538.629     PAX HIGHWAY
XBAR(  5)=     6337.404       SIGMA(  5)=       602.245     KM GROUND IJ
THE PARTIAL REGRESSION COEFFICIENTS.

B(  1)=         4.43188150
B(  2)=        -2.12928120
B(  3)=        -2.94409380
B(  4)=         1.41997500
B(  5)=        -1.00725110
THE Y-INTERCEPT.

ALPHA=      -67079.02200000
```

```
 THE STANDARD ERRORS OF THE REGRESSION COEFS.

SB(  1)=            .93969770
SB(  2)=            .41140133
SB(  3)=            .74374564
SB(  4)=            .44783563
SB(  5)=            .47007088
 THE BETA COEFFICIENTS.

 BETA(  1)=          4.111
 BETA(  2)=         -2.682
 BETA(  3)=         -1.904
 BETA(  4)=          1.001
 BETA(  5)=          -.278

 THE COEFFICIENT OF MULTIPLE DETERMINATION.

 RHO=          .650

 THE COEFFICIENT OF MULTIPLE CORRELATION.

 R=          .806

 THE STANDARD ERROR OF ESTIMATE.

 S(1.23...M)=       1393.146

 THE PARTIAL CORRELATION COEFFICIENTS.

 R(  1)=            .61798346
 R(  2)=            .65317598
 R(  3)=            .55069378
 R(  4)=            .46722919
 R(  5)=            .33032347

 THE F-TEST.

 F=      13.3823

 THE T-TEST.

 T(  1)=           4.71628420
 T(  2)=           5.17567890
 T(  3)=           3.95846860
 T(  4)=           3.17075030
 T(  5)=           2.14276420

 THE DEGREES OF FREEDOM

 N-M-1=        36.
```

```
    MULTIPLE REGRESSION ANALYSIS RESULTS

    ONLY 30 OBSERVATIONS INCLUDED

THE VARIABLE MEANS AND STANDARD DEVIATIONS.

YBAR =    7534.20000            SIGMA(Y) =       1520.984300    PAX BETW IJ
XBAR(  1)=        26875.966      SIGMA(  1)=         1222.061     URBAN POP
XBAR(  2)=        27196.033      SIGMA(  2)=         1966.867     BANK DEPOSIT
XBAR(  3)=        19035.733      SIGMA(  3)=         1835.901     RESTAURA CAP
XBAR(  4)=        16898.933      SIGMA(  4)=         2095.780     PRIVATE AUTO
XBAR(  5)=        26655.200      SIGMA(  5)=         1159.755     TELEGRAMS
XBAR(  6)=         6507.200      SIGMA(  6)=          504.080     KM GROUND IJ
    THE PARTIAL REGRESSION COEFFICIENTS.

    B(  1)=          -1.62140980
    B(  2)=          -1.83545710
    B(  3)=           1.10097610
    B(  4)=           1.31231320
    B(  5)=           1.92414810
    B(  6)=          -1.41459730
    THE Y-INTERCEPT.

    ALPHA=      15810.24100000

    THE STANDARD ERRORS OF THE REGRESSION COEFS.

   SB(  1)=            .43693142
   SB(  2)=            .41780507
   SB(  3)=            .39950088
   SB(  4)=            .33082173
   SB(  5)=            .39177058
   SB(  6)=            .27412765
    THE BETA COEFFICIENTS.

    BETA(  1)=          -1.302
    BETA(  2)=          -2.373
    BETA(  3)=           1.328
    BETA(  4)=           1.808
    BETA(  5)=           1.467
    BETA(  6)=           -.468

    THE COEFFICIENT OF MULTIPLE DETERMINATION.

    RHO=          .877

    THE COEFFICIENT OF MULTIPLE CORRELATION.

