TRANSPORT NETWORKS, ACCESSIBILITY AND URBAN GROWTH: A CASE STUDY OF PANJAB, PAKISTAN

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"He has created horses, mules and donkeys that you may ride them, and also as adornment; and He will create for that purpose other means (of transportation) which you do not yet know".

Qu'ran 16:8

To my parents

ABSTRACT

The study examines the relationship between the structure of transport network and urban growth in the region of the Panjab (Pakistan). This is an area where the growth of urban population had been gradual between 1881 and 1921, but accelerated in the later decades. The study looks at these temporal changes and traces the factors responsible. The temporal relationship between transportation and urban growth is discussed at regional and sub-regional levels and is used as the basis for the examination of additional factors, such as the physical environment, location and commercialization. In addition, different aspects of urban connectivity are discussed and measured through the application of graph theory where a matrix representation of the network accessibility surface at different time periods is also obtained by powering the matrices of connectivity between pairs of nodes. The inter-relationship between changes in accessibility to the road network and urban growth in the region is examined quantitatively at different levels by the application of simple and partial correlations. By comparing the correlation of five divisions (of wide contrast) a leading role of transportation in the process of urban development is assessed. Finally the conclusions are derived with the application of regression analysis, by relating the district level indices of transportation to the indices representing the socio-economic conditions of districts (1971).

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LIST OF ABBREVIATIONS (including towns)

Abadkars	Settlers
Acc.	Accessibility
A.N.	Associated Number
Deptt.	Department
D.G. Khan	Dera Ghazi Khan
Doab	Country lying between two rivers
G.T. Road	Grand Trunk Road
Kacha	Unmetalled
Lyallpur	Faisalabad
Mandi	Market town
N.W.F.P.	North West Frontier Province
Pakka	Metalled
R.Y.Khan	Rahim Yar Khan
S.D.	Standard Deviation
T.D.A.	Thal Development Authority
Tehsil	Administrative sub-division of a district

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Chapter 1
INTRODUCTION

1.1 The Problem

Archaeological remains and historical records show that urbanization in the Panjab is not a recent phenomenon and its history goes back to the days of the Indus Civilization. But it was not until the turn of the present century that the region could claim an appreciable degree of urbanization when the introduction of canal irrigation followed by increased mobility, colonization and agricultural development with special emphasis on the production of food and cash crops have given considerable impetus to the process of urbanization (Ahmad 1966). Since then, the rapidly growing urban population and uneven nature of its growth have played an important role in altering the nature and patterns of urban centres in the region. The towns have been converted into cities and cities into metropolitan centres. As a result of this rapid growth the field of study of the structure and urbanization of cities has become important both as an academic exercise and in government planning.

On the other hand, in spite of a uniform trend of the growth of urban population during 1881-1971 some towns have declined as well. Thus there is need to look at these changes and trace the factors responsible for the growth and decline of these towns. So far, a number of writers like Malik (1963), Siddiqui (1965) and Hameed (1971) have put the responsibility of urban change on factors of irrigation and agriculture in general, and many factors in addition to agricultural development have been ignored.

In the light of considerable work on the region devoted to urbanization and socio-economic development it seems surprising that such an evaluative gap for transportation still exists because no attention has been paid to the possibility that among the regional factors there might be an equally significant group of factors such as 'accessibility'.

