AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523

BIBLIOGRAPHIC INPUT SHEET

FOR AID USE ONLY
Batch 51

1. SUBJECT CLASSIFICATION	A. PRIMARY: TEMPORARY
	B. SECONDARY:

2. TITLE AND SUBTITLE
Structure and requirements of the transport network in Syria

3. AUTHOR(S)
Kanaan, N.J.

4. DOCUMENT DATE	5. NUMBER OF PAGES	6. ARC NUMBER
1965	166p.	ARC

7. REFERENCE ORGANIZATION NAME AND ADDRESS
Brookings

8. SUPPLEMENTARY NOTES *(Sponsoring Organization, Publishers, Availability)*

9. ABSTRACT
(SCIENCE AND TECHNOLOGY--Transportation R & D)

10. CONTROL NUMBER PN-AAD-103	11. PRICE OF DOCUMENT
12. DESCRIPTORS	13. PROJECT NUMBER
	14. CONTRACT NUMBER Repas-5 Res.
	15. TYPE OF DOCUMENT

AID 590-1 (4-74)

PB-AAD-570
(Dec 6-77)

STRUCTURE AND REQUIREMENTS OF THE TRANSPORT NETWORK OF SYRIA

by

Nuhad J. Kanaan

Transport Research Program
The Brookings Institution
Washington, D.C.
March 1965

SCR/OTS
Unavailable Copy

CONTENTS

	Page
PREFACE	ii
LIST OF ILLUSTRATIONS	v
LIST OF TABLES	viii
Chapter	
I. INTRODUCTION	1
Hypotheses and Verifications	1
Contributions of the Study	10
II. GENERAL PATTERNS IN SYRIA RELATED TO TRANSPORT	12
Slope	12
Rainfall Distribution	15
Rivers	18
Population Distribution	20
Agriculture	23
Manufacturing	23
III. DEVELOPMENT OF TRANSPORTATION IN SYRIA	26
Ancient Caravan Roads	27
Roman Roads	29
Wagon Roads	31
Railroads	34
Motor Roads	42
Realignment of the Network Following the Partitioning of Greater Syria	45
IV. ROAD AND RAIL NETWORKS IN SYRIA BETWEEN 1952 AND 1962	50
The Road Network in 1952	50
The Road Network in 1962	55

Page

Motor Vehicles 58
Bridges 59
Railroad Network Between 1952 and 1962 . . . 60
Road-Rail Competition 63
Railway Lines Under Construction 68

V. HYPOTHESES AND RELATIONSHIPS CONCERNING THE TRANSPORT NETWORK . . 71

Structure of Transport Networks 71
Connectivity of Transport Networks 79

VI. GRAPH THEORY MEASURES 82

Measures of Network Structure 84
Measures of Network Connectivity 87

VII. EMPIRICAL VERIFICATIONS 94

The Variables 94
Regression Analysis 100
Interpretation of the Results 104
Analysis of the Residuals from Regression . . 110

VIII. CONNECTIVITY OF THE TRANSPORT NETWORK OF SYRIA 119

Connectivity of the Railroad Network 119
Connectivity of the Road Network 129

IX. SUMMARY AND CONCLUSIONS 141

APPENDICES

A. SYRIAN TRADE 147
B. ECONOMIC DEVELOPMENT PLANNING IN SYRIA 149
C. ROAD MAINTENANCE EQUIPMENT. 151
D. THE VARIABLES 152

BIBLIOGRAPHY 156

LIST OF ILLUSTRATIONS

Figure		Page
1.	The Middle East	13
2.	Slope	14
3.	Rainfall Distribution	16
4.	Rivers and Irrigation	19
5.	Population Density	21
6.	Urban Places	22
7.	Farm Population	24
8.	Wagon Roads (1900)	33
9.	Port Activity (1844) and (1894)	35
10.	The Railway Network at Its Maximum Extension	39
11.	The Road Network During Its Early Stages of Development	44
12.	Superimposition of International Boundaries on the Network	46
13.	Expenditures on Road Building and Maintenance	53
14.	International Highways	56
15.	Railroad Network (1963)	62
16.	Railway Passenger Movement	64
17.	Goods Moved by Railway	65
18.	Al-Latiquiya—Al-Kamishli Railway	69

Figure		Page
19.	Scattered Settlements	72
20.	Growth of a Communications Line	73
21.	Interconnections Among Settlements	73
22.	Growth of a Trunk Line	74
23.	Transformation of Transport Network to a Graph	83
24.	Measuring a Network Structure	85
25.	Effect of Exogeneous Factors on the Structure of a Network	86
26.	Reduction of a Network to a Matrix	88
27.	Example of a Network Connectivity Analysis	89
28.	Relationship of Network Structure to the Shape of an Area	97
29.	Determining the Center of Mass	98
30.	Measuring the Shape of an Area	99a
31.	Measure of Slope	100
32.	Residuals From Regression for the θ Measure of the Primary Road Network	111
33.	Residuals From Regression for the i Measure of the Primary Road Network	112
34.	Residuals From Regression for the θ Measure of Total Road Network	113
35.	Residuals From Regression for the i Measure of Total Road Network	114

Figure		Page
36.	Grouped Negative Residuals for the Primary Road Network	116
37.	Grouped Negative Residuals for the Total Road Network	117
38.	Connectivity of the Regional Railway Network	122
39.	Connectivity of the Railway Network (1963)	125
40.	Connectivity of the Railway Network (1970)	128
41.	Connectivity of the Road Network (1920)	133
42.	Connectivity of the Road Network (1963)	137
43.	Connectivity Values of the Road Network (1920) and (1963)	138

LIST OF TABLES

Table		Page
1.	Total Floor Area of Manufacturing Plants by Muhafaza (1961)	25
2.	Goods Handled in 1844	30
3.	Travel Time and Distance from Damascus to Major Urban Centers	31
4.	Movement of Goods Through Major Ports, 1894	32
5.	Agricultural Production of the Houran (1890)	36
6.	Cost of Freight Movement Between Damascus and Beirut	38
7.	Road Classification in 1952	51
8.	Road Classification in 1962	55
9.	Motor Vehicles in Syria (1953-1962)	58
10.	Railway Rolling Stock (1961)	61
11.	Cumulative Multiple Coefficients of Determination	102
12.	Variance Ratios	103
13.	Grouped Values of the Coefficient of Determination	109
14.	Matrix of Connectivity for the Early Stage of the Railroad Network	120
15.	Connectivity Values of the Major Regional Rail Centers	121
16.	Connectivity Matrix of the Present Day Railroad Network	123

Table		Page
17	Connectivity Values of the Major Rail Centers (1963)	124
18	Connectivity Matrix of the Completed Railway Networks	127
19	Connectivity Values of the Major Rail Centers (1970)	127
20	Road Connectivity Values of the Major Urban Centers (1920)	131
21	Road Connectivity Values of the Major Urban Centers (1963)	135

CHAPTER I

INTRODUCTION

This study examines and tests a number of basic hypotheses regarding the relationship between the geographic, or spatial, structure of a transportation network and other basic distributions of phenomena which reflect the demands for transportation facilities. These ideas are examined within the regional setting of Syria, a country carved out from the age-old Turkish Empire after the First World War by somewhat arbitrary international boundaries, which disrupted old functional or nodal patterns and the well-developed flows of commodities and people associated with them.

Hypotheses and Verifications

One of the basic hypotheses presented in this study is based on the notion that the structure of the road network within any given region is related to population distribution, agricultural production, manufacturing, transit movement, railway competition, and size, shape and slope of the area under consideration. In the case of Syria the above mentioned factors, taken together, account for a high percentage of the variation in the network structure. The degree of relationship of these factors to the geographic structure of the network is identified

in quantitative terms.

In verifying the above hypothesis measures of the degree of complexity of the primary road network structure and the total network structure are derived from graph theory, and, using multiple regression, they are related to the spatial variations of the factors which either generate demand for transport facilities or inhibit their growth.

The results show that the structure of the road network is correlated with the eight factors as hypothesized, although there is great variation in the significance of the factors. It is found that the relationship between road network structure and population distribution is weak, reflecting the low mobility of the population in Syria--one of the general characteristics of most developing countries. Agriculture is highly related to network structure, as might be expected, because of the importance of this sector of the economy to road transportation in Syria. Manufacturing is only moderately related to the road network, reflecting the relatively low position that this activity plays in the economy. Transit movement across the country and railway competition are weakly related to road structure. However the competitive nature of rail transport and road transport is reflected by the negative value of the regression coefficient. The index of area is strongly related to road development while the index of shape, represented by the degree of circularity of an area, is weakly related to road network development.

However, the relationship between shape and road network turn out to be direct, showing that a relatively circular area which has a low index requires a simpler network structure than an elongated area, which has a high index. The final factor, surface configuration, is very highly related to road network structure in an inverse fashion, signifying that rugged areas tend to develop simple networks while less rugged areas develop more complex networks.

In addition to the general hypothesis stated above that the structure of the network is related to at least eight factors, certain more specific hypotheses concerning the relationship are made and supported. First, not only is agriculture more of a determinant of transport structures than is manufacturing because it is a better developed part of the economy, but it is also more of a determinant because its transport demands, based on locational characteristics, are greater than those of manufacturing. Because agriculture is carried on in a dispersed spatial setting, a road network composed of primary, secondary, and tertiary connections is required to efficiently produce and market agricultural commodities. This is in contrast to the transport demands of manufacturing where supply and demand are highly concentrated and are much more dependent on a well developed primary road network, and much less dependent on secondary and tertiary road connections. It is expected that this geographic variation in transport

demands is reflected in the structure of the network as it varies in shape and extent from one part of the country to another. In order to verify this hypothesis separate measures of primary road network and total road network were obtained and related first to agricultural production and then to industrial production. The results substantiated the hypothesis since a high correlation between road network structure, both primary and total, and agricultural production was obtained, while the introduction of the index representing the manufacturing activity provided a moderately significant increase in the case of the primary network measure, and failed to provide an acceptable increase for the total network measure.

Second, supply and demand for transport facilities are seldom, if ever, in a state of equilibrium, and for any given time certain areas have a lag in the development of the transport facilities while in other areas a lead in transport network development exists, in both instances based on the changes of the regional transport demands of the country. In the case of Syria, it is expected that the realignment of the network that took place after the partitioning of the area, and the increase in the productivity of the new agricultural areas of the north and northeast, have affected the regional variation of transport demands, and have brought about transport lags in certain areas and leads in others. The identification of this regional variation in the theoretical lag or lead in

transport development makes it possible to predict changes that are likely to occur based on the relationship between transport and development, and enables the identification of the areas where changes in the network ought to be undertaken.

In order to verify the "lag or lead" hypothesis, the relationships expressed as departures from the expected values obtained by multiple regression are mapped and cartographically analyzed. These residuals from regression point up the variation of the road network development from one part of the country to another, based on the supported assumption that variables introduced in the study reflect the transport demands of the country. Analysis of the maps of residuals reveal that there are certain areas in the country that have a more developed network structure than expected, such as the areas of As-Suweida, Maarrat-en-Nouman, Izaz, and Al-Bab, while other sections of the country, namely Al-Kamishli, Ain-el-Arab, Deir-ez-Zor, Ifrin, and Harem, have a simpler road network than it would be expected, based on the previously given assumption. The latter are considered as the areas where a lag in network development has taken place and where attention in the future ought to be directed.

Third, due to the severing of the transport network following World War I, and to the extensive agricultural development in the northeastern part of the country, the connectivity of a number of important

urban centers decreased due to the realignment of the network to serve the country's demands, while the connectivity of the other centers increased in relative importance, placing these centers in an advantageous position on the country's developing network. The identification of these centers where connectivity increased makes it possible to predict the centers where growth can be expected in the future, while the identification of the important centers where connectivity decreased, points up the places where stagnation can be expected if improvement in the connectivity of these centers is not undertaken. This analysis is done for both the rail and the road network. In the case of the rail network three time cross-sections are taken:

1) The regional network at its maximum growth.
2) The network after partitioning.
3) The network after the completion of the segments that are proposed or that are under construction.

In the case of the road network two time cross-sections are taken:

1) In 1920, soon after the creation of present day Syria.
2) In 1963.

At the time when the railway network reached its maximum extension, the best connected centers to the whole network were Damascus, Homs, and Riyak. These three cities were the focal axis of the network upon which the northern, the southern, and the westerr

lines converged. After the partitioning, the connectivity of Damascus, Homs, and Riyak decreased and the focus of the network shifted to Aleppo and Hama.

The structure of the network by 1970 will see a number of additions to the rail system and the emergence of new, well-connected centers such as Rakkah in the agricultural north, as well as the strengthening of the position of Aleppo and Hama. The realignment of the railway network will be the first major project since the partitioning of the region, when the important ports of Alexandretta, Beirut, Haifa and Tripoli were included in other states. The new northern rail line will link Al-Latiquiya, the main port of the country, which has been handling a large amount of imports and exports, with its hinterland to the east. The proposed link joining Homs and Damascus will make the southern region accessible to Al-Latiquiya and will allow the movement by railway from one part of the country to another, something which is not possible at present without crossing an international boundary.

Two time cross-sections are examined in order to analyze the changes through time of the total connectivity of the road network at different periods, and the relative connectivity of the major urban centers. The first cross-section is taken at 1920, the period when Syria became an independent state, and political boundaries were superimposed on the road network which grew on a regional basis. The second time

cross-section is taken for 1963 when the network developed on a national base, serving the transport demands of the state of Syria Due to this shift in orientation a number of distinct changes in the relative connectivity of urban centers is observed. This is especially obvious in the case of the centers along the Euphrates River, namely Abou Kamal, Deir-ez-Zor and Rakkah, centers located on the eastern frontier, which decreased in relative connectivity between 1920 and 1963. The main reason for this decrease is the fact that their early growth as focal points on the transport lines which connected the ports of the eastern Mediterranean to the regions of Iraq and Iran, was curbed when they became peripheral centers on a road network which expanded on a national basis, with little consideration for outlying areas beyond the national borders. Thus there is a serious lag in the development of the road network in this newly developed agricultural area of the northeast, where a large increase in agricultural production, especially in the two important export items of cotton and wheat, has taken place in recent years. The completion of a number of irrigation projects in this area within the next few years will increase the production even further. Since the agricultural products of Syria mature at an earlier time than most of those of its competitors, they command a high price in world markets, and it is of the utmost importance to be able to move these products to the port of export as fast as

possible. The railway that is under construction in this area will certainly carry an important share of the movement of these goods, but the road network in the area will have to be improved in order to supplement the railway (feeder lines), and in order to aid in the movement of Syria's important products.

Another important lag in the development of roads in Syria stems from attempts to realign the country's network in order to focus the imports and exports of the country on the main port city of Al-Latiquiya. Even though the relative connectivity of Al-Latiquiya in 1963 was greater than it had been in 1920, the port of Tartous, which is in the process of being modernized and expanded still has a higher connectivity index than Al-Latiquiya. From this fact two important points emerge: 1) Al-Latiquiya, by far the busiest port of the country, handling over one million tons of goods per year, is not as well connected to the area it serves as it ought to be; 2) that the port of Tartous, once expanded and modernized, will be in a relatively good position to compete with Al-Latiquiya for handling the country's foreign trade.

A final point that emerges from an examination of the connectivity changes between 1920 and 1963 is the way in which the accessibility of some of the important urban centers in the south decreased. Particularly important for the economic and political

interpretation that may be given is the lower index for the capital city of Damascus. This is in contrast to its chief competitor, Aleppo, the major urban center of the north, which retained its relatively advantageous position on the country's road network. Since Aleppo and Damascus have been traditional rivals for the dominating position of the Syrian markets, the shift in relative connectivity might in future years swing the balance in favor of Aleppo.

Contributions of the Study

The main contributions of this study may be summarized under three headings:

1) General analysis of the transportation system of Syria. No previous study exists which analyzes the structure, development and relationships of the transportation network, despite the critical role transportation plays in the spatial organization of this Middle Eastern nation.

2) Expanding the methodology of transportation geography, in that there is the explicit examination of theoretical measures of structure within the regional setting. Many measures of network structures that have been devised in recent years have been examined only at a fairly high level of abstraction. Yet it is the region that provides the geographer with his laboratory where the utility of these measures may be tested under a variety of circumstances. This study

represents the first attempt to relate measures of road structure to other variables and examine the spatial implications of the significant relationship derived.

3) Specific analysis of the effects of network severance at the international boundary due to changes in political-spatial organization. In no other geographic study have attempts been made to measure the changes in accessibility of urban centers to changing political boundaries. In most geographical studies today, emphasis has been placed upon the nodal or functional organization of a region under the implied assumption that the political framework, within which economic activity and development take place, will remain static. Thus, Syria represents a case study of a dynamic political framework changing in turn the functional organization of an area.

CHAPTER II

GENERAL PATTERNS IN SYRIA RELATED TO TRANSPORT

Syria, located on the eastern shore of the Mediterranean Sea, is a part of the important bridge which connects the land masses of Europe, Asia and Africa (Figure 1).

There are a number of general patterns in Syria of a basic nature which are important to transportation in the country. A general description of these patterns will be undertaken in this chapter in order to lay the groundwork for their use in the analytical section of the study which follows in later chapters.[1]

Slope

The complexity of slope in Syria, which is one of the basic factors that are related to transport development, varies from one part of the country to another. Figure 2 represents the general pattern of slope complexity and divides the country into three parts: 1) steep slope, 2) moderate slope, and 3) slight slope.[2] On the whole, the eastern, the northeastern and the central parts of the country are composed of relatively flat areas where the lack of steep slope does

---

[1] Other background information on Syria may be found in Appendix A and B.

[2] For method of slope calculation see page 100.

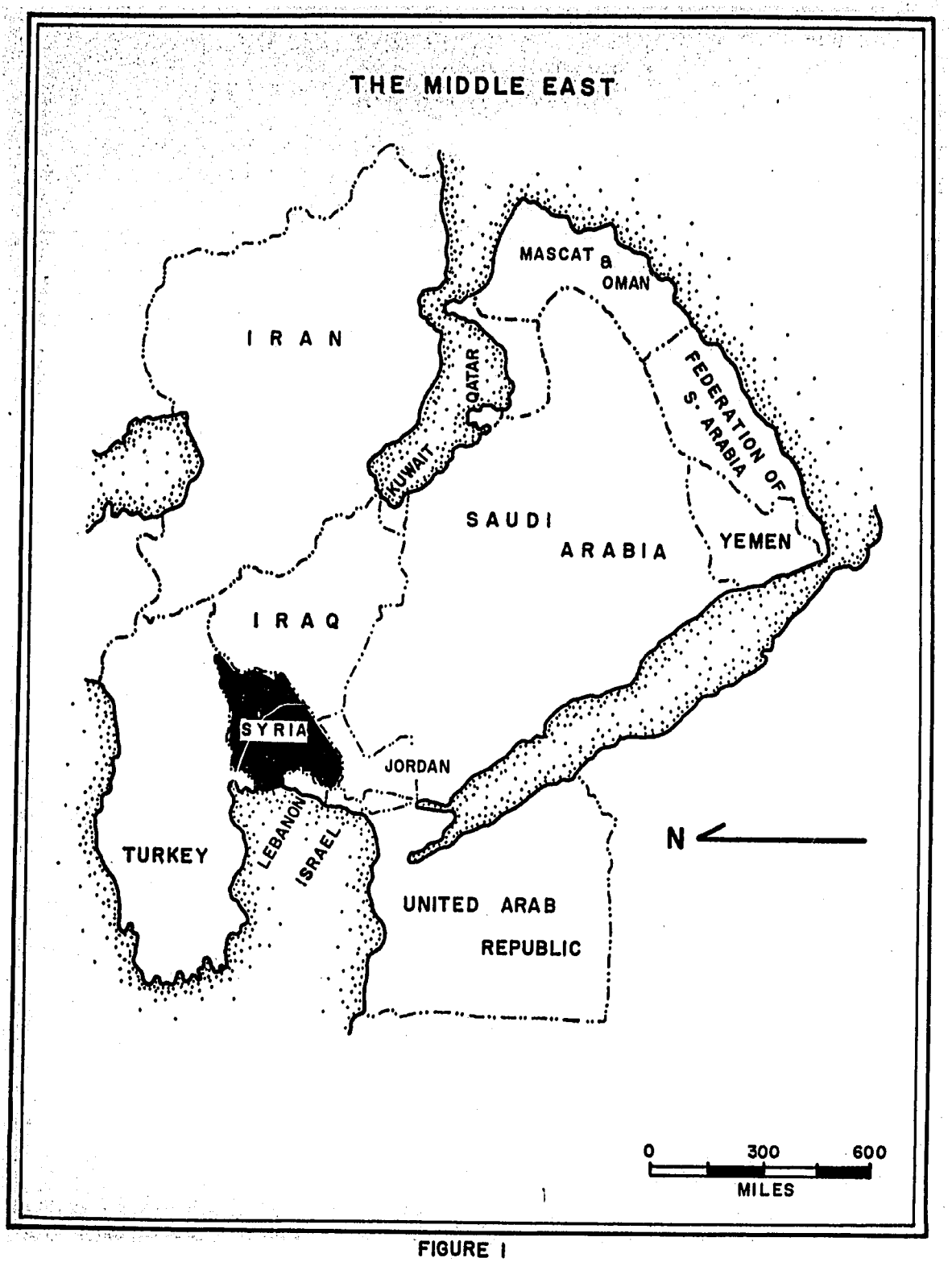

THE MIDDLE EAST
IRAN
MASCAT & OMAN
QATAR
KUWAIT
FEDERATION OF S. ARABIA
SAUDI ARABIA
YEMEN
IRAQ
SYRIA
JORDAN
LEBANON
ISRAEL
TURKEY
UNITED ARAB REPUBLIC
N
0
300
600
MILES

FIGURE I

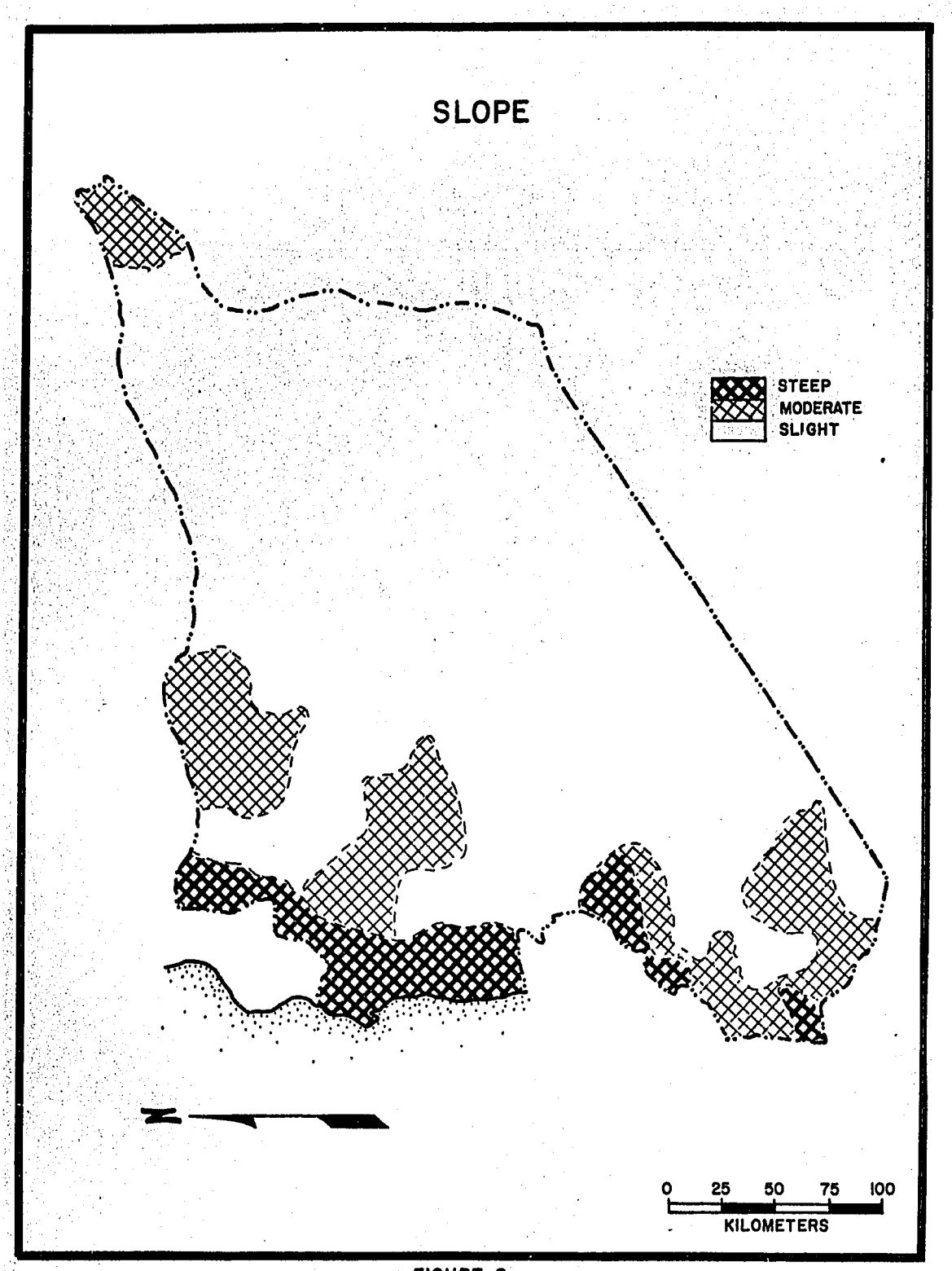


FIGURE 2

not hinder transport network development. To the west of these flatlands lies an elevated area where slope is of a moderate nature, presenting some difficulty to road and rail development. The western part of the country contains the most rugged hills and mountains found in Syria, where the steepest slopes exist, and where the hinderance to transport network growth is at its highest.

Rainfall Distribution

Syria has a Mediterranean type climate which is characterized by a rainy season from November to March and a dry season for the rest of the year. This is the result of a location between two migrating climatic zones, a dry zone to the south and a wet zone to the north. This transitional characteristic is the main cause of the country's two distinct seasons, a rainy one when under the influence of the climatic effects of the wet zone from the north, and a dry season when under the influence of the climatic effects of the semi-arid zone to the south.

There is much variation in rainfall from one year to another, and from one part of the country to another (Figure 3). Many years may pass without a trace of rain falling at a certain village, yet this same village may be washed away by a flash flood during an unusually wet season. However, the variation in rainfall from one part of the country to another is much more pronounced than the yearly variations. The winter cyclonic storms, which are mainly responsible for rainfall

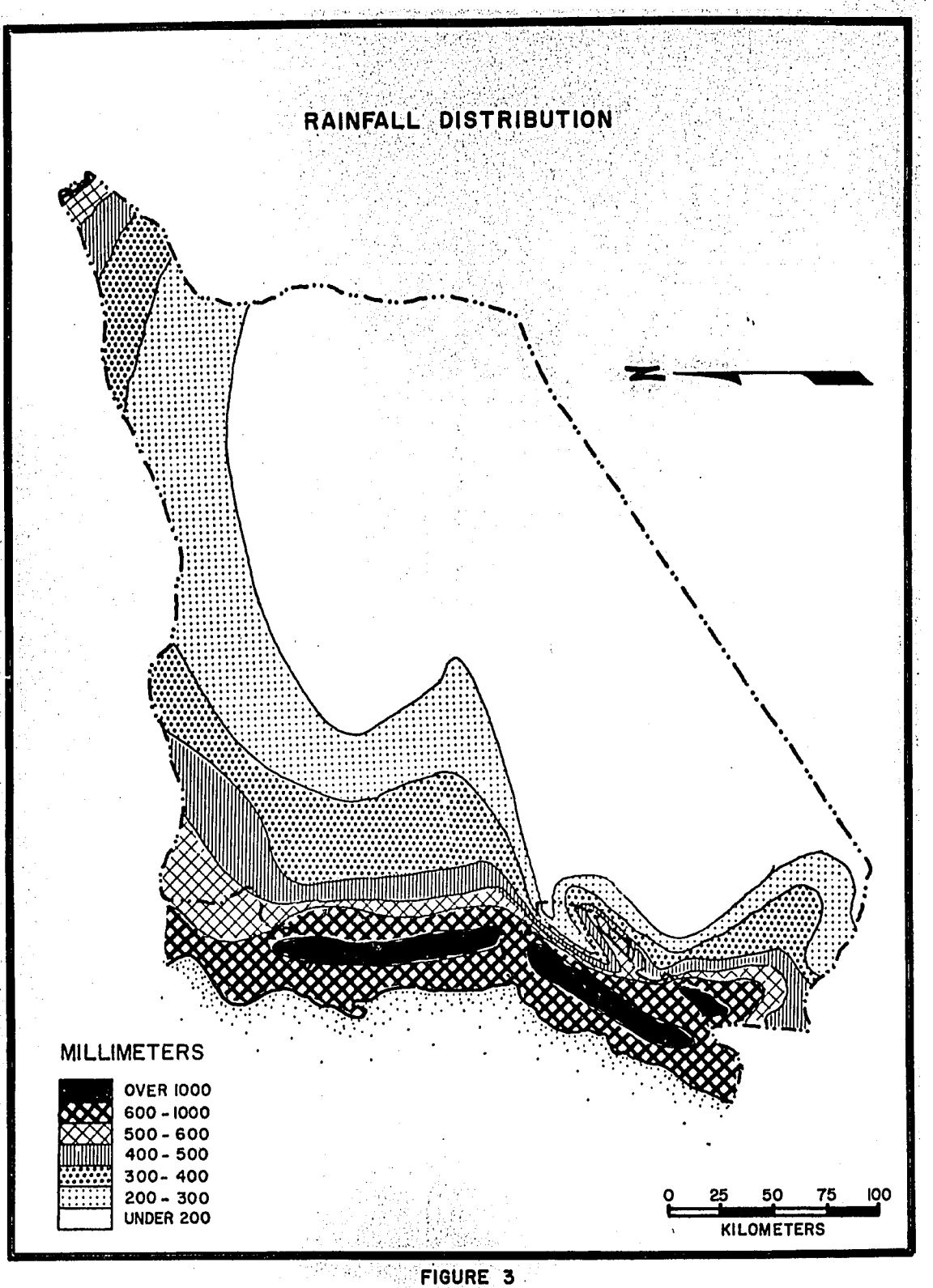

RAINFALL DISTRIBUTION
N
MILLIMETERS
OVER 1000
600 - 1000
500 - 600
400 - 500
300 - 400
200 - 300
UNDER 200
0 25 50 75 100
KILOMETERS

FIGURE 3

in the area, move from west to east across the Mediterranean dumping large amounts of rainfall as they reach the land and start to rise over the western slopes of the coastal mountain ranges. This rain is heaviest on the mountain slopes which face the sea, and decreases in intensity as it moves eastward, where large parts of the country receive less than 200 mm. per year, an amount considered too low to allow the practice of agriculture. However, an opening in the mountain ranges in the northern part of the country permits the rain-bearing clouds to dispose of their moisture more slowly, and over a larger area which receives enough precipitation (between 200 and 500 mm. per year) to make agriculture in this sub-humid area possible.[3] An examination of the amount of rainfall in three of the major cities of the country reveal that Al-Latiquiya, which is a sea port, receives an average of 700 mm. per year, while Damascus, located in the rain shadow of the Lebanon mountains receives about 220 mm. per year, and Aleppo, which lies in the semi-humid area of Fertile Crescent, receives about 400 mm. per year.

---

[3] This is part of the area traditionally referred to as the Fertile Crescent.

Rivers

The Euphrates River, with its tributaries, the Khabour and the Baleekh, form the largest river system in Syria (Figure 4). They are located in a narrow valley several hundred feet in depth which they have carved out of the lowland area through which they flow.

The Orontes River rises in Lebanon and flows northward through the Beqaa plain, the Homs and Hama plains, onto the marshy area of the Ghab (now in the process of being drained), and finally through the plain of Antioch in Turkey before emptying into the sea.

The Barada River gives life to the Damascus area, which would be arid otherwise, springs in the Anti-Lebanon mountains and flows through the alluvial fan on which the city of Damascus is located. Whatever little water is left empties into a salt lake in the desert area, a short distance to the east of Damascus.

The Yarmuk River, which springs in the southern section of Syria, flows in a southerly direction and forms the boundary between Syria and Jordan before emptying its waters into the Jordan River.