    R=          .936
```

THE STANDARD ERROR OF ESTIMATE.

S(1.23...M)= 607.812

THE PARTIAL CORRELATION COEFFICIENTS.

| | |
|---|---|
| R( 1)= | .61196700 |
| R( 2)= | .67546689 |
| R( 3)= | .49823685 |
| R( 4)= | .63736410 |
| R( 5)= | .71547557 |
| R( 6)= | .73750543 |

THE F-TEST.

F= 27.4764

THE T-TEST.

| | |
|---|---|
| T( 1)= | 3.71090220 |
| T( 2)= | 4.39309430 |
| T( 3)= | 2.75587900 |
| T( 4)= | 3.96682890 |
| T( 5)= | 4.91141550 |
| T( 6)= | 5.16035970 |

THE DEGREES OF FREEDOM

N-M-1= 23.

==================================================================

MULTIPLE REGRESSION ANALYSIS RESULTS

ONLY 27 OBSERVATIONS INCLUDED
THE VARIABLE MEANS AND STANDARD DEVIATIONS.

| | | | | |
|---|---|---|---|---|
| YBAR = | 7660.33330 | SIGMA(Y) = | 1517.418500 | PAX BETW IJ |
| XBAR( 1)= | 26975.962 | SIGMA( 1)= | 1217.024 | URBAN POP |
| XBAR( 2)= | 27312.000 | SIGMA( 2)= | 1997.526 | BANK DEPOSIT |
| XBAR( 3)= | 17032.666 | SIGMA( 3)= | 2104.403 | PRIVATE AUTO |
| XBAR( 4)= | 23900.185 | SIGMA( 4)= | 1584.192 | REG. RADIOS |
| XBAR( 5)= | 26745.370 | SIGMA( 5)= | 1144.455 | TELEGRAMS |
| XBAR( 6)= | 28578.629 | SIGMA( 6)= | 1414.894 | LONGDIS CALL |
| XBAR( 7)= | 6493.259 | SIGMA( 7)= | 512.329 | KM GROUND IJ |

```
THE PARTIAL REGRESSION COEFFICIENTS.

B(  1)=          -2.76202880
B(  2)=          -4.29410150
B(  3)=           2.84614150
B(  4)=           4.27788360
B(  5)=           3.14943130
B(  6)=          -2.14153380
B(  7)=          -1.35150870
THE Y-INTERCEPT.

ALPHA=       34474.73300000

THE STANDARD ERRORS OF THE REGRESSION COEFS.

SB(  1)=           .64146760
SB(  2)=          1.19669360
SB(  3)=           .47890710
SB(  4)=          1.44003740
SB(  5)=           .63017674
SB(  6)=           .75555876
SB(  7)=           .32300156
THE BETA COEFFICIENTS.

BETA(  1)=        -2.215
BETA(  2)=        -5.652
BETA(  3)=         3.947
BETA(  4)=         4.466
BETA(  5)=         2.375
BETA(  6)=        -1.996
BETA(  7)=         -.436

THE COEFFICIENT OF MULTIPLE DETERMINATION.

RHO=          .888

THE COEFFICIENT OF MULTIPLE CORRELATION.

R=          .942

THE STANDARD ERROR OF ESTIMATE.

S(1.23...M)=       605.109

THE PARTIAL CORRELATION COEFFICIENTS.

R(  1)=            .70275998
R(  2)=            .63556193
R(  3)=            .80635942
R(  4)=            .56316841
R(  5)=            .75362825
R(  6)=            .54513526
R(  7)=            .69250376
```

```
THE F-TEST.

F=      21.5411

THE T-TEST.

T(  1)=               4.30579620
T(  2)=               3.58830480
T(  3)=               5.94299290
T(  4)=               2.97067530
T(  5)=               4.99769520
T(  6)=               2.83437090
T(  7)=               4.18421720

THE DEGREES OF FREEDOM

N-M-1=        19.

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MULTIPLE REGRESSION ANALYSIS RESULTS
REGRESSION OF POTENTIAL TRAFFIC FORMULA (BASED ON 30 OBSERVATIONS)

THE VARIABLE MEANS AND STANDARD DEVIATIONS.

