THE LIBYAN INTERNAL TRANSPORTATION NETWORK: A GRAPH THEORY ANALYSIS

By

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CHAPTER I

INTRODUCTION

The importance of transportation in the development of a nation can hardly be overemphasized. Until recently however, very little research in geography has focused on improving the transportation structure in the underdeveloped and developing countries. An exception to this statement is Peter Gould's Transportation in Ghana.[1] Among other related studies are: "Evaluating Construction Priorities of Farm-to-Market Roads in Developing Countries: A Case Study," by W. R. Stanly,[2] "Government Influence on Transport Decision-Making in Thailand," by P. J. Rimmer,[3] and Transport in Libya, by Doxiades Associates.[4] Since development and efficient distribution systems for passengers and goods are closely linked, a well-planned and well-maintained transportation network is the life-line of a country and the life blood of its economy.[5]

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[1]Peter R. Gould, Transportation in Ghana. (Department of Geography, Northwestern University, Evanston, Illinois, April 1960).

[2]Michael E. Eliot Hurst, Transportation Geography: Comments and Readings, (New York: McGraw-Hill, 1974), pp. 417-440.

[3]Ibid., p. 292.

[4]Doxiades Associates, Transport in Libya: A General Survey and Study of Means of Communications, 2 Vols. (Athens, 1965).

[5]Ibid., p. 5.

Furthermore, it might be argued that transport is "unquestionably the most important industry in the world."[6]

The subject of transportation is the concern of various disciplines, such as economics, engineering, marketing, administration, planning, and geography. While the perspective of each discipline is important, the approach of geography is crucial because of the strong connection that exists between the characteristics of regions and of transportation networks. Taaffe and Gauthier, in their definition, indicate that transportation geography is an important aspect of the organization of an area.

> Transportation geography is concerned with 1) the particular linkages and flows that comprise transportation networks 2) the centers of nodes connected by these linkages and 3) the entire system of hinterland and hierarchial relationships associated with the network.[7]

Statement of the Problem

In a rapidly developing country like Libya, with its strong economy and ambitious plans for the future, there is an urgent need for planning its transportation system. To keep pace with other developments the success of industrial, agricultural and social development in Libya depends on the

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[6]R. J. Paquette, et al., Transportation Engineering: Planning and Design. (New York: The Ronald Press Co., 1972), p. 3.

[7]E. J. Taaffe, and H. L. Gauthier, Jr. Geography of Transportation. (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1973), p. 7.

efficiency of transportation resources. At present the country's top planners are facing the question of defining the specific problems, evaluating alternative courses of action, and formulating policies for long and short term needs. In line with these general themes the principal purposes of this study is to:

1. Review specific geographic factors related to transportation in Libya,
2. Discuss the role of transportation with respect to the Libyan economy,
3. Analyze the expansion of the Libyan transportation network in terms of graph theory, and
4. Consider the alternative choices in the development of the Libyan internal transportation system in terms of related government priorities.

Methodological Framework

The greatest difficulty in carrying out a study such as this is the lack of suitable data. Existing studies tend to be descriptive and not based on rigorous data analyses. Often, the emphasis is on political aspects rather than economic development specifically.[8] The greater part of the data in the present study was obtained from various government ministries, departments, and agencies during field work in Libya in the Winter of 1974. The conceptual orientation

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[8] A valuable exception is Doxiades Associates, Transport in Libya, Volumes 1 and 2.

of the study is derived from literature in transportation geography, and is discussed in Chapter IV.

Physical geographic factors and the role of transportation in the Libyan economy are the topics of Chapters II and III, respectively. The approach in these two chapters is descriptive. In contrast, the graph theory investigation of the Libyan transportation network (Chapter IV) is analytical in its approach. In the concluding chapter, alternative choices to develop Libyan internal transportation and related government priorities and government policies are discussed.

CHAPTER II

FACTORS AFFECTING LIBYAN INTERNAL TRANSPORTATION

Libya: A Brief Description

Libya is a country situated in the middle of North Africa, with an area of about 685,000 square miles. It is bounded by the Arab Republic of Egypt and the Sudan on the east, Chad and Niger on the south, Algeria and Tunisia on the west, and the Mediterranean Sea on the north. The estimated population is 2,257,037 as of August, 1973. The overall population density is estimated to be 3.29 persons per square mile.

Libya consists of three natural regions: the Mediterranean littoral which has dry summers and mild winters with sufficient rainfall for agriculture, a parallel region further south of semi-arid steppe country, and the immense Sahara. Less than five percent of the land is economically useful; the remaining 95 percent is desert. The accompanying two maps illustrate the natural regions and precipitation characteristics of Libya, respectively (Figures 1 and 2). From these illustrations it is apparent that Libya extends from the Mediterranean coast to the very heart of the Sahara and includes a wide variety of different physical features.

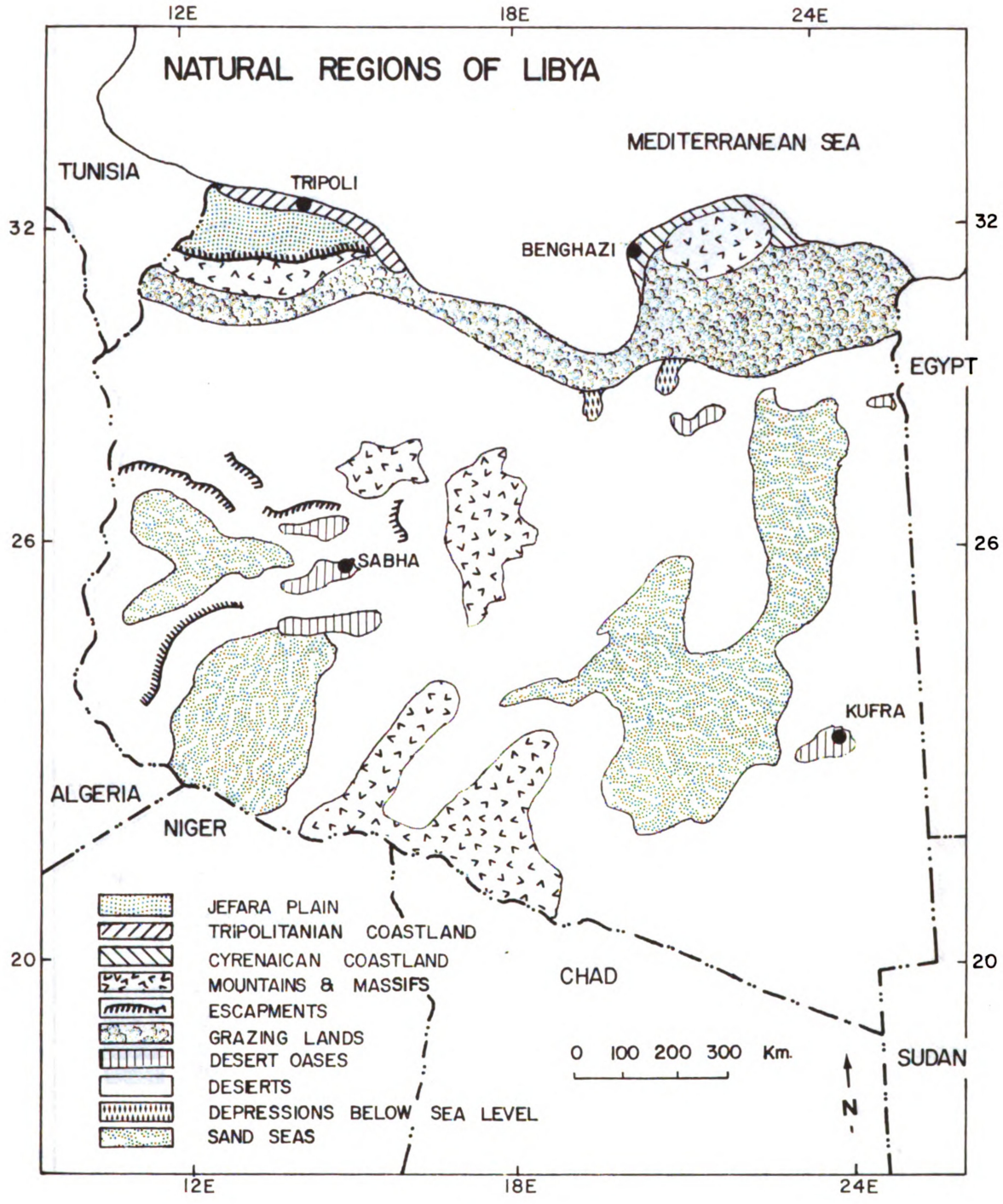
NATURAL REGIONS OF LIBYA
12E
18E
24E
32
26
20
MEDITERRANEAN SEA
TUNISIA
TRIPOLI
BENGHAZI
EGYPT
SABHA
KUFRA
ALGERIA
NIGER
CHAD
SUDAN
JEFARA PLAIN
TRIPOLITANIAN COASTLAND
CYRENAICAN COASTLAND
MOUNTAINS & MASSIFS
ESCAPMENTS
GRAZING LANDS
DESERT OASES
DESERTS
DEPRESSIONS BELOW SEA LEVEL
SAND SEAS
0 100 200 300 Km.
N

Figure 1.

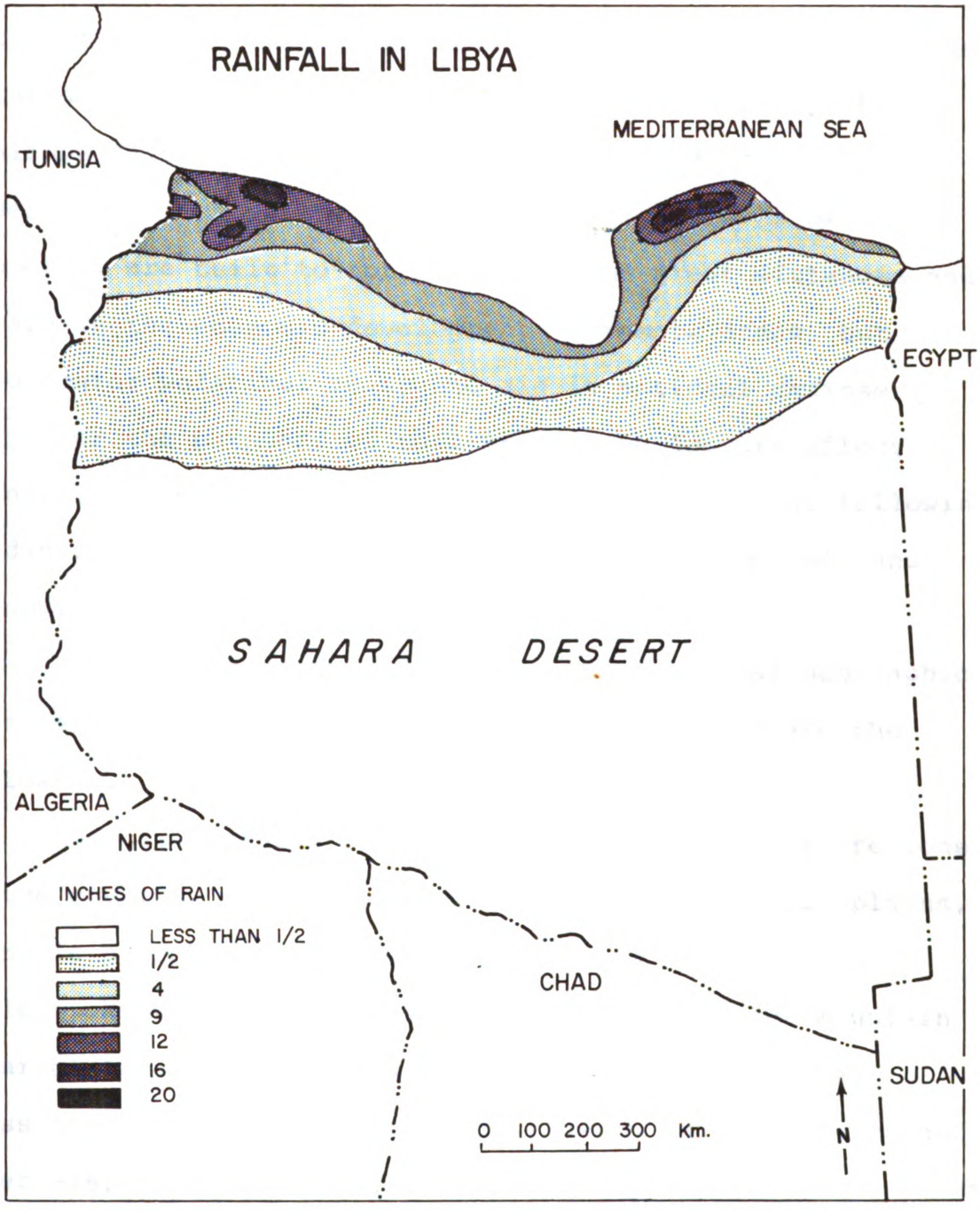
RAINFALL IN LIBYA
MEDITERRANEAN SEA
TUNISIA
EGYPT
SAHARA DESERT
ALGERIA
NIGER
CHAD
SUDAN
INCHES OF RAIN
LESS THAN 1/2
1/2
4
9
12
16
20
0 100 200 300 Km.
N

Figure 2.

Factors Affecting Libyan Transportation

Any attempt to analyze the factors that affect the Libyan transportation system must take into account numerous related circumstances. For example, roads built by the Italians filled both a military and economic need. The desert roads, which are now under construction or are proposed, are built to not only overcome great distances and to aid in the economic development of remote areas, but also foster political unity and aid in national defense.

For the purposes of this study, the factors affecting transportation development are considered under the following headings: physical geographic, human, technological, and economic.

Physical Geographic Factors: The principal geographical factors affecting Libyan internal transportation are the following.

Runoff. Because of the relief in the northern regions of the country, and especially in the narrow coastal plains, there is a problem of water runoff during the winter. Valleys, known by the name wādī,[1] descend over the mountain escarpments and interrupt traffic movements where they cross the roads (Figure 3). When flowing wādīs carry eroded materials, sand, and gravel, which are deposited on the roads thus creating obstacles which can be difficult or impossible

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[1] Wādī. Valley in Arabic. Usually refers to a water course which flows only following rainfall.

Figure 3. Illustration of the effect of run off in dry-land environments.

Fig #3

to cross. Bridges are rarely constructed over wādīs, since they would be frequently washed away by water (Figure 4).

Topography and Surface Features. The various surface features of Saharan topography are: stony desert (called locally hamāda or reg), sandy (erg), or gravel desert (sarīr). Each of these surface types of the desert poses considerable problems for both road builders and transportation movement (Figure 5). The road builders usually avoid the sand areas in their construction of roads. For motor vehicles the stony or gravel desert is more desirable for travel than sandy surfaces, while the opposite is true for camels.

Winds. With regard to transportation in Libya, there are three types of winds which should be taken into consideration: the northwest, west, and south. Winds pose problems in terms of visibility, discomfort, and obstructions. These problems usually happen in both coastal areas and further into the desert, especially during the spring and summer seasons. Especially severe is the south wind, called Ghibli, which carries dust and loose materials, removes the sand, sometimes depositing it on the roads and rendering them difficult or impossible to cross (Figure 6).

> In the desert, it is said that the prevailing wind is the north wind. However, the most notable wind is the Ghibli which is a scorching sand-laden south wind that can carry dust as far as Europe. It can occur at any season, but is most frequent in the spring, and occurs progressively later from west to east. It usually dies down at sunset, often to start again the next day and can last for several days. Sand-storms are more frequent phenomena than

Figure 4. A road washed away by run off in a wādī (near Bir-Ganam).