In addition to these major rivers, there are two types of minor streams of some economic importance to the country. The first of these groups is the mountain streams which spring on the western slopes of the coastal ranges and flow into the sea. An example of this group is the El Kabir River which empties its waters near Al-Latiquiya. The

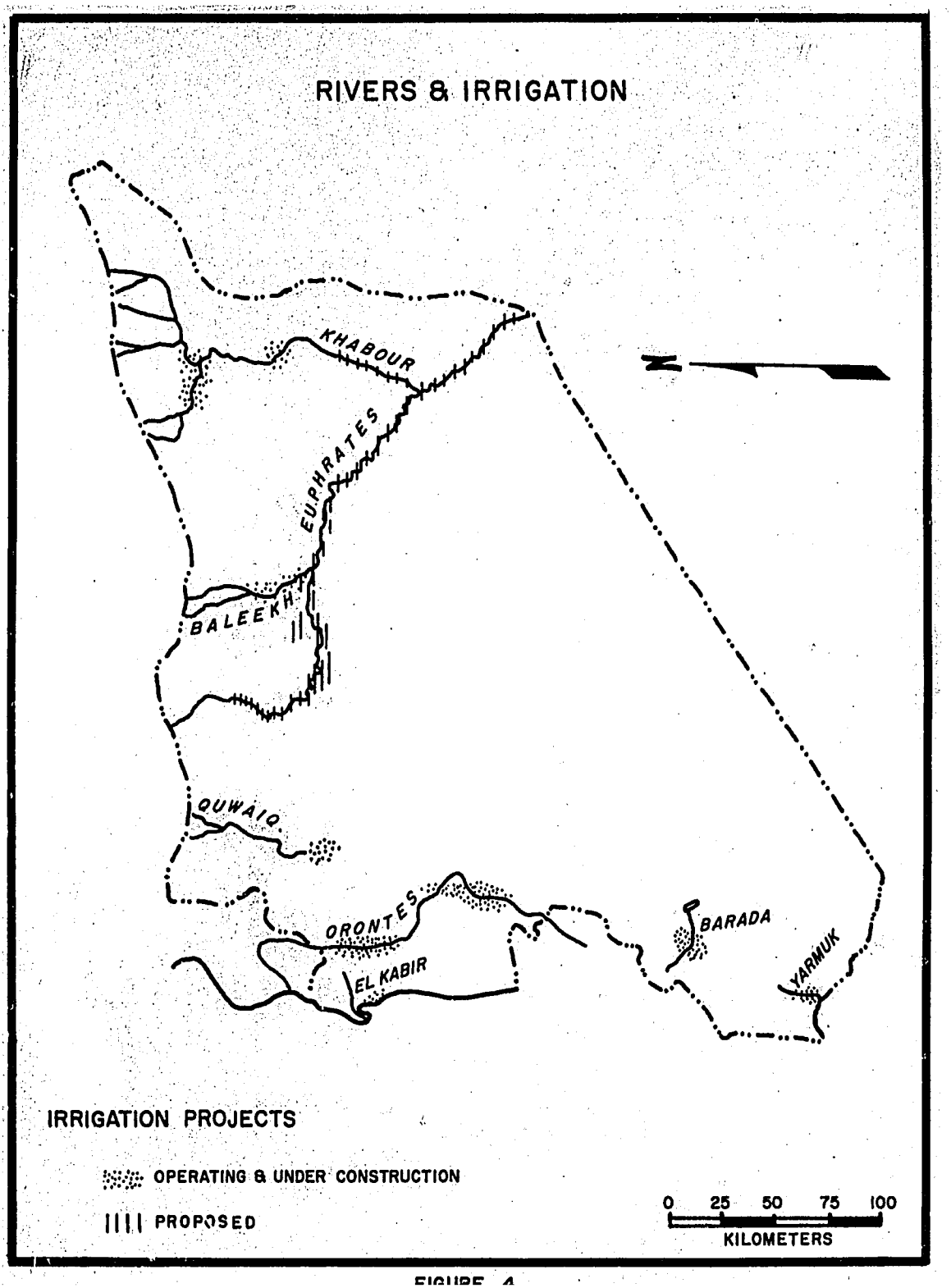

RIVERS & IRRIGATION
KHABOUR
EUPHRATES
BALEEKH
QUWAIQ
ORONTES
EL KABIR
BARADA
YARMUK
IRRIGATION PROJECTS
OPERATING & UNDER CONSTRUCTION
PROPOSED
0 25 50 75 100
KILOMETERS

FIGURE 4

second group are streams which spring on the inland slopes and drain internally, usually terminating in a salt lake on the desert fringe. An example of this group is the Quwaiq River which flows through Aleppo and terminates in a salt lake to the south of the city.

The fluctuation of the Syrian rivers is as variable as the country's rainfall. During the rain and snow melt seasons, the rivers reach their maximum flow which results in the inundation of the surrounding areas in many cases. In the dry season, however, the flow of the major rivers decreases sharply, while the beds of the minor streams dry up.

Population Distribution

In 1962 Syria's population was estimated at 4,777,000, projected from the 1960 ennumeration. The population is unevenly distributed throughout the country (Figure 5). In the western section there is a high density of over 100 persons per square kilometer, while the central and eastern regions are thinly populated with under 10 persons per square kilometer in most cases.

The distribution of urban centers (Figure 6), is closely related to the general pattern of population distribution. Most of the large urban centers are located in the eastern half of the country led by Damascus and Aleppo with about 1/2 million persons each.

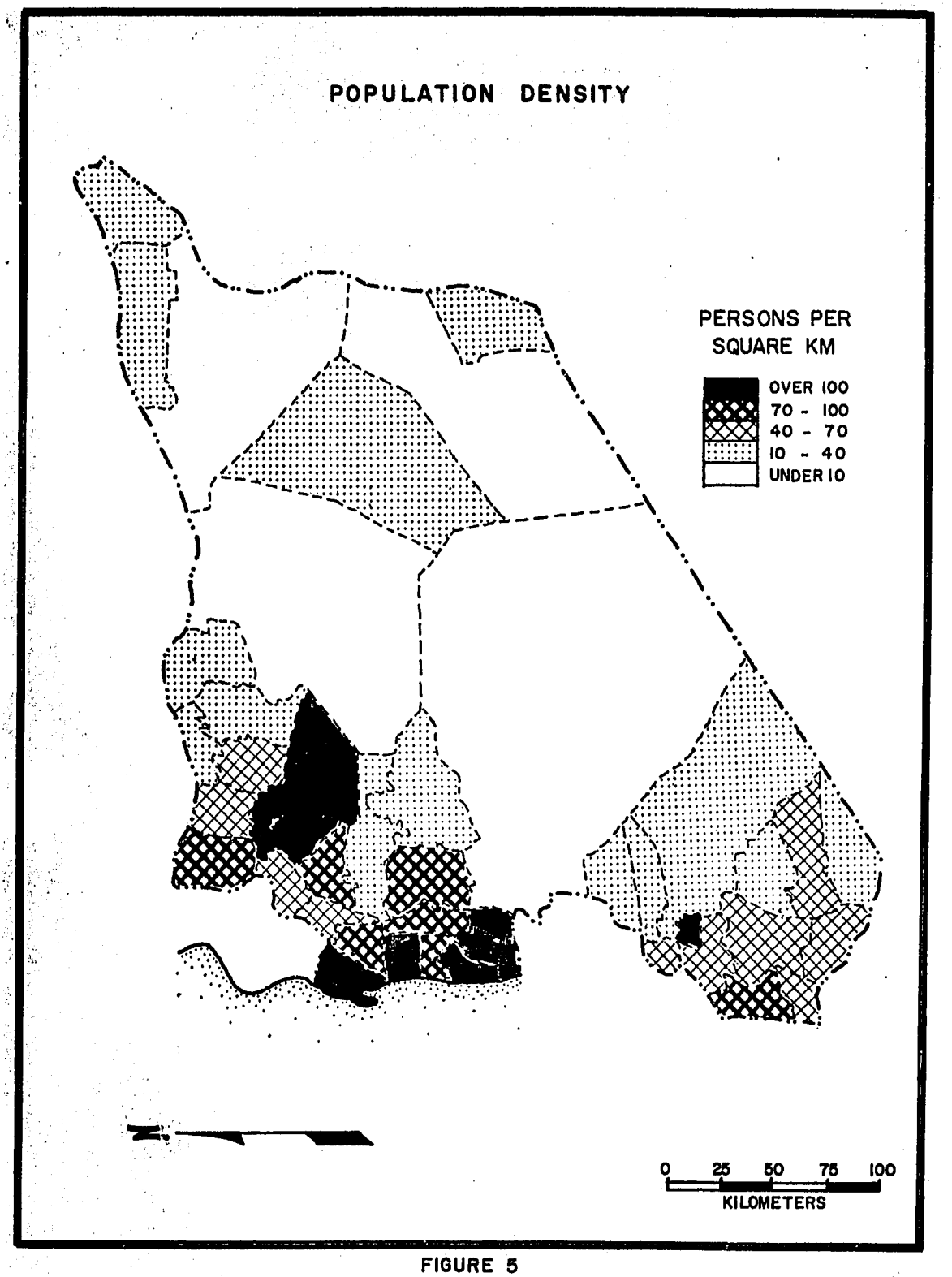

POPULATION DENSITY
PERSONS PER SQUARE KM
OVER 100
70 - 100
40 - 70
10 - 40
UNDER 10
0 25 50 75 100
KILOMETERS

FIGURE 5

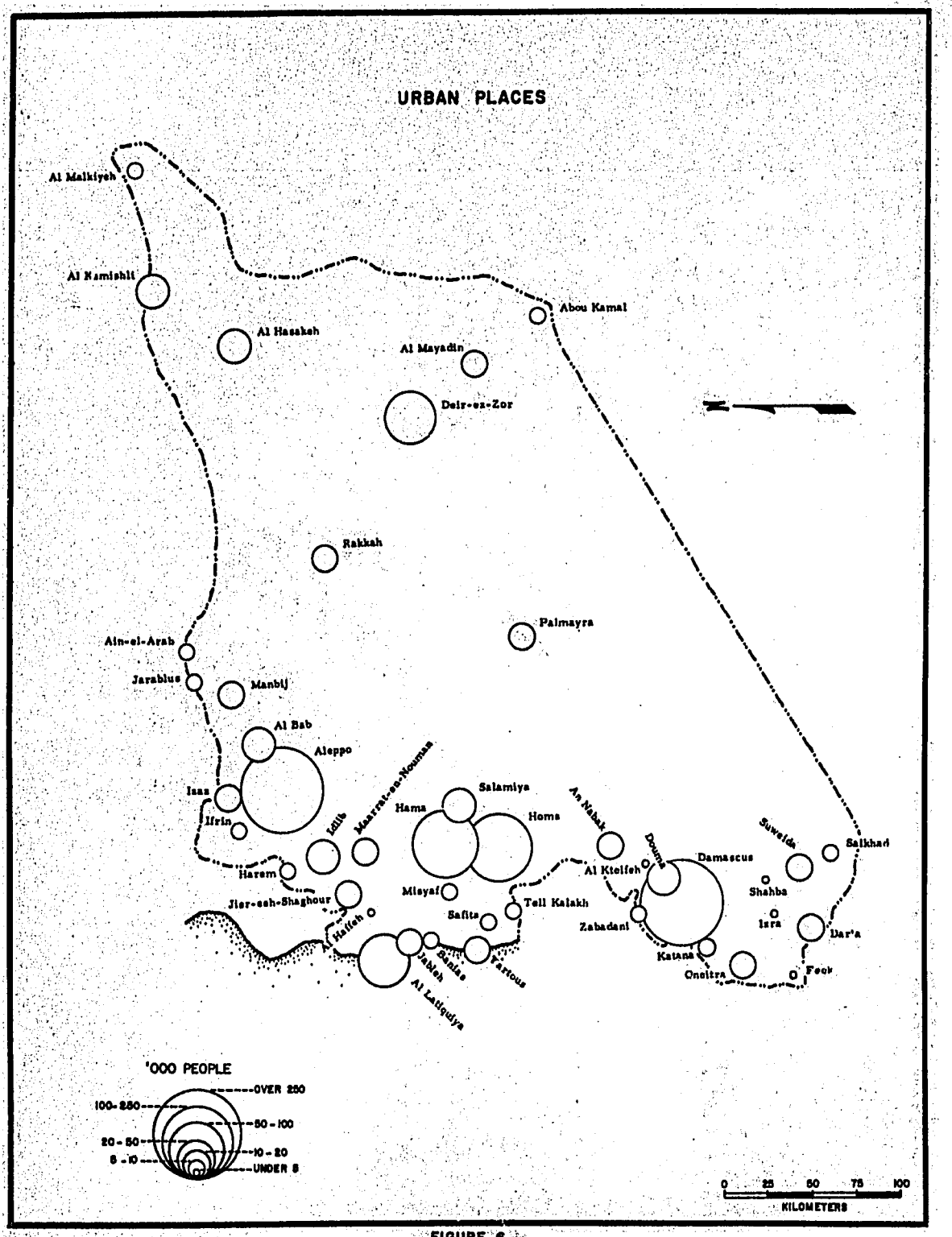

URBAN PLACES
Al Malkiyeh
Al Namishli
Al Hasakeh
Abou Kamal
Al Mayadin
Deir-ez-Zor
Rakkah
Palmayra
Ain-el-Arab
Jarablus
Manbij
Al Bab
Aleppo
Isaz
Ifrin
Idlib
Maarrat-es-Nouman
Hama
Salamiya
Homs
An Nabak
Douma
Damascus
Suweida
Salkhad
Harem
Jier-esh-Shaghour
Al Hafeh
Misyaf
Safita
Tell Kalakh
Al Ktelfeh
Zabadani
Shahba
Izra
Dar'a
Katana
Onsitra
Feek
Jableh
Banias
Tartous
Al Latiquiya
'000 PEOPLE
OVER 250
100-250
50-100
20-50
10-20
5-10
UNDER 5
0
25
50
75
100
KILOMETERS

FIGURE 6

Agriculture

Approximately 70 percent of Syria's population is engaged in agriculture and its related fields. The concentration of farm population is especially high in the southern part of the country, which was the traditional agricultural region of Syria from the very early history of the country until a few decades ago. Other concentrations are in the northeast area, which is the newly developed agricultural region of Syria (Figure 7).

Cotton, Syria's most important summer crop, is totally dependent on irrigation. The superior quality of this long staple cotton creates a high demand on the world market and has become Syria's most important export commodity.

The agricultural areas of wheat and barley, the two most important winter crops, are dependent on rainfall. Supplementary irrigation is introduced in areas with a deficiency of precipitation.

Manufacturing

There has been a steady increase in the manufacturing development and production in Syria within the last decade. However, agriculture contributes 50 percent of the national income compared to manufacturing's 12 percent. Most of the recent development is in light industry such as textiles and related manufactured products.

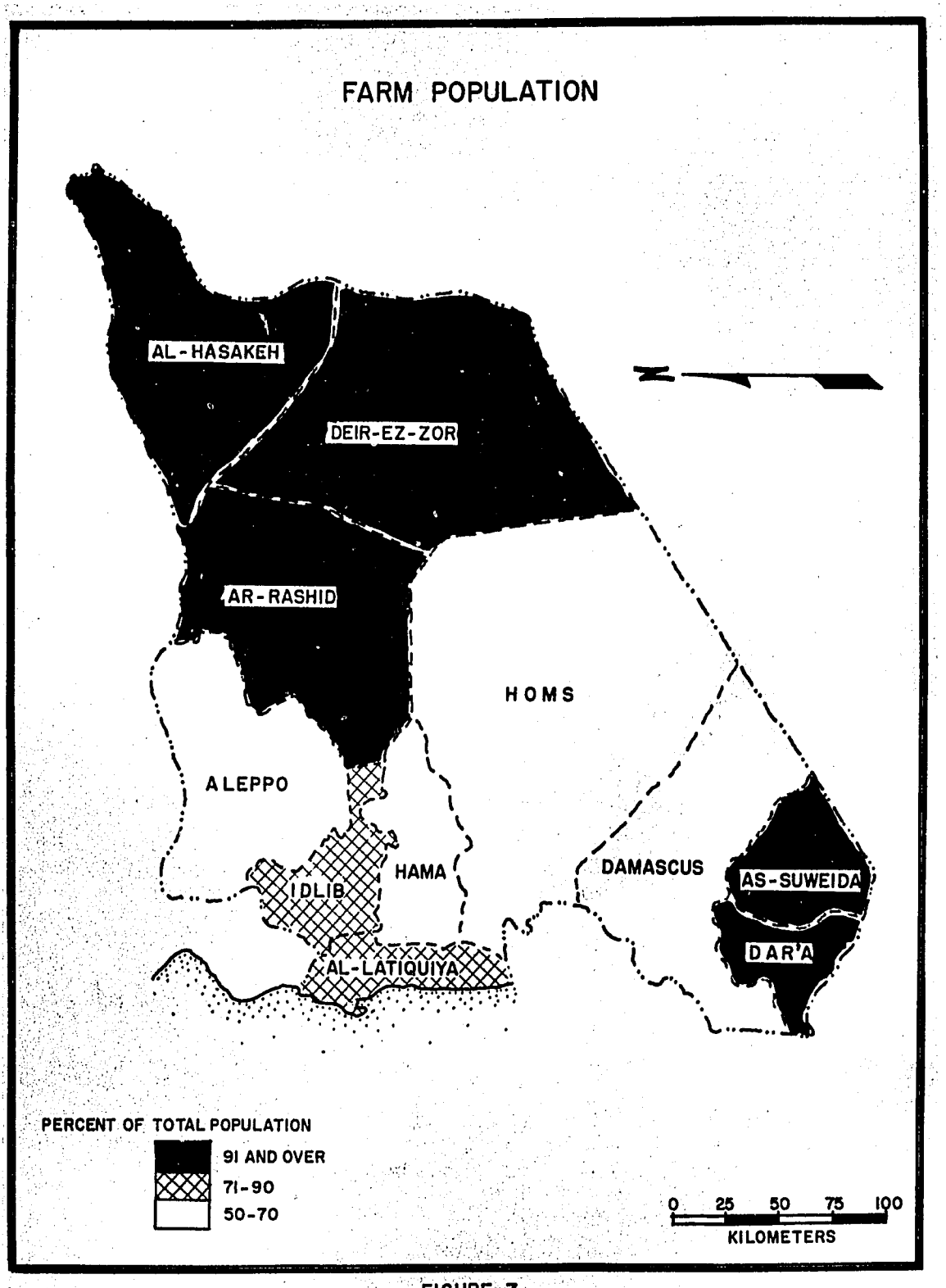

FARM POPULATION
AL-HASAKEH
DEIR-EZ-ZOR
AR-RASHID
HOMS
ALEPPO
IDLIB
HAMA
DAMASCUS
AS-SUWEIDA
DAR'A
AL-LATIQUIYA
PERCENT OF TOTAL POPULATION
91 AND OVER
71-90
50-70
0 25 50 75 100
KILOMETERS

FIGURE 7

Damascus and Aleppo account for the largest part of the manufacturing output, with 70 percent of the total floor area of manufacturing plants (Table 1).

TABLE 1

TOTAL FLOOR AREA OF MANUFACTURING PLANTS BY MUHAFAZA (1961)[a]

Name	Floor Area (in sq. meters)
Damascus	322,418
Homs	63,069
Hama	36,986
Aleppo	218,486
Idlib	7,909
Al-Latiquiya	88,367
Deir-ez-Zor	18,474
Rakkah	4,420
Al-Hasakeh	3,211
As-Suweida	10,865
Dar'a	9,482
Total	777,714

Source: Statistical Abstracts (1961), Syrian Arab Republic, pp. 245-6.
[a] Muhafaza is the largest administrative unit in Syria.

This then, is a brief presentation of some of the important factors which have influenced the distribution of transport facilities in Syria, some more important than others to be sure, but all playing a role in the spatial layout of the network.

CHAPTER III

DEVELOPMENT OF TRANSPORTATION IN SYRIA

Although the main focus of this study is on the modern transport network of Syria, the following discussion describes the fashion in which the present day network of the country developed through time. This historical perspective provides a certain degree of understanding of the variables that are related to the transport network, and the manner in which the present day alignment of the network evolved.

The present day transport network of Syria is the product of six distinct stages of growth. These are:

1) Ancient caravan routes.
2) Roads built during the expansion of the Roman Empire into the country.
3) Wagon roads built during the latter part of the 19th century.
4) The railroad building era.
5) Motor roads.
6) Realignment following the partitioning of Greater Syria.

These stages should not be considered independent of one another, nor should it be thought that when a new stage emerged the older one ceased to exist. In fact, the present day network should be considered

the result of a combination of these six stages, some more important than others certainly, but each contributing a share in serving the movement of goods and people from one part of the country to another.

Ancient Caravan Routes

The location of Syria[1] at the meeting point of the three continents of Africa, Europe, and Asia brought about the growth of trade across its territory linking east to west since the dawn of civilization. Before the coming of the Roman Empire there were two main caravan routes that passed through Syria; the first across Turkey moving south into northern Syria and then eastward into Iraq following the grasslands of the Fertile Crescent. The second extended from the port cities of the eastern Mediterranean eastward across Syria into Iraq and onward to India and East Asia.

In addition to these two international routes, there were a number of local routes joining the interior sections of Syria to the coastal towns. After leaving the plains, the goods and people in transport had to make a sharp ascent of the two mountain chains of The Lebanon and Anti-Lebanon. This made it necessary to unload the

[1] In this chapter this name refers to Greater Syria, a part of the Ottoman Empire that was composed of what is now Lebanon, Syria, Jordan, and Palestine.

camels, which were the main animals of burden across the plains, and transfer the loads onto mules or donkeys, the two animals primarily used in rugged terrain transport.

It was in this strategic zone, the meeting point of the flat desert and the rugged mountain, that the interior break-of-bulk points developed and were later to become the large urban centers of Damascu Homs, Hama, and Aleppo. Once the transfer of goods was completed, the caravans continued their journey to the coastal area of the eastern Mediterranean, crossing the mountain chains that separated them from the sea at the few natural passes that cut across what might otherwise have been an insurmountable obstacle.

The second type of break-of-bulk point evolved through the development of settlements located at strategic points along the coast.[2] These ports were the terminal points of the land routes, where the goods and people coming from the east had to change carriers before sailing for their ultimate destination in the west. There was a corresponding movement from west to east in the same manner as the movement from east to west. Once these centers became important enough to generate their own traffic movement, new routes developed connecting them to one another and to Turkish cities to their north

---

[2] The most important settlements became the port cities of Sidon, Tyre, Byblos, Tripoli, Antioch, and Alexandretta.

and Egyptian cities to their south. This early development played an important role in the structure and growth of the subsequent stages of transport development in the area, as it was the formative era in which the location of the major urban centers took place. Their position had to be taken into account whenever any new connections were introduced.

Roman Roads

The Romans were noted road builders, and with the extension of their rule over Syria, a well constructed and connected road network developed, the physical remains of which are still in evidence. Since Syria was one of the most important Roman outposts, this network was designed to move troops efficiently from one part of Syria to another, and to join the local areas of agricultural production to the various army installations, thus insuring a dependable flow of food products from the supply to the demand areas.

Subsequent to the fall of Rome, major powers utilized the Roman road network in Syria when carrying on their contacts, even though they themselves did very little to improve the roads or to construct new ones.

During the first half of the 19th century, the period immediately prior to the coming of the wagon to Syria, a number of urban centers were engaged in profitable trade ventures in their role as middlemen

between east and west. During this period, Aleppo was the largest urban and commercial center in the region. Caravans which came to it from East Asia, India, Iran, Yemen, and Iraq followed the natural route of the Fertile Crescent carrying high cost goods that were in demand in Europe, and so were able to bear the high cost of transport in addition to the initial high cost of the goods themselves. Among the goods in highest demand were silk, dyes, coffee, and medicines. At Aleppo the goods were sold to European merchants, who then transported them to one of the three ports of Tripoli, Alexandretta, and Al-Latiquiya. In return, the merchants of Aleppo purchased a large number of European-manufactured products and moved them eastward to the areas of demand. Of the three ports handling the flow of goods across the area, Tripoli handled by far the largest overall volume (Table 2). In addition to shipping most of Aleppo's incoming and outgoing flow of goods, it handled most of the goods passing through the smaller but nevertheless important cities of Hama and Homs.

TABLE 2

GOODS HANDLED IN 1844

City	Metric Tons
Al-Latiquiya	165,000
Tripoli	330,000
Beirut	68,000

Source: Abdul Karim Gharaibek, Syria During the Nineteenth Century, Institute of Higher Arabic Studies (Cairo, 1962). In Arabic.

Even though most of the large urban centers were connected to one another, the journey between any two of them was both lengthy and costly (Table 3).

TABLE 3

TRAVEL TIME AND DISTANCE FROM DAMASCUS TO MAJOR URBAN CENTERS

(Round Trip)

Round Trip	Time (in days)	Distance (in kms.)
Damascus-Homs	5	165
Damascus-Hama	7	211
Damascus-Aleppo	10-12	364
Damascus-Beirut	4	111

Wagon Roads

In 1856 Count Edmond de Perthius, a French national, was granted a fifty-year concession by the Turkish sultan giving him the rights to build and exploit a wagon road joining Damascus to Beirut. Work on the 111 km. road was started in 1859 and was completed in 1863. This new connection cut down traveling time between the two cities from the previous four days to thirteen hours for the round trip.

This substantial decrease in the friction of distance between the two cities stimulated growth at both ends. A number of industries in

Beirut that were of minor local importance before 1863 expanded their facilities to meet the demand that was generated in the interior with the coming of fast and relatively cheap transport costs. The position of Beirut at the terminal point of this new line gave it a comparative advantage over other port cities such as Tripoli, Sidon, and Haifa, all competing for handling the trade of the interior regions. The position of Damascus, like that of Beirut, was also greatly enhanced by the building of this new road, while the other competing centers continued to depend on the slower and more expensive animal transport. However, the merchants of these interior centers and port cities did not take long to realize the importance of rapid and cheap transport facilities that was apparent in the rapid growth of the volume of goods moving between Beirut and Damascus. Aleppo was linked to Alexandretta by a wagon road in 1873, Homs to Tripoli by 1883, and others were quick to follow (Figure 8).

By 1894 Beirut was handling by far the largest volume of goods among all the ports of the area, a position it still holds.

TABLE 4

MOVEMENT OF GOODS THROUGH MAJOR PORTS, 1894

Port	Tons
Beirut	740,551
Tripoli	429,723
Alexandretta	290,323
Al-Latiquiya	170,891
Haifa	110,626
Acre	73,377
Saidon	43,987

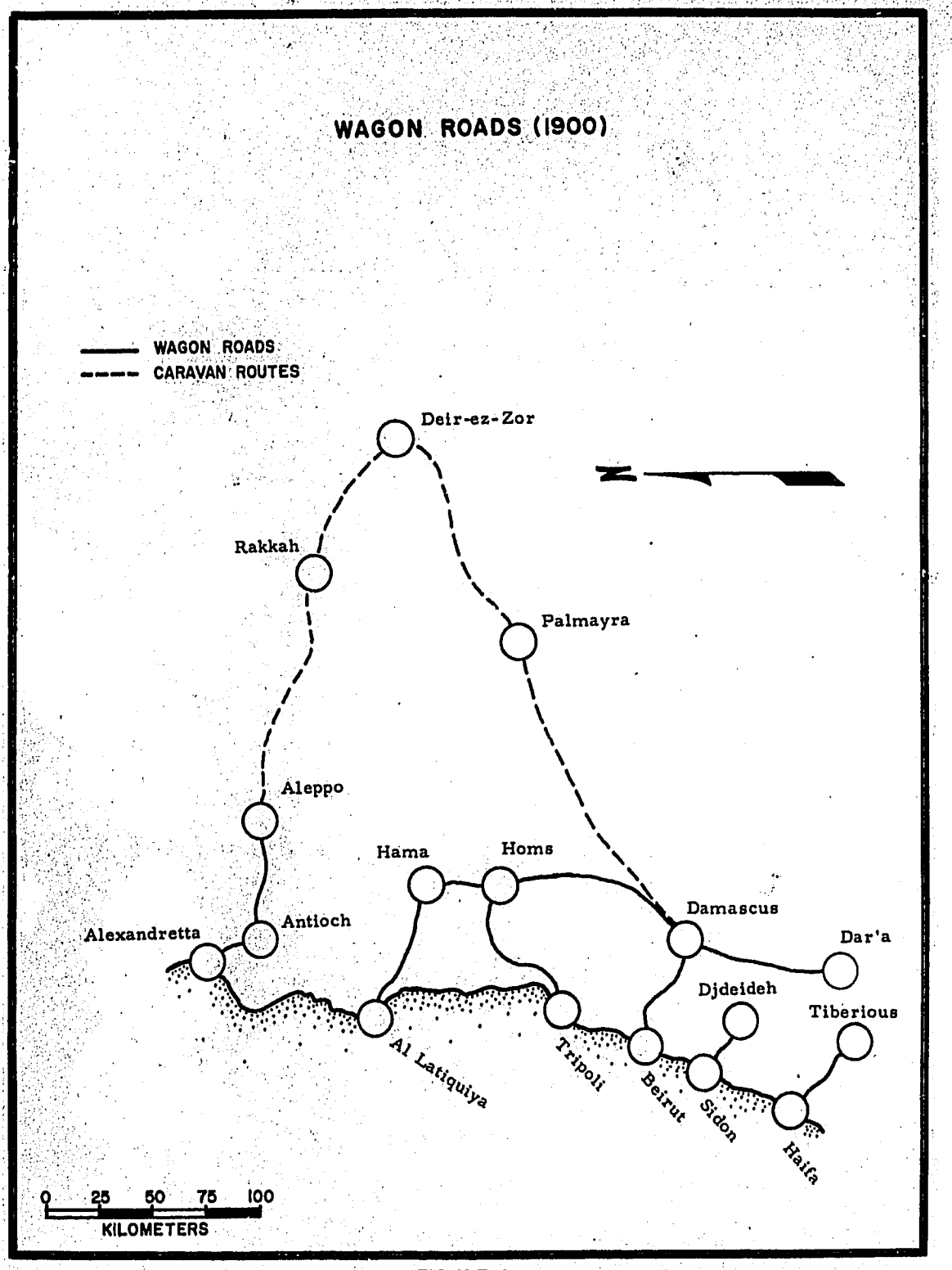

WAGON ROADS (1900)
WAGON ROADS
CARAVAN ROUTES
Deir-ez-Zor
Rakkah
Palmayra
Aleppo
Hama
Homs
Damascus
Antioch
Alexandretta
Dar'a
Djdeideh
Tiberious
Al Latiquiya
Tripoli
Beirut
Sidon
Haifa
0 25 50 75 100
KILOMETERS

FIGURE 8

An examination of the movement of goods through the three main ports of the region for the periods before and after the coming of the wagon roads reveals that change was not confined only to the increase in the volume of goods handled but also to an increase in the relative positions of ports, especially that of Beirut, which handled the smallest volume of goods in 1844 and subsequently grew to become the largest port by 1894 (Figure 9).

Railroads

In 1865 a report by the administrative council of the society which owned the Beirut-Damascus wagon road stated that "the agricultural products of the Houran and Ledja that are routed for the major part to the ports of Haifa and Acre, will move via the Damascus-Beirut road if a link between Damascus and Mezeireb is built."[3] The plains of Houran, an important agricultural area in the southern part of Syria had always been a high quality grain surplus area since the early days of the Roman Empire. In 1890 the area produced 615,000 tons of grain, of which 190,000 tons were exported (Table 5).

---

[3] Elauthere Elefteriades, Les Chemins de Fer En Syrie et au Liban (Beyrouth, 1944), p. 40.

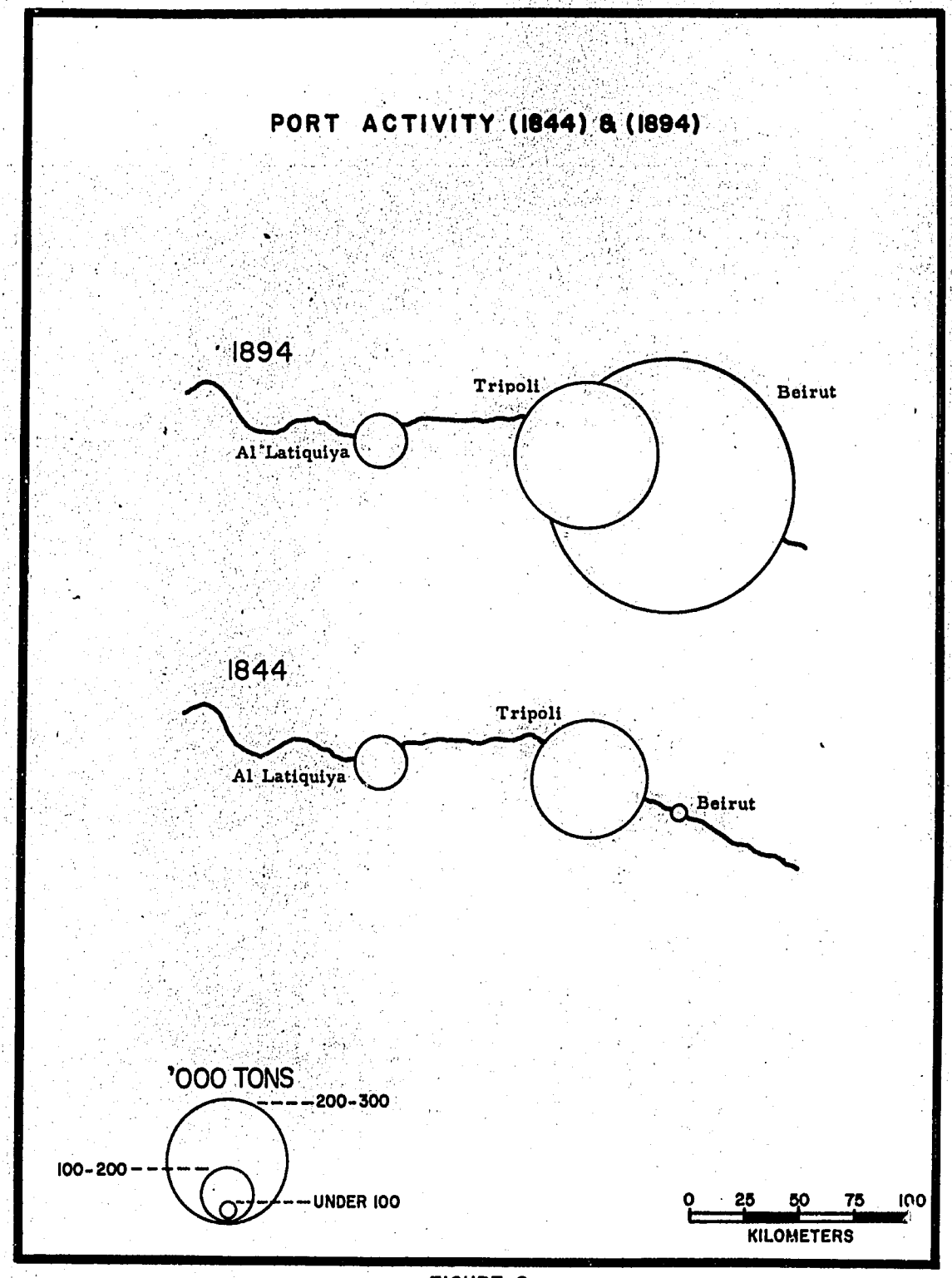

PORT ACTIVITY (1844) & (1894)
1894
Tripoli
Beirut
Al Latiquiya
1844
Tripoli
Al Latiquiya
Beirut
'000 TONS
200-300
100-200
UNDER 100
0 25 50 75 100
KILOMETERS

FIGURE 9

TABLE 5

AGRICULTURAL PRODUCTION OF THE HOURAN (1890)

Produce	Tons
Wheat	160,000
Barley	170,000
Corn	189,000
Others	96,000
Total	615,000

Of the total exports of that year, 63,320 tons went north to Damascus and Beirut, while 126,668 tons went to Haifa and Acre. In order to maintain this favorable situation, a concession for building a railroad joining the Houran plains to Haifa and extending northward to Damascus was granted by the sultan to a British firm. This serious threat to the Damascus-Beirut line, and the fact that the wagon road was fast reaching its full capacity due to the large increase in movement of both people and commodities that it was called upon to handle, made the possibility of the renewal of its sole exploitation rights of the connection quite unlikely. Meanwhile, a Lebanese financier, Joseph Moutran, was given a concession to exploit the port of Beirut under the name of "Companie du Port des Quais et Entrepôts de Beyrouth." An expansion of the port facilities was soon undertaken by this new company to enable the efficient handling of the ever-increasing flow of goods.