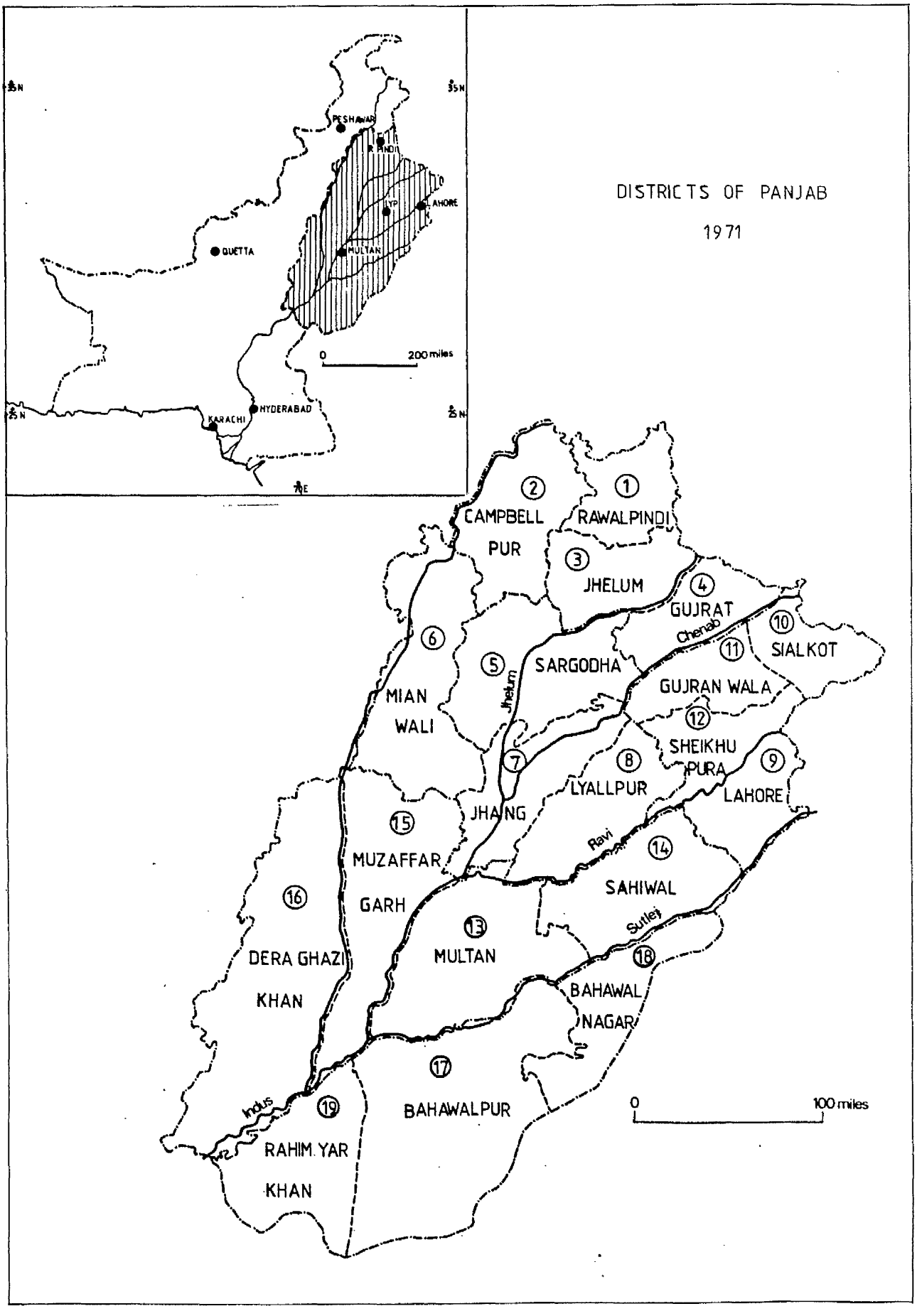
The reason for this gap may be explained in part by the lack of initiative (in collecting historical data), measurement parameters, but is mainly due to the approach which views transportation and urban development independently and in isolation. This study hopes to bridge the gap with a view to assess the role of transport in maintaining and shaping the settlement pattern as well as reviving old and creating new settlements. It is possible by examining the role of accessibility as a spatial factor significant in the development process of the region along with the analysis of the structure of the transport network.

In the analysis of the growth of transportation in Nigeria and Ghana the study by Taaffe, Morrill and Gould (1973) has pointed out a strong correlation between population and area and density of road system in the regions. There is a need for this type of study in the region of the Panjab to assess the precise role of accessibility by using measurement techniques, which will be useful for understanding regional contrasts as well. However, scale is an important factor in accessibility. It is therefore necessary to analyse the structure of the transport network on regional and sub-regional levels. This analysis includes the periods of pre and post partition thus giving an idea of development and change through time.