Fig 4

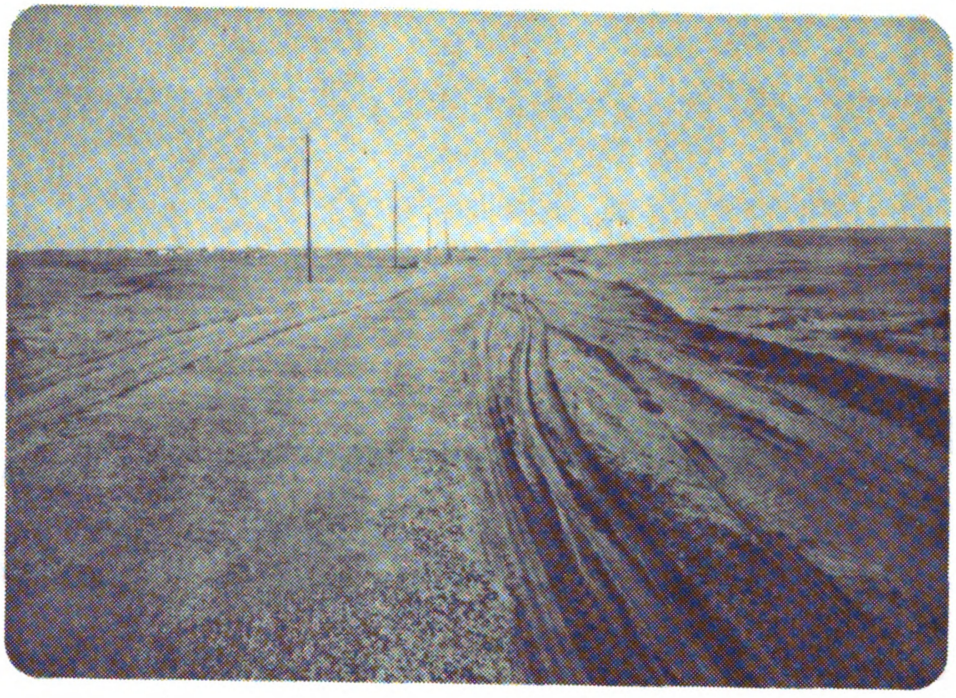

Figure 5. The effect of blowing sand on roads near Zentan.

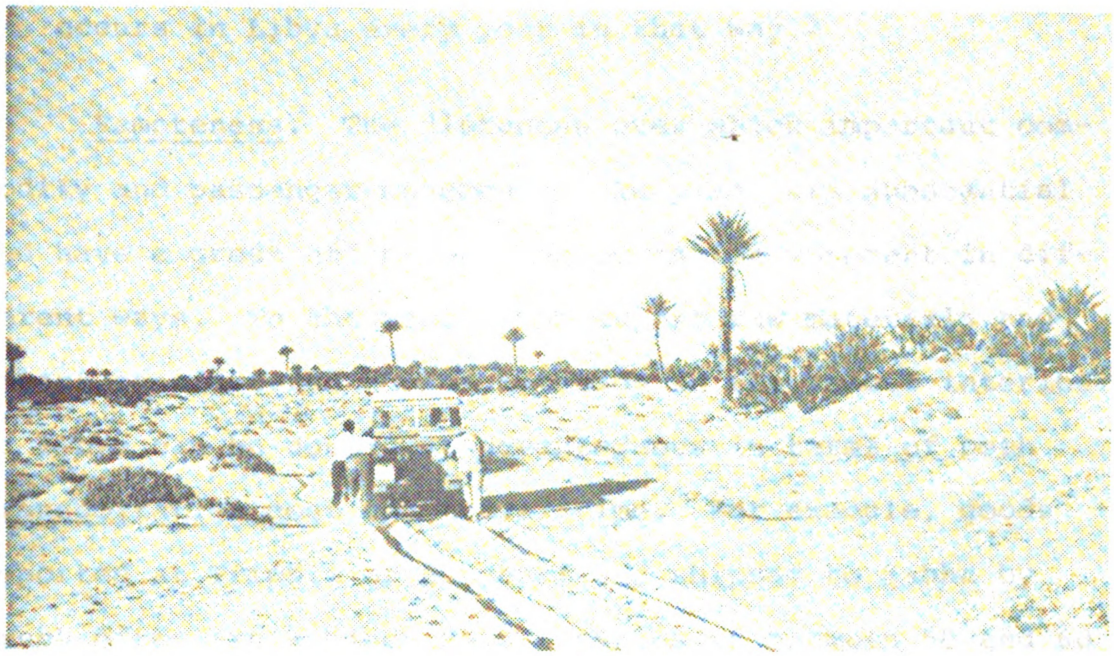

Figure 6. Sand is hazardous to traffic movement, near Brak.

Source: Doxiades Associates, Transport in Libya Vol. 2, p. 136.

> rainstorms, and can have disastorous effects on crops, particularly fruit and blossom or domestic animals and even on human life. They can be particularly hazardous to aviation and travellers in the desert. Whether on foot, animal or car--who loose their orientation and never reach their destination. A considerable loss of human life occurs in Libya every year in that way.[3]

Remoteness. The distances over which important commodity and passenger movements take place are substantial and have a great effect on transportation movement in different ways. To the people who export raw materials and import manufactured goods, location in the remote interior of Libya can be doubly disadvantageous in terms of both transportation cost and travel time. For example, goods imported at Tripoli or Benghazi and shipped to Sabha by truck often are subject to surcharges of between 50 and 60 percent over the standard ton-mile cost in the northern areas. At the same time, the travel time over the same route is nearly doubled. For example truck drivers who carry goods from Tripoli to Sabha need a minimum of 24 hours to complete the journey, while they can cover the same distance along the Coastal road in 14 hours.

An additional problem is the distance between services such as water resources and gas stations. This factor is especially crucial in the Sahara. Both vehicle and camel drivers have to check their water before setting out. This is especially so for camel drivers because water and other supplies reduce space allocated to merchandise.

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[3] Doxiades, Transport in Libya, p. 41.

Human Factor. The human factor is important in transportation development particularly as it pertains to population and its distribution, which in turn is closely related to the magnitude of economic activity in Libya. As Doxiades states,

> The human element in its broad sense, being of the factors of production, determines to a large extent the pattern and magnitude of economic activity in any given country.[4]

The size and development of the transportation network is closely linked to the regional distribution of population. The most recent census of Libya took place in 1973 and shows an estimated population to be 2,257,037, with an annual population growth rate estimated to be 4.2 percent over previous years. This increase includes both natural increase and net immigration. Overall population density is estimated to be 3.29 persons per square mile. The population is concentrated mainly in the two regions along the coast, in the highlands, and in the scattered oases of the interior (Figure 7). This pattern of population distribution is of critical importance for transportation. Consequently transportation links mainly connect the major areas of population concentration in the regions of Tripoli and Benghazi and the region of Sabha, while most other areas are poorly linked.

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[4]Doxiades Associates, Transport in Libya, Vol. 1, p. 42.

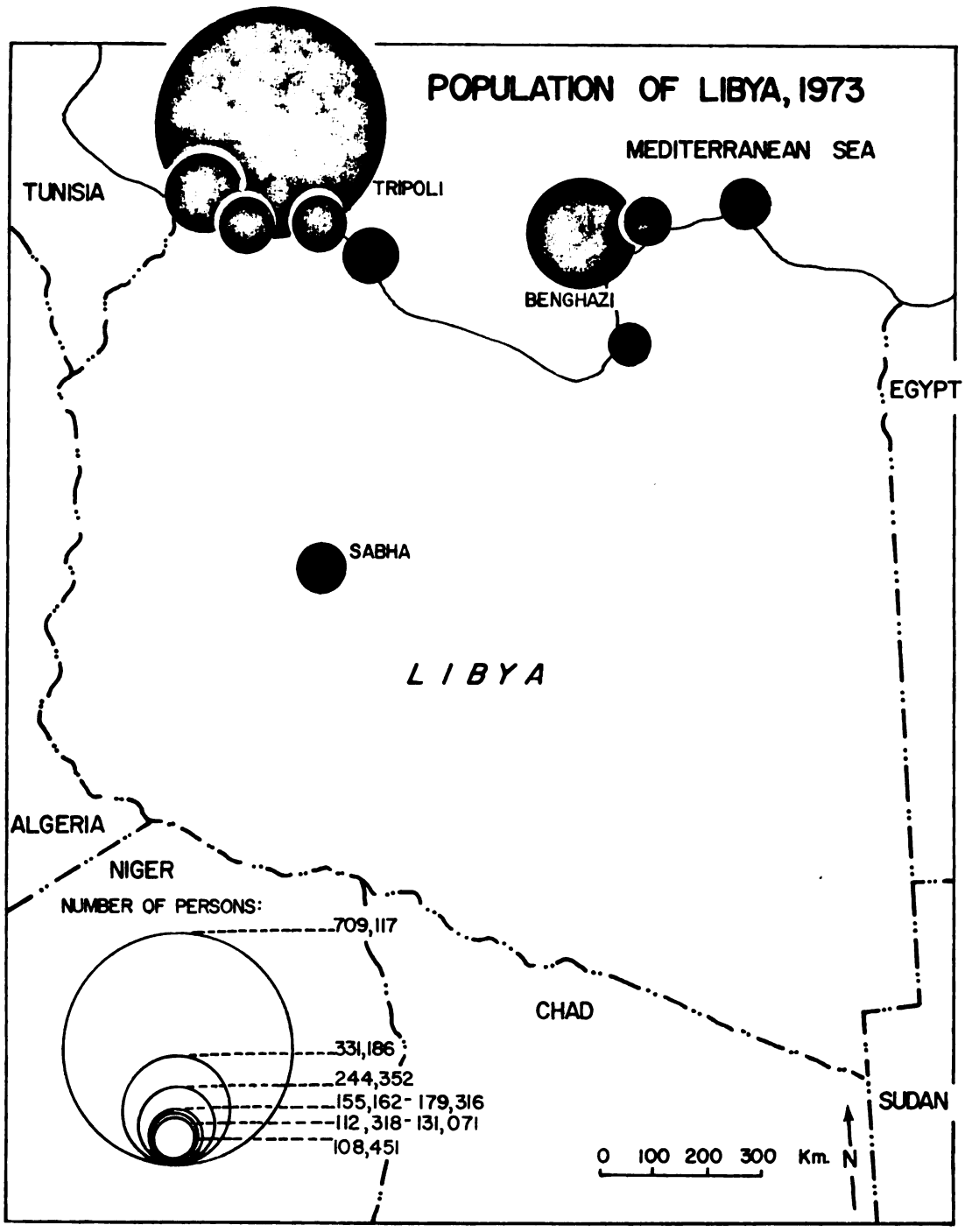
POPULATION OF LIBYA, 1973
MEDITERRANEAN SEA
TUNISIA
TRIPOLI
BENGHAZI
EGYPT
SABHA
LIBYA
ALGERIA
NIGER
NUMBER OF PERSONS:
709,117
331,186
244,352
155,162- 179,316
112,318- 131,071
108,451
CHAD
SUDAN
0 100 200 300 Km.
N

Figure 7.

Technological Factor. Transportation planning and development in Libya are frequently inhibited by a lack of technological expertise. Among the specific problems are:

1. A shortage of experts such as planners who have the experience and ability to undertake research, suggest plans, and implement the necessary projects required for national development.
2. Lack of adequate repair and maintenance facilities.
3. A poorly developed system of road signs and traffic control signals.
4. Insufficient facilities and equipment for road maintenance.

Economic Factor. Because of the importance of economic factors, both in general and to the subject of this study, the following chapter focuses entirely on the role of transportation in the Libyan economy.

CHAPTER III

TRANSPORTATION IN THE LIBYAN ECONOMY

In this chapter the position of transportation in the Libyan economy is discussed. For purposes of organization, the discussion is divided into two sections. The first section of the chapter provides a brief survey of the position of transportation in the Libyan economy with reference to two time periods: pre-1962 and post-1962. The second section of the chapter is a discussion of the development of land and air transportation.

Transportation in the Libyan Economy

It is useful to discuss the Libyan economy with reference to two time periods: pre-1962 and post-1962. Prior to 1962 the Libyan economy was based on the production of a few agricultural commodities, primarily wheat and barley, and import of a wide variety of foodstuffs and manufactured goods. An accurate picture of the Libyan economy during this period is obtained by examining the balance of payments for the period, 1954-1958 (Table 1).

From Table 1, it is clear that most of the cost of imports has been covered by economic aid. Additional income was provided by the local expenditures of British and American military forces stationed in Libya, and money spent in the country by oil companies for exploration.

Table 1. Balance of Payments: 1954-1958 (In Thousands of Libyan Dinars)[1]

	1954	1955	1956	1957	1958
Imports	11,286	14,282	16,487	22,787	23,933
Exports	3,479	4,340	3,961	5,201	4,835
Visible Balance	-7,807	-9,942	-12,526	-17,586	-19,098
Net National Income	2,974	4,239	5,638	12,940	14,388
Official Economic Aid	5,093	8,411	10,074	7,460	9,370
Surplus	260	2,708	3,186	2,814	4,660

[1]Libyan Dinar = $3.30.

Source: O. Roger. Libya A Brief Political and Economic Survey. Royal Institute of International Affairs. Information Department. [Rev. ed. London] (Oxford University Press, 1961), p. 43.

During this period the resources of the country, including aid, were not adequate to support the very large investment needed to develop the economy in general and transportation in particular. An accurate picture of the amount of expenditure devoted to transportation is obtained by examining the expenditure on transportation during the years 1954-1959 by each local administrative unit (Table 2).

After 1962, the value of Libya's exports regularly exceeded the value of its imports (Table 3). More recently, Libya has shown a significant favorable balance of trade (Table 4). In Table 4, the increase in the balance from one year to the next is presented in absolute terms and in terms of percentage increase. Additional data for the increasing

strength of the Libyan economy is given for different currency areas (Table 5).

Table 2. Expenditure on Transport by Administrative Unit: 1954-1959 (In Thousands of Libyan Dinars)[1]

Administrative Unit	1954/ 1955	1955/ 1956	1956/ 1957	1957/ 1958	1958/ 1959
Tripoli	233	170	182	140	184
Cyrenaica[2]	35	45	40	78	54
Fezzan	6	4	4	3	3
Federal Government	201	205	169	157	166
Aid Agencies	8	191	895	805	495
Total	484	615	1,299	1,183	902[3]

[1]Libyan Dinar = $3.30.

[2]Estimated.

[3]Excluding expenditure on the Fezzan road to Sabha.

Source: International Bank for Reconstruction and Development, The Economic Development of Libya, (Baltimore: Johns Hopkins Press, 1960), p. 489.

These rapid increases were accounted for by crude oil revenues (Table 6). The value of the crude oil exports accounted for 99.9 percent of the total Libyan exports by 1970.

Along with the increasing strength of the Libyan economy, transportation became one of the major items in the national budget. Furthermore, it is one of the major sectors in terms of employment, occupying 3.9 percent of the gainfully employed population in 1964 and 7.7 percent in 1969. It has always been given priority in government planning. As part of the 1973-1975 three year development

Table 3. Value of Exports, Re-Exports and Imports: 1954 to 1971

During Year	Imports		Re-Exports		Exports	
	Value in LD '000	Percent Increase or Decrease Over Preceding Year	Value in LD '000	Percent Increase or Decrease Over Preceding Year	Value in LD '000	Percent Increase or Decrease Over Preceding Year
1954	11,198	NA	170	NA	3,668	NA
1955	14,388	28.5	329	93.5	4,265	16.3
1956	16,601	15.4	349	6.0	3,805	-10.8
1957	28,076	69.1	663	90.0	4,753	24.9
1958	34,501	22.9	763	15.1	4,313	- 9.3
1959	40,585	17.6	641	-16.0	3,659	-15.2
1960	60,388	48.8	920	43.5	3,111	-15.0
1961	53,274	-11.8	1,345	46.2	6,519	109.5
1962	73,444	37.9	1,448	7.7	49,016	652.0
1963	85,277	16.1	1,317	- 9.1	118,573	141.9
1964	104,379	22.4	2,948	123.8	218,487	84.3
1965	114,416	9.6	2,463	-16.5	281,873	29.0
1966	144,662	26.4	3,047	23.7	357,819	26.9
1967	170,145	17.6	3,406	11.8	416,612	16.4
1968	230,219	35.3	1,771	-48.0	665,110	60.1
1969	241,301	4.8	1,177	-33.5	772,765	16.2
1970	198,002	-17.9	3,044	158.6	841,829	8.9
1971	250,352	26.4	2,586	-15.0	959,918	14.0

Source: Libyan Arab Republic, Ministry of Planning, External Trade Statistics, 1971. (Tripoli: Government Printing Office, 1971), p. 1.