Damascus-Mezeireb Railroad. Mr. Moutran subsequently obtained another concession from the Turkish sultan, this time to build a railway line connecting Mezeireb, in the heart of the Houran agricultural area, to Damascus 103 km. to the north. This was a narrow gauge line (1.05 m.), completed in the summer of 1894. It cut down traveling time between Damascus and Mezeireb from 2-1/2 days on horseback to 3 hours by train. This new connection stimulated the flow of goods between the two areas and greatly affected the flow on the already overburdened wagon line between Damascus and Beirut, making it very obvious that this connection alone could no longer handle the total flow.

Damascus-Beirut Railway. Mr. Moutran's company, under its new name, "Société des Chemins de Fer Ottomans Economiques de Beyrouth-Damas-Houran en Syrie," purchased the exploitation rights of the wagon road and began planning a railway connection between Damascus and Beirut. Original plans called for a standard gauge line, but since a speedy completion was very necessary, due to the competition with the Damascus-Haifa line already proposed, a narrow gauge was decided upon. This narrow gauge would be much easier to build and much faster to complete than a standard gauge line, as the two mountain ranges of The Lebanon and the Anti-Lebanon were to be crossed. The line, 147 km. in length, with five tunnels the longest of which was 7 km.,

was completed in August 1895. The trip between Damascus and Beirut was cut down to 9 hours, and the ascent of the steep mountain sides was simplified by the use of cogs. The cost of shipment of goods between Damascus and Beirut was reduced to half the amount of what it had been before the coming of the railway (Table 6).

TABLE 6

COST OF FREIGHT MOVEMENT BETWEEN DAMASCUS AND BEIRUT

Method	Length of haul (in kilometers)	Cost per ton-kilometer (in francs)
Wagon	122	63.3
Railway	144	28.8

Riyak-Hama-Aleppo Railway. Mr. Moutran's company, now renamed "Société Ottomane du Chemins de Fer Damas-Hama Prolongements," obtained a new concession from the sultan to build a railroad line joining Riyak, located at midpoint of the Beirut-Damascus line, to Aleppo in the northern region, passing through the cities of Homs and Hama (Figure 10). Riyak was chosen as the head of the line instead of Damascus because the area between Riyak and Homs is a fertile agricultural plain, while the area between Damascus and Homs is a desert. By the time the line reached Hama in 1902, the company ran into financial difficulty and work had to be stopped temporarily. It was resumed the following year, and the standard gauge line (1.435 m.)

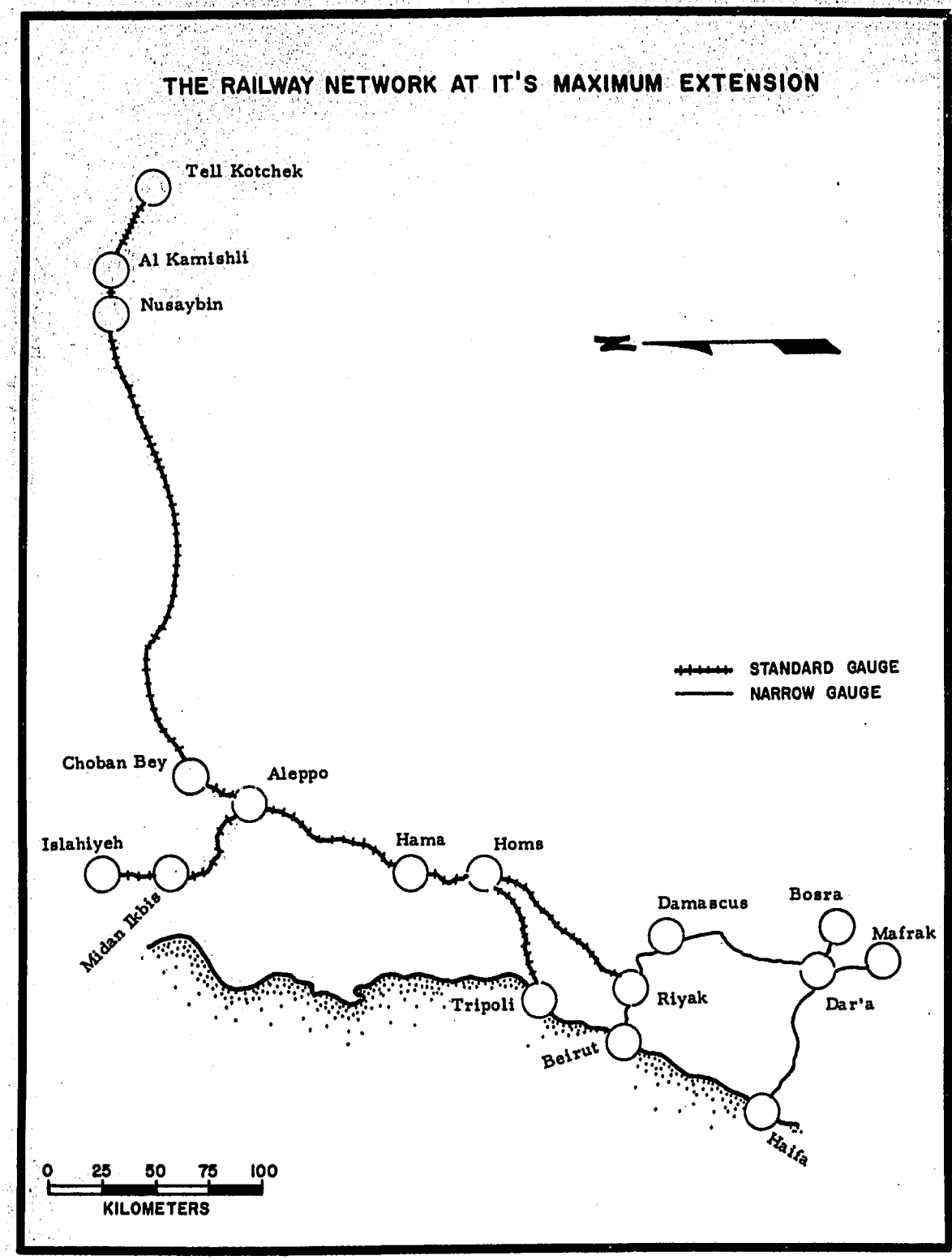

THE RAILWAY NETWORK AT IT'S MAXIMUM EXTENSION
Tell Kotchek
Al Kamishli
Nusaybin
STANDARD GAUGE
NARROW GAUGE
Choban Bey
Aleppo
Islahiyeh
Hama
Homs
Midan Ikbis
Damascus
Bosra
Mafrak
Tripoli
Riyak
Dar'a
Beirut
Haifa
0 25 50 75 100
KILOMETERS

FIGURE 10

which was 331 km. in length, reached Aleppo in 1906.

In 1903, the year after the line reached Homs, the movement of goods between that city and Damascus reached 37,180 tons, whereas it had never gone over 10,000 tons in previous years.

Homs-Tripoli Railway. In 1909 a concession to build a standard gauge line connecting Tripoli to Homs was granted to D.H.P.[4] This line covered the distance of 102 km. and was completed in 1911, joining the second largest port of the region to the growing rail network in the interior.

Hijaz Railway. In 1900 work was begun on a narrow gauge line to join Damascus and Mecca, the religious capital of the Islamic world in the western part of the Arabian peninsula. There were a number of reasons why Sultan Abd-ul-Hamid undertook to have this line constructed with funds provided by public conscription. The two most important reasons were: (1) to make the difficult land journey to Mecca easier and safer for the pilgrims, and (2) to connect the Arabian peninsula to the heart of his empire, so that he could control this peripheral part of the empire more efficiently.

The above points may be considered the main justification for building this line. From an economic point of view it was unjustifiable.

---

[4] Abbreviation for "Société Ottomane du Chemins de Fer Damas-Hama et Prolongements."

The only part that might have had any economic benefits was the Syrian segment, from Damascus to Dar'a, but this duplicated the Damascus-Mezeireb line already in existence, where the lines are 12 km. apart at the farthest point and come to within 5 km. of one another at several points. The rest of the line, south of Dar'a, ran in an area too dry for any commercial agriculture to develop in it, and too thinly populated to generate continuous passenger traffic. The only substantial use of the line would be during the time of the yearly pilgrimage, and this traffic was too small and highly seasonal to warran a railway. However, its strong religious appeal to Muslims all over the world brought large amounts of subscriptions to support this project.

D.H.P., sensing the consequences of a competing line so close to its own, offered to sell out its facilities at cost to the Turkish government. The Turkish government refused this offer, and in a partial settlement paid the D.H.P. company 150,000 Turkish pounds for damages. D.H.P. continued its service on the line for a few years, but the losses were too great to bear, so service was permanently terminated on this line in 1914.

The Syrian segment of the Hijaz Railway extending from Damascus to Dar'a was completed by 1903 with a length of 140 km. [5]

---

[5] The line reached Medina 1,400 km. away by 1908.

Two connections, one joining Dar'a to Haifa and the other joining it to Bosra, were completed in 1904. The segments within Syria are 73 km. and 32 km. respectively.

Syrian Segment of the Berlin-Bagdad Railway. In 1903 a company by the name of "The Ottoman Empire Company for the Bagdad Railroad" was established in order to extend the Berlin-Bagdad railway line from Konia, Turkey to Bagdad, the ultimate destination. At the outbreak of the war the line had reached northern Syria, and with work continuing all through the war, the line reached Nusaibin in the northeastern part of the country. The final segment of this railway that is within the Syrian border was finally completed in 1935.

Motor Roads

The first car that was ever seen in Syria crossed from Alexandretta to Aleppo in 1909, using one of the wagon roads that had been built in the previous century, linking the major urban centers to one another. The condition of these wagon roads had become very poor due to lack of maintenance during the latter part of the 19th century when the railways became the primary carriers in the movement of goods and people throughout the area.

Road conditions remained very poor until the coming of the French forces during World War I. This occupation marked the beginning of the modern road building era in Syria. Systematic road

building was introduced. New roads were planned, and old ones were expanded and improved.

After the end of the war the French mandate government continued its systematic plans of road improvement giving preference to connections that were of economic or strategic importance. The improvement program dealt mainly with rebuilding the existing old links, improving the grades in rugged areas, widening the surface and the shoulder areas in most cases, applying new surfaces, and in general using the improved techniques of road building developed by their engineers. The road network that developed during this period can be divided into two groups (Figure 11). The first type, the transverse lines, joined the port cities to the interior urban centers. The main transport lines were:

1) Beirut-Damascus road.
2) Jubail-Baalbek road.
3) Tripoli-Homs road.
4) Banias-Hama road.
5) Al-Latiquiya-Aleppo road.
6) Alexandretta-Aleppo road.

The second type, the longitudinal lines, ran in a north-south orientation across the three lowland areas of the region. These were:

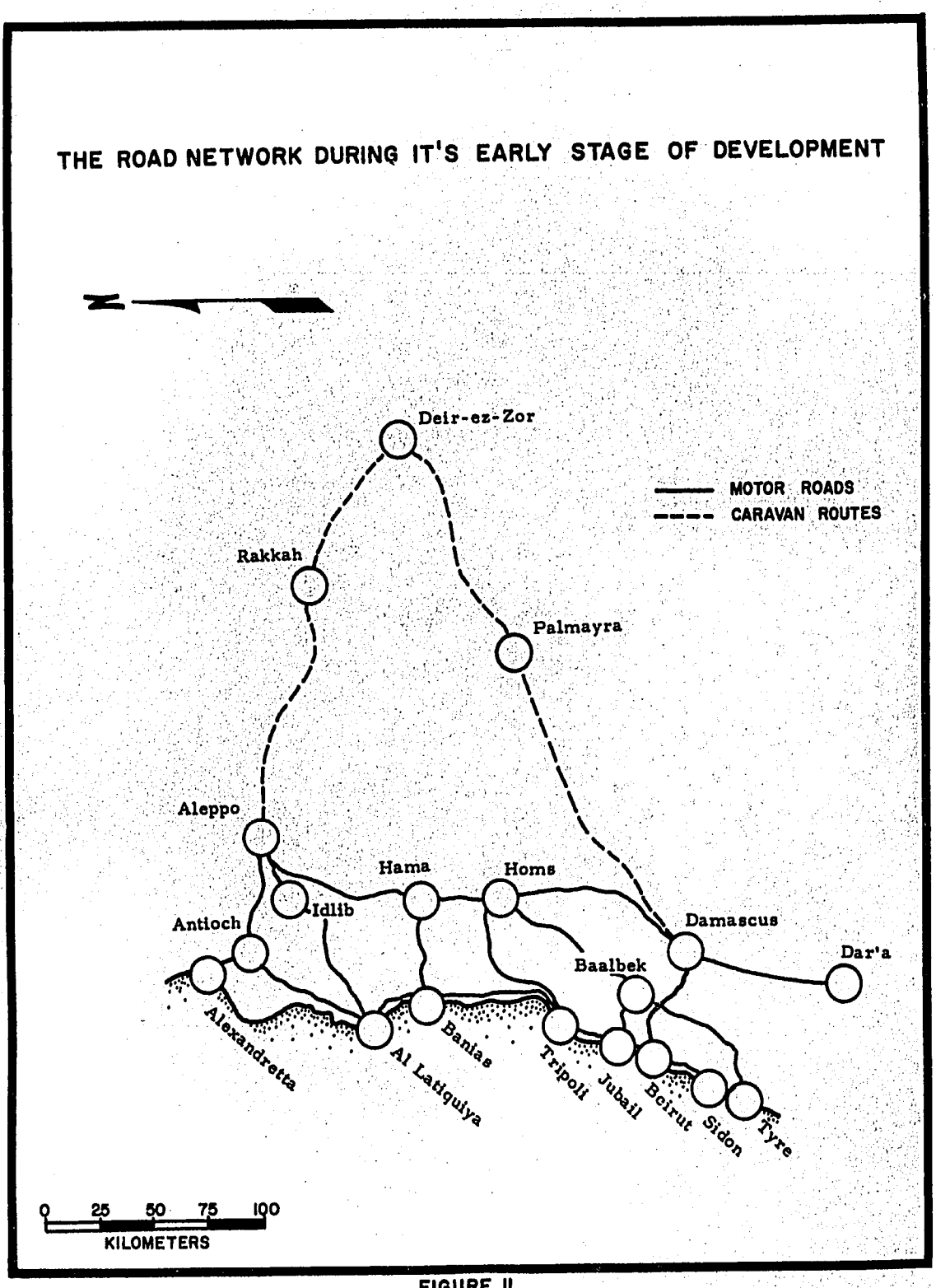

THE ROAD NETWORK DURING IT'S EARLY STAGE OF DEVELOPMENT
N
MOTOR ROADS
CARAVAN ROUTES
Deir-ez-Zor
Rakkah
Palmayra
Aleppo
Hama
Homs
Idlib
Antioch
Damascus
Baalbek
Dar'a
Alexandretta
Al Latiqulya
Baniae
Tripoli
Jubail
Beirut
Sidon
Tyre
0 25 50 75 100
KILOMETERS

FIGURE II

1) The coastal road beginning at Tyre in the south and terminating at Alexandretta to the north, passing through Sidon, Beirut, Jubail, Tripoli, Al-Latiquiya, and Antioch.

2) The central valley road from Tyre to Zahleh, Baalbek, and then Homs.

3) The interior road joining the major urban centers of Syria, namely Aleppo, Hama, Homs, Damascus, and southward to Dar'a.

Realignment of the Network Following the Partitioning of Greater Syria

At the end of World War I, the Ottoman Empire, an ally of defeated Germany, lost most of its possessions outside the Anatolian Peninsula. The Wilayet of Syria was subsequently removed from under the Ottoman rule and partitioned into a number of newly created states, one of which became the modern state of Syria. Creation of political boundaries cutting across transport lines that grew on a regional basis was detrimental to the connectivity of the network of the area and especially to that of the newly created state, Syria. Syria, which before the partitioning had seven major ports on the Mediterranean, was left with only one port, namely Al-Latiquiya (Figure 12). The partitioning resulted in a decrease in the connections linking the main urban centers to one another, especially the ones that joined the inland urban centers to their respective ports of entry. The port of Alexandretta, which served the northern region of Aleppo, was

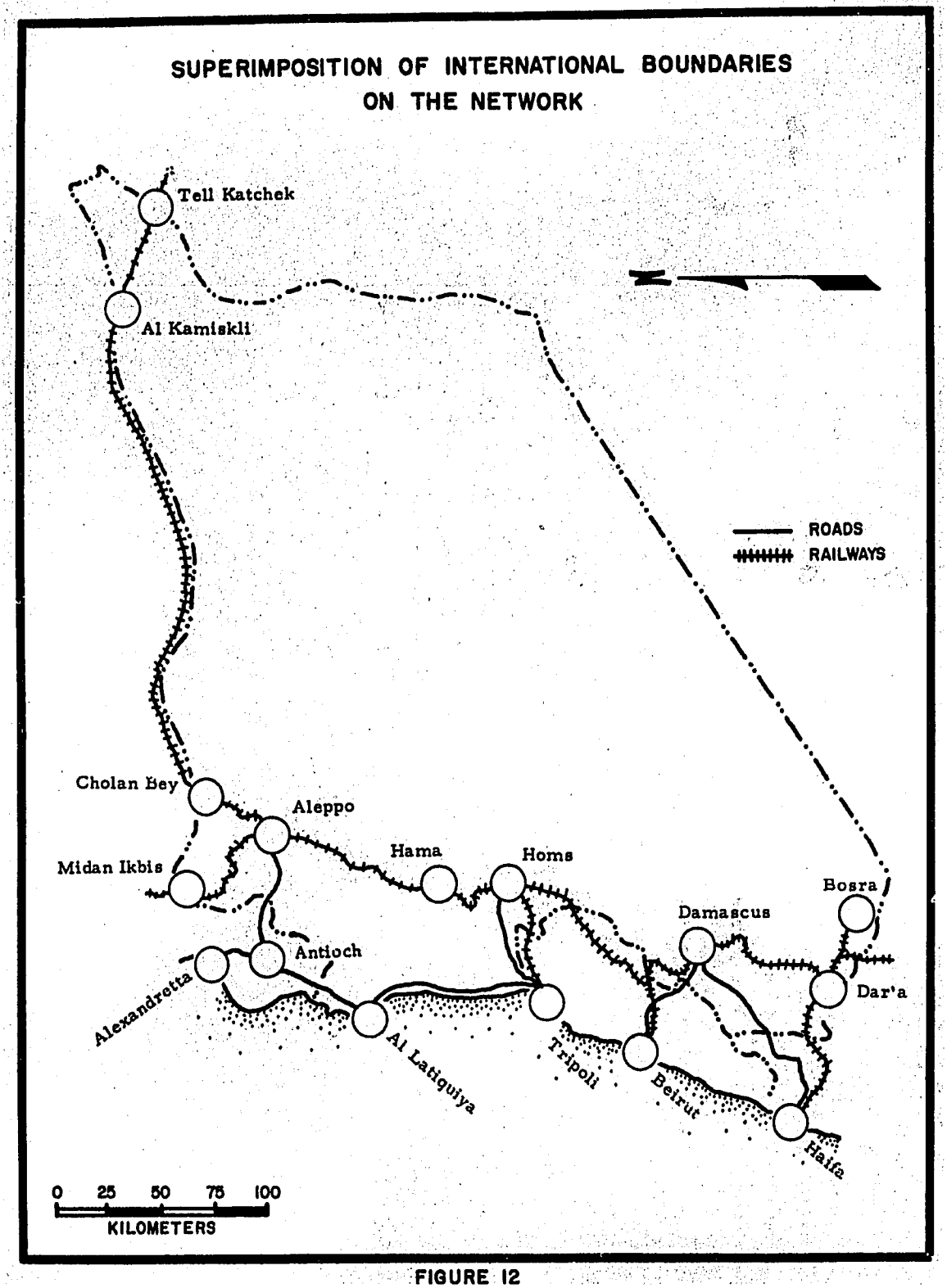

SUPERIMPOSITION OF INTERNATIONAL BOUNDARIES
ON THE NETWORK
Tell Katchek
Al Kamiskli
ROADS
RAILWAYS
Cholan Bey
Aleppo
Hama
Homs
Midan Ikbis
Bosra
Damascus
Antioch
Alexandretta
Dar'a
Al Latiquiya
Tripoli
Beirut
Haifa
0 25 50 75 100
KILOMETERS

FIGURE 12

given to the state of Turkey. Lebanon received the port of Tripoli, which serves the Homs-Hama area, the important port of Beirut, which was the entrepôt to Damascus, and the smaller ports of Sidon and Tyre to the south. The ports of Haifa and Acre, serving the southern region, were incorporated into the state of Palestine.

The role of the railroad network in serving the economy of the area, already hindered by the existence of two types of gauges, was further disrupted by the political boundaries that were superimposed on the region after the whole network had already been built. The network, as it had developed prior to partitioning, connected the major urban centers, ports and agricultural regions to one another. The north-south line between Dar'a and Aleppo passed through the agricultural region of the Houran, Damascus and its rich ghouta,[6] the agricultural region of the Beqaa, the large urban centers of Homs and Hama with their rich agricultural uplands, and finally the highly productive Aleppo area. This longitudinal line was connected to the port cities of Beirut, Tripoli, and Haifa, the three important entrepôts of the region, by three short transverse lines. Two other important connections existed, one joining Aleppo to Bagdad, and the other joining Aleppo to a number of important Turkish cities to the north.

The partitioning of Syria brought about a serious disruption of the flow of goods on the railway system. The north-south line had

[6] The name given to the rich agricultural plain on which Damascus is located.

to cross into Lebanon on its way from Damascus to Homs, disrupting the flow between the two major segments of the country. The east-west flow was also interrupted as the three terminal points on the Mediterranean were outside Syria. This made it necessary for virtually all the imports and exports of the country which were moved by rail to cross international boundaries and depend on foreign port facilities for the country's international trade.

The boundary between Turkey and Syria disrupted the flow of the two lines joining Aleppo to Turkey and Iraq. The Aleppo-Turkey line crossed the international border 117 km. north of Aleppo. The Aleppo-Bagdad line crossed into Turkey 65 km. out of Aleppo, ran parallel to the Syrian-Turkish border on Turkey's side for 382 km., re-entered Syria for 81 km., and then crossed into Iraq. This situation made it necessary for agricultural products of the Jazireh in the northeastern section of Syria to cross into Turkey before reaching Aleppo, the regional center of the area.[7]

The connectivity of the road network was also disrupted by the creation of international boundaries. Unlike the railroads, however, the road movement between the Damascus region to the south and the Homs, Hama and Aleppo regions to the north was not disrupted, because the connecting trunk line remained inside the territory of

---

[7]The situation is still aggravated by the inability of Syria and Turkey to arrive at a reasonable solution of the problem.

Syria. On the other hand, the coastal and the central valley longitudinal lines were disrupted by the international boundary between Syria and Lebanon, the former between Tripoli and Al-Latiquiy- and the latter between Baalbek and Homs. In addition to this, the three important transverse lines joining Beirut to Damascus, Tripoli to Homs, and Alexandretta to Aleppo were disrupted, the first two by the boundary with Lebanon and the third by the boundary with Turkey.

Thus the second quarter of the twentieth century found independent Syria with a dissected segment of a transport network which had developed on a regional basis, creating a need for the realignment of the network this time based on national rather than regional demands.

CHAPTER IV

ROAD AND RAIL NETWORKS IN SYRIA BETWEEN 1952 AND 1962

Until now the discussion has centered around the underlying factors that are related to transportation in Syria, and the historical development of the transport network in that country. This chapter takes stock of the present day conditions of transportation in Syria by examining the growth that has taken place in the ten-year period between 1952 and 1962, growth based on the national transport demands of the country.[1]

This ten-year period is an important phase in the growth of the network in Syria when the government became aware of the important role that transport plays in economic development, thus initiating systematic planning to foster this growth.

The Road Network in 1952

In 1952 the total road network of Syria was 8,200 km., or 44 km. per 1,000 sq. km. of land. Large variations existed in the quality of the roads, and the widths of their surface and their shoulders.

---

[1] Most of the data used in this chapter were obtained from the records of the Ministries of Public Works and Transportation in Syria. Detailed footnoting will be left out to avoid continuous repetition.

The overall width of surface and shoulders varied from 6 to 8 meters, with the actual macadam or asphalt part ranging from 4 to 5 meters.

The road network was broken down into three classes depending on the location of the line and on the role that it played in the country's pattern of movement. Roads of international benefit

TABLE 7

ROAD CLASSIFICATION IN 1952

(in kilometers)

Class	Asphalt	Macadam	All-weather dirt roads	Dry season roads	Total
Roads of international benefit	1,700	290	210	800	3,000
Roads of economic benefit	600	640	350	650	2,240
Roads of local benefit	300	270	440	1,950	2,960
Total	2,600	1,200	1,000	3,400	8,200

were the Syrian segments of the main trunk lines that connected the port cities on the Mediterranean coast of Syria, Lebanon and Turkey to the major interior cities of Syria and Iraq and those lines that extended from the Turkish border in the north to the Jordanian border in the south.

The economic benefit roads were the ones that joined the major agricultural surplus regions to the major urban centers of Syria where the demand for this surplus existed. They also connected the cities with Syria's major summer and winter resorts.

Roads of local benefit were either the agricultural roads connecting the lesser important production areas to one another, or were feeder roads supplementing the other two groups of roads.

In 1953 the national budget included 1,780,000 Syrian pounds [2] for the building of new roads, and 3,350,000 Syrian pounds for maintenance (Figure 13). Of the maintenance budget 10 percent or 335,000 S.P. were spent on dirt roads and the balance of 3,015,000 S.P. on macadam and asphalt roads. This meant that the dirt roads' share of the maintenance budget was 76 S.P. per km. and that of macadam and asphalt roads was 792 S.P. per km. However, the maintenance program at this time was not very effective, as the techniques that were used were quite primitive, leading to the deterioration of the roads a short time after the work was completed. There was a serious shortage of maintanance equipment which was partially offset by the intensive use of cheap hand labor.

---

[2] About 3.6 Syrian pounds are equal to one dollar.

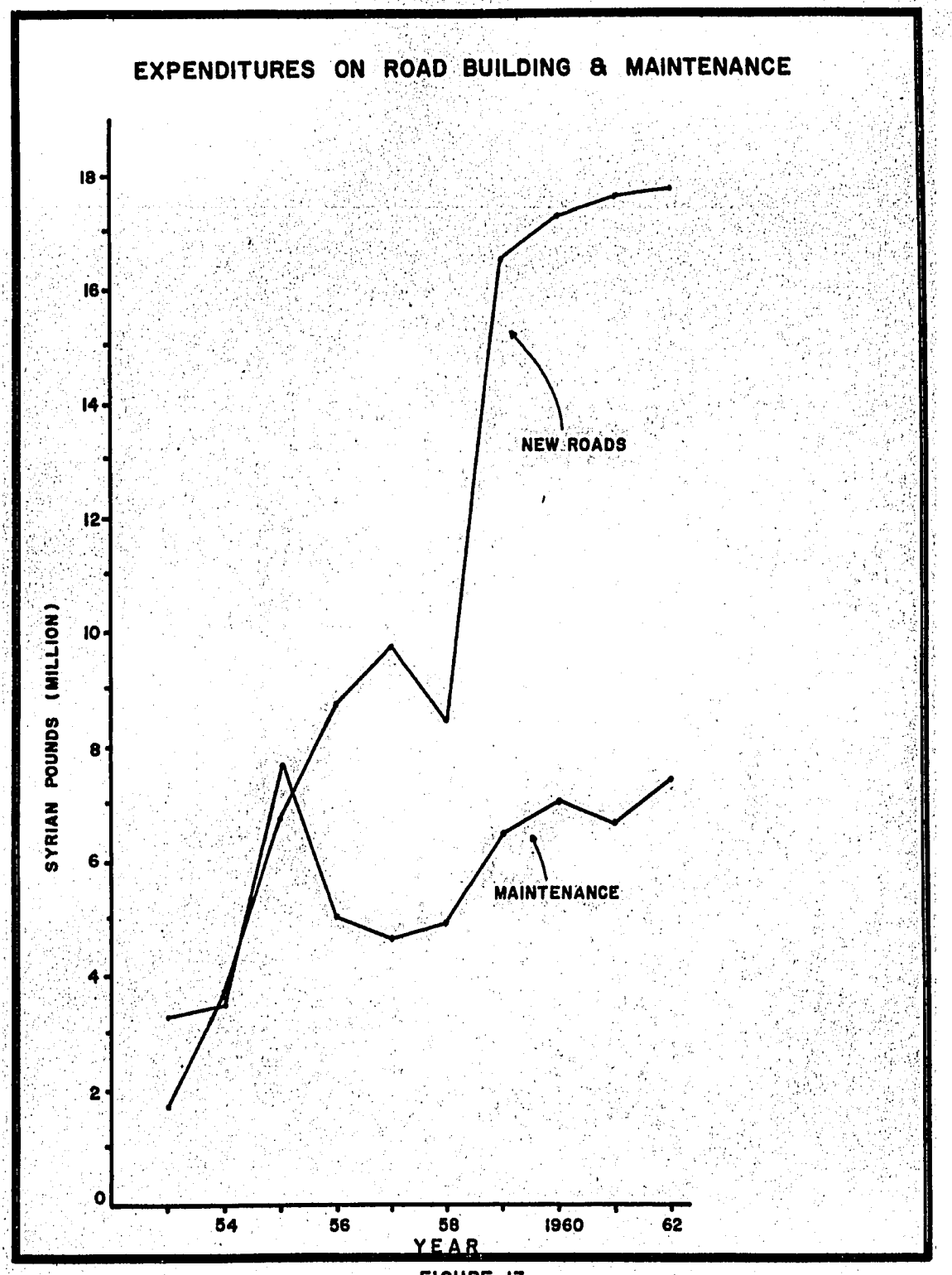

EXPENDITURES ON ROAD BUILDING & MAINTENANCE
SYRIAN POUNDS (MILLION)
0
2
4
6
8
10
12
14
16
18
NEW ROADS
MAINTENANCE
54
56
58
1960
62
YEAR

FIGURE 13

In 1955 Syrian Law #117 was the first formal move towards long range planning for building and maintaining transportation lines. A number of development schemes were outlined between 1955 and 1960, but most of them were discontinued after a year or two from the time they were begun. However, in 1960 a comprehensive Five Year Plan was put into effect and the share of the transport sector was 60 million S.P., allocated as follows:

1) Improving the network in general, 30 million.

2) Gravelling and asphalting primary roads, 20 million.

3) Building new roads, 10 million.

In 1957 the Ministry of Transport formalized the road classification of the country when it issued Syrian Law # 495, classifying the various roads into six groups. These were:

1) Wide Roads(Autostrad). Included all roads which handled a large volume of traffic flow. These were the roads that were enlarged to meet the specifications of the Geneva International Agreement of 1950, which recommended that main roads of all countries should be at least 11 meters wide with 7 meters of asphalt.

2) International Roads. Using basically the same definition as the previous classification already mentioned.

3) First Class Roads. Roads which joined the seats of the major administrative divisions (muhafazat) to one another.

4) Second Class Roads. These were the roads that linked the seats of the muhafazat to the seats of the minor administrative divisions (Qadas) and to the summer and winter resorts.

5) Third Class Roads. Roads joining the Qada seats to one another.

6) Agricultural Roads. Linking the small agricultural centers together, and to the agricultural areas themselves.

In 1959 a declaration issued by the Ministry of Public Works and Transportation assigned numbers to the international roads, and identified the existing autostrads (Figure 14).

The Road Network in 1962

By 1962 the road building and improvement program was well on its way as indicated by the overall increase in the total mileage of the network (Table 8).

TABLE 8

ROAD CLASSIFICATION IN 1962 [a]

(in kilometers)

Type	Asphalt	Macadam	All-weather (dirt surf.)	Dry weather (dirt surf.)	Total
International benefit	2,050	-	400	550	3,000
Economic benefit	1,650	650	700	3,000	6,000
Local benefit	900	350	500	3,250	5,000
Total	4,600	1,000	1,600	6,800	14,000

[a] Broken down according to the 1952 classification for the sake of comparison.