1.2 The Region

The word 'Panjab' consists of two Persian words 'Panj' and 'Aab'. It means five waters and signifies five rivers (Indus, Jhelum, Chenab, Ravi and Sutlej). Before the partition of 1947, it was a single state but after that was divided into east and west Panjab. The area of study is west Panjab (a province of Pakistan) including the State of Bahawalpur. It lies between latitudes $27^{o}42'$ and $34^{o}2'$N and longitudes $69^{o}18'$ and $75^{o}23'$E, covering an area of 79,542 square miles. According to the Census of 1971, the region includes five political divisions of Rawalpindi, Sargodha, Lahore, Multan and Bahawalpur, with a total of 19 districts (see Fig. 1.1). The Panjab is the most populous of all the provinces of Pakistan with 37.37 million people or 57.6 per cent of the entire population in 1971. During the planning period it underwent a process of rapid change in the activities

FIGURE 1·1 LOCATION MAP OF PANJAB



of economic and legislative reform particularly in agriculture. It remained the most urbanized province of Pakistan and India (previously) with one of the best developed urban systems. By 1971, it was known as the province with the most rapidly growing economy of Pakistan. The rapid changes in its urbanization are also significant as compared to the remaining regions. All these points strongly recommend it as an area for the study of urban development. In addition, the factor which made it particularly suitable for the present study, is its highly developed transport (road and rail network) system in Pakistan. It makes it possible to examine in detail the role of accessibility in the development of regional contrasts in urban change.

1.3 Historical Background

It is beyond the scope of the Chapter to give a detailed historical survey of the region. However, it is possible to give a brief sketch of its historical background, which has undergone rapid political changes throughout its history.

Looking at it from an urbanization point of view, the ruins of Harappa (in Sahewal district) show that it was a well arranged city during the pre Muslim period. It is thought that in 1500 BC Aryans came from some far distant parts of Asia, they seized Harappa and killed the inhabitants. All the invaders of the Panjab came through the Khyber Pass, which was the only natural gateway to India, before the advent of navigation. In 326 BC Alexander fought his way to near Taxila and advanced as far as the river Beas; he returned after making Porus the governor of all the conquered country west of the Beas. The Greek rule came to an end in northern India after the death of Porus. Later on the region came under the Buddhist rule of Asoka and his successors.

In 712 AD the Muslim invasion took place when Muhammad Bin Qasim conquered Sind and Multan and later on in 986-87 AD the Turkish Sultan Subaktagin crossed the Indus to invade the kingdom of Lahore. His successor Mahmud Ghaznavi gained a victory over the Rajas of Ajmer and in 1008 AD he annexed the northern Panjab. He was followed by Mahmud

Ghori, who was assassinated by Gakhars in 1205 AD and until the Mughal period (1526 AD) when Babar defeated Ibrahim Lodhi near Panipat, Lahore was held by the representative of the Shane Dynasties of Khilji, Tughlak, Syed and Lodhi. After the death of Babar in 1530, his son Humayun (who succeeded him) was driven away by the Afghan General Sher Shah Suri (in 1540) who remained in possession of Lahore for some years and connected Multan and Lahore by road. Humayun returned and occupied Lahore one year before his accidental death in 1556, when his son Akbar was proclaimed the Emperor of India and the empire was established and the region enjoyed a comparative peace after many years.

After the death of Akbar the region was ruled by his son Jehangir, grandson of Shah Jehan,and then by Aurang zeb until 1759, when Mughal rule came to an end. It was followed by the Sikhs, who were defeated by British troops with heavy losses in 1849, and the Panjab became a province of British India. After the Mutiny of 1857 the region made rapid progress in commercial and industrial wealth. In the partition of 1947, the Panjab was divided into East (India) and West (Pakistan) Panjab.

The rivers of the Panjab have played the most important role in the history of the region. These rivers have not only added to the agricultural prosperity of the province but have also been of use in various administrative and strategic ways. They have served as the boundaries since the time of Akbar. Their role as a defence barrier against invaders and means of navigation has also had a significant effect on the old settlements. Most of the forts are built on the river banks for the protection of the inhabitants. Because of the general state of insecurity the population was to be found along the rivers (see Fig. 2.2). This gave birth to a number of Ferry towns along the course of these rivers. The first Ferry at Attock was built by Akbar in 1583. Similarly, the other important Ferries are near Kalabagh, Jhelum, Wazirabad and Shah dara.