Table 4. Libya: Favorable Trade Balance: 1967-1971

Sr. No.	Year	Trade Balance LD '000	Increase in Trade Balance Over the Previous Year	
			Actual LD '000	Percent
(1)	(2)	(3)	(4)	(5)
1	1967	249,873	33,669	15.57
2	1968	436,662	186,789	74.75
3	1969	532,641	95,979	21.98
4	1970	646,871	114,230	21.45
5	1971	712,152	65,281	10.09

Source: Libyan Arab Republic, Ministry of Planning, External Trade Statistics, 1971. (Tripoli: Government Printing Office, 1971), p. ii.

Table 5. Trade Surplus by Currency Area, 1970-1971

Sr.	Area	Trade Balance (LD '000)	
		1971	1970
(1)	(2)	(3)	(4)
1	Sterling Area	+189,519	+126,642
2	Dollar Area	+ 44,842	- 4,911
3	Rest of the World	+477,791	+525,140
4	Total	+712,152	+646,871

Source: Libyan Arab Republic, Ministry of Planning, External Trade Statistics, 1971. (Tripoli: Government Printing Office, 1971), p. ii.

Table 6. Value of Exports by Commodity Groups, 1970-1971

Commodity Description		Value of Exports in LD '000		Percent	
		1971	1970	1971	1970
(1)	(2)	(3)	(4)	(5)	(6)
0	Food and Live Animals	23	27	0.0	0.0
1	Beverages and Tobacco	-	17	0.0	0.0
2	Crude Materials Inedible Except Fuels	503	648	0.1	0.1
3	Mineral Fuels, Lubricants and Related Materials	959,392	841,134	99.9	99.9
4	Animal and Vegetable Oils and Fats	-	-	-	-
5	Chemicals	-	-	-	-
6	Manufactured Goods Classified Chiefly by Materials	-	3	0.0	0.0
7	Machinery and Transport Equipment	-	-	-	-
8	Miscellaneous Manufactured Articles	-	-	0.0	0.0
9	Commodities and Transactions not Classified According to Kind	-	-	-	-
	Total	959,918	841,829	100.0	100.0

Source: Libyan Arab Republic, Ministry of Planning, External Trade Statistics, 1971. (Tripoli: Government Printing Office, 1971), p. iii.

plan, 190,232,000 Libyan dinars have been allocated to this sector, of which 53,304,000 Libyan dinars have been ear-marked for 1973, nine percent of the total budget for that year. A detailed breakdown of the budget plan is presented in Tables 7 and 8.

Land Transportation

Road Transportation Network

The economic history of Libya is largely the story of the opening of its vast area by various forms of transport resulting in economic growth which, in turn, stimulated the demand for transport. At first the European traders were content to operate solely along the coast through African agents who used caravans as their mode of transport.

The beginning of modern transportation dates from the 1920s, but until World War II the country had only a very restricted road network along the coast, with a few minor roads serving the interior. By 1952 some 800 miles of rural farm roads were constructed to connect the regions of Tripoli and Benghazi with certain interior points. Under the five-year plan, 1954-1959, the sum of LD 13,325 was ear-marked for road development work. This sum included substantial amounts for the provision of new roads into agricultural areas as well as amounts for improvement for existing roads.

Only in 1959 did the government consider opening the Sahara by building a new road into the Fezzan. This road

Table 7. Development Fund Allocation per Sector: Estimates for the Period 1973-1975.

	Sector	Estimates of 73/75 in Libyan Dinars
1.	Agriculture and agricultural reform	137,906,000
2.	Agricultural development	278,128,000
3.	Industry and mineral wealth	238,128,000
4.	Petroleum	164,564,000
5.	Electricity	190,513,-00
6.	Transport and communications	190,332,000
7.	Education and teaching	189,290,000
8.	Public health	70,963,000
9.	Labor	24,343,000
10.	Youth and social affairs	14,046,000
11.	Housing and utilities	277,850,000
12.	Economy and tourism	9,280,000
13.	Information and culture	29,365,000
14.	Local administration	129,968,000
15.	Planning	3,900,000
16.	Administration development	2,515,000
17.	Reserves for projects	23,883,000
	Total LD	1,965,000,000

Source: Libyan Arab Republic, Ministry of Information, Achievements of the First of September Revolution. (Tripoli: Government Printing Office, 1973)

Table 8. Development Fund Allocations by Sector, 1973

	Sector	Allocation in the 1973 Budget in LD
1.	Agriculture and agricultural reform	39,923,000
2.	Agricultural development	65,450,000
3.	Industry and mineral wealth	79,777,000
4.	Petroleum	36,370,000
5.	Electricity	58,105,000
6.	Transport and communications	53,304,000
7.	Education and teaching	48,207,000
8.	Public health	16,712,000
9.	Labor	6,596,000
10.	Youth and social affairs	4,011,000
11.	Housing and utilities	76,900,000
12.	Economy and tourism	2,720,000
13.	Information and culture	7,868,000
14.	Local administration	41,380,000
15.	Planning	1,400,000
16.	Administration development	555,000
17.	Reserves for projects	5,852,000
	Total	545,000,000

Source: Libyan Arab Republic, Ministry of Information, Achievements of the First of September Revolution. (Tripoli: Government Printing Office, 1973)

followed the route of former motorable tracks from a point on the coastal road at Bugreen to Sabha, the capital of Sabha province. The road was planned to extend from Sabha to Ghat and the Algerian border and from Sabha to the south west across the desert to Kufra Oasis (Figure 8).

In 1966 the Libyan government undertook the construction of a major road paralleling the coast, a modern highway scheduled to cost LD 27 million. This road, completed in 1972, extends from the Tunisian border to the frontier with the Arab Republic of Egypt. In 1975 the total road mileage of the entire country is 9,779 miles, of which 3,559 are paved roads.[1] The remainder are unpaved roads and desert tracks.

At the present time most parts of the country are now served by at least one road, although the concentration of roads is much heavier in the two nothern regions compared with the southern regions (Figure 9).

Motor Vehicle Trends

The higher level of capital expenditure devoted to improving the Libyan road system is paralleled by the rapid rise in the number of private and commercial motor vehicles in Libya (Table 9).

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[1]Libyan Arab Republic, Ministry of Transportation and Communications, Planning Department, Report on Road Construction. (Tripoli: Government Printing Office, 1975), p. 19.

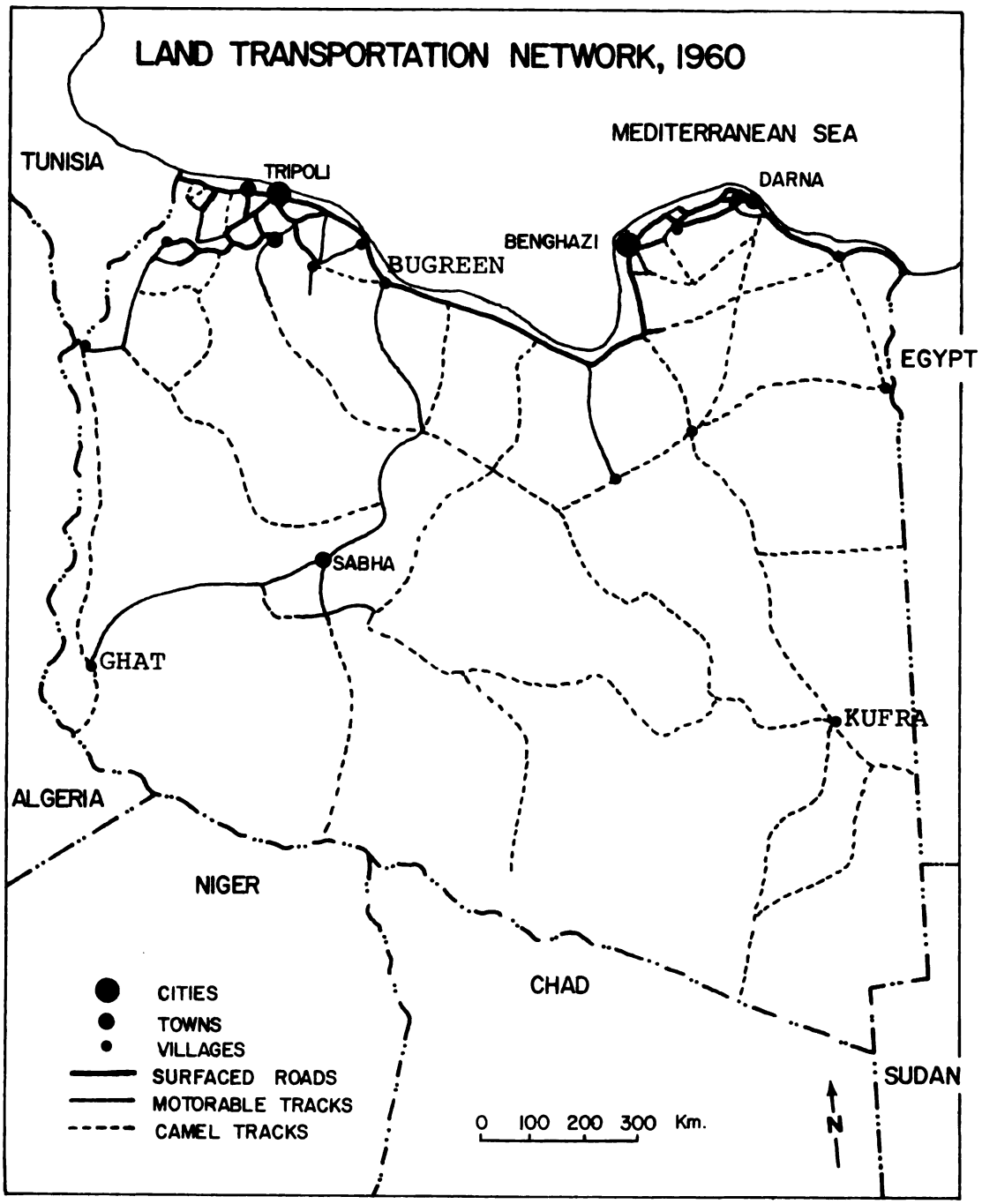
LAND TRANSPORTATION NETWORK, 1960
MEDITERRANEAN SEA
TUNISIA
TRIPOLI
DARNA
BENGHAZI
BUGREEN
EGYPT
SABHA
GHAT
KUFRA
ALGERIA
NIGER
CHAD
SUDAN
CITIES
TOWNS
VILLAGES
SURFACED ROADS
MOTORABLE TRACKS
CAMEL TRACKS
0 100 200 300 Km.
N

Figure 8.

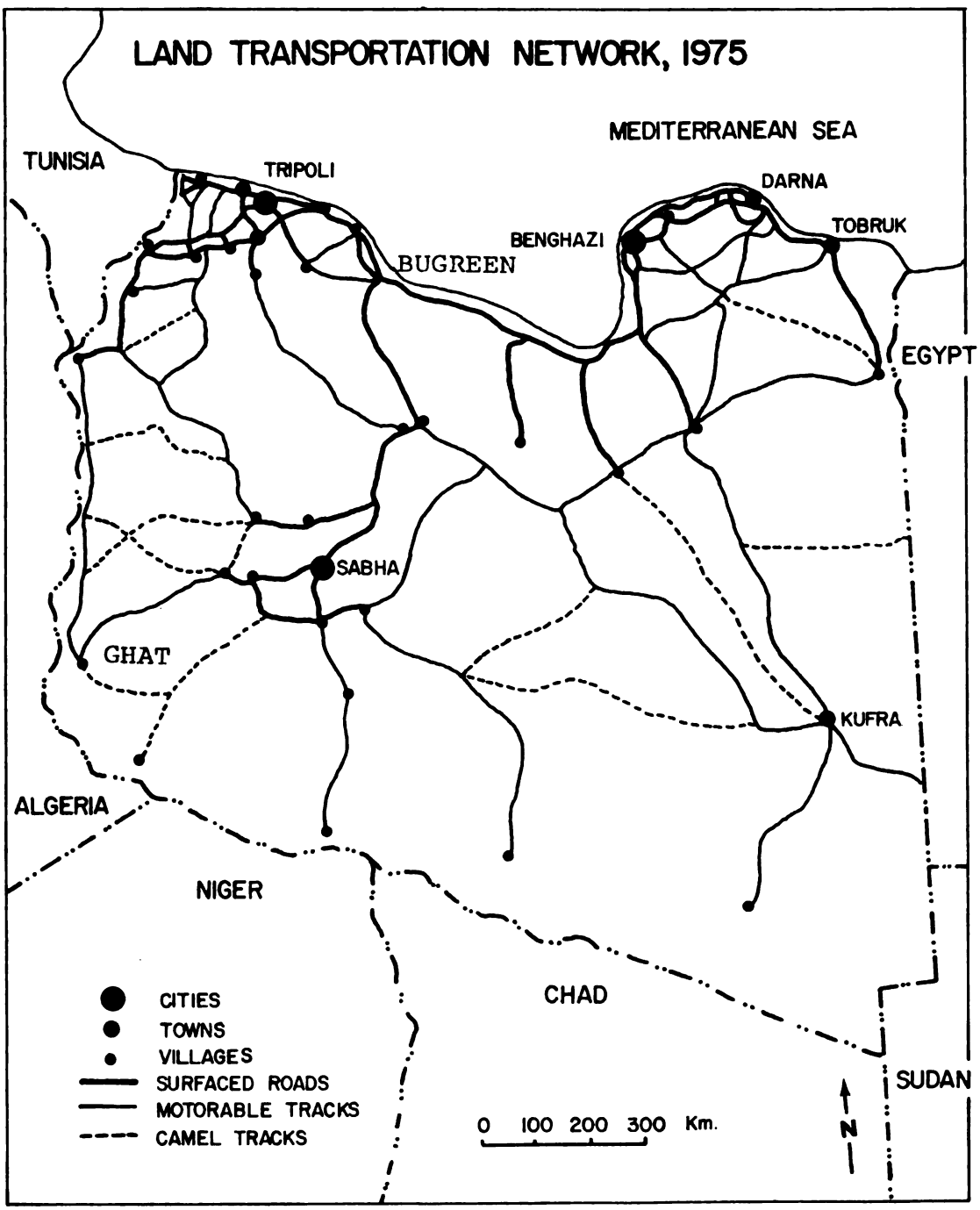
LAND TRANSPORTATION NETWORK, 1975
MEDITERRANEAN SEA
TUNISIA
TRIPOLI
DARNA
BENGHAZI
TOBRUK
BUGREEN
EGYPT
SABHA
GHAT
KUFRA
ALGERIA
NIGER
CHAD
SUDAN
CITIES
TOWNS
VILLAGES
SURFACED ROADS
MOTORABLE TRACKS
CAMEL TRACKS
0 100 200 300 Km.
N

Figure 9.

Table 9. Number of Vehicles Registered in Libya by Type, 1962-1971

Period	Private Automobiles	Taxis	Buses	Trucks	Total
1962	23,274	477	482	12,533	35,766
1963	27,879	829	507	14,994	47,209
1964	33,575	1,390	516	17,592	53,073
1965	40,199	2,126	532	20,196	65,053
1966	50,555	2,446	278	24,625	97,904
1967	60,292	2,921	617	28,960	92,790
1968	73,579	3,731	700	34,547	112,557
1969	86,814	3,884	727	39,947	130,572
1970	95,762	4,367	820	44,582	145,431
1971	110,312	4,703	877	50,435	166,377

Source: Libyan Arab Republic, Ministry of Planning, Statistical Abstracts, 1971. (Tripoli: Government Printing Office, 1971), p.299.