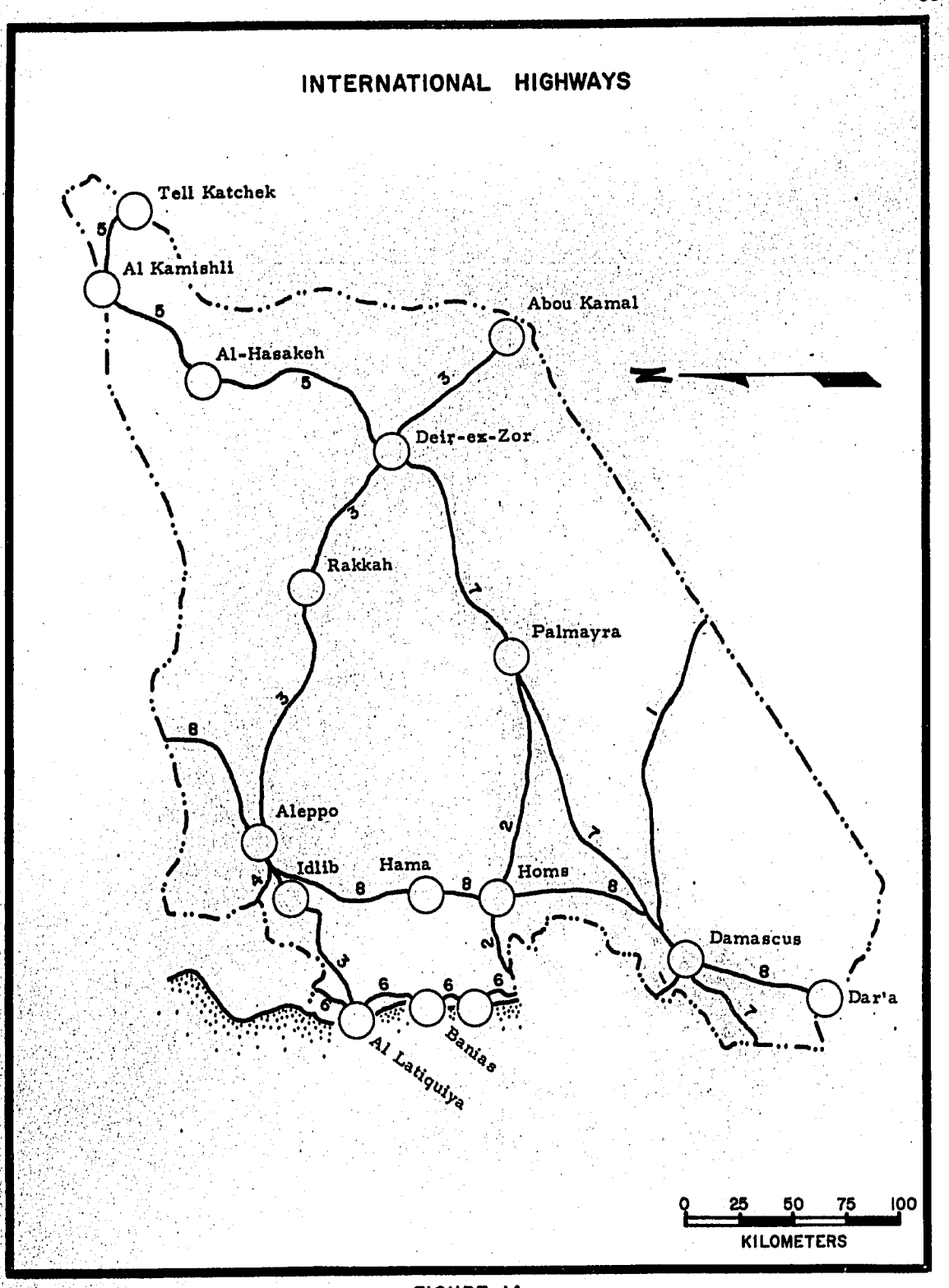

INTERNATIONAL HIGHWAYS
Tell Katchek
Al Kamishli
Abou Kamal
Al-Hasakeh
Deir-ex-Zor
Rakkah
Palmayra
Aleppo
Idlib
Hama
Homs
Damascus
Dar'a
Al Latiquiya
Banias
N
0 25 50 75 100
KILOMETERS

FIGURE 14

Comparison between Table 8 and Table 7 reveals a large increase in the total mileage of the economic benefit and the local benefit roads, and while the overall mileage of the international benefit roads did not increase, there was a marked increase in the mileage of the asphalt roads, going from 1,700 km. in 1952 to 2,050 km. in 1962. However, a glance at the dry weather (dirt roads) column indicates that this type of road was much too large, especially since 550 km. of international benefit roads and 3,000 km. of economic benefit roads were still in this group.

In 1962, 7,424,000 S.P. were appropriated for the maintenance of the highway system, of which 10 percent, or 742,000 S.P., were spent on dirt roads, and the remaining 6,681,000 S.P. were spent on the macadam and asphalt roads. This meant that 88 S.P./km. was spent on the maintenance of the former and 1,193 S.P./km. on that of the latter. This showed an increase of 15 percent in expenditures on dirt roads between 1953 and 1962, and a 50 percent increase in the expenditures on the macadam and asphalt roads during that same period.

The early 1960's witnessed a distinct improvement in road-building and maintenance techniques, and for the first time chemical laboratories were established to analyze the quality and types of soils in the areas where road building was planned, in order to determine the best types of materials that would be suitable. Between 1953 and

1962, 12,000,000 S.P. were spent on the purchasing of road-building and maintenance machinery, filling out many of the gaps that existed in the maintenance fleet prior to 1953 (Appendix C).

The asphalt used in road-building and maintenance appropriations increased from 5,000 tons per year in 1953 to 25,000 tons per year by 1962. Most of it was obtained from the Homs refinery, and only small quantities were imported.

Motor Vehicles

Even though there was a fairly strict quota controlling the importation of motor vehicles to the country, their number more than doubled between 1953 and 1962. The increase in the number of cars and trucks was very high, while the increase in the number of buses was moderate.

TABLE 9

MOTOR VEHICLES IN SYRIA (1953-62)

Type	1953	1962	Percent Increase
Cars	6,065	16,534	173
Buses	1,119	1,417	21
Trucks	4,594	11,103	142
Total	11,778	29,054	147

Bridges

In the ten-year period under discussion, a number of bridges were planned in order to improve the connections among various segments of the country. The Euphrates, which is by far the largest and longest river flowing through the country, offered the most serious obstacle to road transport. Only two bridges cross the river which flows 510 km. across Syrian territory. The northern bridge is at Rakkah, 260 km. south of the Turkish border, and the southern one is at Deir-ez-Zor, 120 km. from the Iraqi border. The two bridges are 130 km. apart.

The bridge at Rakkah was built in 1942 by the British army and was purchased by the Syrian government after the war. This bridge was built for temporary use, and in 1957 two spans were washed away. It was later restored by the government, but due to its temporary nature the Ministry of Transport decided to build a more modern and more permanent bridge. This bridge is now under construction and is at the same site as the old bridge.

The bridge at Deir-ez-Zor was built in 1929. Since it was only 2 meters wide, traffic could move in only one direction at a time and trucks with a gross weight over 12 tons could not cross over it. However, the movement of heavy trucks has greatly increased in the last decade, especially ones with 20-ton weight and over, carrying agricultural products from the Jazireh east to Aleppo and Al-Latiquiya.

In order to facilitate this movement the government decided to construct a new bridge at Deir-ez-Zor, and work on this bridge is also in progress.

A number of other bridges were constructed during the period between 1953 and 1962, and a number of older bridges were reinforced and enlarged.

Railroad Network Between 1952 and 1962

In 1952 the railway system of Syria was composed of a number of disconnected lines (see discussion on the effects of partitioning on the network), each serving the immediate area that it passed through with little regard to the network's extensions that crossed the international boundaries and resumed their way through the neighboring countries. The government policy on this matter was spelled out in an official government publication which read ". . . this is due to the fact that the parts of the international lines in Syria are considered national lines and have no relation with their complementary parts in the neighbouring countries."[3] In 1952 the railroad network was composed of three lines:

1) The northern lines, owned and operated by the government.
2) The D.H.P. lines, owned by a French company.
3) Hijaz Railway

[3] Statistical Abstract of the Syrian Arab Republic (1961).

In 1954 the Syrian government began negotiations with the French company aimed at purchasing the assets and concessions owned by the D.H.P. Final agreement was reached in 1956 and the government became the sole owner of the country's railroads.

Subsequently, two agencies were established to control and direct the railway system: (1) the Directorate General of Syrian Railroads (SRR), with its headquarters at Aleppo, was placed in control of the northern segment of the system, which was composed of all the standard gauge lines (Figure 15); (2) the Directorate of the Hijaz Railway (HRR), with headquarters at Damascus, controlled all the narrow gauge lines after the segment of the Beirut-Damascus line was added to it.

TABLE 10

RAILWAY ROLLING STOCK (1961)

	HRR	SRR	Total
Automatrice	4	4	8
Locomotive	35	41	76
Passenger vehicle	48	50	98
Cargo wagon	452	985	1,437
Fuel wagon	24	107	131
Other (wagon)	21	48	61

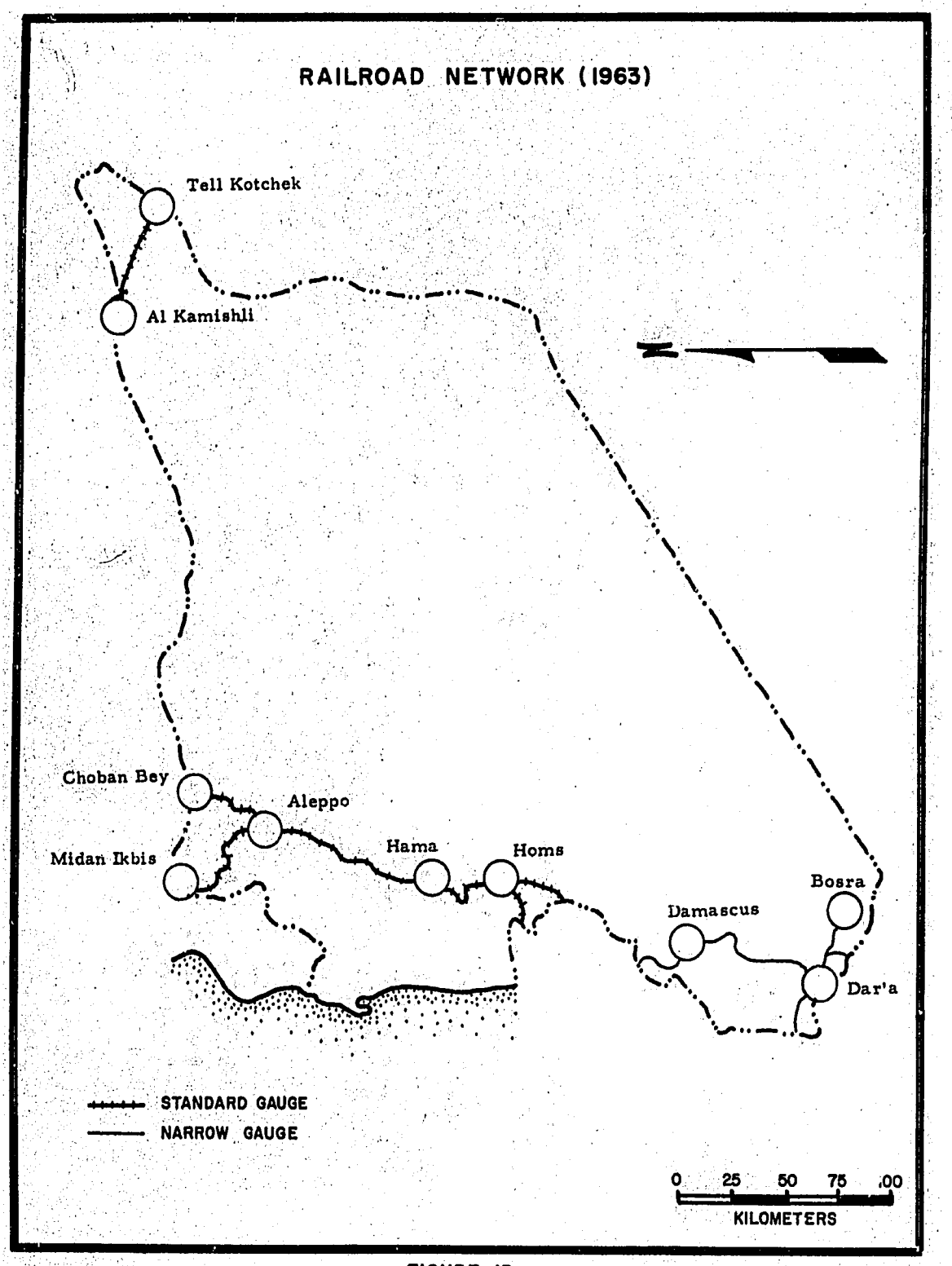

RAILROAD NETWORK (1963)
Tell Kotchek
Al Kamishli
Choban Bey
Aleppo
Midan Ikbis
Hama
Homs
Damascus
Bosra
Dar'a
STANDARD GAUGE
NARROW GAUGE
0 25 50 75 100
KILOMETERS

FIGURE 15

Road-Rail Competition

In the early 1950's the railroads of Syria witnessed a steady increase in the number of passengers , but in the middle 1950's this increase began to level off and a slight decrease followed in the subsequent years, except for the slight increase on the Syrian Railway lines during the period of 1960-61.(Figure 16). The main reason for this decrease was traced to the competition presented by the passenger car service system, which became very efficient by the middle 1950's. This efficient and inexpensive mode of travel provided regular service among the major urban centers, using passenger cars with a seating capacity of five to eight persons. Each traveler would occupy one seat, and once the car was filled to capacity it left for its destination. The efficiency, speed, and comfort which this mode of travel provided, along with a rather inexpensive fare, offered the railways strong competition for passenger service.

The movement of goods on the Syrian Railway lines witnessed a steady increase between 1952 and 1957 (Figure 17). In 1958 a sharp drop was experienced followed by a steady increase in 1959 and 1960 and a drop in 1961. The Hijaz Railway lines showed a steady increase during the period under discussion, with minor fluctuations occurring in 1958 and 1961.

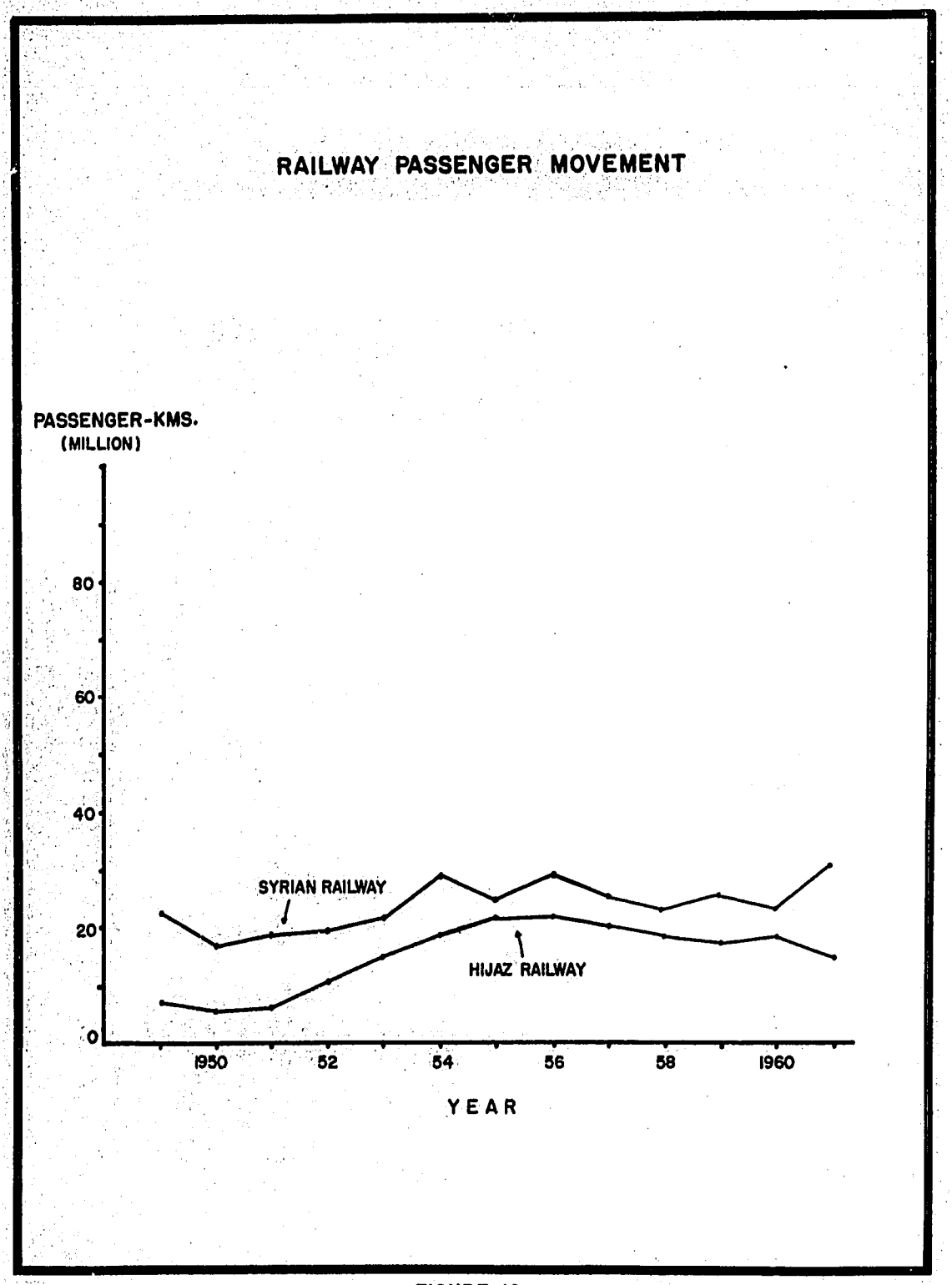

RAILWAY PASSENGER MOVEMENT
PASSENGER-KMS.
(MILLION)
80
60
40
20
0
SYRIAN RAILWAY
HIJAZ RAILWAY
1950
52
54
56
58
1960
YEAR

FIGURE 16

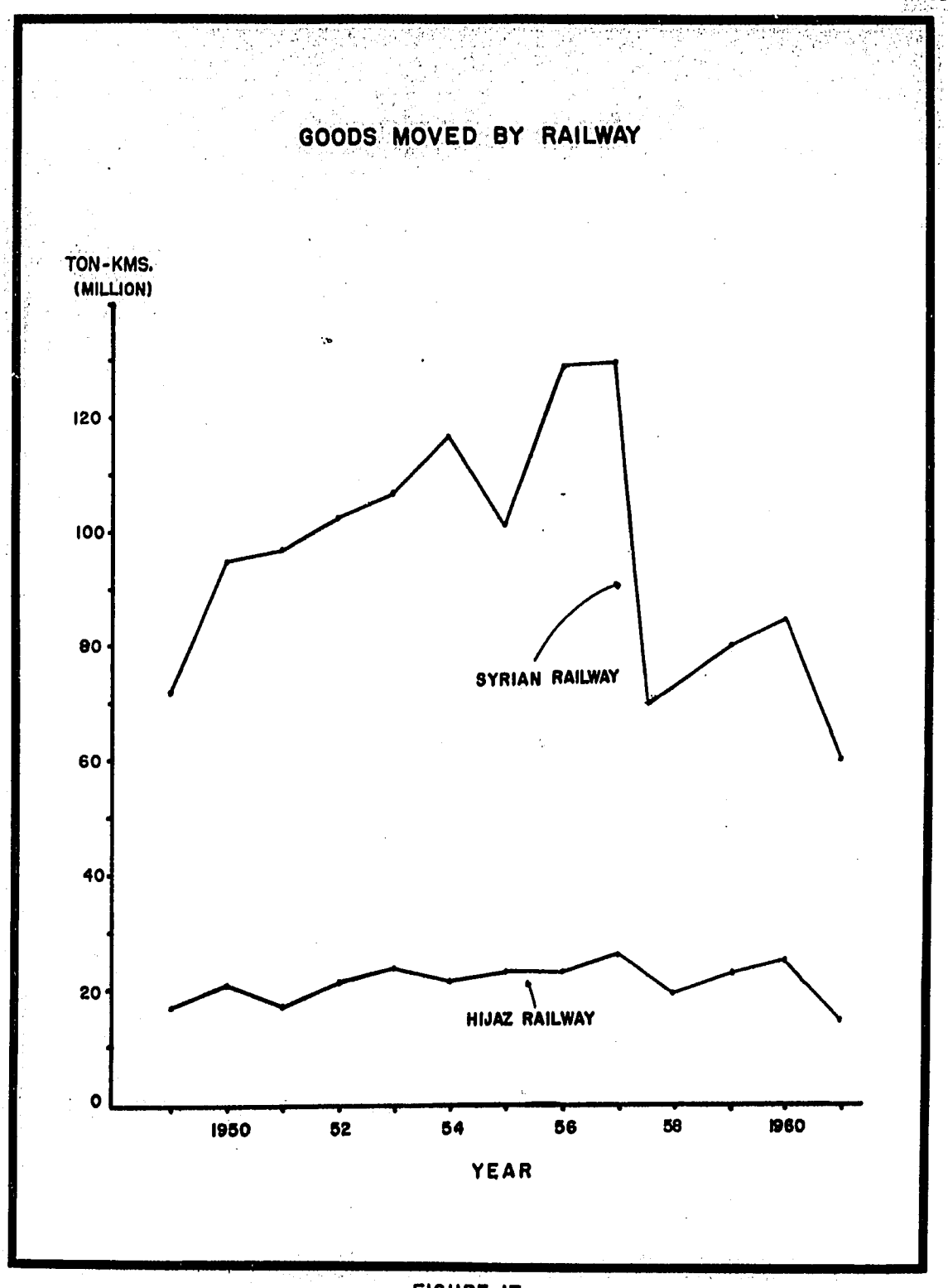

GOODS MOVED BY RAILWAY
TON-KMS.
(MILLION)
120
100
80
60
40
20
0
SYRIAN RAILWAY
HIJAZ RAILWAY
1950
52
54
56
58
1960
YEAR

FIGURE 17

The changes that occurred in the amount of goods transported by railways were influenced by three major factors:

1) Fluctuations in the amount of production, especially in the agricultural sector of the economy.

2) Amount of transit goods that moved across Syria.

3) Truck competition.

Fluctuations in Production. A large amount of the bulk goods transported by railways in Syria were agricultural products. Since most of the agricultural regions depended on rainfall for their water supply, variations of a few centimeters of rain during a given year meant the difference between a good harvest and a bad one. Even though precipitation was not the only variable related to agricultural yields, a close correlation existed between the two, with comparatively higher yields per hectare in the wetter years and comparatively lower yields during drier years. This variation in yields affected the amount of total agricultural production, which, in turn, affected the amounts transported by rail.

Transit Movement. A large amount of goods in transit that passed through Syria on the way to Iraq and Jordan was transported by rail. Most of Jordan's international trade moved through the port of Beirut, which was joined to Amman by the narrow gauge line, Beirut-Damascus-Amman. Large amounts of Jordan's imports and its most

important export, phosphate, were transported on this railway.

Goods moving between Iraq and the Mediterranean ports depended in most instances on the facilities of the rail network of Syria, as Bagdad was connected to its three major ports of entry, Beirut, Tripoli, and Alexandretta, by way of the Syrian Railways. This meant that increases or decreases in the amounts of imports and exports of Jordan and Iraq affected the amount of goods transported by the Syrian railroads. The importance of transit goods to the Syrian railroads is obvious by the fact that out of 417,995 tons handled in 1961, 304,165 tons were labeled external transport and only 113,830 tons were labeled internal transport.

Truck Competition. A large increase in the number of trucks used for the movement of goods in Syria took place in the last decade. The increase in the number of trucks from 4,594 in 1952 to 11,103 in 1962 presented the railroads with competition that is expected to increase in the coming years. Discussion with a number of merchants in Syria concerning their preference between the services of the railroads and those of the trucks revealed that preference was increasingly shifting in favor of the trucks, especially by the merchants handling Syria's main export commodities, cotton and wheat. Some of the recurring reasons given for choosing truck over rail were:

1) The railroad network was fragmented by both international boundaries and different gauges, which interrupted the flow of goods from one part of the country to another.

2) The orientation of the railway lines was not in line with the direction of the flow of goods, especially in the northern agricultural region which is served by a small segment of the existing line.

3) Although the government's policy was to direct the trade and especially the exports of the country through the port of Al-Latiquiya, there were no rail links leading to that port.

4) The railroads lacked adequate facilities required to handle the highly seasonal flow of agricultural products.

Railway Lines under Construction

Since the day Al-Latiquiya became the major port of Syria, there were visions of joining it by a railway to the rest of the country, and expecially to the agricultural northeast. However, it was not until 1956 that the first feasibility study of a railway line joining Al-Latiquiya to Al-Kamishli, passing through Aleppo, Rakkah, Deir-ez-Zor, and Al Hasakeh, was undertaken (Figure 18). In 1960, after the completion of all the technical aspects of the study, the Soviet Union agreed to provide loans and equipment to aid the Syrian government in constructing this line, which is expected to be completed in 1967. By that time the technical studies show that over one million tons of agricultural and

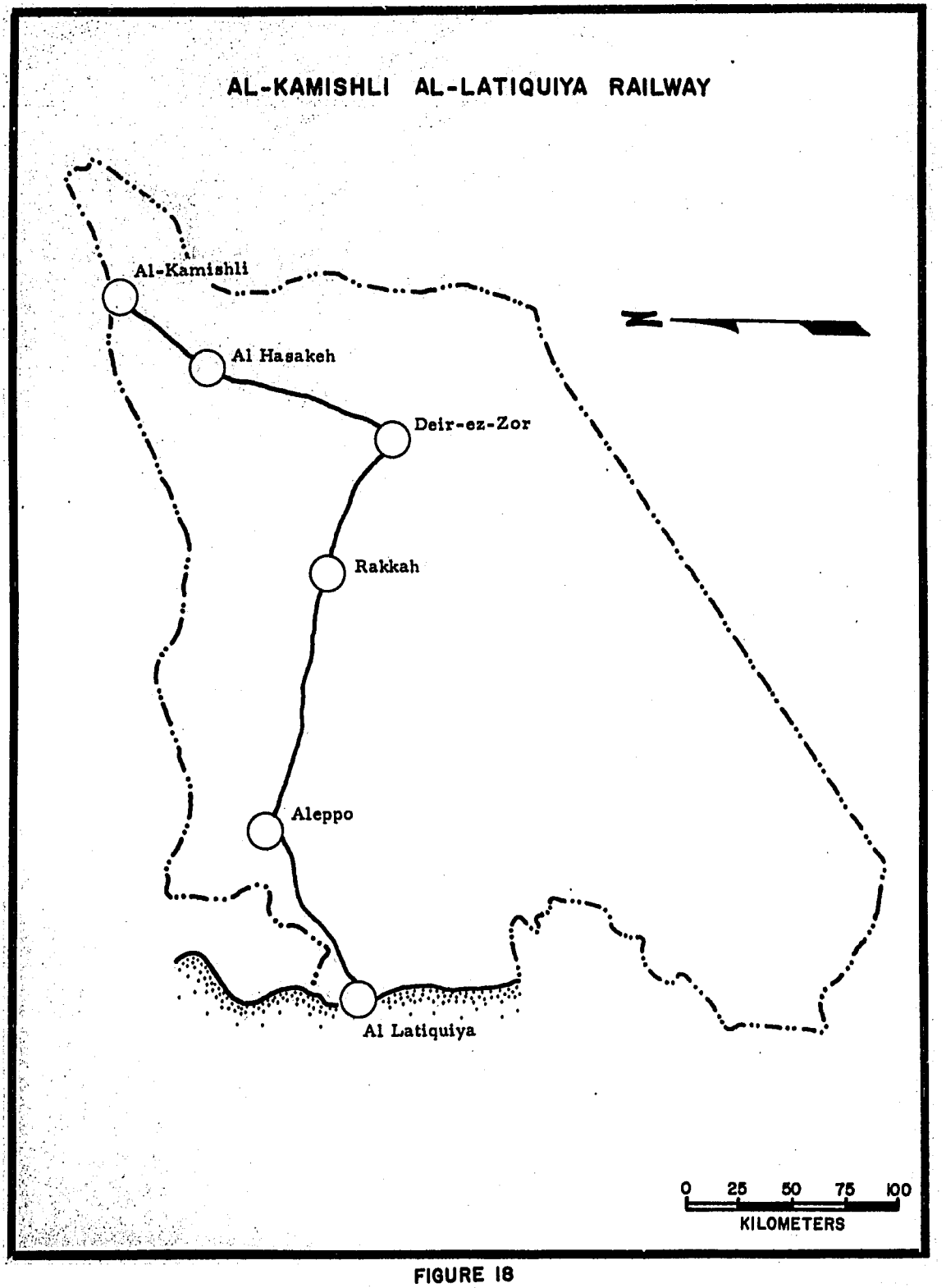

AL-KAMISHLI AL-LATIQUIYA RAILWAY
Al-Kamishli
Al Hasakeh
Deir-ez-Zor
Rakkah
Aleppo
Al Latiquiya
0 25 50 75 100
KILOMETERS

FIGURE 18

manufactured products will be moving between the two areas linked by this line, and it is expected that the railway will be able to attract a large share of this movement. This figure is expected to increase significantly once all the irrigation projects that are under construction in the north and northeast are completed.

Another line which will be constructed once the above mentioned project is completed will be one joining Homs and Damascus. This is a badly needed connection which will link the northern and southern rail systems together once again and will provide rail connections among the major urban centers and agricultural regions of the country.

The completion of these two lines is expected to increase the connectivity provided by the railway network in Syria, and will most probably bring about the growth of new rail centers which will have a comparative advantage due to their strategic location on the rail lines.

It can then be concluded that by 1962 the transport facilities in Syria were greatly improved due to the active part that the government was undertaking in planning and executing projects that improve the transport network, even though much work remained to be done. The country's trunk lines were being improved, old bridges replaced, dirt roads surfaced, and new connections constructed. The railway line joining the Jazirah to Aleppo and Al-Latiquiya, now under construction, and the proposed line joining Homs to Damascus, should increase the effectiveness of the role of rail transport in the country.

CHAPTER V

HYPOTHESES AND RELATIONSHIPS CONCERNING TRANSPORT NETWORKS

The objective of this chapter is to examine a number of theoretical notions concerning the structure of road networks and the changes in the connectivity of urban centers as the network structure evolves through time. This is done in two parts: the first part examines the structural development of a road network, and the second part considers the connectivity of the total road and rail network. The structure of the road network is examined in light of a number of variables which are considered to be related to the spatial layout of the network in a probabelistic fashion. The connectivity of the network is analyzed at different periods of development in order to evaluate the changes in the accessibility of urban centers over time.

Structure of Transport Networks

This study assumes that the shape and the extent of a network are related to a number of variables such as population and economic activity which are unevenly distributed in an area, and that this structure is a reflection of the spatial differentiation and the interaction among these variables. Due to this uneven distribution, it is expected that the network varies in complexity from place to place, the variation in

complexity following directly from the degree of intensity with which the pertinent variables appear.

For the sake of illustration, a very simple model demonstrates the point under discussion. Consider a number of scattered settlements in a certain region (Figure 19).

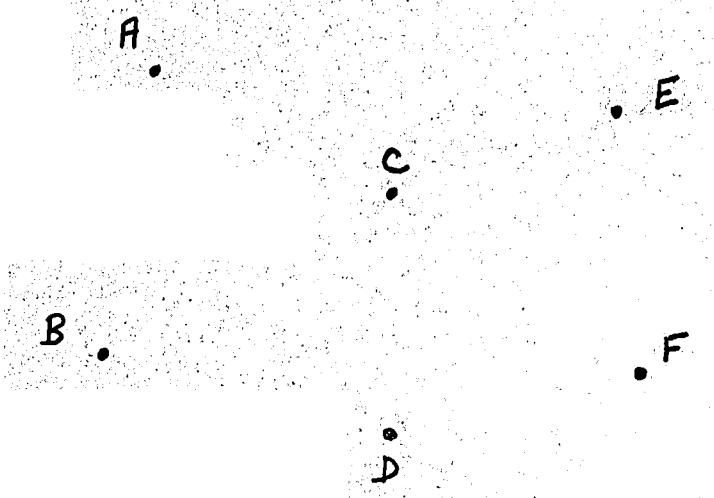


Figure 19. SCATTERED SETTLEMENTS

For a number of reasons (economic, social, political, etc.), interaction among these centers develops and movement of people and goods occurs among them. Once interaction between any two centers reaches a certain high level and achieves a consistent rate of growth, a communication line develops joining these two places (Figure 20). In a sense this is a visible impress upon the landscape of the interaction and complementarity between two places.

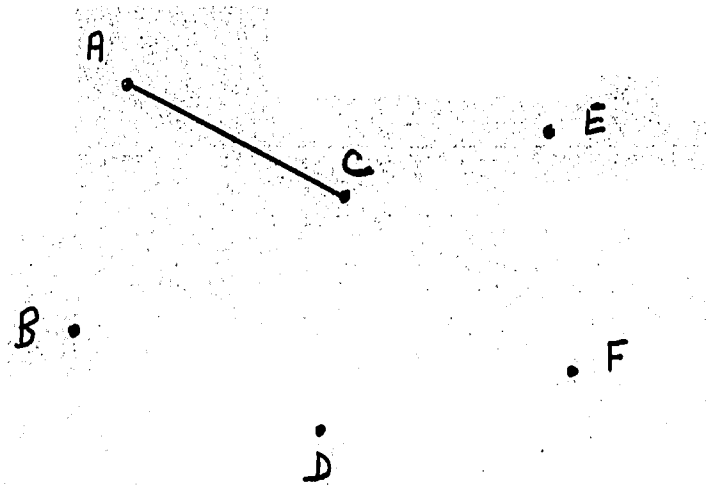


Figure 20. GROWTH OF A COMMUNICATIONS LINE

As interaction increases among the other settlements, similar routes connecting these points to one another are introduced. With still further interaction, routes continue to evolve until most, or all, the settlements become interconnected. (Figure 21).