YBAR =  29529.05200        SIGMA(Y) =    56839.949000   POT. TRAFFIC
XBAR(  1)=     581962.420   SIGMA(  1)=     619836.770   URBAN POP
XBAR(  2)=     852122.840   SIGMA(  2)=    1522724.500   BANK DEPOSIT
XBAR(  3)=       7134.631   SIGMA(  3)=       7765.589   HOTEL BEDS
XBAR(  4)=      14756.315   SIGMA(  4)=      24433.774   RESTAURA CAP
XBAR(  5)=       5573.263   SIGMA(  5)=      10567.003   PRIVATE AUTO
XBAR(  6)=     138770.150   SIGMA(  6)=     169466.490   REG. RADIOS
XBAR(  7)=     484021.940   SIGMA(  7)=     516266.070   TELEGRAMS
XBAR(  8)=    1397594.800   SIGMA(  8)=    1544449.900   LONGDIS CALL

THE PARTIAL REGRESSION COEFFICIENTS.

B(  1)=              -.08232672
B(  2)=              -.20225524
B(  3)=              4.90996740
B(  4)=             -2.02992650
B(  5)=             26.74625700
B(  6)=               .92839569
B(  7)=               .12533313
B(  8)=              -.06756726
THE Y-INTERCEPT.

ALPHA=         579.98200000
```

```
THE STANDARD ERRORS OF THE REGRESSION COEFS.

SB(  1)=              .01078761
SB(  2)=              .02950491
SB(  3)=             1.02227690
SB(  4)=              .50432475
SB(  5)=             3.71136140
SB(  6)=              .14223190
SB(  7)=              .01951201
SB(  8)=              .01323987
THE BETA COEFFICIENTS.

BETA(  1)=         -1.385
BETA(  2)=         -8.359
BETA(  3)=          1.034
BETA(  4)=         -1.346
BETA(  5)=          7.671
BETA(  6)=          4.270
BETA(  7)=          1.756
BETA(  8)=         -2.832

THE COEFFICIENT OF MULTIPLE DETERMINATION.

RHO=          .995

THE COEFFICIENT OF MULTIPLE CORRELATION.

R=          .997

THE STANDARD ERROR OF ESTIMATE.

S(1.23...M)=      3565.056

THE PARTIAL CORRELATION COEFFICIENTS.

R(  1)=            .92382961
R(  2)=            .90803764
R(  3)=            .83522317
R(  4)=            .78634229
R(  5)=            .91571841
R(  6)=            .89994894
R(  7)=            .89717081
R(  8)=            .85003528

THE F-TEST.

F=    252.3614
```

THE T-TEST.

```
T(  1)=          7.63159890
T(  2)=          6.35496670
T(  3)=          4.80297200
T(  4)=          4.02503840
T(  5)=          7.20658920
T(  6)=          6.52733800
T(  7)=          6.42338180
T(  8)=          5.10331530
```

THE DEGREES OF FREEDOM

N-M-1=      10.

==========================================================================

MULTIPLE REGRESSION ANALYSIS RESULTS

REGRESSION OF POTENTIAL TRAFFIC FORMULA (BASED ON 27 OBSERVATIONS)
THE VARIABLE MEANS AND STANDARD DEVIATIONS.

```
YBAR =  30390.31500          SIGMA(Y)  =    37466.057000    POT. TRAFFIC
XBAR(  1)=    324642.210      SIGMA(  1)=     404181.750     LITERATE POP
XBAR(  2)=     57351.578      SIGMA(  2)=     105164.780     KWH ELEC ILL
XBAR(  3)=      7134.631      SIGMA(  3)=       7765.589     HOTEL BEDS
XBAR(  4)=     14756.315      SIGMA(  4)=      24433.774     RESTAURA CAP
XBAR(  5)=      5573.263      SIGMA(  5)=      10567.003     PRIVATE AUTO
XBAR(  6)=    138770.150      SIGMA(  6)=     169466.490     REG. RADIOS
XBAR(  7)=     13828.105      SIGMA(  7)=      23194.417     PHONE SUBSCR
XBAR(  8)=    484021.940      SIGMA(  8)=     516266.070     TELEGRAMS
XBAR(  9)=      1450.631      SIGMA(  9)=       1319.718     NO. ASSNS
XBAR( 10)=      6864.684      SIGMA( 10)=       6393.200     PAX HIGHWAY
```

THE PARTIAL REGRESSION COEFFICIENTS.