Table 9 shows that the total number of vehicles in Libya has increased about 464 percent from 1962-1971, or an average of 13,000 vehicles per year. A breakdown of these trends by vehicle type during the period 1962 to 1971 indicates several important sub-themes. The number of private cars increased from 23,224 in 1962 to 110,312 in 1971, an increase of about 474 percent, or an average of 8,700 vehicles per year. The number of taxis increased from 482 in 1962 to 4,703 in 1971 an increase of 985 percent or an average of 4,200 vehicles per year. The number of buses increased from 12,533 in 1962 to 50,435 in 1971, an increase of 500 percent or an average of 3,700 vehicles per year.

The rapid increase in such a short time of all vehicles is significant, but this is especially so for taxis and passenger cars. Public transportation, as represented by buses, has not increased as rapidly as private forms.

Although the annual rate of increase in motor vehicles is high, the increase was not evenly distributed throughout the country. It is concentrated in the urban centers. For example, in 1970 Tripoli City accounted for more than 60 percent of the total number of vehicles registered in Tripoli province and 30 percent of the total number of vehicles registered in the country. Benghazi accounted for more than 50 percent of vehicles registered in Benghazi province and 12 percent of the total number of vehicles in the country. Misurata City accounted for more than 55 percent of the total number of vehicles registered in Misurata province, and 12 percent of the total vehicles registered in the country, while Sabha City accounted for more than 60 percent of the total number of vehicles registered in Sabha province and 7 percent of the total vehicles registered in the country.[2]

The average age of vehicles is low, reflecting recent growth and short life span, not exceeding four or five years for private cars, three years for trucks, three years for buses and two years for taxis. This short vehicle life span

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[2]Libyan Arab Republic, Ministry of Transportation and Communication, Driver Licensing Department, Report on Motor Vehicles Registration. (Tripoli: Government Printing Office, 1970).

is due to the following factors: problems of the physical conditions of roads, high accident rates resulting from speeding and lack of traffic law enforcement, the predominance of unsafe vehicles in bad repair, largely reflecting bad maintenance, the heavy incidence of over loading trucks, and the high accident rates resulting from dangerous road design.

Motor Vehicle Accidents

A major problem of Libyan roads is the number of accidents (Table 10).

Table 10. Number of Accidents, Persons Injured and Killed, and Estimated Damage, 1962-1971

Year	No. of Accidents	No. of Persons Killed	No. of Persons Injured	Estimated Damage to Vehicles and Property (In Libyan Dinars)
1962	4,939	146	2,063	161,880
1963	5,958	205	2,196	194,052
1964	6,768	230	3,150	176,719
1965	6,875	252	3,117	243,131
1966	8,416	306	4,071	270,680
1967	9,336	353	4,390	419,463
1968	8,890	377	4,554	377,463
1969	9,570	361	5,898	552,282
1970	9,336	423	5,828	445,129
1971	12,413	375	7,992	1,179,163

Source: Libyan Arab Republic, Ministry of Planning, Statistical Abstracts, 1971. (Tripoli: Government Printing Office, 1971), p. 300.

From the table the great increase in the number of road accidents, number of passengers injured and killed, and the estimated damage is clear. This increase is related to the rapid increase in the number of motor vehicles, as well as other factors such as road conditions.

Traffic Movement and Transportation Cost

Traffic Movement

Freight or commodity movement has increased rapidly in importance in the Libyan economy during the past ten years. Accurate data on road transport are not available in Libya and are difficult to estimate because of the many small firms in the industry. Data are available, however, for total freight carried by trucks during the period 1962-1971 (Table 11).

Table 11. Total Freight Carried by Truck, 1962-1971

Year	Number of Trucks	Total Freight Carried (In Tons)
1962	12,533	62,404
1963	14,994	94,518
1964	17,592	106,595
1965	20,196	116,995
1966	24,625	134,349
1967	28,960	151,969
1968	34,547	172,651
1969	34,947	186,377
1970	44,582	196,876
1971	50,435	207,113

Source: Libyan Arab Republic, Ministry of Planning, External Trade Statistics, 1971. (Tripoli: Government Printing Office, 1971), p. 299.

Detailed measurement of the movement of freight and traffic is necessary for national planning of future highway systems. For Libya, two bodies of traffic flow data are available. The first set of traffic flow data was obtained in 1964, when the Ministry of Planning and Development of Libya charged Doxiades Associates with carrying out a project entitled "General Survey and Study of the Means of Communications."[3] The second acquisition of traffic flow data was obtained, again for a specific sixteen-hour period, on March 1972 by the Ministry of Transportation.[4] A comparison between these two sets of data is presented in Figures 10, 11, 12. These figures indicate the following two important results. First, they give a strictly comparable picture of rapid growth in the movement of freight, passenger, and motor vehicles on the national road system between the two time periods. Second, they show the high concentration of traffic movement adjacent to the principal urban centers along the coastal road, such as Tripoli and Benghazi.

Rate Structure. For freight traffic, the rate structure is controlled by the Board of Rate Control of the Ministry of the Economy (BRCME), under government act number

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[3]A part of this study was devoted to traffic counts and information on the origin and distination of traffic. Interviews were carried out over a sixteen-hour period on August 1964.

[4]Libyan Arab Republic, Ministry of Transportation, Road Department. Official Documents. (Tripoli, 1972).

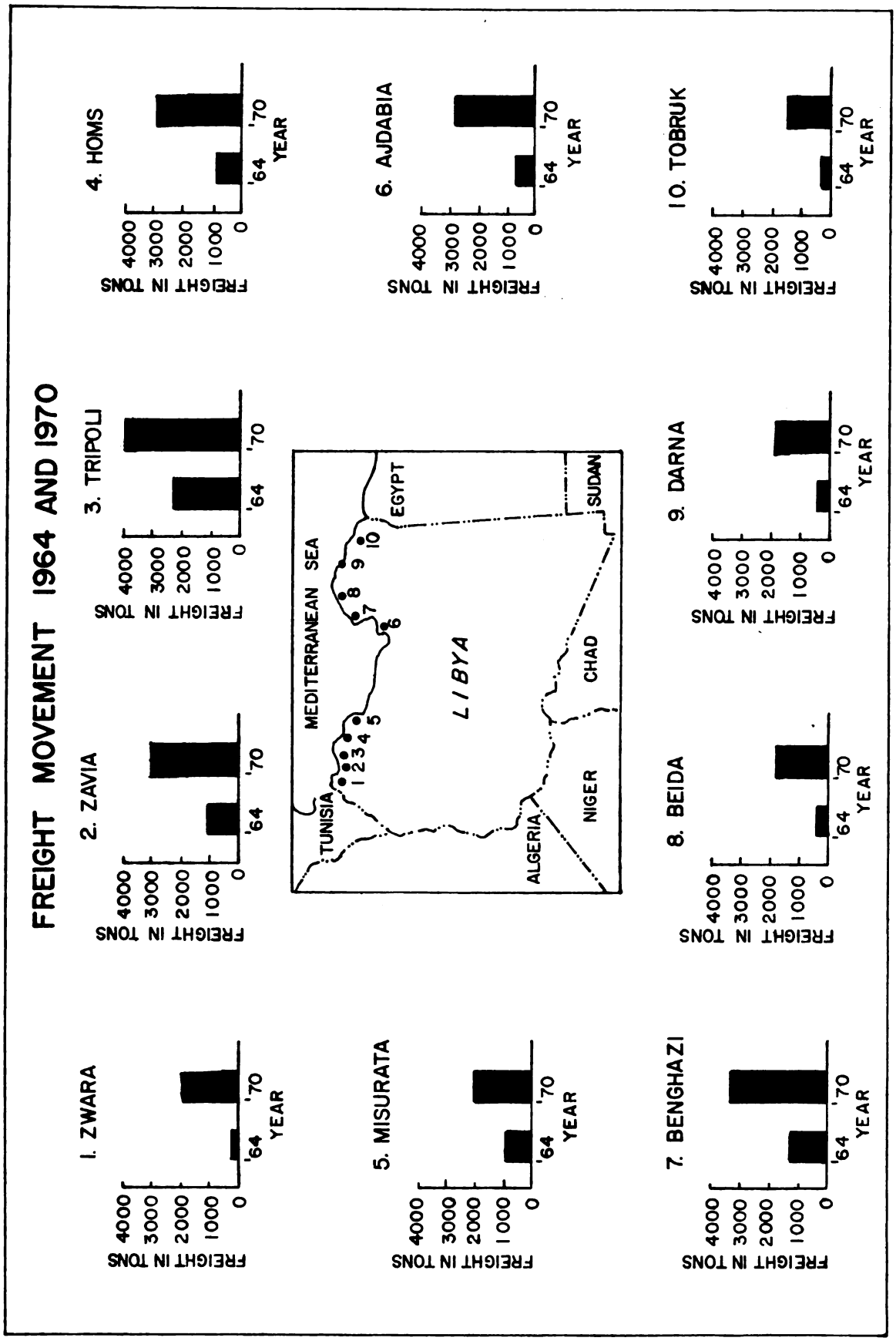
FREIGHT MOVEMENT 1964 AND 1970
1. ZWARA
2. ZAVIA
3. TRIPOLI
4. HOMS
5. MISURATA
6. AJDABIA
7. BENGHAZI
8. BEIDA
9. DARNA
10. TOBRUK
FREIGHT IN TONS
4000
3000
2000
1000
0
'64
'70
YEAR
MEDITERRANEAN SEA
TUNISIA
ALGERIA
LIBYA
EGYPT
SUDAN
NIGER
CHAD
1
2
3
4
5
6
7
8
9
10

Figure 10.

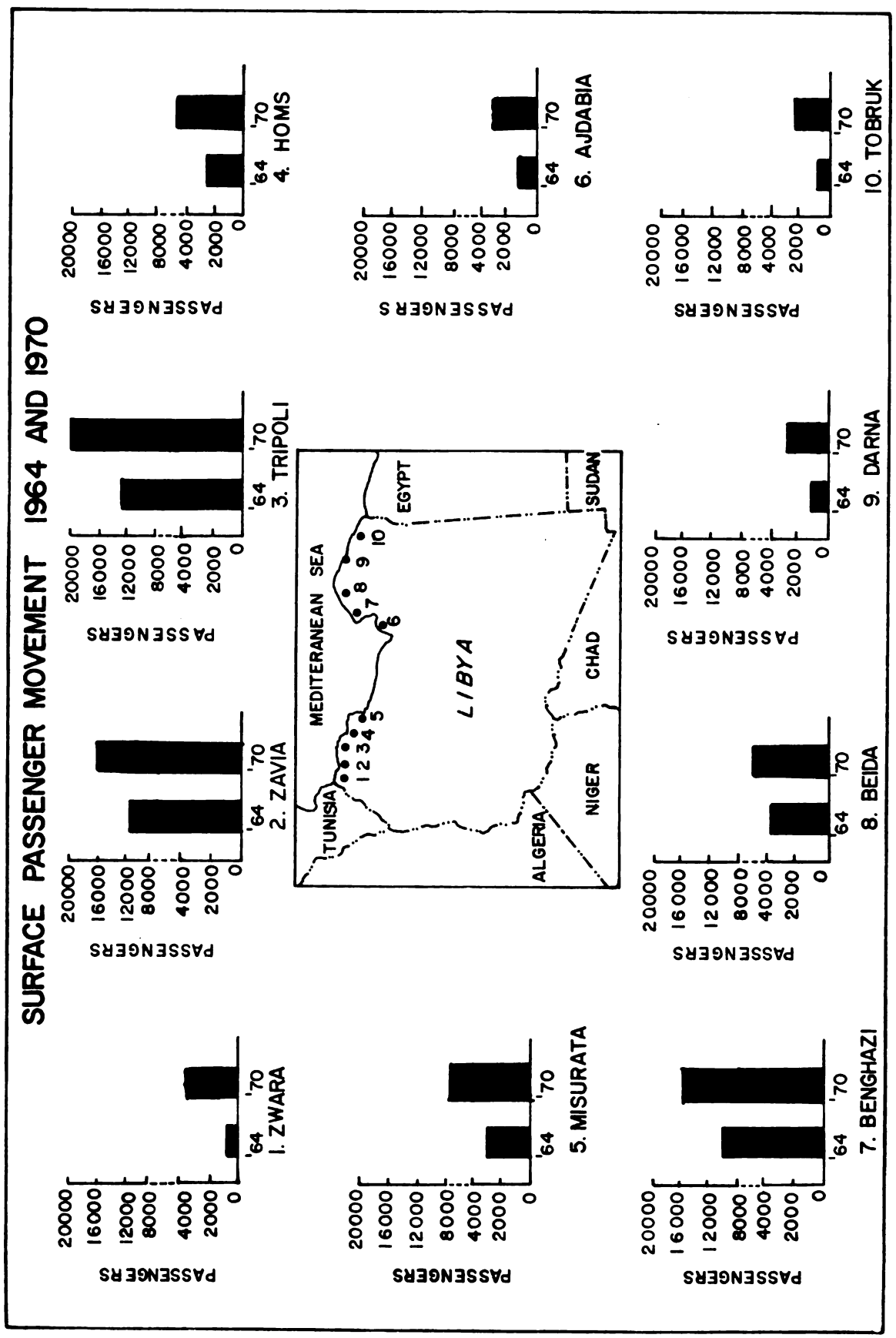
SURFACE PASSENGER MOVEMENT 1964 AND 1970
1. ZWARA
2. ZAVIA
3. TRIPOLI
4. HOMS
5. MISURATA
6. AJDABIA
7. BENGHAZI
8. BEIDA
9. DARNA
10. TOBRUK
PASSENGERS
20000
16000
12000
8000
4000
2000
0
'64
'70
MEDITERANEAN SEA
LIBYA
TUNISIA
ALGERIA
NIGER
CHAD
SUDAN
EGYPT
1
2
3
4
5
6
7
8
9
10

Figure 11.

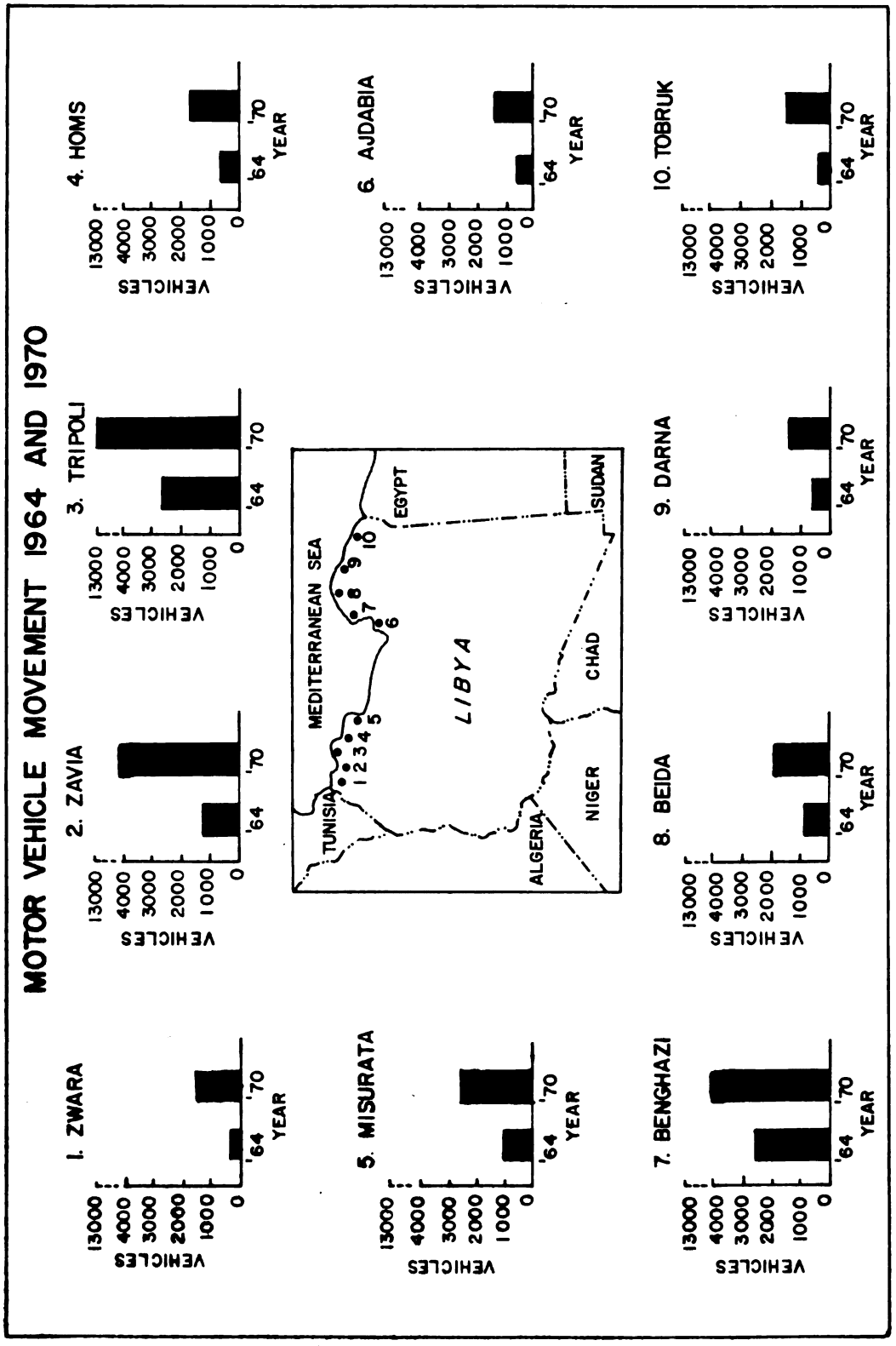
MOTOR VEHICLE MOVEMENT 1964 AND 1970
1. ZWARA
2. ZAVIA
3. TRIPOLI
4. HOMS
5. MISURATA
6. AJDABIA
7. BENGHAZI
8. BEIDA
9. DARNA
10. TOBRUK
VEHICLES
YEAR
'64
'70
0
1000
2000
3000
4000
13000
MEDITERRANEAN SEA
TUNISIA
ALGERIA
LIBYA
EGYPT
SUDAN
CHAD
NIGER
1
2
3
4
5
6
7
8
9
10

Figure 12.