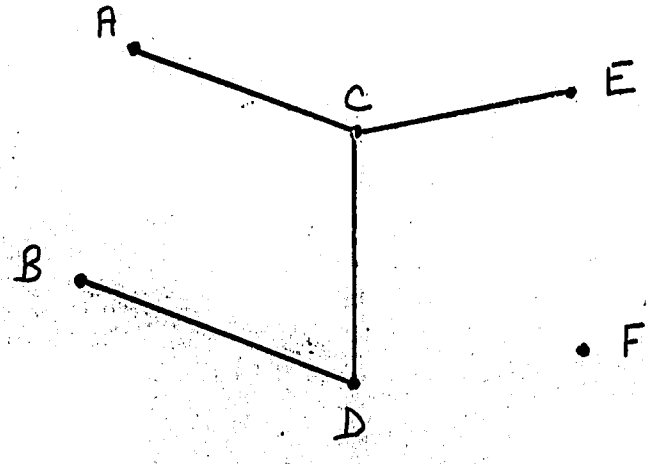


Figure 21. INTERCONNECTIONS AMONG SETTLEMENTS

Due to a number of advantages, among which is favorable location on the developing network, a number of settlements increase in size and in importance faster than the growth of centers with less favorable locations. This leads to an increase in the movement of goods and people on the connections leading to these growing centers while the movement on the connections leading to the less important centers remains the same or decreases in quantity. Improvement or expansion of the important connections is then undertaken in order to meet the demand for the increased movement along these lines (Figure 22).

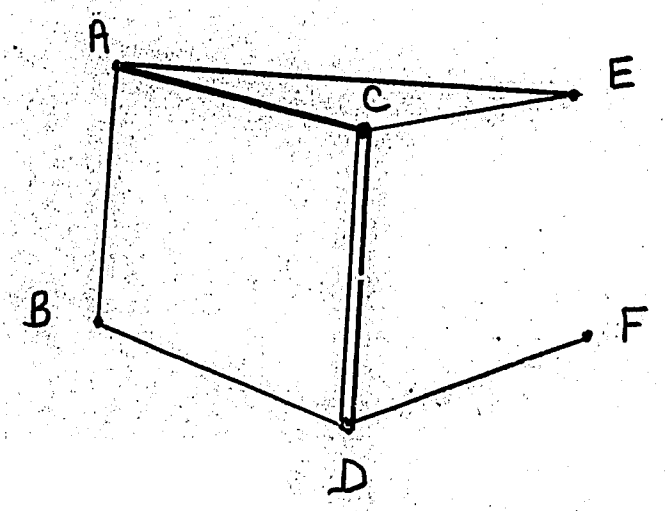


Figure 22. GROWTH OF A TRUNK LINE

In this fashion primary connections among the more important centers come into being, while secondary and tertiary connections continue to exist between the important centers and the less important ones, as well as between the smaller centers themselves.

As time goes on and innovations in modes of transportation occur, they are introduced to strengthen the connections among the important centers in which the demand for expanded and improved transport facilities is high enough to withstand the expense of the new lines.

Once an area has been inhabited continuously over a period of time, a transport network develops which may be composed of various modes of transport such as road, rail, and waterways, and within these different modes there will be a further breakdown of primary, secondary and tertiary connections. Therefore, it can be stated that the structure of the transport network within an area which has been continuously inhabited is related to a number of factors unevenly distributed in area. These variables may be divided into two groups:

1) Ones that are directly related to the complexity of the network, i.e., the complexity of the structure of the network increases with higher values of the variables.

2) Ones that are inversely related to the structure of the network, i.e., that the complexity of the network decreases with increased values of the variables.

The above statement implies that the structure of the transport network is relatively more complex in the areas where the significant variables that are directly related to the structure of the network are

found in large quantities and is relatively simple in the areas where the significant variables are found in small quantities, or where the inversely related variables are found. The variables that will be examined in this study are broken down into three main groups:

1) Distribution of population.

2) Distribution of economic activity.

3) Some physical factors.

Population Distribution. It is assumed that heavily populated areas generate a high demand for circulation within that region, as well as between that region and neighboring ones with which the region has a high degree of complementarity. This allows us to hypothesize that if we examine two areas with similar characteristics but for the size of their population, we would find a more complex network in the area with a large population than in the less populated area. In other words, all things being equal, the complexity of a transport network varies directly with the size of the population of any given region.

Economic Activity. Economic activity, like population, is unevenly distributed from place to place, with certain areas containing a high concentration of economic activity, while in other areas economic activity may be small or non-existent. Again, we assume that areas with a high degree of economic activity would develop a more complex road network than areas with less intensive economic activity and

hypothesize that the structure of the road network in a region varies directly with the intensity of economic activity within that area, other things being equal.

Physical Factors. The uneven characteristics of the physical base, the mountains, the valleys, the marshes, the plains, etc., that play an important role in location of population and economic activity have an important bearing on the structure and the development of a transport network. In certain instances the physical base offers difficult obstacles for interaction between two places which transport lines have to overcome before a link between the two points develops, while in other instances the obstacles to a connection between two places are almost negligible. One can then hypothesize that the complexity of the structure of the road network is inversely related to the degree of ruggedness of a given area, other things being equal.

Summarizing the above relationships in the form of an equation, we obtain

$$S = P + E + B$$

where S is a measure of the structure of the network, P represents the population distribution, E is a measure of economic activity, and B is an index representing the physical factors. The important point in this part of the study is the fact that now that the above relationships have been identified, they are examined and described quantitatively

and the relative value of the more important and the less important factors in the case of Syria are obtained.

Another relationship between road network structure and transport demand is based on the notion that transport demand for agriculture is different from that of industry. The reason for this variation is the fact that in an agricultural economy the activity takes place in a dispersed spatial setting, while in an industrial economy where supply and demand are highly concentrated the activity is much less dispersed than is the case with agriculture. Due to the above reasons and to the fact that agriculture is much more developed in Syria than industry is, it is hypothesized that the variation in transport demands between agriculture and industry is reflected in the structure of the network, and that this reflection shows that the relationship between network structure and agricultural production is much stronger than the relationship between network structure and industry.

A third hypothesis is based on the idea that a state of equilibrium between a country's transport supply and demand is very seldom found. In Syria, where the realignment of the network took place due to the partitioning of the region and where a big change in productivity among the agricultural regions has taken place in recent years, it is hypothesized that these recent imbalances in the transport demands of the country have caused lags in certain areas and leads in others to occur. These imbalances are measured and analyzed.

Connectivity of Transport Networks

The schematic examples that were given to illustrate the underlying notions of the structure of transport networks may be used to illustrate the fashion in which changes in the connectivity of urban centers takes place. Figure 20 represents what may be considered a poorly connected network with little difference in the degree of connectivity among the individual centers. Figure 22 represents a well-connected network, with a marked difference in the degree of connectivity among the various centers. On the assumption that a high degree of connectivity provides a high degree of accessibility, one may state that the places that have a large number of strong connections are more accessible than those that are weakly connected to the network. Each new connection that is introduced to the network has an uneven effect on the system as a whole. This effect is strong at the two points directly linked by the new connection and weak at the places that are far removed from it.

In analyzing the connectivity of the transport network in Syria, two main points are examined:

1) Total network connectivity at different stages of development.

2) Changes in connectivity of important urban centers through time.

The connectivity of the railway system and of the road network is examined separately. The railway network is examined at two important periods: (1) before the partitioning of the area, and (2) after the creation of present-day Syria as an independent state. In this fashion the dislocating effects of international boundaries on the railway network are examined, and changes in the connectivity of the whole system as well as of the individual centers are analyzed. The hypothesis is that there was a marked decrease in the connectivity of the network as a whole, and that the relative importance of certain strategic centers was decreased in relation to the other centers, while the importance of other centers increased relative to the others.

The connectivity of the road network is examined at two stages of its development. The first cross section in time is taken at the early period of the development of the present network, after the partitioning of the region. This stage represents the network as it developed while it was a part of a larger regional network unrestricted by international boundaries. The second cross section is taken at the present period. This illustrates the manner in which the network developed in order to serve the needs of Syria as an independent state, with little regard to connections beyond the country's international boundaries. In this fashion, the changes in the connectivity of the country's urban centers from the early 1920's to the present are

examined. In addition, the centers that have become highly connected in recent years, but that are still relatively small, will be identified as the places where future rapid growth may be expected as a result of the newly acquired advantageous location on the road network.

Thus other hypotheses derived from the above relationships which are tested are: 1) that there was a large increase in the total connectivity of the reoad network between 1920 and 1963; 2) that the degree of connectivity of a number of important urban places have decrease relative to the connectivity of the whole network, while other places that were poorly connected in 1920 increased in relative importance by 1963. This might be particularly true in the case of the port cities of Syria which, though relatively unimportant before the partitioning of the region, became the country's major ports after independence, handling a large portion of its international trade. The same increase in relative importance may be expected to occur at the urban places of the northeastern part of the country where Syria's recent increase in agricultural production for export has taken place.

CHAPTER VI

GRAPH THEORY MEASURES

A number of transportation geographers have utilized measures derived from graph theory,[1] a branch of combinational topography, in their studies of transportation networks. William Garrison and Duane Marble[2] devised a number of indices based on graph theoretic notions applicable to geographic investigations of the structure of transport networks. Garrison[3] in another pioneering study, applied graph theoretic measures in his analysis of the connectivity of a part of the interstate highway system. Nystuen and Dacey[4] used a number of modified graph theory measures to examine the nodal structure of regions, by weighing links with flow data purporting to measure the varying strengths of the

---

[1]For a detailed study of the uses of graph theory see Claude Berge, Theorie des graphes et ses applications (Paris: Dunod, 1958). This study has been translated to English: Theory of Graphs and Its Applications, translated by Alison Doig (London: Methuen; New York: Wiley, 1962). See also Giuseppe Avondo-Bodino, Economic Applications of the Theory of Graphs (Gordon and Beach, New York, 1962).

[2]W. L. Garrison and D. F. Marble, "The Structure of Transportation Networks," unpublished report for the U.S. Army Transportation Research Command, Transportation Center, Northwestern University (Evanston, 1961).

[3]W. L. Garrison, "Connectivity of the Interstate Highway System," Papers and Proceedings, Regional Science Association, Vol. VI (1960), 122-137.

[4]John D. Nystuen and Michael F. Dacey, "A Graph Theory Interpretation of Nodal Regions," Papers and Proceedings, Regional Science Association, Vol. VII (1961).

interaction between urban centers. Kansky[5] examined a large number of graph theory measures and analyzed the relationship between transport networks and economies, both on the regional and national scale. These studies provided a clear demonstration of the usefulness of applying graph theory measures in examining the spatial aspects of transportation networks.

In its natural form, graph theory is a body of mathematics that examines the relationship of points and linking lines. In its adaptations to transport network analysis, the points may be looked upon as the nodes of the network, and the lines as the road segments connecting the nodes. In this fashion any network under consideration is reduced in shape from its actual form (Figure 23a) to a simplified form, with its significant properties left intact (Figure 23b).

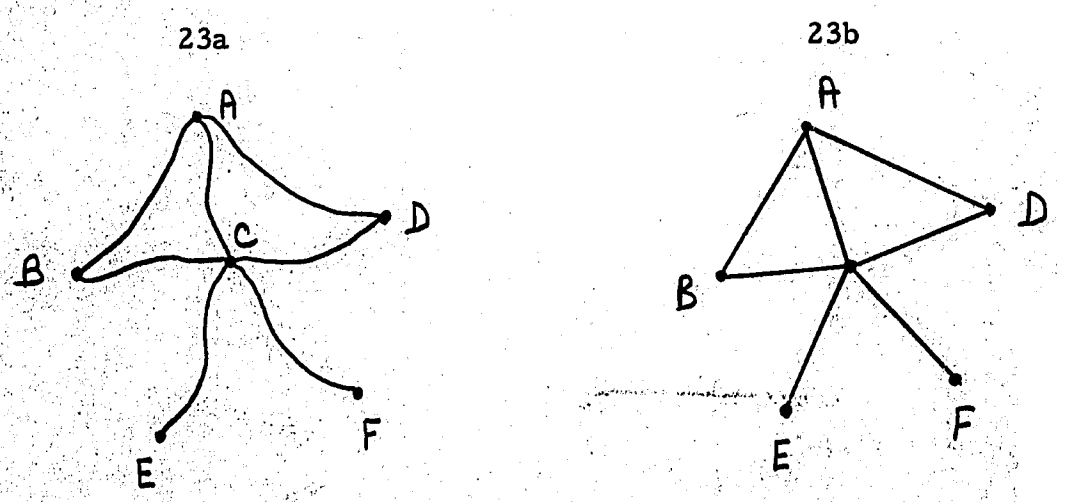


Figure 23. TRANSFORMATION OF A TRANSPORT NETWORK TO A GRAPH

[5] K. J. Kansky, Structure of Transportation Networks, Department of Geography Research Paper No. 84, University of Chicago (1963).

In the language of graph theory that has developed the network is referred to as a graph; a node in the network is referred to as a vertex; and the route between two vertices is called an edge. Thus graph theory as applied in the area of transport network analysis is a mathematical tool relating the vertices of the network to its edges. Since edges and vertices may be represented in a variety of ways, depending upon the aim of the study, they have to be defined prior to any investigation. The vertices may be representing urban centers in one study, while in another they may include any point where two lines intersect. Similarly, edges may be represented in many fashions. In one case they may be representing the road connections, while in another they may be representing distance or travel time between two points, while in still other cases they may be considered in terms of traffic flow. The graph may be directed or non-directed indicating whether there is a reflexive flow relationship between the nodes; or it may be connected or disconnected, etc.

Measures of Network Structure

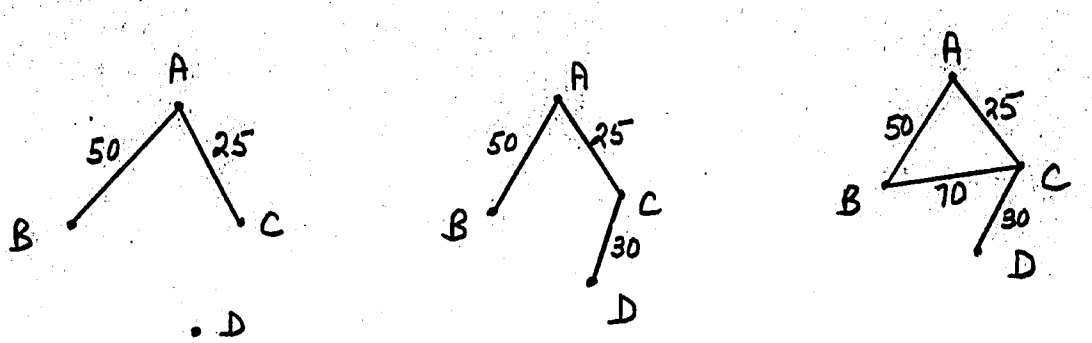
Two graph theoretic measures are used to give numerical values to the structure of the transport network of each unit of study. The first of these two indices is the theta index,[6]

$$\theta = \frac{M}{V}$$

where M represents the total miles of which the network is comprised

[6] The notations used in this section are based on that of previous geographic studies. For a discussion of various graph theory indices, see Kansky, op.cit.

and V the number of its vertices. This is an index providing information concerning the layout of the network, the mileage of the network, and the connectivity of the system. Figure 24 shows three different network structures.



M = 75	M = 105	M = 175
V = 4	V = 4	V = 4
$\theta = \frac{75}{4} = 18.75$	$\theta = 26.25$	$\theta = \frac{175}{4} = 43.75$
24a	24b	24c

Figure 24. MEASURING A NETWORK STRUCTURE

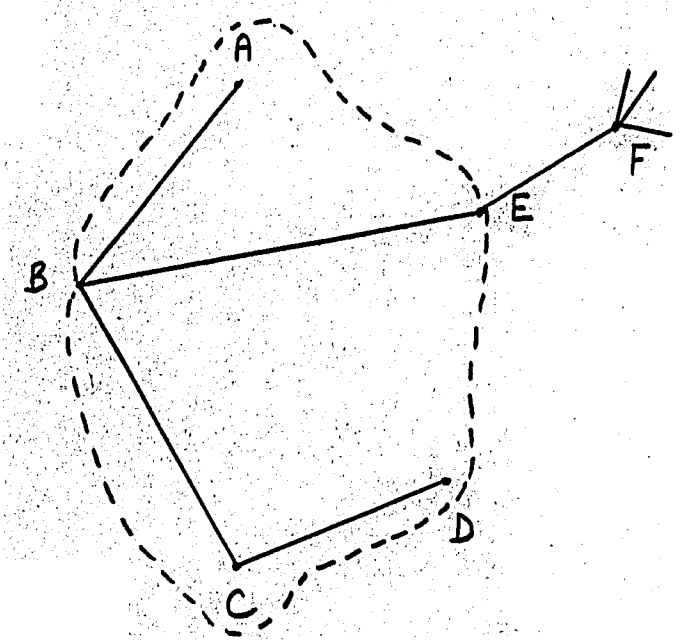
Figure 24a shows a network with four vertices and two edges totaling 75 miles, so the θ index in this case is 18.75. Figure 24b shows that an addition of a 30-mile edge to the system increased the value of θ to 26.25, and Figure 24c shows that a further addition of a 70-mile edge increased the value of θ to 43.75. This shows that different combinations of mileage and vertices yield different values of θ, with lower values

obtained for the simple and disconnected networks, and higher values obtained for the well-connected ones.

The second measure used in this study is the iota index,

$$i = \frac{M}{W + We}$$

where M is the total mileage of the network, W is the total number of vertices with weights assigned to them, and We is the number of weighted vertices in surrounding areas directly linked to the network (Figure 25).



$$M = 125$$
$$W = 9$$
$$We = 4$$
$$i = \frac{125}{9+4} = 9.6$$

Figure 25. EFFECT OF EXOGENEOUS FACTORS ON THE STRUCTURE OF A NETWORK

The effects of two factors that are believed to influence the structure of the network that were not included in determining the value of θ are taken into consideration when computing the value of i. The first of these

incorporates the idea that a connection to a first order vertex has a different effect on the system than a connection to a second or third order vertex. The second brings in explicitly the idea that the connections crossing the boundary lines from the surrounding areal units influence the structure of the network within the specific area under consideration. The weighting of the vertices is done arbitrarily with a value of 1 assigned to a first order vertex, a value of 2 assigned to a second order vertex, etc. The vertices We are similarly weighted.

As in the case of θ, higher values of i are expected for more developed networks, and lower values are expected for disconnected or for simple networks.

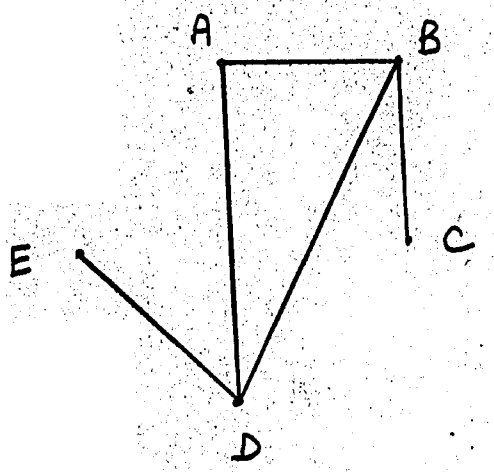
It is felt for the reasons already stated, that the i index will portray a closer picture of the relationship between the network structure and the population, economic and physical characteristics of the area than the θ index would.

Measures of Network Connectivity

Another fashion in which graph theory concepts are used in network analysis is to reduce the graph to a matrix of connectivity (Figure 26). This is done by constructing a matrix in which the vertices that are connected to one another are indicated by unit elements, while vertices that are not connected are indicated by zeros. The matrix is then powered

to the diameter of the graph, which is the minimum number of one step connections required to join the farthest pair of vertices, and the connectivity of the different vertices is then calculated by totaling the rows of the matrix, and the hierarchy of connectivity is determined.

26a

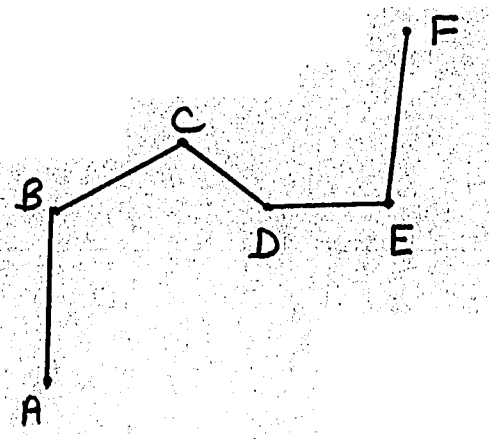


26b

	A	B	C	D	E
A	0	1	0	1	0
B	1	0	1	1	0
C	0	1	0	0	0
D	1	1	0	0	1
E	0	0	0	1	0

Figure 26. REDUCTION OF A NETWORK TO A MATRIX

This technique points up the changes in connectivity over time, by examining basic measures of the structure of the network for any desired date, past, presentor future. This is based on the fact that as new connections are added to the graph, the value of the connectivity indices changes, not only that of the two vertices concerned, but the vertices of the whole system. Consider, for example, the graph in Figure 27. It has six vertices and five edges connecting them. Figure 27b represents the connection matrix of the graph, and Figure 27c is its matrix of connectivity.



27a

	A	B	C	D	E	F
A	0	1	0	0	0	0
B	1	0	1	0	0	0
C	0	1	0	1	0	0
D	0	0	1	0	1	0
E	0	0	0	1	0	1
F	0	0	0	0	1	0

27b

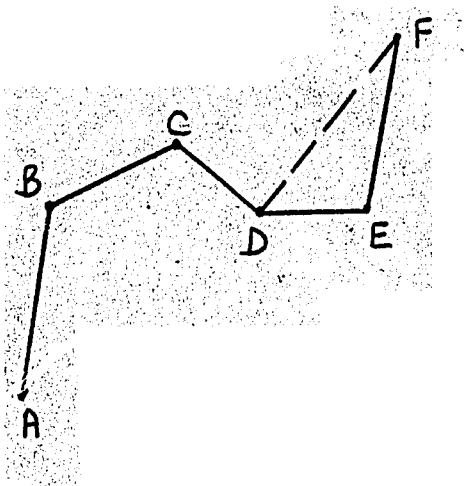
	Connectivity Matrix						Connectivity Index	Percent of Total Connectivity
A	0	5	0	4	0	1	10	9.6
B	5	0	9	0	5	0	19	18.2
C	0	9	0	10	0	4	23	21.1
D	4	0	10	0	9	0	23	22.1
E	0	5	0	9	0	5	19	18.2
F	1	0	4	0	5	0	10	9.6
						Total Connectivity	104	

27c 27d 27e

Figure 27d represents the connectivity index for each vertex and Figure 27e the percentage of total connectivity. The results show that vertices A and F have the lowest indices, with 10 and 9.6 percent of the total connectivity for each of them. This is what we would expect, as A and F have only one edge, each connecting them to the system. Although vertices B, C. D and E are connected by two edges each, B and E have an index of

19 or 18.2 percent of total connectivity, while C and D have an index of 23 and 21.1 percent of the total connectivity for each. A close examination of the graph reveals that vertex B is connected to vertex A, which has one connection, and to vertex C which has two connections, while vertex C is connected to B and D with two connections each. The same comparison holds for vertices D and E. This gives higher values for C and D, which are connected to higher order vertices than B and E are, even though the four have the same number of edges connecting them.

To demonstrate the changes in connectivity that occur within the graph when a new edge is added to it, examine Figure 27b, which is basically the same as 27a but with one edge added joining vertices D and F. Figure 27g, 27h and 27i are the connections matrix, the connectivity matrix and the connectivity index matrix respectively of the new graph. Figure 27i reveals the changes that have occurred to the connectivity of the graph by the introduction of the edge between D and F.



27f. Graph

	A	B	C	D	E	F
A	0	1	0	0	0	0
B	1	0	1	0	0	0
C	0	1	0	1	0	0
D	0	0	1	0	1	1
E	0	0	0	1	0	1
F	0	0	0	1	1	0

27g. Connection Matrix

	Connectivity Matrix						Connectivity Index	Percent of Total Connectivity
A	2	0	3	0	1	1	7	5.6
B	0	5	0	5	1	1	12	9.7
C	3	0	7	2	5	5	22	17.7
D	0	5	2	12	6	6	31	25.0
E	1	1	5	6	7	6	26	20.9
F	1	1	5	6	6	7	26	20.9
						Total Connectivity	124	
			27h				27i	27j

Figure 27. EXAMPLE OF NETWORK CONNECTIVITY ANALYSIS

The first significant fact is that the total connectivity index increased from 104 in the first case to 124 in the second case. Another result is that even though nothing new was added to A, B, C, and E, their values as well as their rank were affected the same as were those of D and F, which were directly concerned with the change.

Vertex A remains the lowest within the system, with an index of 7, 5.6 percent of the total connectivity, a decrease in relative importance from its previous position. Even though B and E had the same value before the introduction of the connection between D and F, and even though neither was directly affected as far as actual connections are concerned, E now has an index of 26, while B has an index of 12. This is due to the fact that E is now connected to a second and to a third order vertex, while B remains connected to a one and to a two order vertex. Their relative

position within the total connectivity of the graph also changed, with B going down from 18.2 to 9.7 percent while E increased from 19 to 26 percent.

The connectivity of C, which shared the highest index with D in the first case at 22.1 percent of the total connectivity, decreased in relative importance in the second case to 17.7 percent, while D became the best connected vertex with 25 percent of the total connectivity. This is due to the fact that with the introduction of the edge between D and F, D became a third order vertex connected to two vertices, E and F, both of the second order, while C remained a second order vertex connected to third and second order vertices, namely D and B. Vertex F, which shared the lowest position with A in the first example, increased from 9.6 percent to 20.9 percent of the total connectivity due to the introduction of the new edge joining it to D.

The above examples demonstrate a technique which enables the researcher to measure and describe changes in connectivity of urban centers as the transport network of an area develops through time. This is useful for two main reasons: 1) it enables the examination of present day conditions in a historical perspective, and 2) given a number of proposed new links to an existing network, this technique makes it possible to examine the future connectivity of the urban places in the area under

examination and to begin to predict possible changes based on the given changes that may result due to the change in the accessibility of these urban places.

CHAPTER VII

EMPIRICAL VERIFICATIONS

In this chapter, the hypothesized relationships concerning the structure of the road network in Syria is empirically tested. This is done by first obtaining measures for the structure of the network, to be considered as dependent variables, and measures of population distribution, economic activity, and some physical factors to be treated as independent variables. The second step is to relate in turn the dependent variables to the independent variables in order to determine the relationship that exists between them. In those cases where the relationships are significantly high, it is possible to state that the hypotheses are acceptable; while conversely, those relationships that are low refute the hypotheses as stated. Multiple regression analysis is used as a tool to measure the degree of statistical correlation between the dependent variables considered in turn and a number of independent variables considered simultaneously.

The Variables

For the purpose of this analysis, the 42 administrative divisions (Qada) of Syria were used as units since all the statistical information obtained used these units as the basis for data collection. Using the θ and i indices, two separate sets of graph theory measures were obtained

for each unit, one set representing the structure of the primary road network, and the other representing that of the road network as a whole. A total of four structural indices were computed. In addition to these dependent variables, eight independent variables that were considered to be related to the road network were obtained. These eight variables provided quantitative values for the three factors that were hypothesized to be related to road network structure:

Population factor

1) Population index

Economic factors

2) Agricultural index

3) Manufacturing index

4) Transit movement index

5) Railroad competition index

Physical factors

6) Size index

7) Shape index

8) Surface configuration index

1. Population index: This was obtained by adding up the population of each minor census unit for each of the 42 Qada.

2. Agricultural index: This was arrived at by totaling up all the tonnage of agricultural products grown within each of the Qadas.

3. Manufacturing index: Since there were no available figures of the quantities of manufactured products for each of the Qadas, the floor area of manufacturing concerns of each of the 42 units was used. This implied that the number and the size of industrial buildings in an area reflected the amount of its industrial production.

4. Transit movement index: Since there were no origin-destination studies of the movement of goods in Syria, neither on a national nor international basis, a rough index was worked out in the field by observing the major routes used by carriers handling international trade and by inquiries at major customs centers at the boundaries. Since no figures were obtainable, a qualitative variable indicating the presence or the absence of international trade crossing each of the Qadas was obtained.

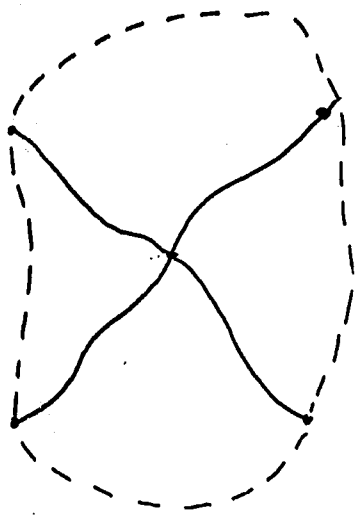
5. Railroad competition index: This was another qualitative variable where the weighting was assigned on the presence or absence of railroad lines within each Qada.

6. Size index: This was obtained by calculating the area of each of the 42 units.

7. Shape index: In graph theory there exists an idea that a measure of network structure is affected by the shape of the graph where the network is located. This idea was incorporated in this study to examine if the structure of a transport network is affected by the shape of

the area in which it is located. Based on the above statement, it is expected that the structure of the network serving a circular area (Figure 28a) would be structurally different from that of an elongated area (Figure 28b). This feeling, shared by a number of geographers[1] dealing

28a. Circular Area



28b. Elongated Area

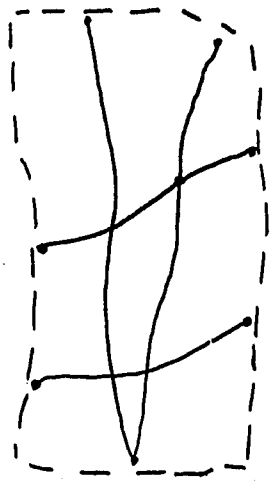


Figure 28. RELATIONSHIP OF NETWORK STRUCTURE TO THE SHAPE OF AN AREA

with similar problems, led to the calculation of an index for each of the 42 units under consideration. In essence this index was designed to indicate how close each of the Qadas were to being circular. The center of

---

[1] K. J. Kansky, Structure of Transportation Networks, Department of Geography Research Paper No. 84, University of Chicago (1963).

mass of each of the units was calculated. This was done by outlining each unit on graph paper and dividing it into squares or triangles (Figure 29).

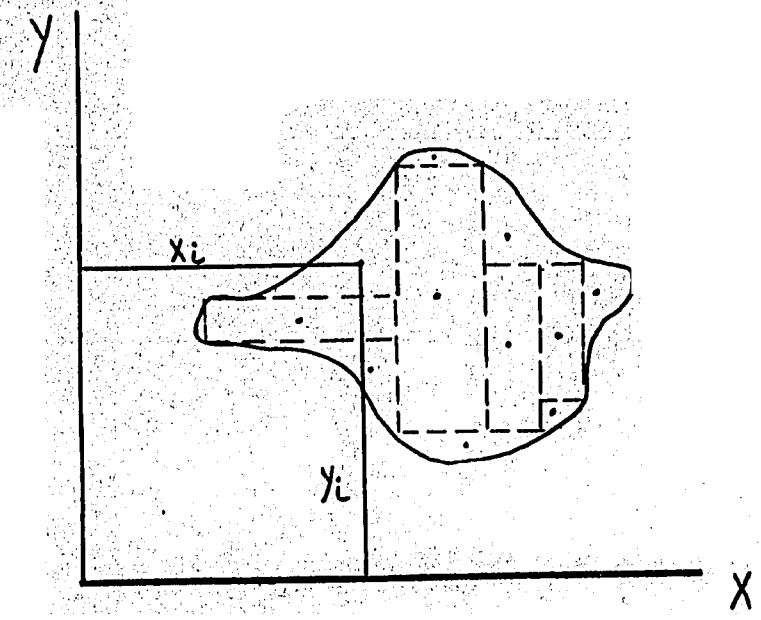


Figure 29. DETERMINING THE CENTER OF MASS

The center of mass, and the area of each of the subdivisions were calculated, and then the center of mass of the whole area was obtained. This was done by first calculating the center of mass in relation to the Y axis, using the following relationship:

$$\bar{y} = \frac{\sum a_i x_i}{A_i}$$

where $\bar{y}$ was the center of mass on the Y axis; a_i was the area of each of the subdivisions; x_i was the distance of the center of each of the small

subdivisions on the X axis; and A_i was the area of the whole unit. Similarly, the center of mass in relation to the X axis was calculated using the following relationship:

$$\bar{x} = \frac{\sum a_i y_i}{A_i}$$

where $\bar{x}$ was the center of mass on the X axis; a_i was the area of the small divisions; y_i was the distance of each center of the subdivisions on the Y axis, and A_i was the total area of the unit. The center of mass of the whole unit was then located at the intersection point of the two centers of mass on the X and Y axes. The smallest circle that contained the whole area was then drawn, using the center of mass as the center of this circle.

The area of the circle was then calculated and a ratio of the actual area of the figure under consideration to the area of the circle was obtained. The shapes that were nearly circular would then have low ratios, since the difference between their size and that of the the circle containing them was small (Figure 30), while the ratio of the long, narrow areas would be large (Figure 30b). In order to remove the effect of size, the shape index was normalized by dividing it by the total area of the unit. In this fashion, two units that had a similar shape but that were different in size would have the same index of shape.