```
B(  1)=          -.41300040
B(  2)=          1.45823570
B(  3)=          4.06820070
B(  4)=         -4.53841760
B(  5)=        -25.98915900
B(  6)=          1.25495150
B(  7)=          9.22890540
B(  8)=           .05325088
B(  9)=        -61.60204600
B( 10)=          4.00329490
```

THE Y-INTERCEPT.

ALPHA=       738.43100000

THE STANDARD ERRORS OF THE REGRESSION COEFS.

```
SB(  1)=          .04577513
SB(  2)=          .36832609
SB(  3)=          .83077112
SB(  4)=          .70703461
SB(  5)=         6.40524640
SB(  6)=          .15552297
SB(  7)=         2.45089780
SB(  8)=          .01283559
SB(  9)=         9.85760940
SB( 10)=          .96778945
```

THE BETA COEFFICIENTS.

```
BETA(  1)=     -4.455
BETA(  2)=      4.093
BETA(  3)=       .843
BETA(  4)=     -2.959
BETA(  5)=     -7.330
BETA(  6)=      5.385
BETA(  7)=      5.713
BETA(  8)=       .733
BETA(  9)=     -2.169
BETA( 10)=       .683
```

THE COEFFICIENT OF MULTIPLE DETERMINATION.

RHO= .996

THE COEFFICIENT OF MULTIPLE CORRELATION.

R= .998

THE STANDARD ERROR OF ESTIMATE.

S(1.23...M)= 3425.002

THE PARTIAL CORRELATION COEFFICIENTS.

```
R(  1)=          .95421055
R(  2)=          .81368421
R(  3)=          .86593332
R(  4)=          .91509992
R(  5)=          .82035203
R(  6)=          .94202395
R(  7)=          .79956285
R(  8)=          .82624806
R(  9)=          .91102735
R( 10)=          .82547774
```

```
THE F-TEST.

F=      226.5567

THE T-TEST.

T(  1)=           9.02237500
T(  2)=           3.95908880
T(  3)=           4.89689710
T(  4)=           6.41894680
T(  5)=           4.05747990
T(  6)=           7.94063730
T(  7)=           3.76552020
T(  8)=           4.14868790
T(  9)=           6.24906030
T( 10)=           4.13653490

THE DEGREES OF FREEDOM

N-M-1=        8.


====================================================================

MULTIPLE REGRESSION ANALYSIS RESULTS

REGRESSION OF GRAVITATIONAL FORMULA (42 OBSERVATIONS)
THE VARIABLE MEANS AND STANDARD DEVIATIONS.

YBAR =     7207.9285           SIGMA(Y) =     2180.746300    PAX BETW IJ
XBAR(  1)=       7414.619      SIGMA(  1)=       1655.587    MOBILITY IND
XBAR(  2)=       6337.404      SIGMA(  2)=        602.245    KM GROUND IJ
THE PARTIAL REGRESSION COEFFICIENTS.

B(  1)=              .80778659
B(  2)=             -.08486265
THE Y-INTERCEPT.

ALPHA=        1756.30780000

THE STANDARD ERRORS OF THE REGRESSION COEFS.

SB(  1)=             .18263037
SB(  2)=             .50145088
THE BETA COEFFICIENTS.