27 of 1974. The following is a detailed breakdown of the rate structure:

1. If the distance is more than 150 km:
   A. On the Coastal road from Msaid on the Egyptian border to Abokamash on the Tunisian border, and on the Fezzan road from Sabha to Bugreen the revenue for one ton-km is as follows:
      17 Dirhams per ton-km for the first 200 km.
       9 Dirhams per ton-km for the second 200 km.
       8 Dirhams per ton-km for more than 400 km.
   B. In the mountain areas between Benghazi and Darna, the average revenue for ton-km is as follows:
      25 Dirhams per ton-km for the first 200 km.
      15 Dirhams per ton-km for more than 200 km.
2. In the Coastal areas where the distance is less than 150 km:
      25 Dirhams per ton-km for the first 60 km.
      12 Dirhams per ton-km from 61 km to 150 km.

However the BRCME allows a higher rate, of up to 40 dirhams per ton-km, on nonpaved roads and on Garian province roads. This is because of special problems such as the short life of vehicles that operate on nonpaved roads compared with those that operate on paved roads,[5] empty

[5]Libyan Arab Republic, Ministry of Transportation and Communication, Report on Transportation Cost, 1974. (Garian: Government Printing Office, 1974).

return trips, length of time consumed, and road conditions. Figure 13 illustrates differential transportation costs in the northwestern region in Libya.

The rate structure for buses, in contrast, is based on distance alone. the quality of road does not have much influence on fares because most of the buses usually operate on good roads. Furthermore, the bus lines are operated by the government authorities, who determine the fares. Bus passengers pay an average fare per kilometer based on distance alone. For example, the rate for a trip under 200 km is 3.5 dirhams per km. and for a trip over 200 kms, the rate is 3.6 dirhams per km.

Air Transport

As has been ponnted out above, Libya is a country of great distances. In the absence of satisfactory land transportation in certain areas, there is little alternative but to employ air transport for connecting certain parts of the country with one another. Additionally Libya occupies a strategic position, lying at the crossroads of two great continents: Africa and Europe. Both these features foster the development of aviation, both on an internal and an international scale.[6]

Local aviation was developed in Libya after the first World War. The Italians were responsible for its operation

[6]Doxiades Associates, Transport in Libya, p. 212.

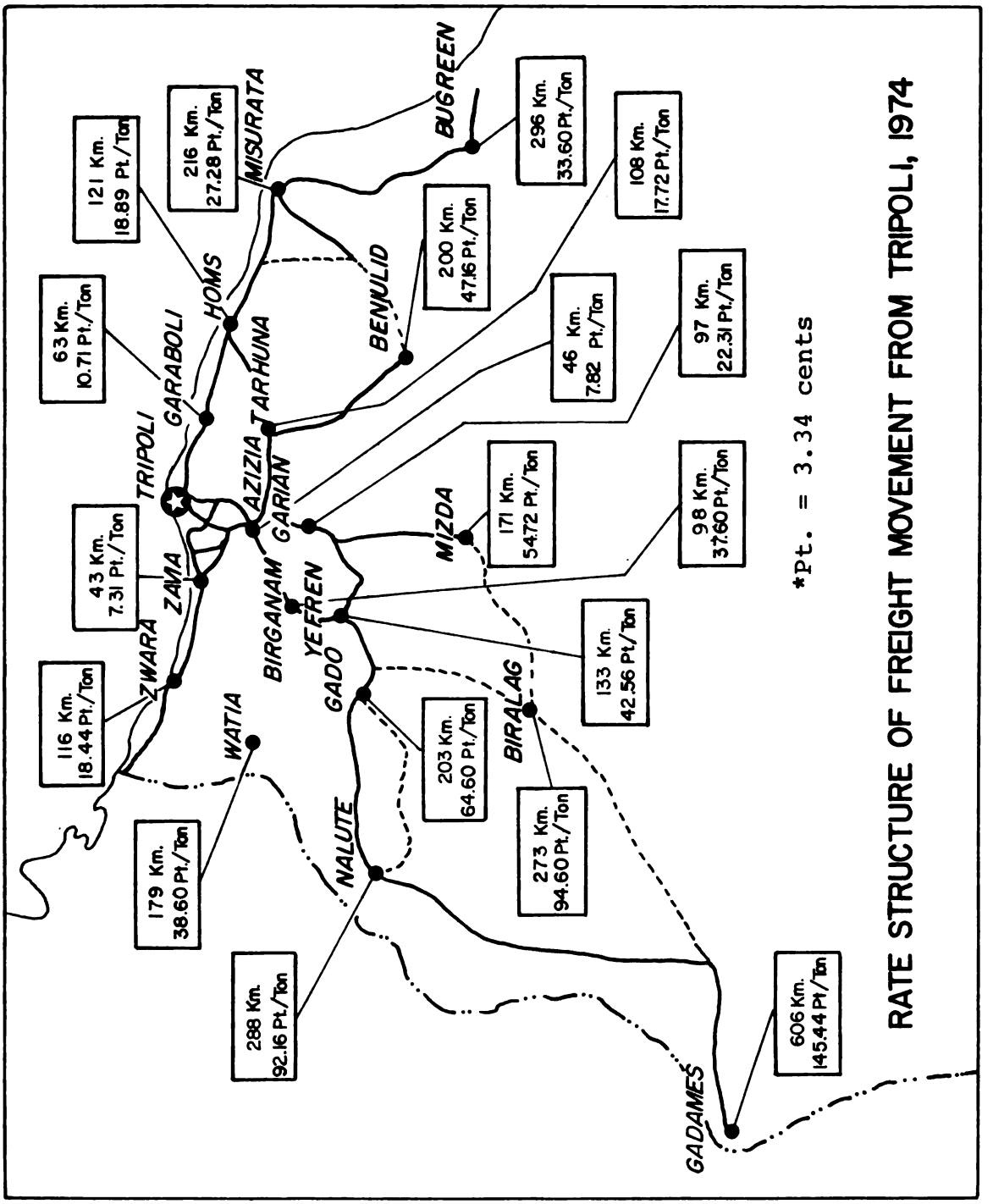
RATE STRUCTURE OF FREIGHT MOVEMENT FROM TRIPOLI, 1974
*Pt. = 3.34 cents
TRIPOLI
GARABOLI
HOMS
MISURATA
BUGREEN
TARHUNA
AZIZIA
GARIAN
BENULID
MIZDA
ZAMA
ZWARA
YEFREN
BIRGANAM
GADO
BIRALAG
NALUTE
WATIA
GADAMES
121 Km. 18.89 Pt./Ton
216 Km. 27.28 Pt./Ton
296 Km. 33.60 Pt./Ton
63 Km. 10.71 Pt./Ton
200 Km. 47.16 Pt./Ton
108 Km. 17.72 Pt./Ton
46 Km. 7.82 Pt./Ton
97 Km. 22.31 Pt./Ton
43 Km. 7.31 Pt./Ton
171 Km. 54.72 Pt./Ton
98 Km. 37.60 Pt./Ton
116 Km. 18.44 Pt./Ton
133 Km. 42.56 Pt./Ton
203 Km. 64.60 Pt./Ton
179 Km. 38.60 Pt./Ton
273 Km. 94.60 Pt./Ton
288 Km. 92.16 Pt./Ton
606 Km. 145.44 Pt./Ton

Figure 13.

primarily for military purposes. These operations were stopped after World War II by the British Royal Air Force.

By 1965 there were seventeen international airlines providing services from Tripoli and Benghazi airports to European countries and the United States, with fairly frequent services by major airlines, such as BOAC operating from Tripoli, Benghazi, London and Aden, and Alitalia to Rome. However, only the major centers of Libya received regular service.

In March 1966, the Libyan government inaugurated the government airline, beginning with two single small jet aircraft which linked Tripoli and Benghazi and the towns of the coastal belt such as Misurata, Marsa briga, and Tobruk with the interior towns such as Sabha, Gadames, Ghat and Kufra (Figure 14).

All regular services are operated by the Libyan Arab Airlines, except for the oil field routes on which services are provided by the oil companies themselves.[7] By 1974 the Libyan Arab Airlines provided daily connections between the main airports and at least weekly connections between main airports and secondary airports (Figure 15).

The principal airports of Libya are Tripoli, 13 miles from Tripoli City, Benina Airport, 13 miles from Benghazi

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[7]These companies are Esso Standard, Mobil, Lanco, Lienur, Accidental, Automobile, and Oasis.

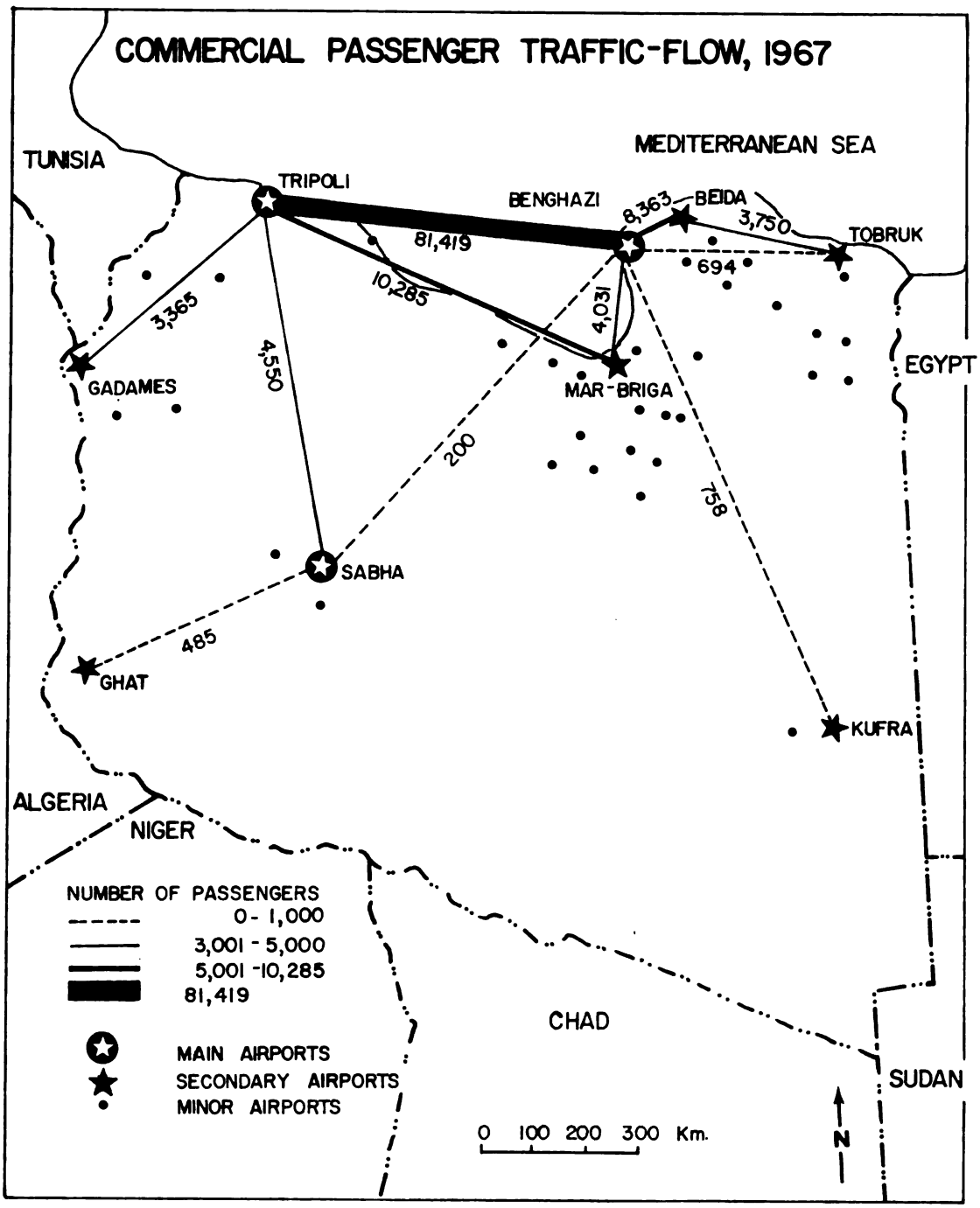
COMMERCIAL PASSENGER TRAFFIC-FLOW, 1967
MEDITERRANEAN SEA
TUNISIA
TRIPOLI
BENGHAZI
BEIDA
TOBRUK
EGYPT
GADAMES
MAR-BRIGA
SABHA
GHAT
KUFRA
ALGERIA
NIGER
CHAD
SUDAN
81,419
8,363
3,750
694
10,285
4,031
3,365
4,550
200
758
485
NUMBER OF PASSENGERS
0 - 1,000
3,001 - 5,000
5,001 -10,285
81,419
MAIN AIRPORTS
SECONDARY AIRPORTS
MINOR AIRPORTS
0 100 200 300 Km.
N

Figure 14.