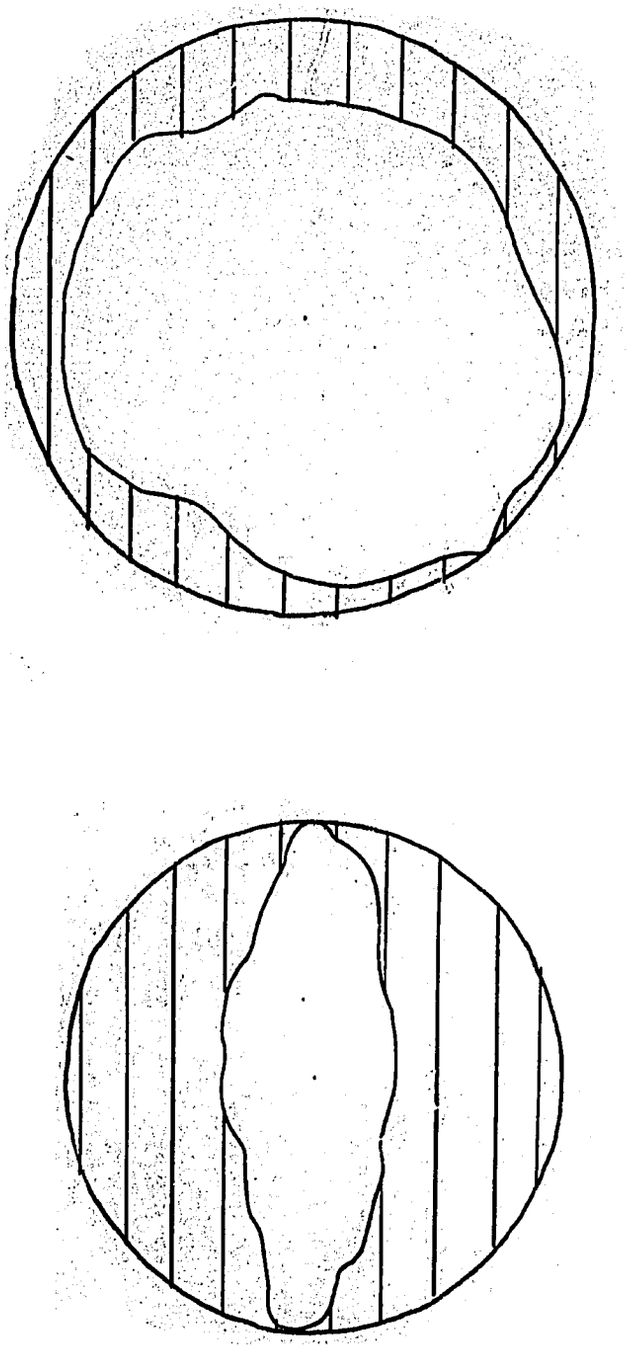


Figure 30. MEASURING THE SHAPE OF AN AREA

8. Slope: The slope index was calculated by taking three cross sections at random across each of the 42 units outlined on topographic maps of Syria with 50 meter contour intervals (Figure 31).

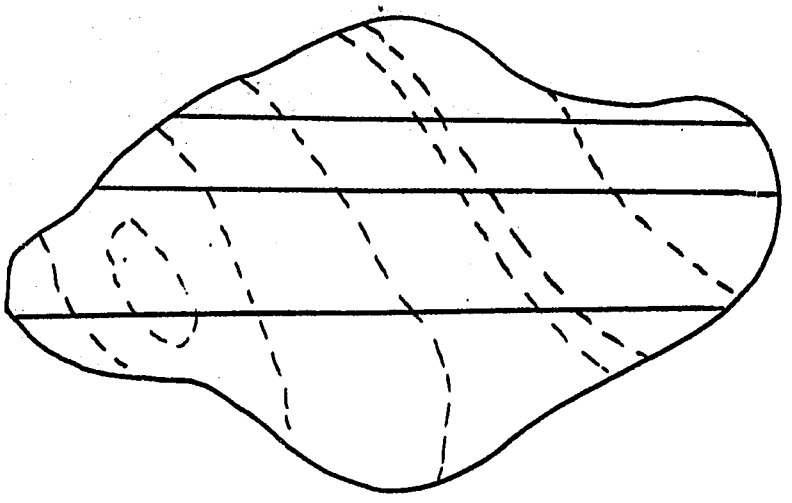


Figure 31. MEASURE OF SLOPE

The cross-sections were then measured and the number of contour lines that each of them crossed was counted. A ratio of the number of contour lines crossed to the length of the grid lines was then calculated and assigned for each of the units of study. High index values represented areas with a complex local relief, while low index values represented areas with little variation in local relief.

Regression Analysis

The 4 dependent and 8 independent variables were tested to determine if they were normally distributed so that statistical tests of

significance could be applied to the results. Since they were not, they were all transformed to common logarithms.[2] The result of the multiple regression analyses which was the relationship between each dependent variable and the independent variables, added one by one, is shown in Table 11.

For example, reading the first row from left to right it was found that 12 percent of the total variation in X_1 was statistically explained by X_5, 49 percent of the total variation was explained by X_5 and X_6, etc.; and finally 90 percent of the total variation was explained by all the 8 independent variables. The same readings can be taken for X_2, X_3, and X_4. The second step was to test the significance of the four final coefficients of multiple determination which were found to be acceptable at the 0.1 percent level of significance.[3]

Table 12 shows the variance ratios which were used to determine the significance of the increase in the explained variation that was attributed to the addition of each new variable. The values that are marked (*) are acceptable at the 5 percent level, while the ones that are marked (**) are acceptable at the 1 percent level of significance.

---

[2]Appendix A shows the 4 dependent variables (from X_1 through X_4) and the 8 independent variables (from X_5 through X_{12}) after the common logarithmic transformations were applied to the original data.

[3]The 5 percent level is usually considered significant, while the 1 percent level is considered highly significant. When a relationship is said to be significant at the 0.1 percent level, the implication is that one time out of a thousand a value of R^2 this high will be obtained, if no relationship in fact exists.

TABLE 11

CUMULATIVE MULTIPLE COEFFICIENTS OF DETERMINATION

		Population X_5	Agri-culture X_6	Manu-facturing X_7	Transit X_8	Railway X_9	Area X_{10}	Shape X_{11}	Surface Configuration X_{12}
θ Primary (X_1)	R^2	.12	.49	.56	.56	.57	.86	.86	.90
i Primary (X_2)	R^2	.01	.40	.46	.46	.47	.79	.80	.84
θ Total (X_3)	R^2	.02	.35	.37	.38	.40	.83	.83	.88
i Total (X_4)	R^2	.003	.34	.37	.38	.38	.80	.81	.88

TABLE 12

VARIANCE RATIOS

	Population X_5	Agri-culture X_6	Manu-facturing X_7	Transit X_8	Railway X_9	Area X_{10}	Shape X_{11}	Surface Configuration X_{12}
θ Primary (X_1)	2.5*	5.4**	2.5*	0.0002	0.06	8.9**	0.5	3.5**
i Primary (X_2)	1.4	4.9**	2.1*	0.6	0.9	7.4**	0.6	2.7**
θ Total (X_3)	0.8	4.6**	0.7	0.9	1.4	9.5**	0.008	3.5**
i Total (X_4)	0.8	4.5**	1.4	0.7	0.7	8.8**	0.7	4.5**

* Significant at the 5 percent level.

** Significant at the 1 percent level.

Interpretation of the Results

The first significant result obtained from the analysis is that all 4 dependent variables are highly correlated with the chosen independent variables. This indicates that there exists a high relationship between both primary and total network structure on the one hand and the 8 indicators on the other.

Contrary to earlier notions that the i measure may be more accurate than the θ measure, the second result shows that both measures θ and i are highly correlated with the independent variables. During the formulation of the problem it was felt that the i measure which took into consideration some of the effects of the surrounding areas, might be a more exact measure than the θ index. The results of the analysis do not substantiate this notion. This may very well be due to the fact that the effects of the surrounding areas on the structure of the area under study are already reflected in the network, and that when the θ measure was computed this effect was picked up by the measure.

One of the surprising results of the analysis is the fact that the correlation between the structure of the network and the distribution of population is quite low, ranging from the highest value of 12 percent to a low of 0.003 percent. Investigation of this fact, however, reveals that in Syria there is a low degree of mobility among the majority of the population and that this low demand for means of mobility on the part of

a large segment of the population has resulted in a weak relationship between road network structure and population distribution. This low degree of mobility is one of the characteristics of transportation in developing countries, as shown by Wilfred Owen in an analysis of mobility in the countries of the world. Owen's analysis shows that passenger mobility in Syria is among the lowest ten countries in the world.[4] This result, however, is contrary to the findings of Peter Gould in Ghana, where population is highly correlated with road development explaining about 50 percent of the variation in road development.[5]

The empirical verification of the variation in degree of population mobility among developing countries which is obtained from this study conducted in Syria and Gould's study conducted in Ghana, are in agreement with Owen's findings in his study of mobility throughout the world where he showed that Ghana has a higher passenger mobility index than does Syria, indicating that there exists a variation in the degree of mobility among developing countries.

Agricultural production is highly correlated with road network structure, both primary and total, reflected by the significant increase in R^2 of the four measures when the agricultural index was introduced

---

[4]Wilfred Owen, Strategy for Mobility, The Brookings Institution, (Washington, 1964), pp. 14-16.

[5]Peter R. Gould, Transportation in Ghana, Northwestern University, Studies in Geography, No. 5 (Evanston, Illinois), p. 111.

to the analysis. This indicates the strong relationship between the agricultural sector, the most important economic activity in the country, to the pattern of road network which links the areas of production to the local, national, and international markets.

The introduction of the index representing the manufacturing activity of the country provides a moderately significant increase in the case of the primary network measures, but fails to provide an acceptable increase for the total network measures. The moderate relationship between network structure and industry compared to the strong relationship between agriculture and network structure confirms the notion that Syria's agricultural production is the country's most important economic activity.

In comparing the correlation of agriculture and industry to road structure, one finds that agriculture has a high correlation to both the primary and the total road networks, while industry has a moderate correlation with the primary network but very little correlation with the total network. This brings out the difference in transport demands of an agricultural and an industrial economy. In an agricultural economy, where the agricultural activity is carried on in a dispersed spatial setting, a complex road network composed of primary, secondary and tertiary connections is required in order to efficiently produce and market agricultural products. This is in contrast to the transport demand of industry

where supply and demand are highly concentrated and are mostly dependent on an efficient primary road network, and much less dependent on secondary and tertiary road connections.

The introduction of the index representing the movement of transit goods across the country has a very small effect on the coefficient of determination, reflecting the very low correlation between movement of goods in transit and network structure. This is mainly due to the fact that most of the transit goods passing across Syria are transported by rail, and have very little relationship to the development of the road network. Another reason for the low relationship may be the fact that Syria did not take the pattern of flow of transit goods into consideration in its recent development plans.

The index representing railroad competition provides a negative value of the regression coefficient, which means that the presence of railways within a certain area is inversely related to road structure, portraying the competitive nature of roads and railroads. However, the inverse relationship is very weak and the increase in the value of R^2 after the introduction of the railroad competition index is not significant. This may be due to a number of reasons: (1) Since the railroad system in Syria is very limited in extent and is fragmented by political boundaries, its importance compared to the structure of the road network may be very small; (2) the measure of railway competition which took into account

the presence or absence of rail lines may not have been the best way in which to examine the effect of railroads.

The introduction of the area index to the analysis brought about a significant increase in the value of R^2 in all cases. This supports the fact that the size of a given area has a high relationship to the structure of the network that develops within that area.

The shape index produced a positive value of the pertinent regression coefficient showing that a circular area, which has a low index value, requires a simpler network structure than an elongated area to serve its transport demands, other things being equal. However, once again the relationship is very weak and the value of R^2 does not increase significantly with the introduction of the index of shape.

The index of slope is inversely related to the structure of the road network which means that a rugged area has a simple network while an area that is flat has a relatively more complex network. The increase in the value of R^2 after the introduction of the surface configuration index was significant reflecting the importance of the physical features of an area on the structure of its transport network.

This is contrary to the findings of Taaffe, Morrill and Gould when they examined the relationship between road network development and a hostile environment and found that ". . . the inclusion of difficult terrain in the analysis, does not add greatly to one's ability to predict

the road mileage in a given unit once population and area have been considered,"[6] However, they concluded that the reporting units used were too large to portray the effect of slope and that if smaller units were used and a refined measure of slope was introduced, the results may have been different.

Summarizing the results of the relationship of the network structure to the three major factors of population, economic activity, and physical factors (Table 13), it is evident that economic activity and the physical factors used are strongly related to network structure, while population distribution is weakly related to network structure except in the case of X_1 where there is a significant relationship.

TABLE 13

GROUPED VALUES OF THE COEFFICIENT OF DETERMINATION

	Population	Economic Activity	Physical Base
X_1	0.12*	0.45**	0.33**
X_2	0.05	0.42**	0,37**
X_3	0.02	0.38**	0.48**
X_4	0.02	0.36**	0.50**

*Acceptable at the 5 percent level of significance.
**Acceptable at the 1 percent level of significance.

[6]Edward J. Taaffe, Richard L. Morril, and Peter R. Gould, "Transport Expansion in Underdeveloped Countries: A Comparative Analysis," The Geographical Review, Vol. LIII, No. 4, 1963, p. 519.

Analysis of the Residuals from Regression

The expected values for each of the dependent variables are calculated with the use of the estimating equation and then compared to the actual values of each entry. The difference between the two represent the residuals from regression. In the cases where the expected values are less than the actual ones, the residuals are negative, while in the cases where they are larger than the actual the values of the residuals are positive. The residuals are then broken down into five groups, using the standard error of the estimate[7] as a criterion of classification and plotted on maps (Figures 32, 33, 34 and 35).

As the correlation between the dependent and the independent variables is high, ranging between 84 percent and 90 percent, it would be appropriate to say that most of the important variables that are related to the structure of the road network in Syria have been identified and incorporated into the study. Based on this assumption, the places that have low negative residual values can be identified as those areas where there is a lag in the development of the road network structure, while the areas that have high positive residuals are those where there is a lead in the development of the road network. In this analysis more attention is given to the areas where a lag exists than to the areas where a

---

[7]The standard error of the estimate indicates that one may expect the estimate value to be within one standard error of the actual value 68 per-percent of the time, within two standard errors 95 percent of the time, and three standard errors 99 percent of the time.

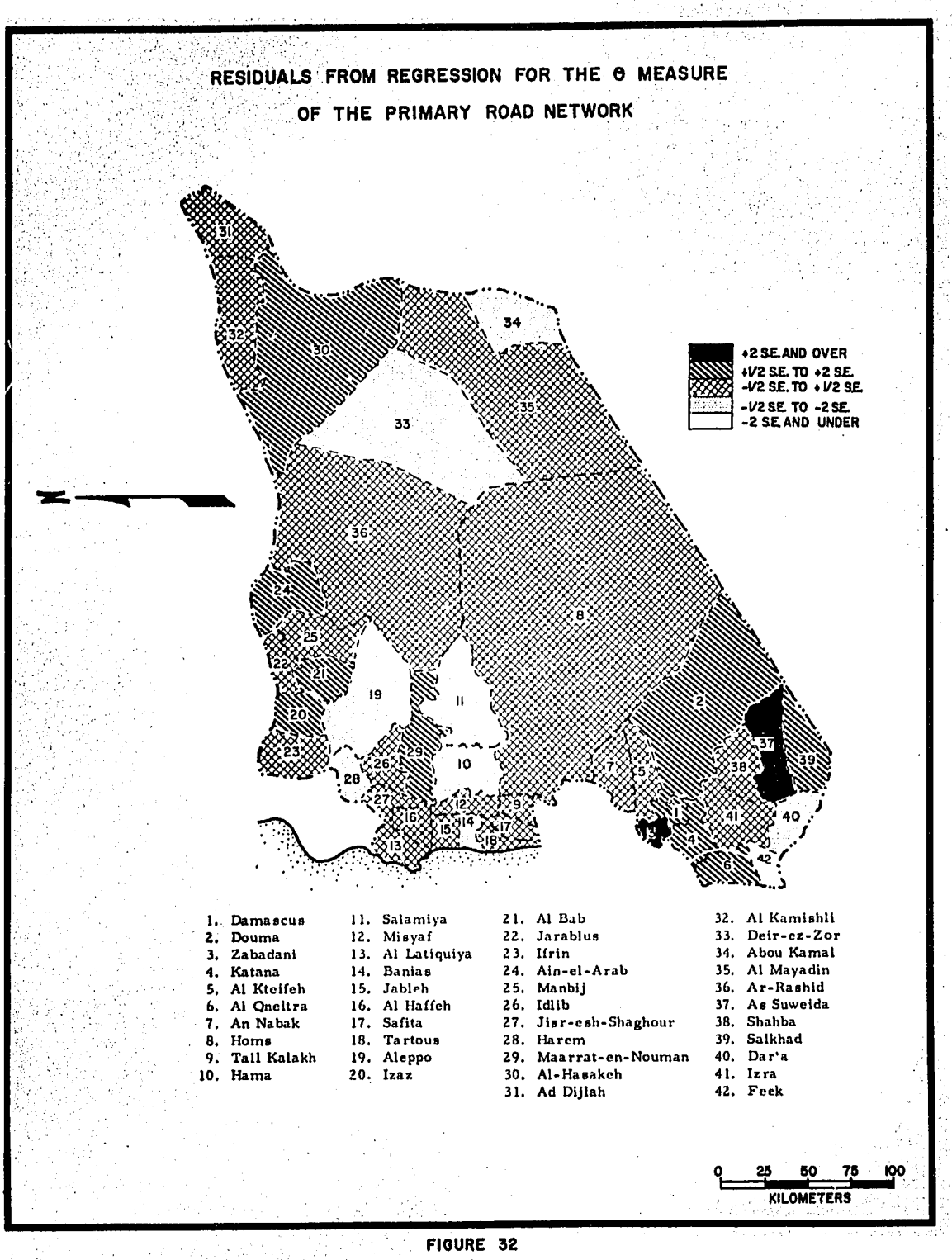

RESIDUALS FROM REGRESSION FOR THE θ MEASURE
OF THE PRIMARY ROAD NETWORK
+2 S.E. AND OVER
+1/2 S.E. TO +2 S.E.
-1/2 S.E. TO +1/2 S.E.
-1/2 S.E. TO -2 S.E.
-2 S.E. AND UNDER
1. Damascus
2. Douma
3. Zabadani
4. Katana
5. Al Kteifeh
6. Al Qneitra
7. An Nabak
8. Homs
9. Tall Kalakh
10. Hama
11. Salamiya
12. Misyaf
13. Al Latiquiya
14. Banias
15. Jableh
16. Al Haffeh
17. Safita
18. Tartous
19. Aleppo
20. Izaz
21. Al Bab
22. Jarablus
23. Ifrin
24. Ain-el-Arab
25. Manbij
26. Idlib
27. Jisr-esh-Shaghour
28. Harem
29. Maarrat-en-Nouman
30. Al-Hasakeh
31. Ad Dijlah
32. Al Kamishli
33. Deir-ez-Zor
34. Abou Kamal
35. Al Mayadin
36. Ar-Rashid
37. As Suweida
38. Shahba
39. Salkhad
40. Dar'a
41. Izra
42. Feek
0 25 50 75 100
KILOMETERS

FIGURE 32

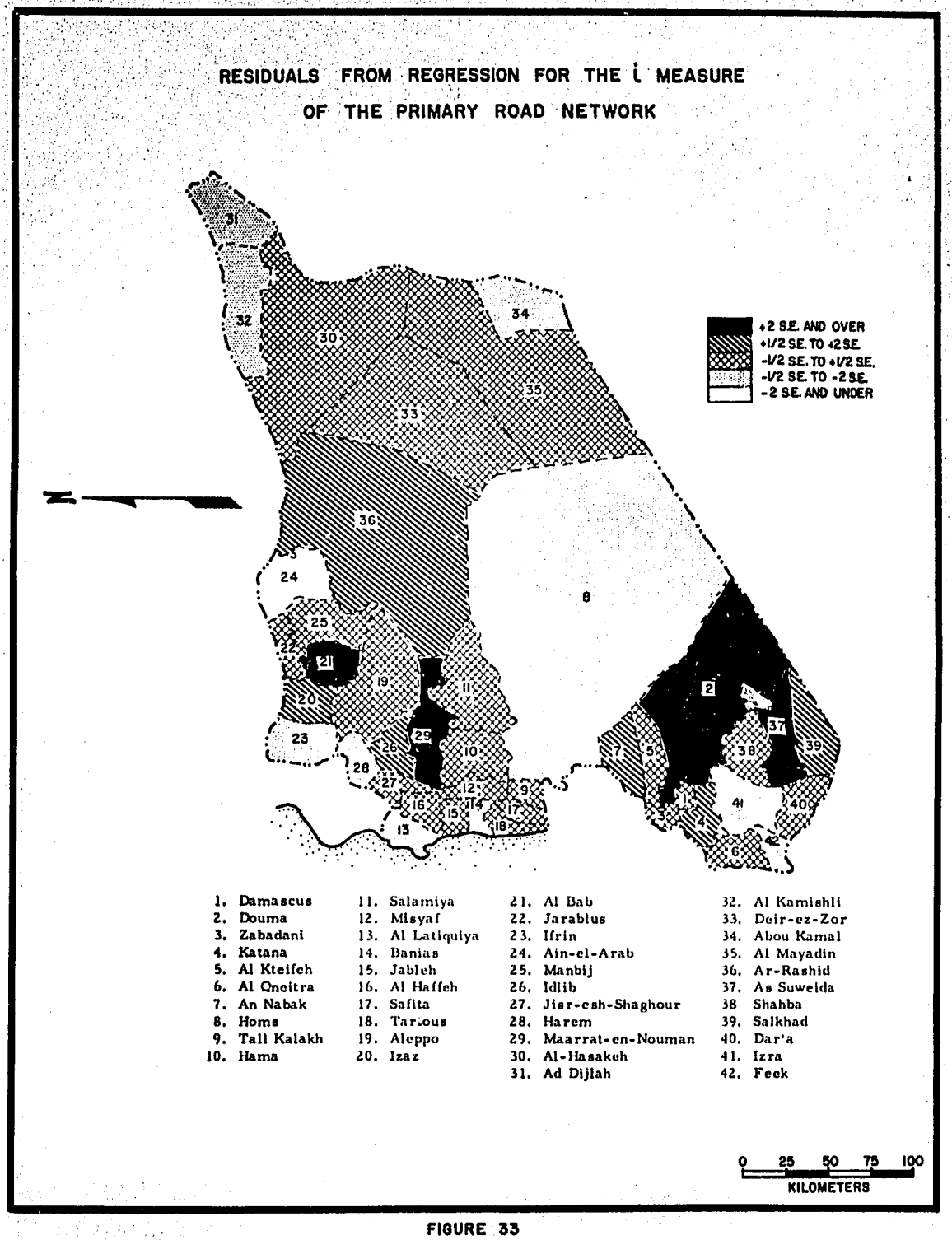
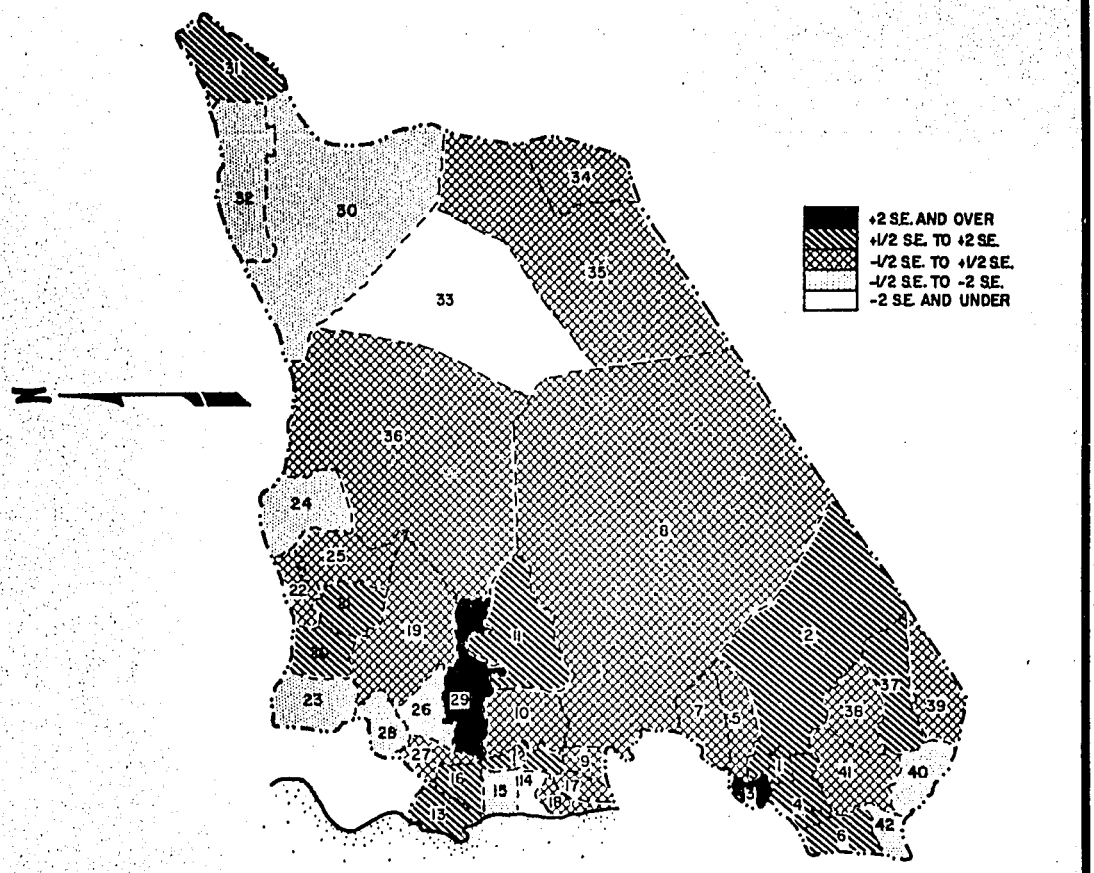

RESIDUALS FROM REGRESSION FOR THE i MEASURE
OF THE PRIMARY ROAD NETWORK
+2 S.E. AND OVER
+1/2 S.E. TO +2 S.E.
-1/2 S.E. TO +1/2 S.E.
-1/2 S.E. TO -2 S.E.
-2 S.E. AND UNDER
N
1. Damascus
2. Douma
3. Zabadani
4. Katana
5. Al Kteifeh
6. Al Oneitra
7. An Nabak
8. Homs
9. Tall Kalakh
10. Hama
11. Salamiya
12. Misyaf
13. Al Latiquiya
14. Banias
15. Jableh
16. Al Haffeh
17. Safita
18. Tartous
19. Aleppo
20. Izaz
21. Al Bab
22. Jarablus
23. Ifrin
24. Ain-el-Arab
25. Manbij
26. Idlib
27. Jisr-esh-Shaghour
28. Harem
29. Maarrat-en-Nouman
30. Al-Hasakeh
31. Ad Dijlah
32. Al Kamishli
33. Deir-ez-Zor
34. Abou Kamal
35. Al Mayadin
36. Ar-Rashid
37. As Suweida
38 Shahba
39. Salkhad
40. Dar'a
41. Izra
42. Feek
0 25 50 75 100
KILOMETERS

FIGURE 33

RESIDUALS FROM REGRESSION FOR THE θ MEASURE OF THE THE TOTAL ROAD NETWORK



1. Damascus
2. Douma
3. Zabadani
4. Katana
5. Al Kteifeh
6. Al Oneitra
7. An Nabak
8. Homs
9. Tall Kalakh
10. Hama
11. Salamiya
12. Misyaf
13. Al Latiquiya
14. Banias
15. Jableh
16. Al Haffeh
17. Safita
18. Tartous
19. Aleppo
20. Izaz
21. Al Bab
22. Jarablus
23. Ifrin
24. Ain-el-Arab
25. Manbij
26. Idlib
27. Jisr-esh-Shaghour
28. Harem
29. Maarrat-en-Nouman
30. Al-Hasakeh
31. Ad Dijlah
32. Al Kamishli
33. Deir-ez-Zor
34. Abou Kamal
35. Al Mayadin
36. Ar-Rashid
37. As Suweida
38. Shahba
39. Salkhad
40. Dar'a
41. Izra
42. Feek

0 25 50 75 100
KILOMETERS

FIGURE 34

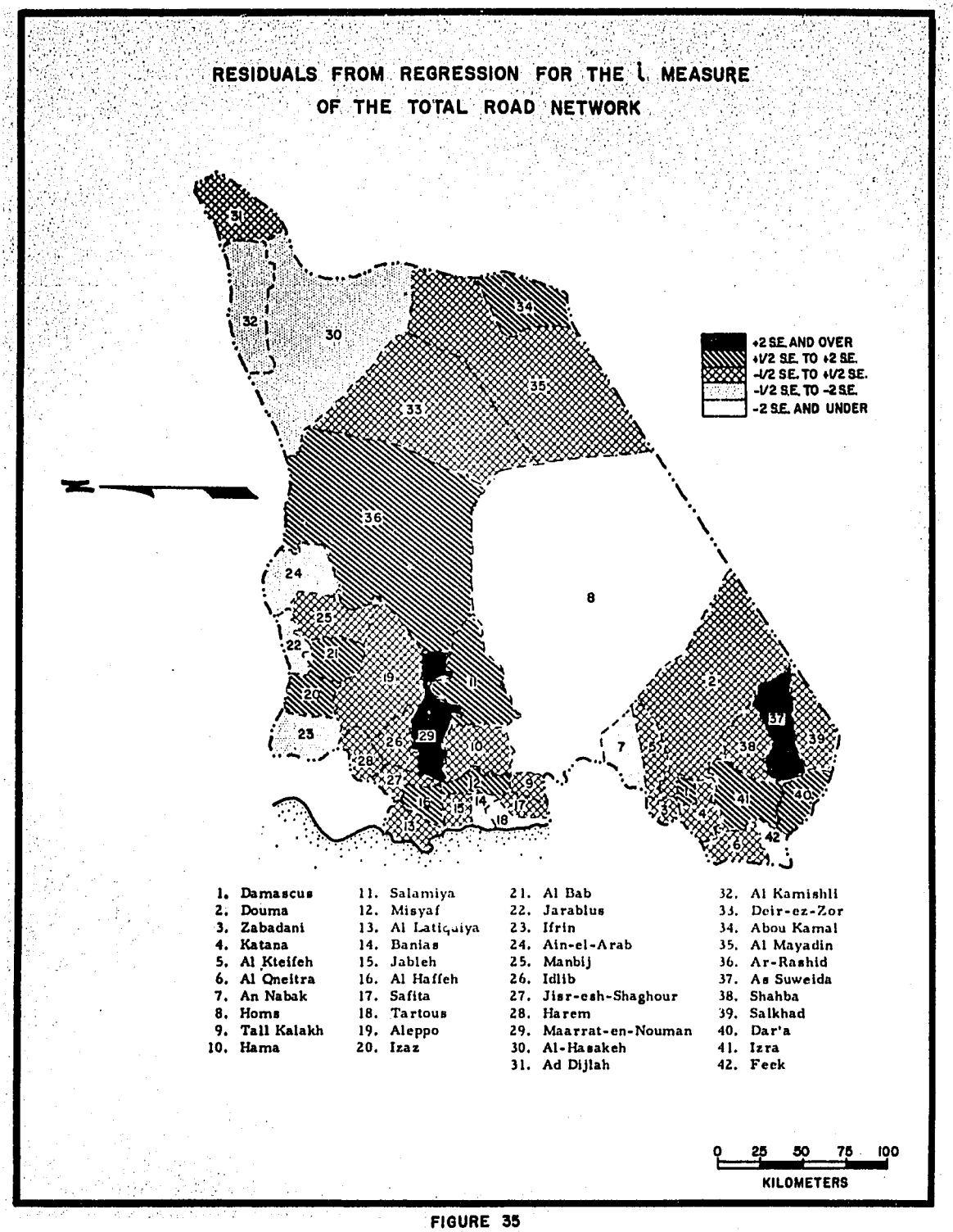

RESIDUALS FROM REGRESSION FOR THE l MEASURE
OF THE TOTAL ROAD NETWORK
+2 S.E. AND OVER
+1/2 S.E. TO +2 S.E.
-1/2 S.E. TO +1/2 S.E.
-1/2 S.E. TO -2 S.E.
-2 S.E. AND UNDER
1. Damascus
2. Douma
3. Zabadani
4. Katana
5. Al Kteifeh
6. Al Qneitra
7. An Nabak
8. Homs
9. Tall Kalakh
10. Hama
11. Salamiya
12. Misyaf
13. Al Latiquiya
14. Banias
15. Jableh
16. Al Haffeh
17. Safita
18. Tartous
19. Aleppo
20. Izaz
21. Al Bab
22. Jarablus
23. Ifrin
24. Ain-el-Arab
25. Manbij
26. Idlib
27. Jisr-esh-Shaghour
28. Harem
29. Maarrat-en-Nouman
30. Al-Hasakeh
31. Ad Dijlah
32. Al Kamishli
33. Deir-ez-Zor
34. Abou Kamal
35. Al Mayadin
36. Ar-Rashid
37. As Suweida
38. Shahba
39. Salkhad
40. Dar'a
41. Izra
42. Feek
0 25 50 75 100
KILOMETERS

FIGURE 35

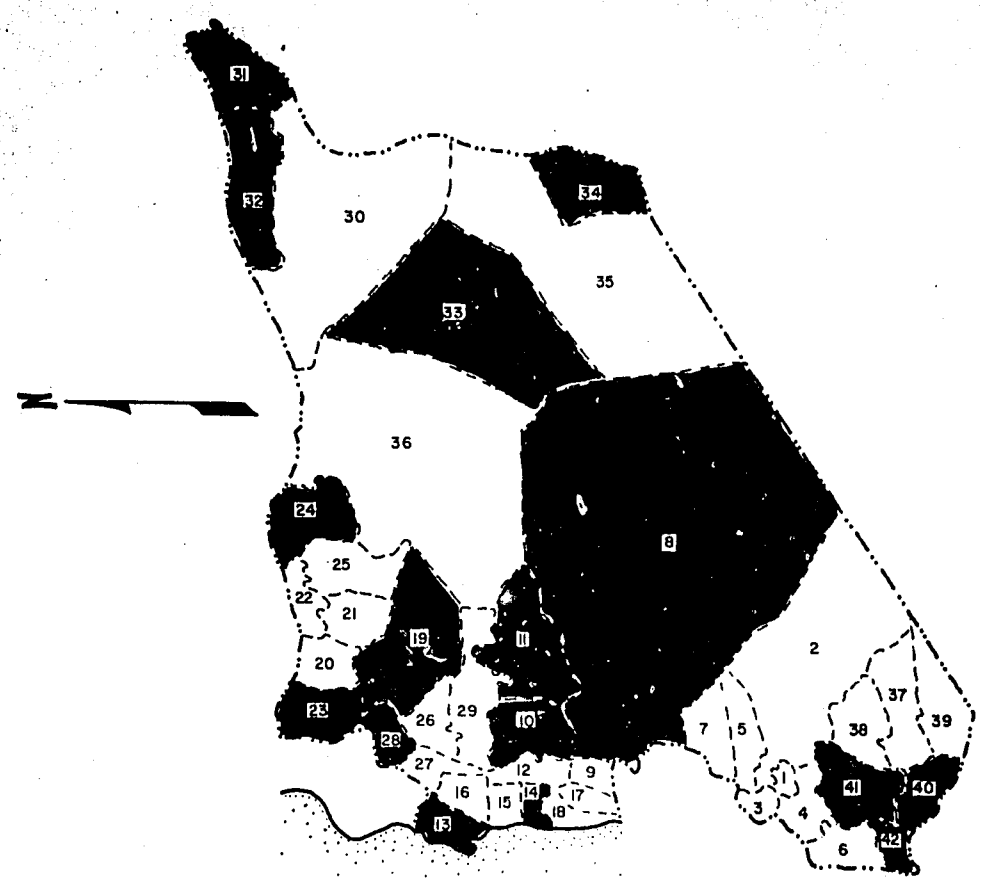
lead exists since the lag areas are the places where improvements in the structure of the network ought to be undertaken to meet the transport demands of the country.