BETA(  1)=           .612
BETA(  2)=          -.023
```

THE COEFFICIENT OF MULTIPLE DETERMINATION.

RHO= .364

THE COEFFICIENT OF MULTIPLE CORRELATION.

R= .603

THE STANDARD ERROR OF ESTIMATE.

S(1.23...M)= 1803.947

THE PARTIAL CORRELATION COEFFICIENTS.

R( 1)= .57797627
R( 2)= .02708922

THE F-TEST.

F= 11.1889

THE T-TEST.

T( 1)= 4.42506820
T( 2)= .16923423

THE DEGREES OF FREEDOM

N-M-1= 39.

==================================================================

MULTIPLE REGRESSION ANALYSIS RESULTS

REGRESSION OF GRAVITATIONAL FORMULA (30 OBSERVATIONS)

| | | | | |
|---|---|---|---|---|
| YBAR =. | 7534.2000 | SIGMA(Y) = | 1520.984300 | PAX BETW IJ |
| XBAR( 1)= | 7700.866 | SIGMA( 1)= | 1541.466 | MOBILITY IND |
| XBAR( 2)= | 6507.200 | SIGMA( 2)= | 504.080 | KM GROUND IJ |

THE PARTIAL REGRESSION COEFFICIENTS.

B( 1)= .95796878
B( 2)= -.93342883
THE Y-INTERCEPT.

ALPHA= 6231.01830000

```
THE STANDARD ERRORS OF THE REGRESSION COEFS.

SB(  1)=          .06681062
SB(  2)=          .20430591
 THE BETA COEFFICIENTS.

 BETA(  1)=          .970
 BETA(  2)=         -.309

 THE COEFFICIENT OF MULTIPLE DETERMINATION.

 RHO=          .884

 THE COEFFICIENT OF MUITIPLE CORRELATION.

 R=          .940

 THE STANDARD ERROR OF ESTIMATE.

 S(1.23...M)=          545.240

 THE PARTIAL CORRELATION COEFFICIENTS.

 R(  1)=          .94016922
 R(  2)=          .66031555

 THE F-TEST.

 F=     103.2250

 THE T-TEST.