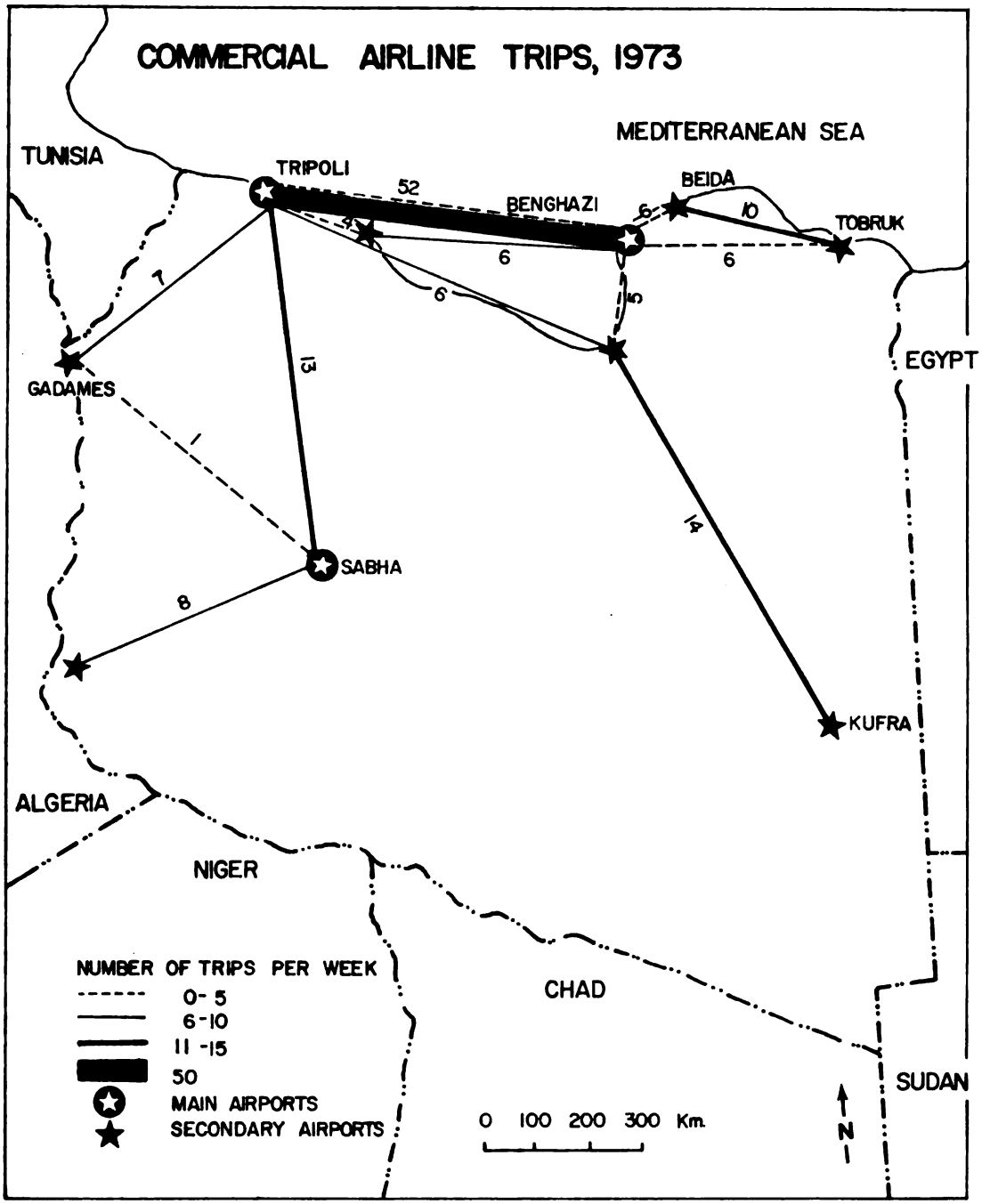
COMMERCIAL AIRLINE TRIPS, 1973
MEDITERRANEAN SEA
TUNISIA
TRIPOLI
52
BENGHAZI
BEIDA
TOBRUK
EGYPT
GADAMES
SABHA
KUFRA
ALGERIA
NIGER
CHAD
SUDAN
NUMBER OF TRIPS PER WEEK
0-5
6-10
11-15
50
MAIN AIRPORTS
SECONDARY AIRPORTS
0 100 200 300 Km.
N

Figure 15.

City, and Sabha Airport in the Fezzan. Both Tripoli and Benghazi Airports are able to handle the large modern jet aircraft operated by major airlines while the Sabha Airport is limited to handling smaller aircraft. Tripoli Airport handles about 54 percent of the total passenger traffic and 80 percent of total internal freiqht traffic while the remainder is handled by Benghazi Airport and other secondary airports. These airports were nationalized beginning in 1969; since 1973 all are operated by the Ministry of Transportation.

CHAPTER IV

GRAPH THEORY ANALYSIS OF THE LIBYAN HIGHWAY NETWORK

In contrast to the preceding chapters, which were descriptive in orientation, the focus of this chapter is analytic; its purpose is to provide a better understanding of the topological structure of the Libyan highway network. Since the amount of information available about the network is limited, the graph theoretic measurement is particularly useful. More specifically, graph theory is used to analyze the expansion of the Libyan highway network from 1960 projected to 1985.

The Expansion of the Libyan Highway Network

In order to measure the expansion of the Libyan highway network, the study is conducted from the point of view of topological analysis, instead of being organized as a simulation procedure. The latter requires data such as demographic and technological information which is not available.[1]

Although the graph theoretic model of the network

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[1]E. J. Taaffe, and H. L. Gauthier, Jr. Geography of Transportation. (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1973, p. 112.

structure proves to be strong in some areas of measurement and evaluation, it is disappointingly weak in others. In the absence of information to evaluate the network as a visual graph, graph theory is the most suitable method of evaluating the expansion of the Libyan highway network.

There are many studies which provide a frame of reference for this type of analysis. Among these are: "Graph Theoretic Concepts," by W. L. Garrison and D. F. Marble,[2] "Linkages Importance in a Regional Highway Network," by C. C. Kissling,[3] "Measure of Network Structure," by Karl Kansky,[4] "Structural Analysis of Transportation Networks: Measure of Nodal Accessibility," by E. Taaffe and H. L. Gauthier, Jr.[5]

Most of these works suggest that graph theory is the best method of evaluating and recording changes in any network abstracted as a graph composed of number of edges and vertices. Furthermore, the necessary data to carry out such a procedure can be obtained directly by cartographic analysis.[6]

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[2]Michael E. Eliot Hurst, Transportation Geography: Comments and Readings, (New York: McGraw-Hill, 1974), pp. 58-80.

[3]Ibid., pp. 92-111.

[4]Chapter 1 in Kansky, K. J., Structure of Transportation Networks,(Chicago: University of Chicago, Department of Geography Research Paper No. 84),pp. 5-30.

[5]E. J. Taaffe, and H. L. Gauthier, Jr. Geography of Transportation, pp. 116-

[6]For convenience in the graph theory analysis the term "edge" will be used instead of "link," and "vertex" will be used instead of "node."

The analysis is carried out in terms of the following hypothesis:

Graph theory shows no significant expansion between the 1960 and 1975 networks, while there is a significant expansion when the proposed highway network for 1985 is compared with 1960 and 1975 highway networks.

In order to apply graph theory to this study, the Libyan highway system is presented as three graphs, the first graph focuses upon the 1960 regional highway network which is composed of 54 edges terminating at 45 vertices (Figure 16). The second graph focuses upon the 1975 regional highway network which is composed of 84 edges terminating at 66 vertices (Figure 17), while the third graph focuses on the proposed regional highway network which is composed of 130 edges terminating at 79 vertices (Figure 18).

The study is based on the following data sources: 1) the data for the 1960 network is obtained from The Economic Development of Libya;[7] 2) the data for the map of the regional highway network of 1975 were obtained from an official Ministry of Libyan Transportation map;[8] 3) the proposed map for the 1985 regional highway network is the author's design, based on the amount of expenditure devoted to the long term plan for construction of Libyan highways

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[7]International Bank for Reconstruction and Development, The Economic Development of Libya, p. 230.

[8]Libyan Arab Republic, Ministry of Transportation and Communication, Official Map, (Tripoli: Government Printing Office, 1974).

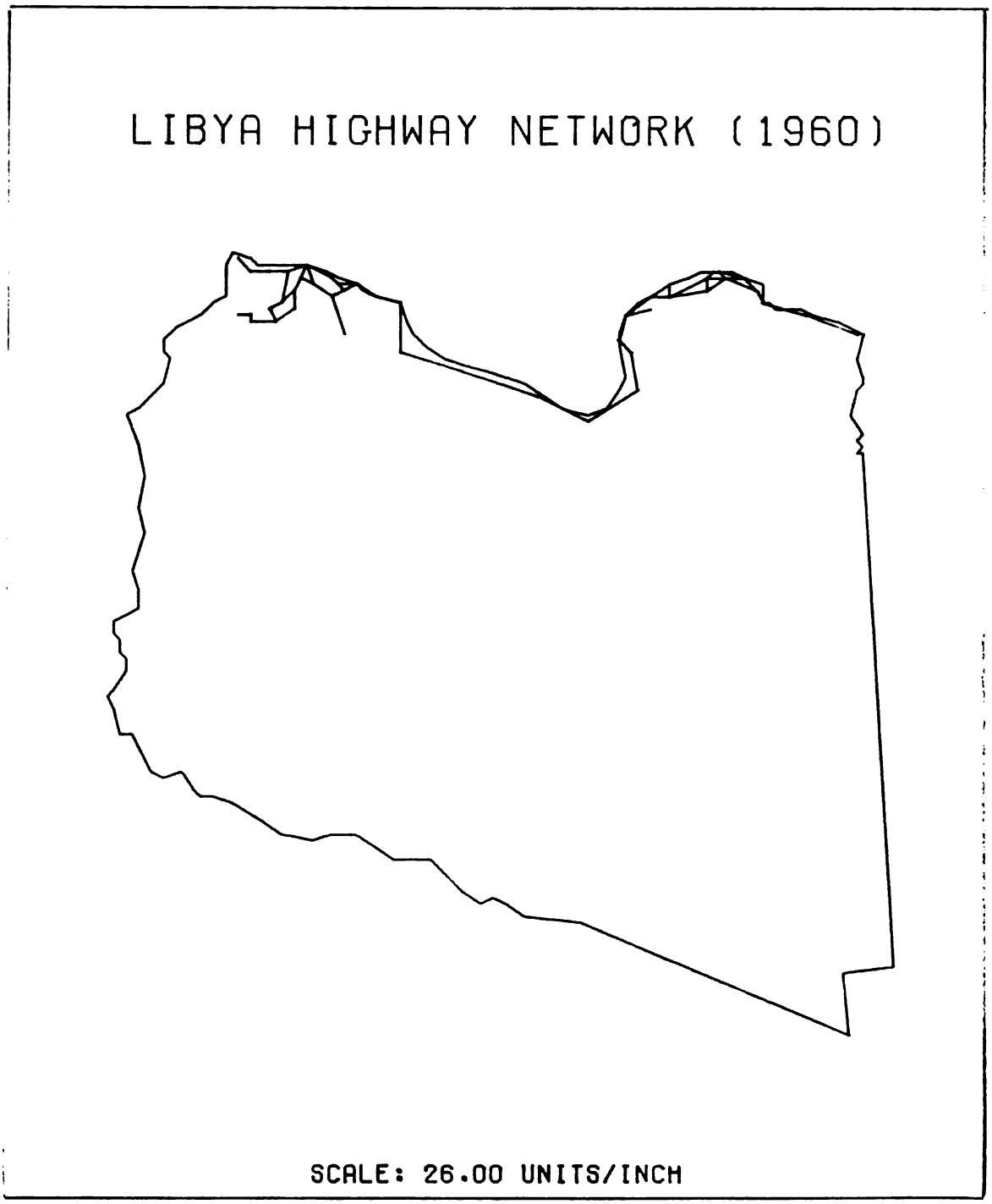


Figure 16.

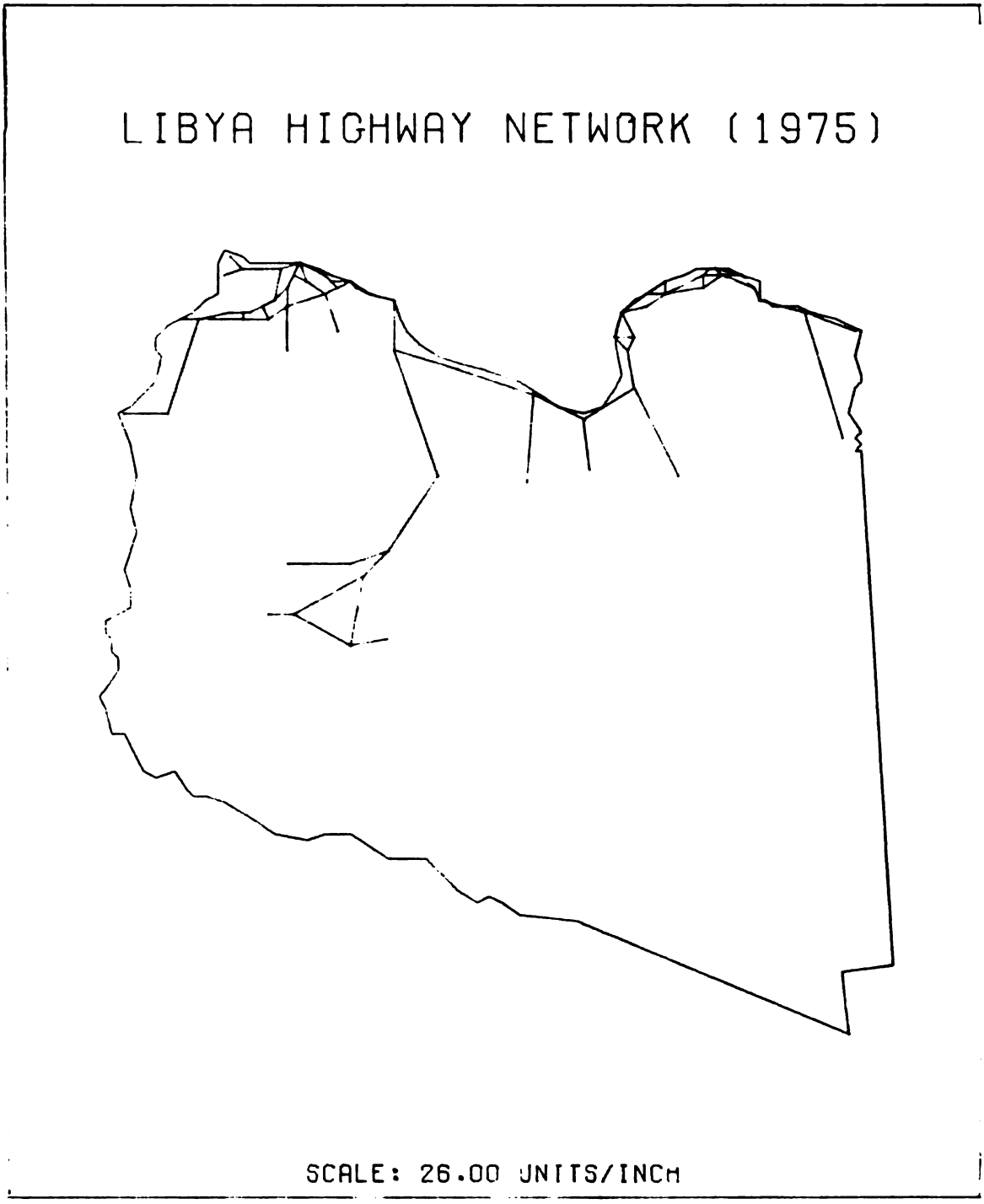


Figure 17.