The multiple regression analysis reveals that the results for the θ and i are very similar (but not identical) to one another so that they may be looked upon as simply complementing or supplementing each other. Under this assumption, the areas of low negative residuals from Figures 32 and 33 are grouped together and plotted on a new map (Figure 36), which points up those parts of Syria that have a primary network structure of a lesser than expected magnitude, based on the underlying assumptions of this study.

It is clear that certain import districts are included in this group such as the Al-Latiquiya area which contains the main port in Syria. Other areas in this group are Aleppo, Hama, and Homs, regions which are among the country's most densely populated areas and most productive agricultural regions. Still other areas are the newly developed agricultural areas of the northeast.

Figures 34 and 35 represent the residuals from regression for the whole road network. Figure 37 represents the areas from both of the above mentioned maps that have low negative residual values for the total network, and that may be considered as having less than expected structural indices based on the already discussed underlying assumptions.

GROUPED NEGATIVE RESIDUALS FOR THE PRIMARY ROAD NETWORK

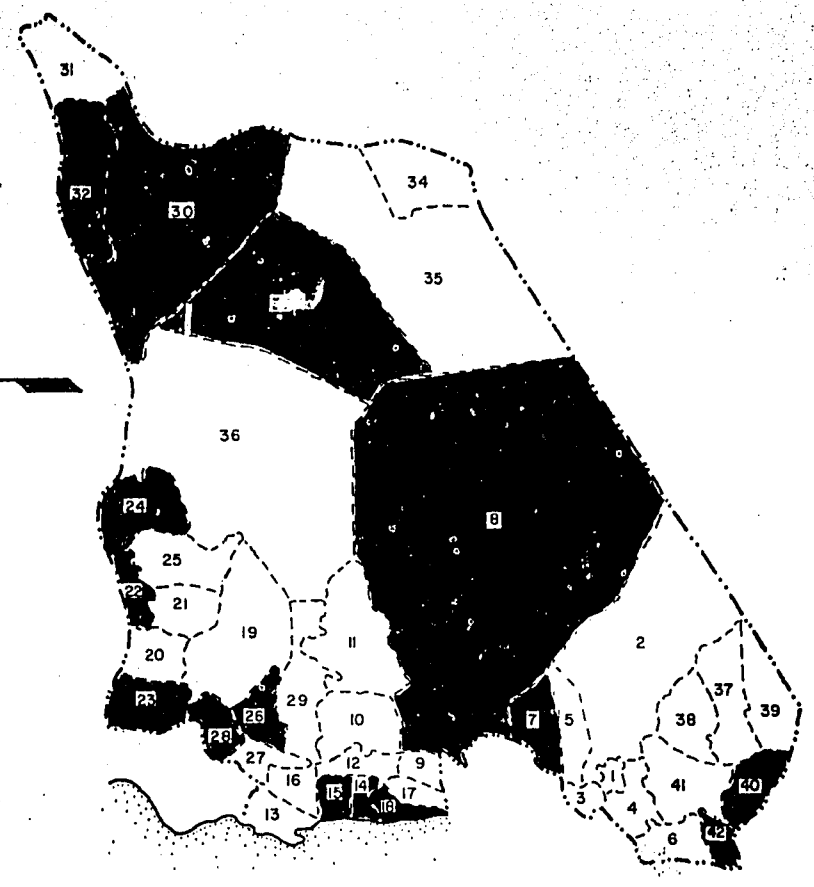


1. Damascus
2. Douma
3. Zabadani
4. Katana
5. Al Kteifeh
6. Al Qneitra
7. An Nabak
8. Homs
9. Tall Kalakh
10. Hama
11. Salamiya
12. Misyaf
13. Al Latiquiya
14. Banias
15. Jableh
16. Al Haffeh
17. Safita
18. Tartous
19. Aleppo
20. Izaz
21. Al Bab
22. Jarablus
23. Ifrin
24. Ain-el-Arab
25. Manbij
26. Idlib
27. Jisr-esh-Shaghour
28. Harem
29. Maarrat-en-Nouman
30. Al-Hasakeh
31. Ad Dijlah
32. Al Kamishli
33. Deir-ez-Zor
34. Abou Kamal
35. Al Mayadin
36. Ar-Rashid
37. As Suweida
38. Shahba
39. Salkhad
40. Dar'a
41. Izra
42. Feek

0 25 50 75 100
KILOMETERS

FIGURE 36

GROUPED NEGATIVE RESIDUALS FOR THE TOTAL ROAD NETWORK



1. Damascus
2. Douma
3. Zabadani
4. Katana
5. Al Kteifeh
6. Al Qneitra
7. An Nabak
8. Homs
9. Tall Kalakh
10. Hama
11. Salamiya
12. Misyaf
13. Al Latiquiya
14. Banias
15. Jableh
16. Al Haffeh
17. Safita
18. Tartous
19. Aleppo
20. Izaz
21. Al Bab
22. Jarablus
23. Ifrin
24. Ain-el-Arab
25. Manbij
26. Idlib
27. Jisr-esh-Shaghour
28. Harem
29. Maarrat-er-Nouman
30. Al-Hasakeh
31. Ad Dijlah
32. Al Kamishli
33. Deir-ez-Zor
34. Abou Kamal
35. Al Mayadin
36. Ar-Rashid
37. As Suweida
38. Shahba
39. Salkhad
40. Dar'a
41. Izra
42. Feek

0 25 50 75 100
KILOMETERS

FIGURE 37

Most of the areas that appeared in Figure 36 are also included in Figure 37. This points to the fact that most of the same areas have both a lag in the structural development of their primary road and total road networks. However, certain places that are included in Figure 37 do not appear in Figure 36, indicating that while no lag in the development of their primary network exists, there is a deficiency in the structural development of their secondary and tertiary connections.

Results of this section of the study indicate that, based on the underlying assumptions that are hypothesized, tested and validated, the areas shown in Figures 36 and 37 represent the places where the structure of the road network is less than expected. This suggests that in order to enable the network to meet its demands, improvements in the structure of the road networks in these areas should be undertaken.

CHAPTER VIII

CONNECTIVITY OF THE TRANSPORT NETWORK OF SYRIA

Analysis of the connectivity of the transport network of Syria and changes in the accessibility of urban places through time is conducted in two parts:

1) Connectivity of the railroad network.

2) Connectivity of the road network.

Connectivity of the Railroad Network

As it has been pointed out previously, the railway network in Syria developed along a regional basis prior to World War I, without any political boundaries to limit or block its growth. After the war the region under discussion was partitioned and the present day state of Syria was created. Analysis of the connectivity of the railway network is applied to the system as it originally developed, and the original important rail centers are identified. The second phase of the analysis examines the condition of the network after the introduction of political boundaries to the area and the effects of this fragmentation on the individual centers. The third step analyzes the connectivity of the railway network of 1970, including the lines planned and under construction.

The first step in the analysis was to construct a matrix of connectivity representing the railway network during its maximum extent (Table 14).[1]

TABLE 14

MATRIX OF CONNECTIVITY FOR THE EARLY STAGE OF THE RAILROAD NETWORK *

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1		1															
2	1		1														
3		1		1				1									
4			1		1												
5				1		1											
6					1		1										
7						1											
8			1						1								
9								1		1	1						
10									1								
11									1			1	1				
12											1						
13											1			1			
14													1		1	1	1
15														1			
16														1			
17														1			

* The examined centers are identified in the next table.

[1] This was done according to the discussion in the second section of the part which outlined the uses of graph theory measures in geographic research.

This matrix of connectivity was then solved and percentage values for the relative connectivity of the major urban centers was obtained (Table 15). The values were divided into quintiles and plotted on a map (Figure 38). Analysis of this map showed that Homs, Damascus, and Riyak had the highest indices of connectivity making them the most accessible urban centers to the network as a whole. These were followed by Dar'a, the main rail center in the south, and Hama and Aleppo, the important rail centers of the north. The rest of the connections on the periphery of the network had low indices of connectivity indicating their relative isolation from the overall network.

TABLE 15

CONNECTIVITY VALUES OF THE MAJOR REGIONAL RAIL CENTERS

City	Percent of total connectivity
1. Islahiyeh	2.08
2. Midan Ikbis	4.78
3. Aleppo	8.27
4. Choban Bey	5.36
5. Nusaybin	3.25
6. Al-Kamishli	2.01
7. Tell Kotchek	0.90
8. Hama	8.31
9. Homs	11.22
10. Tripoli	4.52
11. Riyak	10.04
12. Beirut	5.21
13. Damascus	10.33
14. Dar'a	8.40
15. Haifa	5.11
16. Mafrak	5.11
17. Bosra	5.11

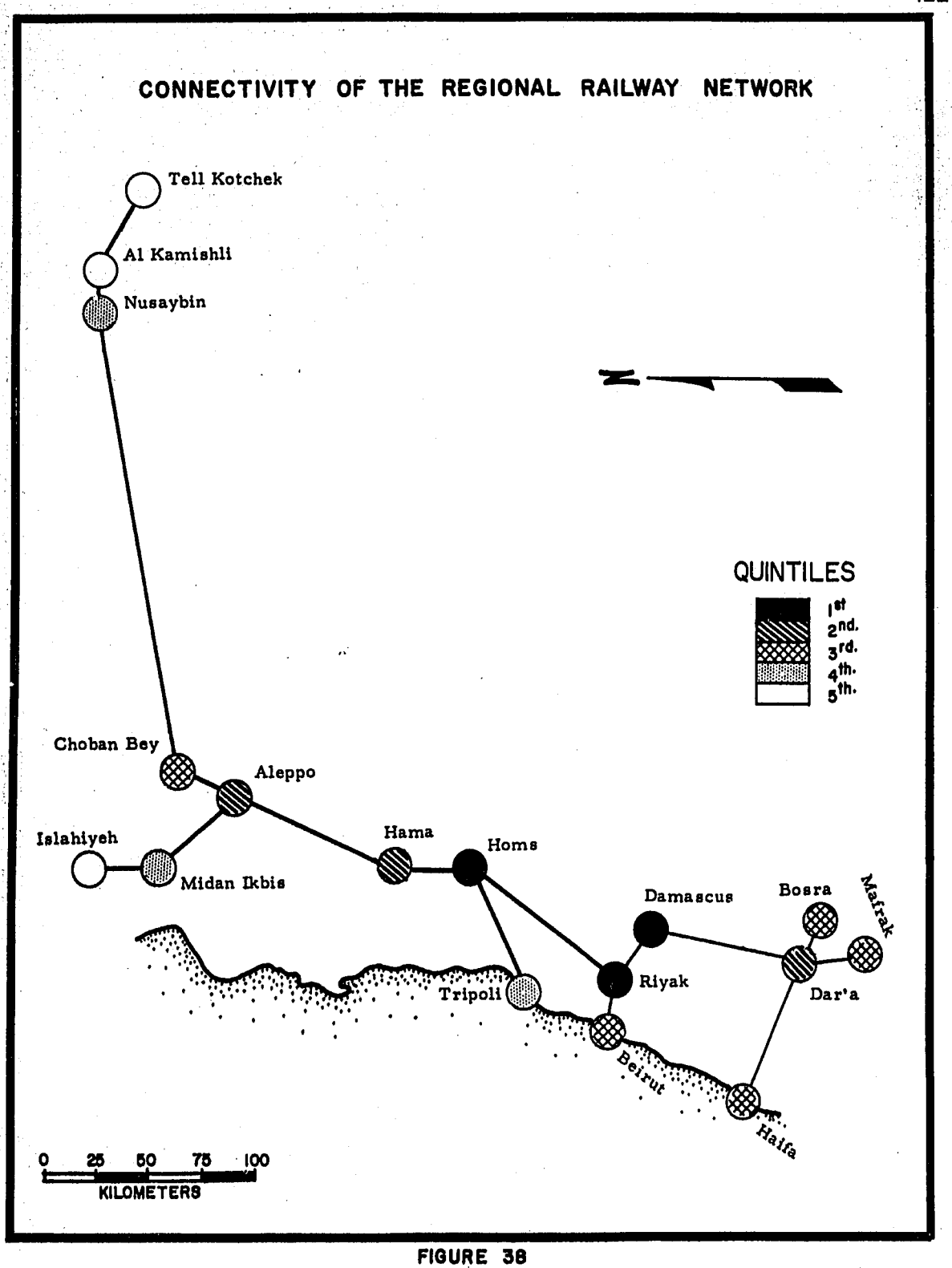

CONNECTIVITY OF THE REGIONAL RAILWAY NETWORK
Tell Kotchek
Al Kamishli
Nusaybin
N
QUINTILES
1st
2nd.
3rd.
4th.
5th.
Choban Bey
Aleppo
Islahiyeh
Midan Ikbis
Hama
Homs
Damascus
Bosra
Mafrak
Riyak
Dar'a
Tripoli
Beirut
Haifa
0 25 50 75 100
KILOMETERS

FIGURE 38

The international boundaries that came into being after World War I dissected the network leaving Syria with small sections, or in graph theory terms sub-graphs, of the whole network. The matrix of connectivity for the present day rail network in Syria was constructed (Table 16) and the percentage connectivity value of each individual center to the total network was obtained (Table 17) and plotted on a map (Figure 39).

TABLE 16

CONNECTIVITY MATRIX OF THE PRESENT DAY RAILROAD NETWORK

	1	2	3	4	5	6	7	8	9	10	11
1		1									
2	1		1				1				
3		1									
4					1						
5				1		1					
6					1						
7		1						1			
8							1				
9										1	
10									1		1
11										1	

TABLE 17

CONNECTIVITY VALUES OF THE MAJOR RAIL CENTERS

(1963)

Rail Center	Percent of total connectivity
1. Midan Ikbis	16.94
2. Aleppo	23.95
3. Choban Bey	16.94
4. Nusaybin	1.36
5. Al-Kamishli	1.36
6. Tell Kotchek	1.36
7. Hama	23.95
8. Homs	9.92
9. Damascus	1.36
10. Dar'a	1.36
11. Bosra	1.36

Examination of this table revealed that Aleppo and Hama became the best connected centers on the rail network, followed by Midan Ikbis and Choban Bey, then Homs and then the rest of the centers, mostly isolated from the main system. These results were in accordance with the hypothesis that the present day rail network of Syria was badly fragmented and that its efficiency decreased in comparison to the early days of its development. It also revealed that individual centers that were well connected during the time when the network developed on a regional basis decreased in importance after the fragmentation of the country.

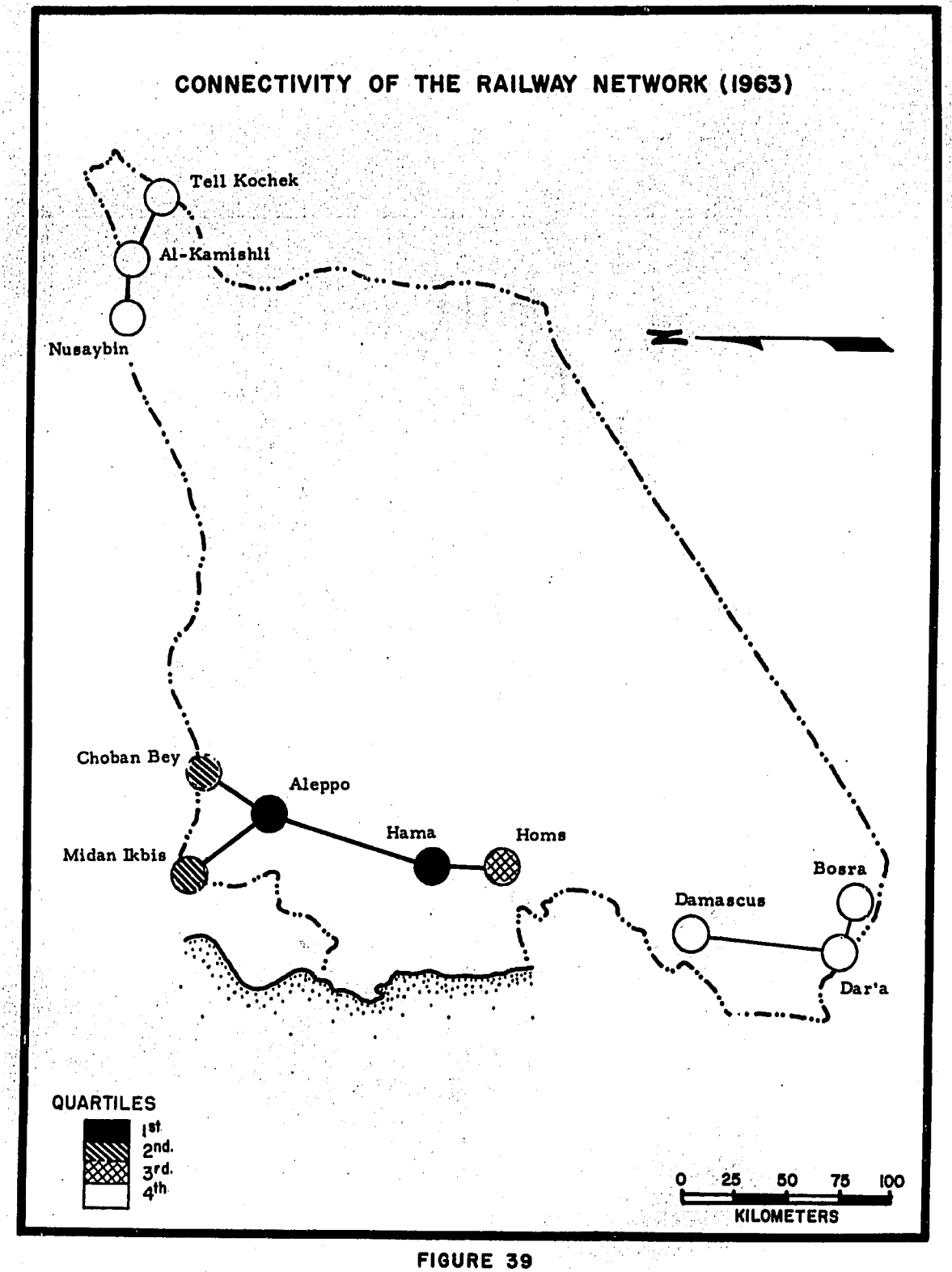

CONNECTIVITY OF THE RAILWAY NETWORK (1963)
Tell Kochek
Al-Kamishli
Nusaybin
Choban Bey
Aleppo
Hama
Homs
Midan Ikbis
Bosra
Damascus
Dar'a
QUARTILES
1st.
2nd.
3rd.
4th.
0 25 50 75 100
KILOMETERS

FIGURE 39

The connectivity of the rail network should increase significantly once the Al-Latiquiya-Al-Kamishli line, which is now being built, is completed and when the proposed connection linking Homs and Damascus is constructed. Table 18 shows the connectivity matrix of the network when these two connections are completed, and Table 19 shows the connectivity values for the major rail centers in Syria. The connectivity indices are divided into quintiles and plotted cartographically (Figure 40). The results show that by 1970 Aleppo will have become the highest connected rail center in Syria, lying between the important agricultural area of the northeast, the port of Al-Latiquiya, and the large urban centers to the south. At that time Rakkah, the second highest on the connectivity scale, may very well become the regional center of the agricultural northeast, due to its favorable location between the small but important centers of Deir-ez-Zor and Al-Hasakeh on one hand and Aleppo on the other.

The port of Al-Latiquiya, now without any rail connections, will have a relatively high connectivity value on the projected rail network. This will increase its accessibility to the rest of the country, both to the east and to the south and will put it in a much better position to serve the shipping movement of the country. This will also give it a strong locational advantage over the port of Tartous, which is being renovated and enlarged, as this new port will not have a rail line linking it to the rest of the country.

TABLE 18

CONNECTIVITY MATRIX OF THE COMPLETED RAILWAY NETWORK

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1		1													
2	1		1	1						1	1				
3		1													
4		1													
5						1									
6					1		1	1							
7						1									
8						1			1						
9								1		1					
10		1							1						
11		1										1			
12											1		1		
13												1		1	
14													1		1
15														1	

TABLE 19

CONNECTIVITY VALUES OF THE MAJOR RAIL CENTERS
(1970)

Rail Center	Percent of total connectivity
1. Midan Ikbis	10.12
2. Aleppo	15.25
3. Al-Latiquiya	10.12
4. Choban Bey	10.12
5. Nusaybin	1.74
6. Al-Kamishli	2.61
7. Tell Kotchek	1.74
8. Al-Hasakeh	5.16
9. Deir-ez-Zor	5.14
10. Rakkah	13.54
11. Hama	13.23
12. Homs	4.73
13. Damascus	4.06
14. Dar'a	1.48
15. Bosra	0.95

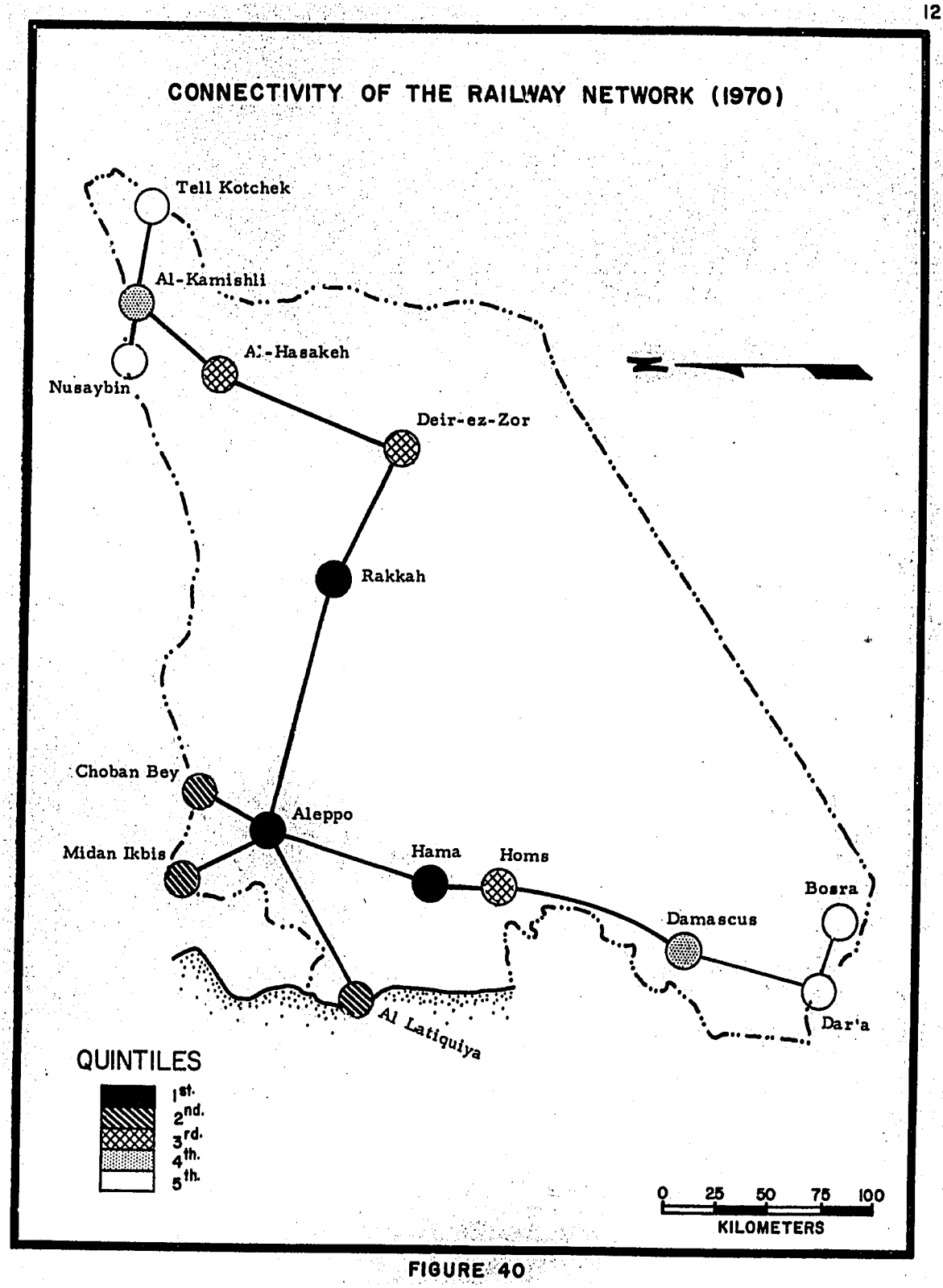

CONNECTIVITY OF THE RAILWAY NETWORK (1970)
Tell Kotchek
Al-Kamishli
Nusaybin
Al-Hasakeh
Deir-ez-Zor
Rakkah
Choban Bey
Aleppo
Midan Ikbis
Hama
Homs
Bosra
Damascus
Dar'a
Al Latiquiya
QUINTILES
1st.
2nd.
3rd.
4th.
5th.
0 25 50 75 100
KILOMETERS

FIGURE 40

The connectivity of the railway centers in the south remains quite low, and especially that of Damascus, the important urban and economic center of the area. This is in contrast with the position of Aleppo, the chief rival of Damascus whose position relative to the developing rail network is very advantageous in its accessibility to Al-Latiquiya, the country's main port, and to the important agricultural region of the northeast, where the country's largest portion of export commodities comes from.

Connectivity of the Road Network

In this section, changes in the connectivity of the road network in Syria and in the relative importance of the connections of urban places through time will be analyzed. This will be done by first examining the network as it existed in the early 1920's, the first decade of modern transport in the country, and then by analyzing the present day network and comparing the changes that have taken place.

In 1920 the beginning of the modern road network in Syria began to evolve. The network that existed at the time had not been designed for motor use, but was a combination of improved caravan and wagon routes. The condition of the individual roads did not differ much from one another, so that in this phase of the analysis all connections were assigned equal weights.

The matrix of connectivity for the road network that existed in 1920 was constructed. The percentage value of the 48 individual centers under consideration was then obtained (Table 20), divided into quintiles, and plotted cartographically (Figure 41). Examination of this map showed that high connectivity values were obtained for the major urban centers of Damascus, Homs, Hama and Aleppo, and for the intermediate points of Jisr-esh-Shaghour, Idlib, and Maarrat-en-Nouman. It also showed the importance of Palmyra, Deir-ez-Zor and Rakkah, the eastern centers located on the important routes joining Syria and Turkey to places further east such as Iraq, Iran, and then India.

Other results showed the high connectivity of the southern centers where early economic growth, especially in the field of agriculture, took place. Most of the northern and northeastern centers, where very little development had taken place, had low connectivity values as did the port cities of Jableh and Tartous, while the port of Al-Latiquiya showed a moderate degree of connectivity.

Between 1920 and 1963 the road network of Syria developed on a national rather than regional basis. The connections that were considered important were widened and improved, so that by 1963 the network was composed of primary secondary and tertiary connections. In this phase of the analysis weighting of roads was undertaken so that

TABLE 20

ROAD CONNECTIVITY VALUES OF THE MAJOR URBAN CENTERS (1920)

Urban Center	Percent of total connectivity
1. Ain Deiwar	0.006
2. Karatchok	0.001
3. Tell Kotchek	0.006
4. Dmir Kabou	0.028
5. Al-Kamishli	0.127
6. Al-Hasakeh	0.562
7. Ras-el-Ain	0.201
8. Abou Kamal	0.517
9. Deir-ez-Zor	2.306
10. Rakkah	4.083
11. Tell Abyad	0.018
12. Ain-el-Arab	0.078
13. Manbij	0.331
14. Jarablus	0.313
15. Al-Bab	1.392
16. Aleppo	5.564
17. Izaz	1.318
18. Ifrin	0.312
19. Rajou	0.070
20. Harem	1.248
21. Idlib	5.809
22. Jisr-esh-Shaghour	5.023
23. Maarrat-en-Nouman	5.809
24. Al-Latiquiya	1.266
25. Al-Haffeh	0.285
26. Jableh	0.332
27. Banias	0.210
28. Kadmous	0.552
29. Misyaf	2.253
30. Hama	9.458
31. Salamiya	6.720
32. Homs	7.367
33. Safita	0.011
34. Tartous	0.049
35. Tell Kalakh	1.650

TABLE 20-continued

Urban Center	Percent of total connectivity
36. Palmyra	9.158
37. Douma	5.322
38. Damascus	7.095
39. Zabadani	1.609
40. Sab Biar	1.609
41. Shahba	2.101
42. As-Suweida	2.204
43. Salkhad	0.125
44. Bosra	0.547
45. Dar'a	0.125
46. Feek	1.609
47. Qneitra	1.609
48. Sheikh Miskin	1.609

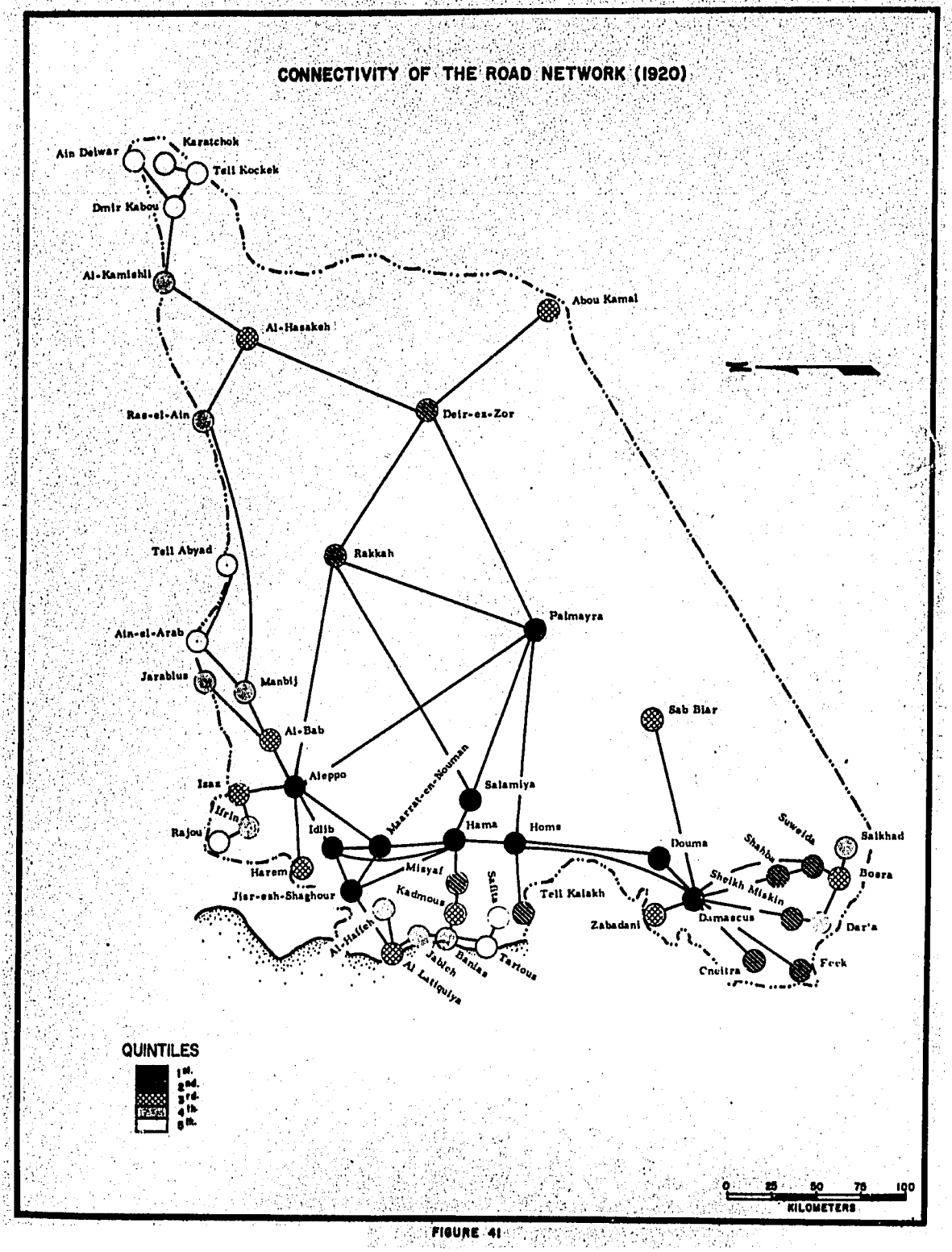

CONNECTIVITY OF THE ROAD NETWORK (1920)
Ain Delwar
Karatchok
Tell Kockek
Dmir Kabou
Al-Kamishli
Abou Kamal
Al-Hasakeh
Ras-el-Ain
Deir-ex-Zor
Tell Abyad
Rakkah
Palmayra
Ain-el-Arab
Jarablus
Manbij
Al-Bab
Sab Biar
Aleppo
Maarrat-en-Nouman
Salamiya
Isaz
Ifrin
Rajou
Idlib
Hama
Homs
Douma
Suweida
Salkhad
Shahba
Bosra
Harem
Misyaf
Safita
Tell Kalakh
Sheikh Miskin
Jisr-esh-Shaghour
Kadmous
Zabadani
Damascus
Dar'a
Al-Haffeh
Jableh
Banias
Tartous
Al Latiquiya
Cneitra
Feek
QUINTILES
1st.
2nd.
3rd.
4th.
5th.
0
25
50
75
100
KILOMETERS

FIGURE 41

primary connection which was more important than a secondary or tertiary one also had a higher index. The value assigned was done arbitrarily with an index of 3 given to a primary connection, a value of 2 given to a secondary connection, and a value of 1 given to a tertiary connection. Again, the percentage values for each of the urban places was obtained (Table 21). These values were then divided into quintiles and plotted on a map (Figure 42).