According to the early historical accounts of Wheeler (1953) and Trevaskis (1928) the settlements of the region can be grouped into the six broad chronological classes of:

i. Pre-Harappa

ii. Harappa or Indus Age (probably 2500-1500 BC)
iii. Post Harappa or Dark Age (probably beginning after 1500 BC)
iv. Proto Historical (522 BC - AD 470 approximately)
v. Historical (470-1843 AD)
vi. British Period (1843-1947) and post-partition settlements.

The historical settlements of these periods are generally located at the points which had either a commercial or strategic values or both. Most of these can be found near the rivers or bridge heads, at the crossing of historical routes (Lahore, Multan) and, in general, the lowlying fertile land near the rivers was selected. The big towns were strongly fortified by massive defence walls, which are still there. Town parks were only built during the Mogul period while the remaining facilities, like drainage, were poor until the British period, which added much to the urbanization of the region by introducing a planned layout of the streets and residential lanes, particularly in cantonments, canal and railway colony towns.

1.4 Relief

A detailed topography of the region has been discussed by Spate (1967) and Wadia (1966); here, only a brief sketch is given in order to get a clear picture of the problem. The region has varied relief consisting of mountains, plateaux and plains watered by the Indus river and its tributaries. In the north some of the area is covered by the Salt Range and the Potwar Plateau, which starts near Jhelum and runs south-west to the north of the river Jhelum and crosses the Indus near Kala Bagh. Near Sakesar the height of the range is about 5,000 feet above sea level. It contains a number of fertile plateaux, passes, and salt lakes. A large quantity of rock salt and other minerals, such as gypsum and coal are found in this range. To the north lies the Potwar plateau with an average height of 1,500 feet above sea level. The prominent features of the landscape are the ridges and troughs - the result of erosion.

South of the Salt Range stretches the vast plain along the rivers. Its height ranges between 400 and 1,000 feet. It changes with an average gradient of one foot to one mile. With the exception of some

old dry hills (near Sargodha, Chiniot and Sangla) the level plain is largely made of fertile alluvium deposited by the rivers. Before the advent of perennial canal irrigation at the beginning of the present century, much of the plains was no better than a desert or semi-desert. The river waters were then used to convert the desert to cultivable land. But now most of these plains are irrigated by rivers and canals and are divided into several interfluves or 'doabs' of fertile and prosperous agricultural land. These central 'doabs' are given names compounded from those of their confining streams - 'Chaj' (between Chenab and Jhelum), 'Rechna' (between Ravi and Chenab), while 'Sind Sagar' and 'Bari' are located in the west and east of the centre respectively.

The areas still unirrigated or with poor irrigation facilities (in the plains) are 'Thal' and 'Thai' deserts lying in 'Sind Sagar Doab' and East of the Sutlej respectively. It is hoped that these areas will not persist for much longer as progress is made to develop the areas under schemes such as the Thal Development Authority (TDA).

1.5 Aims and Objectives

The thesis is addressed to the questions posed by regional patterns of urban change. The fundamental questions are related to the role and importance of environmental, economic and administrative factors in the change of urban process. Focusing on 'connectivity' as one of the important factors, the pattern of change is analysed and inter-relationship is examined against this background.

The detailed objectives of the study include:

- to test the temporal relationship between the growth of railway network and urban population
- to test the validity of the hypothesis in the region that there is an observable relationship between available transport facilities and urban development and/to use as the basis for correlation with additional factors of physical environment and commercialization.
- to extend the use of graph theory to the intra-regional scale and explain spatial variation in network structure in terms of intra-

regional variations in urban development.
- to explore the theme of interaction between urban growth and transport development in a specific regional setting.
- to identify the areas of low and high accessibility, where future development should be considered.

1.6 Framework

To achieve the above objective, the study has been divided into four parts. The first part deals with the introduction of the region and problem, discussing the aim and objectives and the main questions to which the thesis is addressed along with a brief outline of the analytical procedure adopted in the thesis. It also includes the data sources. This introductory section is followed by the descriptive part (Chapters 2 and 3), where Chapter 2 discusses the historical trends of urbanization and urban growth at the regional and sub-regional levels. In addition, it offers the spatial distribution of urban centres. In order to assess and relate the growth of railway network, Chapter 3 looks at temporal growth of the network for similar periods. The temporal relationship of the parameters on regional and sub-regional levels is examined in Chapter 4.