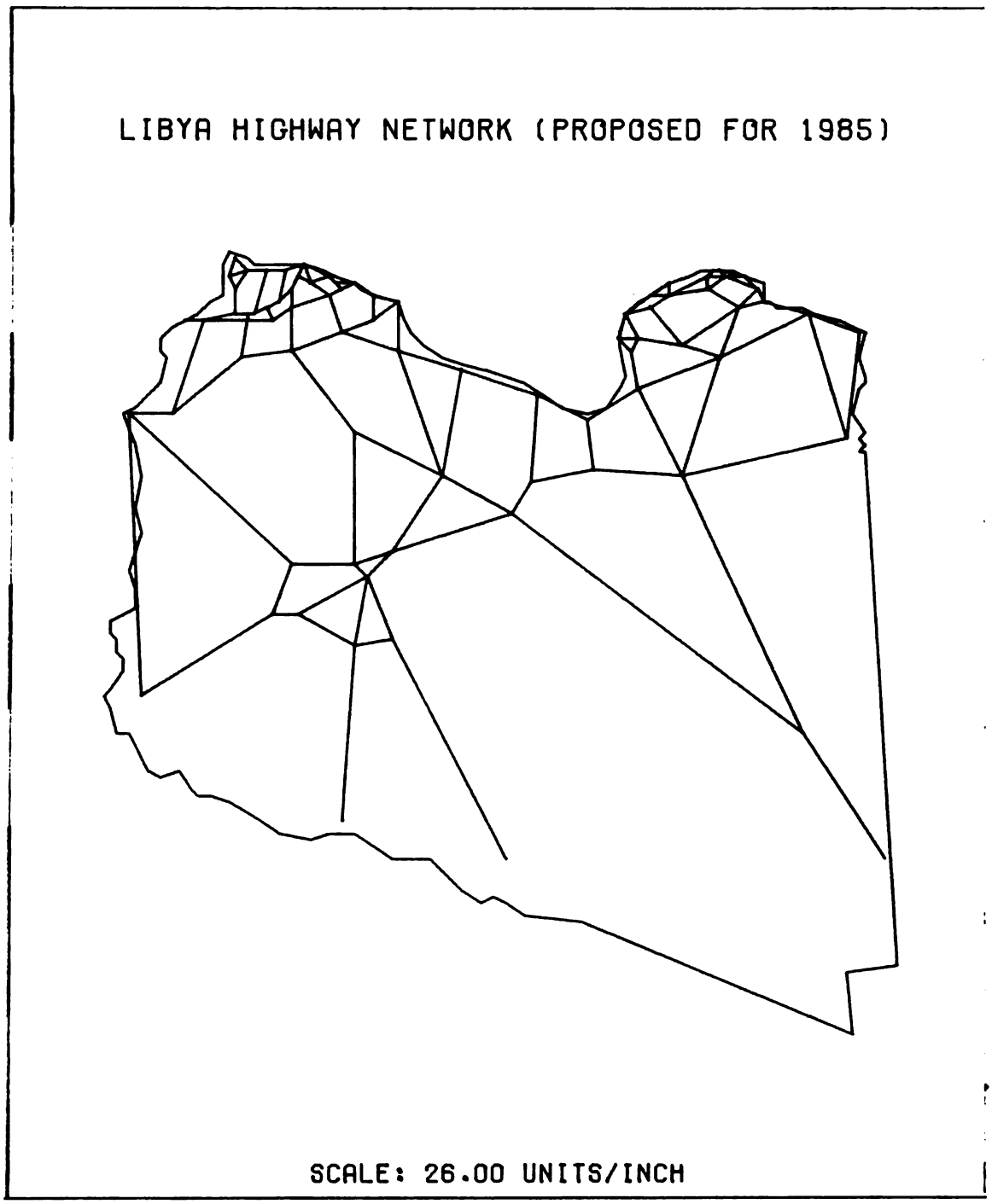
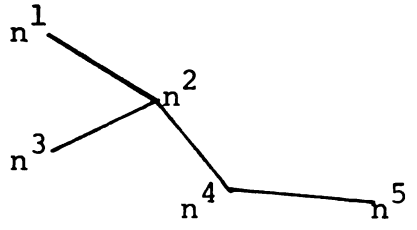

LIBYA HIGHWAY NETWORK (PROPOSED FOR 1985)
SCALE: 26.00 UNITS/INCH

Figure 18.

(see Appendix II). The identification of nodes in the 1985 network was partly topological and partly based on urban criteria, because the graph is a planner graph, that is, all intersections appear on the graph as nodes on the network. Most of the new intersections on the regional highway system have not developed to the degree to which they might even be considered small villages. Rather, they are chosen because they provide services to travelers, such as gasoline and food, even though they do not generate traffic themselves. For example, some of these points are Bogreen, Jalo, Mazda, Uadan, Fiada, Magrun; their only function is as a gas station site or source of water in the desert and other remote areas. However, in areas where urban size criteria exist the higher population and situation of the node play an important consideration in terms of including them in the Libyan highway network.

Since any network or an abstraction of a network such as a graph (Figure 19) may be presented as a matrix (Figure 20), in any graph with n vertices the connection matrix is a n x n matrix where each row and each column correspond to a specific vertices in the graph. The elements of the matrix are zero (0) or one (1) depending upon the existence or nonexistence of a link directly connecting the two vertices. If a linkage exists between any given pair of nodes, the value of 1 is entered. On the other hand, if no direct linkage exists between any two given nodes the value of 0 is recorded (Figure 20).



Graph Representation of a Small Network

Figure 19

	n^1	n^2	n^3	n^4	n^5
n^1	0	1	0	0	0
n^2	1	0	1	1	0
n^3	0	1	0	0	0
n^4	0	1	0	0	1
n^5	0	0	0	1	0

Connection Matrix of the Graph

Figure 20

Although the connection matrix (Figure 20) provides minimum information about whether there is a connection between nodes or not, by summing across rows or columns or by squaring the matrix until zeros disappear from the matrix except on the diagonal, resulting in a solution matrix, other results can be obtained.[9]

Definition of Variables

The following definitions are necessary:

1. A node is, for a planner graph, any intersection of links or terminal links.

2. A link is any connection between two nodes on which intersection could take place between those connected nodes.

3. Diameter, in topological terms, is the minimum number of linkages needed to connect the two farthest nodes in the network. It is the maximum associated number in the network. As the network becomes more connected, the diameter decreases.[10]

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[9]Michael E. Eliot Hurst, Transportation Geography: Comments and Readings, p. 62.

[10]E. J. Taaffe, and H. L. Gauthier, Jr. Geography of Transportation, p. 116.

4. A circuit is an additional link to the minimally connected network which is defined by the following formula

$$e - v + 1$$

where:

e = number of edges
v = number of nodes.

5. The cyclomatic number is the total number of circuits presented in a graph. As the graph becomes closer and closer to being completely connected, the cyclomatic number increases. The higher the value, the more connectivity in a network.

6. The redundancy ratio is a crude measure of the total number of circuits presented in a graph. The higher the value the greater the connectivity in the network.

7. The Alpha index is the ratio between the observed number of circuits and the maximum number of circuits in the network. The relationship is as follows:[11]

$$a = \frac{\text{actual circuits}}{\text{maximum circuits}} = \frac{e - v + 1}{2v - 5}$$

where:

a = Alpha index
v = Number of vertices
e = Number of edges.

when the network is minimally connected, a = 0
when the network is completely interconnected, a = 1.

8. The gama index is the ratio between the number of edges in the network to the maximum number of edges possible in the network. The relationship is as follows:

$$g = \frac{e}{3(v - 2)}$$

---

[11] E. J. Taaffe and H. L. Gauthier, Jr. Geography of Transportation, p. 104-105.

where:

g = the gama index
e = number of edges
v = number of nodes

The value of g ranges from 0 to 1. As the number of edges increases the g index approaches 1, and as the number of edges decreases the g index approaches 0.

9. The mean local degree is the mean number of a node connected to all other nodes in the network.

10. The dispersion index is the dispersion of a network (N)[12] which is defined by the following formula:

$$D(N) = \sum_{i=1}^{n} \sum_{j=1}^{n} d(i,j)$$

where:

d = distance (in miles or any other unit) from a vertix i to a vertix j)

From the formula, first calculate the sum of all values between a vertix i and all other vertices of the network (N) then sum all totals resulting from the first summation, the higher the value the more connection of the network.[13]

The above defined values for a small network of a limited number of nodes can be easily done, but for a large network, their computation is difficult even with the application of a computerized logarithm. While it would be ideal to employ a 100 x 100 matrix, that is 100 x 100 vertices, limitations of the computer available to the author restrict the analysis to 79 vertices.

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[12]K. J. Kansky. Structure of Transportation Networks, p. 30.

[13]Michael E. Eliot Hurst, Transportation Geography: Comments and Readings, p. 87 and 96.

Data for 79 nodes connected with 130 links were put on the CDC 6500 computer, then three different runs for three different networks for each of three different years were made. From the computations for the three graphs, the following values were obtained (Table 12).

Table 12. Computation of the Short Path Matrix for the Three Graphs of the Libyan Highway Network, 1960, 1975, 1985

Variables	1960	1975	1985
The number of nodes	45	66	79
The number of edges	54	83	130
Diameter	28	26	17
The system dispersion index	20234	43462	39792
The redundancy ratio	.1001	.1002	.1568
The mean local degree	2.40	2.52	3.29
The cyclomatic number	10.00	18.00	52.00
The alpha index	1.05	.87	1.73
The gama index	2.73	1.93	2.11

NOTE: For more information of each value for the three graphs see Appendix I.

Interpretation of the Results

The value in the above table show the change in the network. It is clear that expansion has taken place. The network is said to expand if there is an increase in the number of both nodes and links, or there is an increase in the number of links between nodes in an existing network.

Nodes and Edges. From the values associated with the number of nodes and edges for the Libyan highway network

for three separate years, and based on the definition of the expansion of the network, the degree of expansion is seen in the remarkable increase in both the number of nodes and links, and in links alone. This increase is from 45 nodes and 53 links in the 1960 network to 66 nodes and 83 links in the 1975 network and to 87 nodes and 130 links in the proposed network for 1985.

The Diameter. As is evident from the previous discussion of the diameter, the decrease in the diameter value means both an improvement in the connectivity and expansion of the network at the same time. The decrease was from 28 links in the 1960 network to 26 links in the 1975 network and to 17 links in the proposed network for 1985.

The Redundancy Ratio. This ratio is one of the most important measures in determining the expansion of the Libyan network, because it shows the crude measure of the total number of circuits in the network. Although the number of nodes increased, the redundancy ratio also increased from .1001 in the 1960 network to .1002 in the 1972 network and to .1568 in the proposed network for 1985. This means that the crude measure of the total number of circuits also increased, and some of the nodes are served by more than one link,[14] also an indication of network expansion.

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[14]The redundancy ratio between 1960 and 1975 was small, because in the 1975 network, the interest was in serving more nodes minimally than adding more links as in the network of 1985.

The Cyclomatic Number. As the network moves closer and closer to the completely connected graph, the cyclomatic number increases, so the cyclomatic values, which are presented in Table 12, also show the expansion of the network. This change is evidenced by the increase in the number of circuits from 10 circuits in the 1960 network to the 18 circuits in the 1975 network, and to 52 circuits in the proposed network for 1985.

The Dispersion Index. In terms of the dispersion index, the following can be noted. As both the number of nodes and links, or links only increase, the dispersion index value will either increase or decrease, depending on the type of increase in the network. For example as the associated number of the nodes gets smaller, the dispersion index also gets smaller and vice-versa. This previous example is evidenced by the higher value of the dispersion index for both the 1960 and 1975 networks--taking into consideration the number of nodes and links in each network--and lower value for the proposed network for 1985. Although the rate of expansion for the 1975 network resulted in a minimally connected network, the rate of expansion for the proposed network for 1985 was faced by improvement in connectivity of the network in terms of the associated number.

The Alpha Index. The alpha index results show the following: 1) a comparison between the computed value of alpha index for the three networks, shows a decrease in the

alpha index value from .05 in the 1960 network to .0087 in the 1975 network and increase in the alpha index value of the proposed network for 1985 to .073. 2) The decrease in the value of the alpha index for 1975 can be related to the decrease in the actual number of circuits needed to connect the 1975 network after its expansion in the southern region of Libya (Figure 17), while the value of alpha index for the proposed network for 1985 shows an increase in the number of circuits needed to connect maximally the network (Figure 18). 3) Since the increase in the number of nodes and links in the Libyan highway networks is not at the same rate, an increase or decrease in the alpha index value, is expected but with a comparison between the number of circuits in the three networks, the expansion becomes clear.

The Gama Index. The gama index is the ratio between the number of edges in the network to the maximum number possible in the network. As more nodes are added with minimum links to any given network, a decrease in the value of the gama index is expected, because in an underdeveloped country like Libya we are not interested in a highly connected network as much as we are interested in how to minimally link the points of activity in all of Libya. Hence the gama index value decreases as the number of nodes connected by a minimum highway network increases. This can be shown from the gama index value which is equal to 2.73 in the 1960 network, 1.93 in the 1975 network and 2.11 in

the proposed network for 1985, which means that the highway network for 1975 was expanded to the south and this expansion was faced by a minimal connection of nodes, while in the proposed network for 1985 the expansion was less than 1970 network in terms of serving new nodes but expansion was in terms of adding more alternative links to the new and existing nodes.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Libya is one of the developing countries in Africa, with rich potential for accelerated economic growth. It has reached the stage where the development of its industrial and agricultural economy is based on the development of an integrated transportation system.

From the previous chapters it is clear that the rate of economic development in Libya has been significant during the past fifteen years, there is no reason to expect it to be any less in the next fifteen years. Libya's population is estimated at 2,257,037 million and will be over three million by 1985. Exports (other than oil) have decreased while imports have quadrupled in the last ten years. In the field of transportation, the number of passenger movements on national road and air systems has doubled during the past ten years. The number of commerical road vehicles has nearly quadrupled during the past ten years. On the basis of the past trends and potential for future development, the next ten years will mark a period of significant growth in total freight traffic.

For example, the indications are that greater tonnages of cement, live animals, wheat and barley will be produced

and transported.[1] Internal trade will become an ever-increasing proportion of total trade carried by all modes of transport. These rapid increases will be faced by many problems, such as physical geographic, human, technological, economic, as well as inadequate transportation networks. To overcome all mentioned problems the national economic investment in transport of all kinds must keep pace with demand which can be expected to more than double in the next ten years. Since the objective of the policy makers should be to meet the transportation needs of the economy with the minimum necessary expenditure of economic resources, and with tremendous demands upon its limited resources (other than oil), Libya cannot afford to depart from this principle as the basis of policy and action.

In order to achieve the objectives of improving the Libyan internal transportation system, the following remarks are presented in the form of number of specific recommendations, designed to provide alternatives and suggest priorities leading to the coordination and integration of transportation systems in Libya.

The application of the principles of graph theory to the Libyan highway network is extremely helpful in analyzing the expansion of the Libyan highway network through time. The analysis in Chapter IV shows that expansion was not

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[1]Libyan Arab Republic, Ministry of Transportation and Communications, Official Documents, 1975.

significant between the 1975 highway network and the proposed highway network for 1985. The procedure is also useful to show changes in the whole network or a part of it by adding both nodes and links, or links alone to the network. Additionally, the identification of priorities for the system as a whole or individual parts of it is possible. Thus policy makers are able to select a better network expansion program in terms of accessibility and connectivity.

Before attempting to establish a plan of priorities to meet transportation needs, an estimate should be made of the short and long range needs for all other types of public improvements. The purpose of the estimate is to bring into perspective the close relationship between transportation and all other elements of an overall development program. In determining the short or long-range needs, a time period should be selected to provide a base for purposes of analysis. In the 1973-1975 three year plan Libya devoted more than nine percent of its total expenditures to transport, a very high proportion in view of the wide range of other urgent needs.

Although the amount of capital expenditure devoted to the transportation sector in proportion to some other sectors is high, there has been little measurement of benefits or returns from alternative capital expenditure in the transportation field, and it is clear that investment decisions have too often been based on random decisions rather than on the economic measurement of costs and benefits.

The capital allocated to transportation development should not exceed the amount required to enable the essential freight and passenger traffic to be moved at lowest necessary economic cost. Expenditures on transport should be allocated on an economic basis, so as to avoid wasting the resources of the country.

The transportation planning department in the ministry of transportation and communications should have authority to review all government transportation projects, and develop a system of priorities for maintenance of capacity and new construction, based on traffic needs and engineering standards. This kind of planning activity should be strongly supported and carried forward on a continuing basis, a policy which has been notably lacking to date.

Since most of the trunk roads have not yet been constructed to carry large trucks, permits should be issued for such vehicles only in very exceptional circumstances, and the import of trucks capable of carrying more than seven-ton axle loads should be prohibited until most of the road system has been built up to the necessary standard.

Since the Libyan road system does not and will not before the next ten years of development allow high speeds to be safely undertaken with highly increased traffic densities, it is recommended that the maximum speed limit for private car owners throughout the country should be 100 km/hour with 25 km/hour limit in built up areas, while

the speed limit for trucks should be 70 km/hour throughout the country and 15 km/hour limit in built up areas.

It is also recommended that all accident details should be reported to the traffic safety planning department, which will analyse them and make reports which would be more useful in driver education programs and given to highway planning department authorities so that they might correct dangerous road designs.

The motor vehicle administration department and traffic safety department should maintain a separate division to undertake inspection and licensing, and coordinate police enforcement standards throughout the country.