The first result obtained from the analysis was the large increase in the total connectivity of the network from 1920 to 1963. The second result was the fact that the connectivity of a number of urban centers increased between 1920 and 1963 while connectivity index of certain other centers decreased in relative importance. This change was shown in Figure 43, where the left half of the circle showed the relative weight of the center in 1920, and the right half showed the value of the relative weight of the center in 1963. One of the significant results in the analysis was the decrease in the connectivity in a large number of the urban centers in the southern part of the country, especially in the case of Damascus which went down from the first to the second quintiles. However, this was in accordance with the hypothesis that the separation of these centers from the coastal towns by the introduction of international boundaries to the region disrupted the development of the road network in this area. Another

TABLE 21

ROAD CONNECTIVITY VALUES OF THE MAJOR URBAN CENTERS (1963)

Urban Center	Percent of total connectivity
1. Ain Deiwar	0.021
2. Karatchok	0.036
3. Tell Kotchek	0.133
4. Dmir Kabou	0.139
5. Al-Kamishli	0.323
6. Al-Hasakeh	0.657
7. Ras-el-Ain	0.319
8. Abou Kamal	0.310
9. Deir-ez-Zor	0.874
10. Rakkah	1.514
11. Tell Abyad	0.644
12. Ain-el-Arab	0.311
13. Manbij	0.603
14. Jarablus	1.719
15. Al-Bab	0.886
16. Aleppo	5.783
17. Izaz	0.208
18. Ifrin	3.180
19. Rajou	0.075
20. Harem	1.327
21. Idlib	2.696
22. Jisr-esh-Shaghour	4.732
23. Maarrat-en-Nouman	3.606
24. Al-Latiquiya	2.570
25. Al-Haffeh	2.020
26. Jableh	1.963
27. Banias	3.731
28. Kadmous	3.068
29. Misyaf	5.529
30. Hama	5.999
31. Salamiya	2.368
32. Homs	8.651
33. Safita	4.970
34. Tartous	7.304
35. Tell Kalakh	5.542

TABLE 21-continued

Urban Center	Percent of total connectivity
36. Palmyra	1.662
37. Douma	2.372
38. Damascus	3.321
39. Zabadani	0.818
40. Sab Biar	0.464
41. Shahba	1.246
42. As-Suweida	1.583
43. Salkhad	0.650
44. Bosra	0.826
45. Dar'a	1.013
46. Feek	0.144
47. Qneitra	1.891
48. Sheikh Miskin	2.023

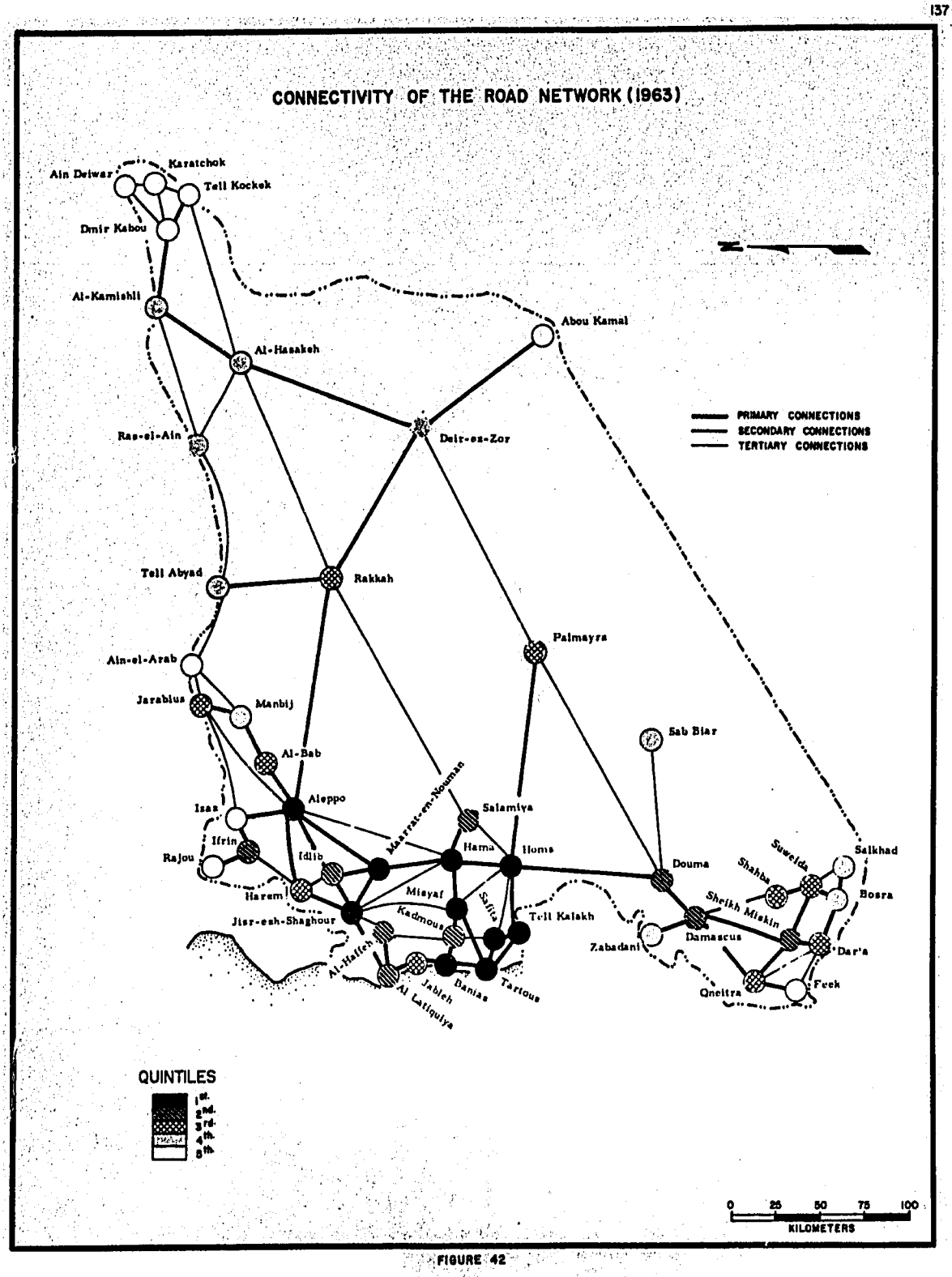

CONNECTIVITY OF THE ROAD NETWORK (1963)
Ain Deiwar
Karatchok
Tell Kockek
Dmir Kabou
Al-Kamishli
Al-Hasakeh
Abou Kamal
Ras-el-Ain
Deir-es-Zor
PRIMARY CONNECTIONS
SECONDARY CONNECTIONS
TERTIARY CONNECTIONS
Tell Abyad
Rakkah
Palmayra
Ain-el-Arab
Jarablus
Manbij
Al-Bab
Sab Biar
Aleppo
Isaa
Ifrin
Rajou
Idlib
Maarrat-en-Nouman
Salamiya
Hama
Homs
Douma
Salkhad
Suweida
Shahba
Bosra
Harem
Misyaf
Safita
Tell Kalakh
Jisr-esh-Shaghour
Kadmous
Sheikh Miskin
Damascus
Zabadani
Dar'a
Al-Hafleh
Jableh
Banias
Tartous
Al Latiquiya
Qneitra
Feek
QUINTILES
1st.
2nd.
3rd.
4th.
5th.
0
25
50
75
100
KILOMETERS

FIGURE 42

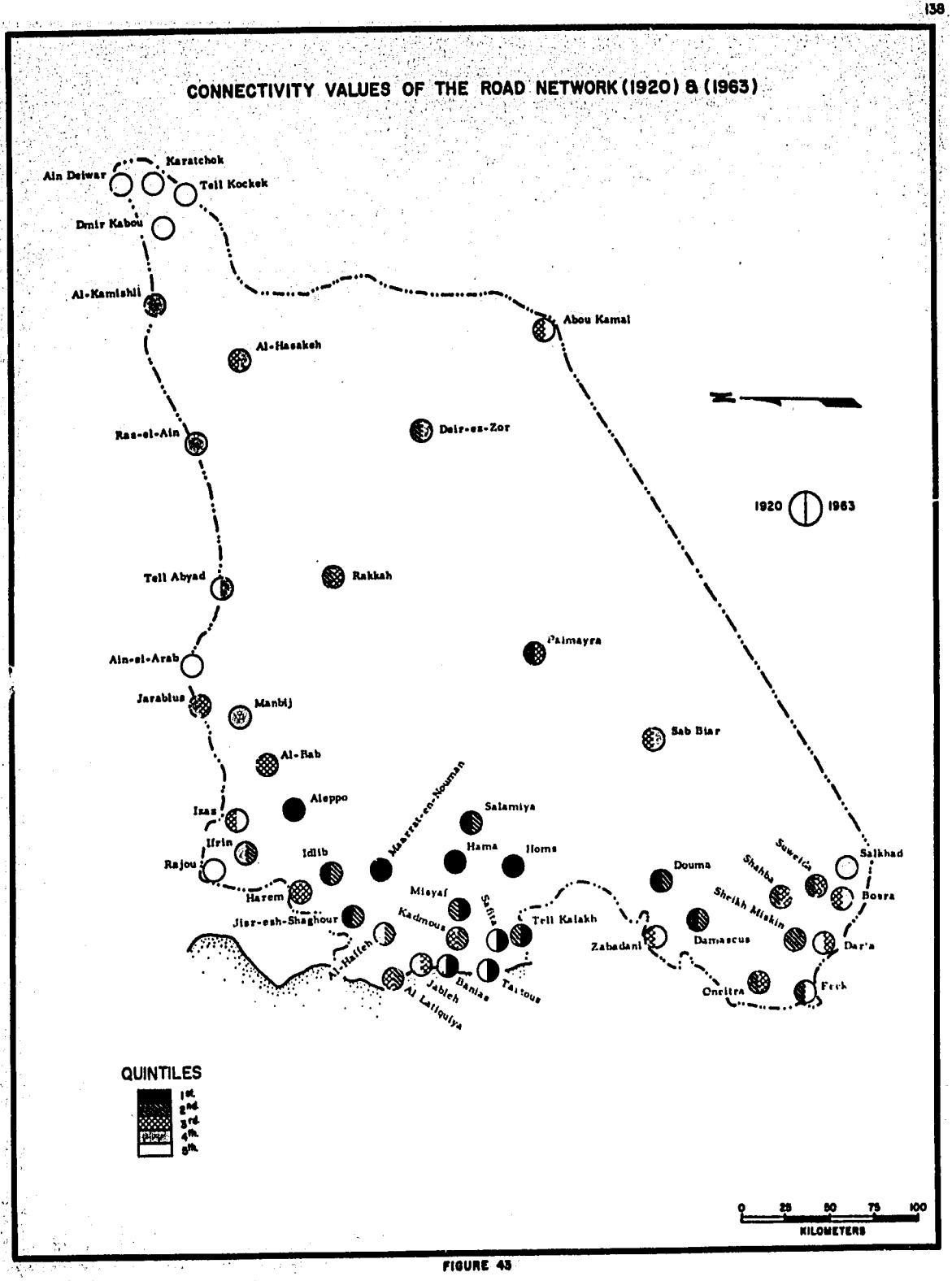

CONNECTIVITY VALUES OF THE ROAD NETWORK (1920) & (1963)
Ain Deiwar
Karatchok
Tell Kocksk
Dmir Kabou
Al-Kamishli
Al-Hasakeh
Abou Kamal
Ras-el-Ain
Deir-ez-Zor
1920
1963
Tell Abyad
Rakkah
Ain-el-Arab
Palmayra
Jarablus
Manbij
Sab Biar
Al-Bab
Aleppo
Izaz
Salamiya
Ifrin
Idlib
Hama
Homs
Rajou
Harem
Douma
Salkhad
Bosra
Jisr-esh-Shaghour
Kadmous
Tell Kalakh
Zabadani
Damascus
Dar'a
Jableh
Banias
Tartous
Al Latiquiya
Fech
QUINTILES
1st
2nd
3rd
4th
5th
0
25
50
75
100
KILOMETERS

FIGURE 43

result showed the increase in the connectivity of the port cities of Syria, namely Al-Latiquiya, Jableh, Banias and Tartous, with Tartous having the highest degree of connectivity among the ports, even though Al-Latiquiya was the country's main port. Two significant facts were obtained from this information: 1) that Al-Latiquiya, which had become a busy port since its completion in 1960, handling over one million tons per year, was not as well connected to the areas that it served as it ought to have been; 2) the port of Tartous, in the process of being modernized and expanded, was well connected to the network and would thus be in a relatively good position to serve the economy of the country, and to provide the port of Al-Latiquiya with competition for handling the country's foreign trade.

Another result which was obtained from the analysis was that the connectivity of the eastern centers of Deir-ez-Zor, Rakkah, Abou Kamal, and Palmyra decreased in the past 40 years. This was due to the fact that their early role as mid-points on transport lines linking the Mediterranean Sea to the regions further east, such as Iraq and Iran, was curbed and that they had become peripheral centers on a road network that developed on a national basis within the last two decades. The northeastern region as a whole was poorly connected to the rest of the country. This was a newly developed agricultural area where a large amount of the country's food supply as well as

most of its wheat and cotton for export came from. Therefore, the regional urban centers where the agricultural products were gathered and then exported should become better connected to the areas of demand and to the port of export so that speed of movement and decrease in transport cost could occur.

CHAPTER IX

SUMMARY AND CONCLUSIONS

The study has examined the structure of the transport network in Syria, with special emphasis on the significant differences in the development of this network from place to place. The relationships between road network structure (both primary network and total network) and the eight factors which affect transport demands were examined and described. Graph theory indices were used to calculate the complexity of the road network which was then related to the indicators representing population distribution, agricultural production, industrial production, transit movement, railway competition, area, shape and slope of the forty-two enumeration units, using multiple regression.

In the case of Syria, it was found that there existed a high degree of correlation between the complexity of the road network and agricultural production, size, and slope of the areas under consideration. This reflected the importance of agriculture to the economy of Syria and demonstrated the significance of area and slope to the development of the road transport within that country. A weak relationship between road network development and population distribution was obtained, pointing up the low degree of mobility among the population of Syria, which is also shared by many of the developing countries. The relationship between the primary road network structure and industry was found to be moderate, while the

relationship between the total network and industry was weak. Two facts may be derived from these results: 1) that the manufacturing sector played a minor role in the economy of Syria compared to agriculture; 2) that the transport demands of manufacturing played a stronger role in the development of primary connections that they did in the development of secondary or tertiary connections. The three remaining factors that were considered, namely transit movement, railway competition and shape of the enumeration units had very weak relationships with the structure of the road network in Syria.

Residuals from regression, which represented the difference between the actual value of the road network structure and the expected value obtained from the estimating equation of the multiple regression were cartographically plotted and analyzed. It was observed that certain places such as Al-Bab, As-Suweida and Izaz had higher network complexity indices than would be expected, while other places such as Al-Kamishli, Deir-ez-Zor and Ifrin had less than expected values of network complexity. Since a number of the regions where an increase in production and population is taking place were among the areas that had less than expected values, such as the Al-Kamishli area, these may be considered as the places where future development ought to take place in order to improve the country's mobility.

Analysis of the changes in the connectivity of the road and railroad networks of Syria revealed that within the last two decades a large increase in the connectivity of the road network took place, while the connectivity of the rail network decreased during the same period. This decrease was due to the fragmentation of the rail network by the superimposition of political boundaries on this network after the First World War.

Due to the realignment of the road network after the partitioning of the area, there was a change in the relative connectivity of the major urban centers within the last forty years, with some showing an increase while others showed a decrease. This realignment is still in process and its effects will be felt more and more as time goes on. Some of the centers that decreased in relative connectivity were those located in the eastern section of the country, namely Rakkah, Deir-ez-Zor and Abou Kamal, which had grown in importance when they were focal points on the regional network which connected the eastern Mediterranean to Iran and Iraq. With the severing effect of the international boundaries these centers have become peripheral on a network which is growing to serve the national transport demands of Syria. Other centers which decreased in relative connectivity were the ones located in the southern part of the country, the most important of which was the capital city of Damascus. The connectivity of a number

of urban centers, especially those that were located in the western section of the country, increased in recent years since these centers have become the focal points of the network with the development of the port facilities of the coastal cities. This is especially true in the case of Al-Latiquiya which has been developed to handle the bulk of the foreign trade of the country, and Tartous where the port facilities are being expanded to accommodate a large volume of the shipping movement.

Analysis of the connectivity of the railway network revealed that in addition to the decrease in the overall connectivity of the network, due to the severing effects of the international boundaries, changes in the relative connectivity of the rail centers had taken place. In the early stages of the network growth, Damascus, Riyak and Homs had the highest degree of connectivity; but on the present day network, Aleppo and Hama were found to be the best connected rail centers in the country. Once the lines that are planned and that are under construction have been completed, further changes in the pattern of connectivity of the railway network will occur, resulting in the emergence of new and well connected rail centers. An example of such a center is Rakkah, located in the agricultural region of the northeast.

This newly evolving pattern of accessibility, via the road and the rail networks of the country, is bound to affect the relative growth of the major urban centers providing an advantage to the ones that are strongly

linked to the rest of the country and a disadvantage to those centers that are poorly linked or have become poorly linked due to major realignments that have taken place.

Some limitations in certain parts of the analysis come to mind now that this study is completed. As in the case of most developing countries, there is a lack of important data that, if obtainable, would have been used where needed. The most important of these limitations is the lack of reliable inter-regional and intra-regional freight rates for the major commodities of the country. If this information had been available, analysis of the connectivity of major urban centers would have been undertaken using a measure reflecting the variation in freight rates, and the results compared to those which are already obtained, based on physical connections. In this fashion variations between physical accessibility and economic accessibility would have been identified.

Another limitation brought about by the lack of data is that certain of the measures used in the multiple regression analysis could have been improved upon if adequate data were available. These are: manufacturing production index and railway competition index. The manufacturing production index was based upon the floor area of manufacturing plants rather than on the actual tonnage of goods produced. Even though it is correct to assume that there is a relationship between plant size and amount of production, it would have been better to use output figures if

they had been available as this would have provided the exact amount of goods actually transported. Railway competition index was based on the presence or absence of rail facilities within any given area instead of the existing amount of goods moved by rail in each unit of study. Since some lines handle more traffic than others do, the actual freight moved would have provided a better measure than the one used in the study. However, it is felt that since most of the variation that existed in the structure of the network was explained by the variables that were used in the study, the limitations resulting from lack of certain data were not unsurmountable ones.

APPENDIX A

SYRIAN TRADE

Damascus and Aleppo have always been important commercial centers where merchants conducted their international trade. Even though the amount and value of Syria's exports have increased during recent years, imports still outstrip exports. Table 23 shows that the trade deficit of 1962 was 245,122,000 S.P., most of it incurred by the imbalance of Syria's trade with the United Kingdom, the United States, and West Germany. These three contribute 225,620,000 S.P. to the deficit, most of which is the result of purchasing manufactured goods, especially heavy machinery. Syria's favorable balance of trade came from its dealings with Lebanon, Bulgaria, Italy, Saudi Arabia, and Portugal, the recipients of a large segment of Syria's agricultural products.

TABLE 23

SYRIA'S BALANCE OF TRADE

Country	Value of Imports	Value of Exports	Excess of Exports Over Imports
United Kingdom	86,150	15,039	- 71,111
Switzerland	16,198	3,772	- 12,426
Belgium	28,177	12,689	- 15,488
Poland	20,542	17,899	- 2,643
Egypt	3,218	5,259	2,041

China	13,326	15,711	2,385
Lebanon	30,951	92,624	61,673
France	64,728	56,795	- 7,933
Czechoslovakia	24,484	21,295	- 3,189
Jordan	10,028	21,984	11,956
Portugal	2,553	19,250	16,697
Italy	43,957	69,034	25,077
U.S.S.R.	13,704	19,001	5,297
Netherlands	25,788	21,801	- 3,987
Saudi Arabia	1,914	18,361	16,447
United States	106,314	8,007	- 98,307
German Federal Republic	97,556	41,345	- 56,211
Rumania	19,571	27,471	7,900
India	9,939	4,082	- 5,857
Spain	11,808	383	- 11,425
Bulgaria	5,997	36,545	30,548
Hong Kong	1,489	3,931	2,442
Iraq	49,520	21,640	- 27,880
Japan	24,879	2,235	- 22,644
Kuwait	880	7,259	6,379
Hungary	5,319	3,193	- 2,126
Denmark	6,674	20,491	13,817
Malta	6	3,122	3,116
Iran	3,124	544	- 2,580
East Germany	7,750	3,689	- 4,061
Yugoslavia	11,505	2,658	- 8,847
Aden	208	1,366	1,158
Other countries	114,016	18,631	- 95,385
Total	862,280	617,158	-245,122

* In Syrian Pounds.

Source: Summary of Foreign Trade, Ministry of Planning, Directorate of Statistics (1962), p. 139.

APPENDIX B

ECONOMIC DEVELOPMENT PLANNING IN SYRIA

Although a number of development plans were drawn during the 1950's, the Five Year Plan introduced in 1960 may be considered the primary step toward development planning. The investment program was set at 2,720 million S.P., 1,000 million S.P. from the private sector and 1,725 million S.P. from the public sector (Table 24). This meant that about one-third would be invested by the private sector and two-thirds by the public sector.

The two columns on the right show the amount of investment that took place during the first year, both for the public and the private sectors. It shows that both sectors invested about 17 percent of the total funds during the first year.

An examination of the Five Year Plan reveals that irrigation and land reclamation are the largest over all recipients, 30 percent of the total budget. This is followed by the Industry and Transport sectors which were each assigned about 20 percent of the total budget.

TABLE 24

PLANNED INVESTMENT DURING THE PERIOD 1960-1965

Sector	Public	Private	Total	Percent	Total Investment During the First Year of the Plan	
					Public	Private
Irrigation and Land Reclamation	780	50	830	30.5	66	10
Agriculture	95	175	270	9.9	23	30
Industry, Electricity, Mines, Oil	240	269	509	18.7	55.5	30
Transport and Communications	387	150	537	19.7	67	20
Housing	15	245	260	3.7	10	55
Education	100	--	100	3.7	17	--
Health	46	10	56	2.1	9.4	2
Public Utilities and Tourism	32	--	32	1.2	31.5	--
Social Affairs	18	--	18	0.7	9.3	--
Recreation	--	11	11	0.4	--	--
Laboratories, Training, Research	7	--	7	0.3	--	--
Change in Inventories	--	90	90	3.3	--	15
Miscellaneous	--	--	--	--	5.2	8
Total	1,720	1,000	2,720	100.0	293.9	170

Source: Ministry of Planning.

APPENDIX C

ROAD MAINTENANCE EQUIPMENT 1952 AND 1962

Type	1952	1962
Truck and citern	73	157
Pick-up truck	17	17
Jeep	--	44
Tractor	5	50
Scraper	--	58
Leveling machine	7	57
Heavy roller	--	7
Gasoline roller	36	43
Fuel oil roller	3	97
Steam roller	45	5
Tire pump	--	9
Mechanical hammer	--	17
Air compressor	1	48
Water pump	--	34
Rock breaker	12	14
Grader	--	6
Welding machine	--	13
Asphalt miner	26	58
Asphalt boiler	43	151
Sand spreading machine	--	3

Source: Ministry of Public Works, Syrian Arab Republic.

APPENDIX D

THE VARIABLES*

Qada	θ Primary X_1	i Primary X_2	θ Total X_3	i Total X_4	Population X_5	Agriculture X_6	Manufacturing X_7	Transit X_8	Railway X_9	Area X_{10}	Shape X_{11}	Slope X_{12}
1. Damascus	0.57	0.45	0.13	0.05	5.78	4.64	4.54	1	1	2.52	$\bar{1}.89$	$\bar{1}.26$
2. Douma	1.00	0.91	0.48	0.55	5.08	4.79	2.68	1	0	3.63	0.33	$\bar{1}.68$
3. Zabadani	0.47	0.46	0.22	0.20	4.51	3.97	2.38	1	1	2.39	0.18	0.75
4. Katana	0.73	0.61	0.29	0.21	4.82	4.36	2.94	1	1	2.70	0.08	0.30
5. Al-Kteifeh	0.73	0.69	0.27	0.28	4.57	4.26	0.00	1	0	2.72	0.60	0.55
6. Al-Qneitra	0.83	0.67	0.51	0.31	4.97	4.55	2.86	0	0	2.72	0.14	0.16
7. An Nabak	0.89	0.73	0.45	0.39	4.82	4.67	2.49	1	0	2.85	0.26	0.54
8. Homs	1.49	1.04	1.15	0.66	5.59	5.41	4.10	1	1	4.25	$\bar{1}.84$	$\bar{1}.50$
9. Tall Kalakh	0.63	0.57	0.18	0.15	4.97	4.78	0.00	1	1	2.43	0.09	0.64
10. Hama	1.14	0.74	0.52	0.59	5.34	5.23	4.51	1	1	2.97	$\bar{1}.92$	$\bar{1}.93$
11. Salamiya	1.23	0.81	0.71	0.33	4.85	4.90	2.44	0	0	3.19	0.21	0.01
12. Misyaf	0.88	0.58	0.37	0.14	4.90	4.73	1.34	0	0	2.56	0.48	0.56

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}
13. Al-Latiquiya	0.90	0.61	0.52	0.26	5.15	4.60	3.89	1	0	2.65	0.26	0.57
14. Banias	0.83	0.69	0.35	0.22	4.84	4.15	2.31	1	0	2.36	0.13	0.80
15. Jableh	0.72	0.65	0.28	0.21	5.04	4.44	3.05	1	0	2.51	$\bar{1}.90$	0.60
16. Al-Haffeh	0.73	0.57	0.26	0.11	4.90	4.40	1.60	1	0	2.56	0.12	0.62
17. Safita	0.64	0.53	0.21	0.13	5.03	4.37	1.90	1	0	2.37	0.[illegible]	0.37
18. Tartous	0.89	0.81	0.41	0.37	4.92	4.47	3.41	1	0	2.50	0.40	0.56
19. Aleppo	1.24	0.79	0.58	0.32	5.81	5.13	4.41	1	1	3.32	0.23	$\bar{1}.73$
20. Izaz	0.76	0.67	0.28	0.26	4.95	4.83	2.59	0	1	2.71	$\bar{1}.89$	$\bar{1}.76$
21. Al Bab	0.93	0.67	0.35	0.30	4.96	5.01	3.14	0	0	2.78	$\bar{1}.89$	0.14
22. Jarablus	0.74	0.69	0.26	0.31	4.60	4.45	0.00	0	1	2.59	0.46	0.22
23. Ifrin	0.89	0.74	0.52	0.33	5.04	5.02	0.00	0	1	2.88	$\bar{1}.93$	0.50
24. Ain el Arab	0.95	0.97	0.95	0.52	4.65	4.90	2.75	0	0	2.99	0.01	0.27
25. Manbij	1.14	0.83	0.71	0.41	4.92	5.15	2.79	0	0	3.00	0.26	0.22
26. Idlib	0.93	0.72	0.35	0.21	5.15	4.93	3.32	1	1	2.73	0.23	0.29

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}
27. Jisr-esh-Shaghour	0.86	0.72	0.46	0.24	4.78	4.69	2.23	1	0	2.60	0.57	0.45
28. Harem	0.84	0.75	0.38	0.26	4.85	4.51	0.00	0	0	2.67	$\bar{1}.85$	0.46
29. Maarrat-en-Nouman	0.83	0.63	0.23	0.15	4.91	5.10	0.00	1	1	3.00	0.54	0.20
30. Al Hasakeh	1.12	1.08	0.80	0.66	5.10	5.44	0.00	0	0	3.75	0.21	$\bar{1}.63$
31. Ad Dijlah	1.04	0.83	0.79	0.51	4.65	5.21	1.98	0	1	3.03	0.12	$\bar{1}.99$
32. Al-Kamishli	1.13	0.95	0.78	0.56	5.13	5.36	2.76	0	1	3.21	0.26	$\bar{1}.49$
33. Deir-ez-Zor	1.41	1.09	0.83	0.57	5.14	4.87	3.27	1	0	3.69	0.24	$\bar{1}.15$
34. Abou Kamal	1.02	0.77	0.58	0.39	4.77	4.42	2.33	1	0	3.06	0.31	$\bar{1}.97$
35. Al Mayadin	1.26	0.96	0.81	0.59	4.86	4.55	2.49	1	0	3.79	0.32	$\bar{1}.18$
36. Ar-Rashid	1.33	1.05	0.95	0.67	5.08	5.34	3.46	1	0	4.00	$\bar{1}.87$	$\bar{1}.45$
37. As Suweida	0.78	0.74	0.24	0.26	4.82	4.69	2.64	0	0	2.98	0.52	0.10
38. Shahba	0.86	0.74	0.37	0.32	4.54	4.19	0.00	0	0	2.87	0.06	0.01
39. Salkhad	0.78	0.80	0.13	0.37	4.65	4.62	1.51	0	1	2.87	0.61	$\bar{1}.96$

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}
40. Dar'a	1.06	0.76	0.51	0.21	4.95	4.80	3.05	1	1	2.72	0.23	0.03
41. Izra	0.91	0.73	0.45	0.30	4.97	4.81	1.30	1	1	2.97	0.11	$\bar{1}.65$
42. Feek	0.93	0.69	0.43	0.27	4.42	4.08	2.30	0	1	2.29	0.46	0.38

* Rounded to nearest hundreth.

A SELECTED BIBLIOGRAPHY

As-Saiyad, Muhammad Mahmoud, Transport in the Arab World, Cairo: Institute of Higher Arabic Studies, 1956. (In Arabic.)

Avondo-Bodino, Guiseppe, Economic Applications of the Theory of Graphs, New York: Gordon and Beach, 1962.

Berge, Claude, Theorie des graphes et ses applications, Paris: Dunod, 1958. English translation by Alison Doig, Theory of Graphs and its Applications, London: Methuen, New York: Wiley, 1962.

British Admiralty, Syria, London: Naval Intelligence Division, 1944.

Cuinet, Vital, Syrie, Liban et Palestine: Geographie, Administrative, Paris, 1901.

Elefteriades, Elauthere, Les chemins de fer en Syrie et au Liban, Beyrouth, 1944.

Ezekiel, Mordecai and Karl A. Fox, Methods of Correlation and Regression Analysis, New York: John Wiley and Sons, 1959.

Garrison, William L., "Connectivity of the Interstate Highway System," Papers and Proceedings, Regional Science Association, Vol. VI (1960), 122-37.

Garrison, William L and D. F. Marble, "The Structure of Transportation Networks," unpublished report for the United States Army Transportation Research Command, Transportation Center, Northwestern University, Evanston, 1961.

Gharaibek, Abdul Karim, Syria During the Nineteenth Century, Cairo: Institute of Higher Arabic Studies, 1962. (In Arabic.)

Gould, Peter R., The Development of Transportation in Ghana, Northwestern University Studies in Geography, No. 5, Evanston, 1960.

International Bank for Reconstruction and Development, The Economic Development of Syria, Baltimore: Johns Hopkins University Press, 1955.

Kansky, K. J., Structure of Transportation Networks, Department of Geography Research Paper No. 84, University of Chicago, Chicago, 1963.

Ministry of Agriculture, Syrian Arab Republic, "Agricultural Statistics," Damascus, 1962.

Ministry of Planning, Syrian Arab Republic, Statistical Abstracts, Damascus, 1962.

_____. Summary of Foreign Trade, Damascus, 1962.

_____. Annual Report on the Economic and Social Development Plan: 1960-1961, Damascus.

Nickoley, Edward F., A Survey of Economic Conditions in Syria, unpublished Ph.D. Dissertation, University of Illinois, Urbana, 1932.

Nystuen, John D. and Michael F. Dacey, "A Graph Theory Interpretation of Nodal Regions," Papers and Proceedings, Regional Science Association, Vol. VII, 1961, 29-42.

Owen, Wilfred, Strategy for Mobility, Washington: The Brookings Institution, 1964.

Shbat, Anis, "Policy of Transport," Seventh Conference of Arab Engineers, Beirut, 1959. (In Arabic)

Taaffe, Edward J., Richard L. Morrill and Peter R. Gould, "Transport Expansion in Underdeveloped Countries: A Comparative Analysis," The Geographical Review, Vol. LIII, No. 4, (1963), 508-529.