After examining the relationship between railway and urban growth, part three (Chapters 5 and 6) analyses the structure of the existing transport network (1971) and also presents the nodal accessibility of the various size towns to their respective regional and sub-regional (division level) transport networks. It is then related to the urban size and growth, through the framework of simple and partial correlations.

To assess the relationship of accessibility with a number of socio-economic factors, part four (Chapters 7 and 8) attempts to analyse district level patterns of connectivity, accessibility and urban change. A number of metricated indices representing the socio-economic position of the districts are discussed and related. Finally, Chapter 9 offers an overall summary, conclusion and implications.

1.7 Methodology

The analysis of transport networks has become an important part of geographical studies in recent years. Before World War II, transport networks developed in an unrelated fashion but post war changes and developments in transport are mainly focused upon the analytical study of networks in both the developed and developing countries (Robinson 1978). Before the introduction of the graph theory a number of techniques were used in the study of transportation by different geographers. Wallace (1963), for example suggested an approach for the functional classification of railways, where it is possible to classify routes according to the direction of the traffic. Some more studies of sea ports by Britton (1965) and Bird (1968) were well known. But these approaches have failed to provide adequate comparative measures of network characteristics which are practically acknowledged to be important (Hay 1973). An alternative approach has been devoted to the identification of topological properties defined in the language of graph theory or matrix algebra. The approach was pioneered by Garrison (1960) but the first geographical application is due to Kansky (1963).

Here the measures of transport network structure are derived from graph theory and are related by regression and correlation methods to spatial variations in the distribution of urban population and the growth of urban centres. Similarly these measures are used to examine the changes through time of the total connectivity of the transport networks and the relative connectivity of the major urban centres. The procedures adopted are briefly discussed in the subsequent sections of the analysis, whereas the details of topological and non-topological indices are given in Appendix A.

1.8 Data Sources

The major part of the study requires historical data for both urban and railway developments in the region. The data for urban growth was derived from the Census reports 1881-1971*, whereas for the development

* They are based on India, Census Commissioner, Census of India, The Panjab, 1881, 1891, 1901, 1911, 1921, 1931, 1941 (Calcutta: Superintendent of Government Printing) and Pakistan, Office of Census Commissioner Census of Pakistan, The Panjab, 1951, 1961 and 1971 (Karachi).

of railway network since 1862, they were collected from the railway records and district gazetteers. It was then verified from the railway time-tables (available at the Railway Board, Lahore). The additional statistical material related to road development (1971) was derived from the district maps, which were available in the field and their accuracy was checked with the help of the 'Statistical Bulletins of Highway Department (Lahore)'.

For the data required for the nodal accessibility (time and distance) the time tables of Government Transport Service were used, while the information for district level metricated indices (traffic flow) were collected from the Panjab Highway Department. The remaining socio-economic indices of the districts were based on the published and unpublished data of the Panjab Bureau of Statistics, which were also collected during the fieldwork of 1979.

Chapter 2
URBANIZATION

2.1 Introduction

One of the most significant features of population in most countries is the degree to which they have become urban in recent years. In the Panjab, urbanization during the last 90 years has signified that one out of every four 'Panjabis' was living in an urban place in 1971, in contrast to only one in 11 in 1881. If the trend continues to the year 2000, more than half of the population would become urbanites. The number of urban places is also increasing in a similar way. The dramatic social and economic change that has taken place in the region since the latter part of the nineteenth century, has accompanied a very rapid rate of urbanization. In this respect the censuses since 1881 provide a large body of data (decade by decade) that can be used to study urbanization. Because of the difficulties like changes in internal and external boundaries of the region, the temporal pattern of urbanization is measured on the basis of existing boundaries of regional and sub-regional political units.

This section of the thesis is focused upon the trends and patterns of urbanization in the Panjab with a view to determin. the speed and nature of the process. How did urbanization proceed during different historical periods at the regional and sub-regional levels? How did the growth of transport affect the pace of urbanization through individual towns of different sizes? How does the trend of urban growth correspond with the trend of railway growth? Has the tempo of urbanization been similar in the large and small towns during the period? Is urban growth more related to the productivity of land or to the access of transport facilities?