For air transportation services, the present system is inadequate to certain respects. The frequency of services offered on almost all routes is too low, and the capacity offered on major routes is inadequate. The addition of air services to smaller centers within Libya will also contribute to the growth of air traffic. Internal air traffic should expect for the next ten years a rate of growth of 15-20 percent per year up to 1985.[2] This increase requires additional planning, such as expanding the capacity of existing airports to meet future internal transport needs.

Since the local planner frequently does not have the experience and ability to undertake the studies, formulate

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[2]Libyan Arab Republic, Ministry of Transportation and Communication, Report on Internal Air Traffic, 1974. (Tripoli: Government Printing Office, 1974.

the designs, and implement the projects required for national development, this deficiency should be overcome by employing skilled individuals, consultant firms, or teams of experts in order to assist in planning, management, operation and training requirements.

At the present time there is no single staff within the government that controls all forms of transport in Libya. The highway department is under the Ministry of Transportation and Communications. The agricultural roads are under the Ministry of Interior and Ministry of Agriculture. The Ministry of Municipality is responsible for establishing, improving, and maintaining transport facilities in urban areas. Navigation and harbours are under the Ministry of Navigation, air transport under air organization which is a part of the Ministry of Transportation. From such lack of coordination it is difficult to achieve the overriding objective of transport planning in Libya, that the development of transportation networks be integrated into an economical and effective system.

Such a goal would be difficult to achieve, since the Minister of Transportation and Communication has only supervisory power over his members, while other individual agencies have considerable autonomy in their departments. Under such circumstances each agency handles its own projects and makes short-run decisions rather than attempting to anticipate long-term needs.

In order to overcome the lack of coordination in transportation planning, a small, expert transport policy staff should be established, capable of analyzing real transport costs and needs on a national basis, and formulating overall transport policy. This staff should be headed by a transport planner. The most appropriate place for such a staff is in the Ministry of transport and communications, primarily because that ministry already has varying degrees of responsibility for all but one important means of transport (sea transport). This staff should look at transport as a whole in terms of achieving the greatest benefits from the least necessary expenditures of resources in each form of transport. It should also review road-vehicle registration, licensing, inspection, finance policies, plans of other ministries related to transportation. Indeed, the staff should maintain close working relationships with other departments and ministries having transport responsibilities; the desirability of formulizing such relationships by establishing an intra-governmental transport policy committee should be considered. It is important that a transport policy staff be established without delay. Such a staff can be only as effective as its personnel are competent, its relations within the government and with the transport community should be close and its support by government officials should be assured.

APPENDICES

APPENDIX I

TABLES OF NODE ACCESSIBILITY INDICES

Libyan Highway Network (1960)
Table of Node Accessibility Indices

Name	Degree	Shimbel One	Percent	Shimbel Two	Percent	Associated Number
1. Tripol	4	382	1.89	382	1.89	21
2. Zawia	3	405	2.00	405	2.00	22
3. Sabrat	2	444	2.19	444	2.19	23
4. Zwara	2	485	2.40	485	2.40	24
5. Bu Kam	1	528	2.61	528	2.61	25
6. Garabo	2	371	1.83	371	1.83	20
7. Ras Kh	3	358	1.77	358	1.77	19
8. Homs	3	349	1.72	349	1.72	18
9. Zliten	2	346	1.71	346	1.71	17
10. Misora	2	345	1.71	345	1.71	16
11. Sirte	2	349	1.72	349	1.72	14
12. Sidra	2	354	1.75	354	1.75	15
13. Ajeila	2	361	1.78	361	1.78	16
14. Ajdabi	2	370	1.83	370	1.83	17
15. Magrun	2	381	1.88	381	1.88	18
16. Gmines	2	394	1.95	394	1.95	19
17. Bengha	3	409	2.02	409	2.02	20
18. Tokra	2	428	2.12	428	2.12	21
19. Tolmit	1	492	243	492	2.43	23
20. Burce	4	449	2.22	449	2.22	22
21. El Abi	1	452	2.23	452	2.23	21
22. Bugree	2	346	1.71	346	1.71	15
23. Swani	3	407	2.01	407	2.01	22
24. Shahat	4	475	2.35	475	2.35	23
25. Rash Hi	3	545	2.69	545	2.69	25
26. Lamlud	5	505	2.50	505	2.50	24
27. Darna	3	542	2.68	542	2.68	25
28. Martob	3	541	2.67	541	2.67	25
29. Tamimi	2	580	2.87	580	2.87	26
30. Tubruk	2	621	3.07	621	3.07	27

Libyan Highway Network (1960) (Continued)

Name	Degree	Shimbel One[1]	Percent	Shimbel Two	Percent	Associated Number
31. Msaid	1	664	3.28	664	3.28	28
32. Aljosh	1	619	3.06	619	3.06	28
33. Shaksu	2	576	2.85	576	2.85	27
34. Gado	2	535	2.64	535	2.64	26
35. Yefren	3	496	2.45	496	2.45	25
36. Bir Ay	2	467	2.31	467	2.31	24
37. Bir Ga	3	433	2.14	433	2.14	23
38. Garian	2	466	2.30	466	2.30	24
39. Azizia	3	432	2.14	432	2.14	23
40. Bengas	3	387	1.91	387	1.91	21
41. Gasbat	3	363	1.79	363	1.79	19
42. Tarhon	3	374	1.85	374	1.85	20
43. Beni U	1	417	2.06	417	2.06	21
44. Susa	2	515	2.55	515	2.55	24
45. Faida	3	476	2.35	476	2.35	23

[1]Shimbel is the summation of links connecting a place to all other places in the network.

Libyan Highway Network (1975)
Table of Node Accessibility Indices

Name	Degree	Shimbel One	Percent	Shimbel Two	Percent	Associated Number
1. Tripol	4	567	1.30	567	1.30	21
2. Zawai	3	598	1.38	598	1.38	22
3. Sabrat	2	656	1.51	656	1.51	23
4. Zwara	3	716	1.65	716	1.65	24
5. Bu Kam	1	780	1.79	780	1.79	25
6. Garabo	2	549	1.26	549	1.26	20
7. Ras Kh	3	511	1.18	511	1.18	19
8. Homs	3	482	1.11	482	1.11	18
9. Zliten	2	472	1.09	472	1.09	17
10. Misora	2	464	1.07	464	1.07	16
11. Sirte	2	472	1.09	472	1.09	14
12. Sidra	3	488	1.12	488	1.12	13
13. Ajeila	3	508	1.17	508	1.17	14
14. Ajdabi	3	532	1.22	532	1.22	15
15. Magrun	3	560	1.29	560	1.29	16
16. Gmines	3	591	1.36	591	1.36	17
17. Gengha	4	624	1.44	624	1.44	18
18. Tokra	3	662	1.52	662	1.52	19
19. Tolmit	2	713	1.64	713	1.64	20
20. Burce	5	701	1.61	701	1.61	20
21. El Abi	2	663	1.53	663	1.53	19
22. Bugree	3	458	1.05	458	1.05	15
23. Swani	3	604	1.39	604	1.39	22
24. Shahat	4	746	1.72	746	1.72	21
25. Ras Hi	3	856	1.97	856	1.97	23
26. Lamlud	5	795	1.83	795	1.83	22
27. Darna	3	852	1.96	852	1.96	23
28. Martob	3	850	1.96	850	1.96	23
29. Tamimi	2	908	2.09	908	2.09	24
30. Tubruk	3	968	2.23	968	2.23	25

Libyan Highway Network (1975) (Continued)

Name	Degree	Shimbel One	Percent	Shimbel Two	Percent	Associated Number
31. Msaid	1	1032	2.37	1032	2.37	26
32. Aljosh	2	750	1.73	750	1.73	25
33. Shaksu	3	694	1.60	694	1.60	24
34. Gado	3	643	1.48	643	1.48	23
35. Gasser	2	689	1.59	689	1.59	24
36. Yefren	3	592	1.36	592	1.36	22
37. Bir Ay	3	634	1.46	634	1.46	23
38. Bir Ga	3	632	1.45	632	1.45	23
39. Garian	4	552	1.27	552	1.27	21
40. Azizia	3	595	1.37	595	1.37	22
41. Bengas	3	566	1.30	566	1.30	21
42. Gasbat	3	502	1.16	502	1.16	19
43. Tarhon	4	520	1.20	520	1.20	20
44. Beni U	1	584	1.34	584	1.34	21
45. Susa	2	807	1.86	807	1.86	22
46. Faida	3	747	1.72	747	1.72	21
47. Assa	1	780	1.79	780	1.79	25
48. Wazen	1	763	1.76	763	1.76	25
49. Nalute	4	699	1.61	699	1.61	24
50. Mazda	1	616	1.42	616	1.42	22
51. Derje	2	761	1.75	761	1.75	25
52. Gadame	1	825	1.90	825	1.90	26
53. Uadan	2	506	1.16	506	1.16	16
54. Umel A	3	556	1.28	556	1.28	17
55. Brak	2	618	1.42	618	1.42	18
56. Edri	1	682	1.57	682	1.57	19
57. Sabha	3	612	1.41	612	1.41	18
58. Garma	3	672	1.55	672	1.55	19
59. Ubari	1	736	1.69	736	1.69	20
60. Umel A	3	672	1.55	672	1.55	19
61. Zuila	1	736	1.69	736	1.69	20

Libyan Highway Network (1975) (Continued)

Name	Degree	Shimbel One	Percent	Shimbel Two	Percent	Associated Number
62. Jufra	1	552	1.27	552	1.27	14
63. Marada	1	572	1.32	572	1.32	15
64. Jalo	1	596	1.37	596	1.37	16
65. Aljagh	1	1032	2.37	1032	2.37	26
66. Sulug	3	591	1.36	591	1.36	17

Libyan Highway Network (1985)
Table of Node Accessibility Indices

Name	Degree	Shimbel One	Percent	Shimbel Two	Percent	Associated Number
1. Tripol	4	522	1.31	522	1.31	13
2. Zawai	3	554	1.39	554	1.39	14
3. Sabrat	3	599	1.51	599	1.51	15
4. Zwara	4	645	1.62	645	1.62	16
5. Bu Kam	2	721	1.81	721	1.81	17
6. Garabo	3	530	1.33	530	1.33	13
7. Ras Kh	3	540	1.36	540	1.36	13
8. Homs	3	508	1.28	508	1.28	12
9. Zliten	3	474	1.19	474	1.19	11
10. Misora	3	439	1.10	439	1.10	10
11. Sirte	3	379	.95	379	.95	9
12. Sidra	3	399	1.00	399	1.00	10
13. Ajeila	3	424	1.07	424	1.07	11
14. Ajdabi	4	438	1.10	438	1.10	12
15. Magrun	3	502	1.26	502	1.26	13
16. Gmines	3	556	1.40	556	1.40	14
17. Bengha	4	606	1.52	606	1.52	15
18. Tokra	3	664	1.67	664	1.67	16
19. Tolmit	2	689	1.73	689	1.73	17
20. Burce	5	617	1.55	617	1.55	16
21. El Abi	3	559	1.40	559	1.40	15
22. Shahat	4	620	1.56	620	1.56	16
23. Ras Hi	3	694	1.74	694	1.74	17
24. Lamlud	5	620	1.56	620	1.56	16
25. Darna	3	627	1.58	627	1.58	16
26. Martob	4	560	1.41	560	1.41	15
27. Tamimi	3	562	1.41	562	1.41	15
28. Tubruk	4	512	1.29	512	1.29	14
29. Msaid	2	535	1.34	535	1.34	14
30. Aljosh	3	562	1.41	562	1.41	14
31. Shaksu	3	516	1.30	516	1.30	13

Libyan Highway Network (1985) (Continued)

Name	Degree	Shimbel One	Percent	Shimbel Two	Percent	Associated Number
32. Gado	4	460	1.16	460	1.16	12
33. Yefren	3	459	1.15	459	1.15	12
34. Bir Ay	3	514	1.29	514	1.29	13
35. Bir Ga	3	518	1.30	518	1.30	13
36. Garian	4	412	1.04	412	1.04	11
37. Azizia	3	468	1.18	468	1.18	12
38. Bengas	4	473	1.19	473	1.19	12
39. Gasbat	3	487	1.22	487	1.22	12
40. Tarhon	4	418	1.05	418	1.05	11
41. Bir Do	3	453	1.14	453	1.14	11
42. Beni U	4	383	.96	383	.96	10
43. Susa	2	694	1.74	694	1.74	17
44. Faida	4	555	1.39	555	1.39	15
45. Assa	3	675	1.70	675	1.70	16
46. Watia	3	616	1.55	616	1.55	15
47. Wazen	1	583	1.47	583	1.47	14
48. Swani	3	514	1.29	514	1.29	13
49. Nalute	4	506	1.27	506	1.27	13
50. Gasser	3	563	1.41	563	1.41	14
51. Mazda	4	376	.94	376	.94	10
52. Bir Al	3	421	1.06	421	1.06	11
53. Derje	3	467	1.17	467	1.17	12
54. Gadame	3	459	1.15	459	1.15	11
55. Bir Sc	3	363	.91	363	.91	9
56. Burgree	4	372	.93	372	.93	9
57. Udan	5	352	.88	352	.88	9
58. Umel A	4	370	.93	370	.93	9
59. Brak	4	381	.96	381	.96	9
60. Edri	3	430	1.08	430	1.08	10
61. Sabha	5	408	1.03	408	1.03	9
62. Garma	3	469	1.18	469	1.18	10

Libyan Highway Network (1985) (Continued)

Name	Degree	Shimbel One	Percent	Shimbel Two	Percent	Associated Number
63. Ubari	3	496	1.25	496	1.25	11
64. Ghat	2	525	1.32	525	1.32	12
65. Umel A	4	478	1.20	478	1.20	10
66. Zuila	3	481	1.21	481	1.21	10
67. Birel	1	555	1.39	555	1.39	11
68. Ozu	1	558	1.40	558	1.40	11
69. Zella	4	359	.90	359	.90	10
70. Jufra	3	405	1.02	405	1.02	11
71. Marada	3	430	1.08	430	1.08	12
72. Jalo	5	409	1.03	409	1.03	12
73. Aljagh	3	476	1.20	476	1.20	13
74. Kufra	3	384	.97	384	.97	11
75. Uweina	1	461	1.16	461	1.16	12
76. Abuhar	5	445	1.12	445	1.12	13
77. Masus	4	498	1.25	498	1.25	14
78. Elmech	5	495	1.25	495	1.24	14
79. Sulug	4	545	1.37	545	1.37	14

APPENDIX II

TOTAL EXPENDITURE DEVOTED TO CONSTRUCTION OF THE PROPOSED ROAD NETWORK FROM 1974-1985

APPENDIX II

Total Expenditure Devoted to Construction of the Proposed Road Network from 1974-1985

Year	Percent of Increase Over Previous Year = 15.3[1]	Total
1974/75	NA	20,797,000
1975/76	3,181,941	23,978,941
1976/77	3,668,777	27,647,718
1977/78	4,230,100	31,877,819
1978/79	4,877,306	36,755,125
1979/80	5,623,534	42,378,659
1980/81	6,483,934	48,862,593
1981/82	7,475,976	56,338,569
1982/83	8,619,801	64,958,370
1983/84	9,938,630	74,897,000
1984/85	11,459,241	86,356,241
1985/86	13,212,504	99,568,745
TOTAL		614,411,780

[1]Libyan Arab Republic, Ministry of Transportation and Communications, Report on Transportation Expenditure, 1974. (Tripoli: Government Printing Office), 1974.

From the above table the total expenditure devoted to road construction in 1974 is 20.797.000 million dinar, and this amount will be increased annually 15.3[1] over the previous year.

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[1]Libyan Arab Republic, Ministry of Transportation and Communications, Report on Transportation Expenditure, 1974. (Tripoli: Government Printing Office), 1974, p. 81.

Since the average total cost of construction 1 klm. road in the desert area is equal to 57,048.447 thousand dinar so the total amount of the expenditure for the future ten years will be enough to construct 10,770 klm. or the proposed network for 1985.

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