 T(  1)=          14.33856900
 T(  2)=           4.56878030

 THE DEGREES OF FREEDOM

 N-M-1=          27.
=================================================================
```

PLOTBACK OF GRAVITATIONAL REGRESSION FORMULA

NUMBER OF PASSENGERS AVAILABLE ON EACH FLIGHT ROUTE

| | | |
|---|---|---|
| 1 | 2 | 607. |
| 1 | 3 | 6859. |
| 1 | 4 | 683. |
| 1 | 5 | 324. |
| 1 | 6 | 1411. |
| 1 | 7 | 627. |
| 1 | 8 | 1213. |
| 1 | 9 | 499. |
| 1 | 10 | 943. |
| 1 | 11 | 732. |
| 1 | 12 | 6310. |
| 1 | 13 | 3096. |
| 1 | 14 | 489. |
| 1 | 15 | 623. |
| 1 | 16 | 1029. |
| 1 | 17 | 738. |
| 1 | 18 | 349. |
| 1 | 19 | 349. |
| 2 | 3 | 3760. |
| 2 | 4 | 376. |
| 2 | 5 | 221. |
| 2 | 6 | 1159. |
| 2 | 7 | 479. |
| 2 | 8 | 186. |
| 2 | 9 | 115. |
| 2 | 10 | 210. |
| 2 | 11 | 120. |
| 2 | 12 | 3725. |
| 2 | 13 | 2382. |
| 2 | 14 | 92. |
| 2 | 15 | 92. |
| 2 | 16 | 351. |
| 2 | 17 | 218. |
| 2 | 18 | 69. |
| 2 | 19 | 80. |
| 3 | 4 | 1997. |
| 3 | 5 | 1721. |
| 3 | 6 | 8458. |
| 3 | 7 | 2948. |
| 3 | 8 | 2112. |
| 3 | 9 | 1465. |
| 3 | 10 | 2528. |
| 3 | 11 | 1461. |
| 3 | 12 | 36308. |
| 3 | 13 | 13382. |
| 3 | 14 | 1447. |
| 3 | 15 | 1159. |
| 3 | 16 | 5266. |
| 3 | 17 | 2724. |
| 3 | 18 | 771. |
| 3 | 19 | 1181. |
| 4 | 5 | 140. |
| 4 | 6 | 573. |
| 4 | 7 | 303. |
| 4 | 8 | 205. |
| 4 | 9 | 105. |
| 4 | 10 | 197. |
| 4 | 11 | 121. |
| 4 | 12 | 2588. |
| 4 | 13 | 1656. |
| 4 | 14 | 80. |
| 4 | 15 | 93. |
| 4 | 16 | 271. |
| 4 | 17 | 186. |
| 4 | 18 | 74. |
| 4 | 19 | 70. |
| 5 | 6 | 2445. |
| 5 | 7 | 1292. |
| 5 | 8 | 127. |
| 5 | 9 | 80. |
| 5 | 10 | 151. |
| 5 | 11 | 82. |
| 5 | 12 | 4149. |
| 5 | 13 | 2185. |
| 5 | 14 | 54. |
| 5 | 15 | 62. |
| 5 | 16 | 232. |
| 5 | 17 | 156. |
| 5 | 18 | 50. |
| 5 | 19 | 52. |
| 6 | 7 | 3165. |
| 6 | 8 | 532. |
| 6 | 9 | 341. |
| 6 | 10 | 631. |
| 6 | 11 | 349. |
| 6 | 12 | 23079. |
| 6 | 13 | 7128. |
| 6 | 14 | 244. |
| 6 | 15 | 265. |
| 6 | 16 | 1019. |

PLOTBACK OF GRAVITATIONAL REGRESSION FORMULA

NUMBER OF PASSENGERS AVAILABLE ON EACH FLIGHT ROUTE

(CONTINUED)

| | | | |
|---|---|---|---|
| 6 17 | 660. | | |
| 6 18 | 208. | 10 16 | 766. |
| 6 19 | 227. | 10 17 | 1432. |
| 7 8 | 232. | 10 18 | 503. |
| 7 9 | 145. | 10 19 | 255. |
| 7 10 | 273. | 11 12 | 1620. |
| 7 11 | 149. | 11 13 | 721. |
| 7 12 | 6779. | 11 14 | 121. |
| 7 13 | 5854. | 11 15 | 793. |
| 7 14 | 97. | 11 16 | 362. |
| 7 15 | 112. | 11 17 | 486. |
| 7 16 | 412. | 11 18 | 218. |
| 7 17 | 281. | 11 19 | 176. |
| 7 18 | 92. | 12 13 | 22091. |
| 7 19 | 92. | 12 14 | 1097. |
| 8 9 | 540. | 12 15 | 1225. |
| 8 10 | 912. | 12 16 | 5132. |
| 8 11 | 1279. | 12 17 | 3289. |
| 8 12 | 2481. | 12 18 | 986. |
| 8 13 | 1144. | 12 19 | 1048. |
| 8 14 | 157. | 13 14 | 464. |
| 8 15 | 564. | 13 15 | 541. |
| 8 16 | 541. | 13 16 | 1883. |
| 8 17 | 642. | 13 17 | 1312. |
| 8 18 | 438. | 13 18 | 447. |
| 8 19 | 211. | 13 19 | 438. |
| 9 10 | 1186. | 14 15 | 106. |
| 9 11 | 526. | 14 16 | 212. |
| 9 12 | 1704. | 14 17 | 152. |
| 9 13 | 687. | 14 18 | 51. |
| 9 14 | 108. | 14 19 | 129. |
| 9 15 | 256. | 15 16 | 310. |
| 9 16 | 468. | 15 17 | 284. |
| 9 17 | 790. | 15 18 | 127. |
| 9 18 | 164. | 15 19 | 171. |
| 9 19 | 190. | 16 17 | 1280. |
| 10 11 | 769. | 16 18 | 201. |
| 10 12 | 3137. | 16 19 | 346. |
| 10 13 | 1300. | 17 18 | 270. |
| 10 14 | 169. | 17 19 | 227. |
| 10 15 | 417. | 18 19 | 63. |

THE NUMBERS FROM 1 TO 19 REPRESENT CITIES IN THE ORDER OF TABLE 2.

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