We proceed in this chapter by presenting a historical perspective

of urbanization to answer these questions.

The definition of urbanization varies according to the approach. This study is basically geographic in approach and is mainly concerned with the change in the settlement pattern from a dispersed pattern related to agriculture to a more concentrated one, related to non-agricultural functions. In this study urbanization has a twofold meaning. The level of urbanization refers to the percentage of a region's total population residing in urban centres, whereas the change in level is simply the absolute change in this level, that is the change in a relative phenomena (Davis, 1962). Here we will look at both aspects and will place major emphasis on the change in urbanization, with which we are primarily concerned, because the development of urbanization takes place through time and the conditions are constantly changing. This analysis of the absolute changes on the level of the urbanization of the sub-regions during the period will be useful for the inter-correlation in the subsequent section of the thesis. The discussion includes a tentative description of the processes of urbanization along with the major factors, which must be taken into account, because the distribution of towns in any region is a result of a long interplay of forces. Morrill (1963) suggests that the historical dimension is of crucial importance to the study of urban development for the reasons of technological change, locational decisions and characteristics of urban population.

According to Hauser (1965) the development of towns is a function of four closely interrelated factors:

i size of total population
ii degree of control over the natural environment
iii level of technological development
iv the type of social organization.

The pre-colonial urban situation of the region shows that a very high infant mortality rate and disease did not allow marked population increase where man's mobility and settlement sizes were rigidly limited by the environment. The caravan routes between east and west through the region caused the first widespread transformation of settlements where many centres and markets developed and produced goods for trade. Later on with the (increase in the degree of control over the natural environment) introduction of rail and facilities like medicine and education, the towns gradually developed along the lines at

communication nodes and the introduction of these new forces of urbanization caused constant changes in the developing urban patterns. New centres emerged as others declined, some experienced rapid growth while others stagnated. Similarly, places were saved from total decline by the introduction of new activities and enhancement of certain older political economic functions. Cities also arose at strategic points where military necessity required a permanent camp, such as on either side of a bridge, mountain passes and cross roads.

The intention here is to sketch the historical background with emphasis on the factors and events that led to the development of certain places as important nodes while once flourishing towns, declined. Some of the factors that were important in producing certain centres in the past are not operating at present. This raises questions concerning the viability of some centres in the light of changing cultural patterns and transportation technology. The answer to such questions can also be found by looking at the changing pattern of urban growth in the region.

Absolute growth is defined as the net addition of people to existing population and can take place mainly either by migration or by natural increase (births minus deaths) which does not affect the spatial pattern of the region as significantly as migration. To analyse the growth patterns of the region, the first section traces the absolute changes of urban population on regional and sub-regional levels, whereas the second section examines the changing network of individual towns both within and outside the framework of their respective size groups.

2.2 Growth of Urban Population

Table 2.1 gives the percentage variation for total, urban and rural population during the last nine decades separately. It shows that during the decade 1881-91, the growth rate of rural population was higher than that of urban population and until 1901-11, it remained almost equal. In the next decade (1911-21) there was a modest increase in the urban population. A more distinctive difference between the growth rates appears during 1921-31 when rural population increased by 14.93 per cent, while the urban population increased more than three times (45.95 per cent) compared to the previous decade. After a

Table 2.1

DECADE WISE VARIATION (PERCENTAGE)
IN TOTAL, URBAN AND RURAL POPULATION
OF THE PANJAB 1881-1971

Decade	Total population	Urban population	Rural population
1881-1891	11.71	8.68	12.03
1891-1901	13.22	13.67	13.17
1901-1911	6.55	6.66	6.55
1911-1921	7.00	14.85	6.21
1921-1931	17.98	45.95	14.93
1931-1941	23.73	49.59	20.15
1941-1951	20.21	40.69	16.67
1951-1961	23.96	53.32	17.85
1961-1971	46.62	68.47	40.71

Source: Computed from the Census reports of the Panjab 1881-1971.

slight decline in the rate of increase in 1941-51, the urban population maintained its growth in the next decade. During 1961-71 a higher increase is also witnessed in the rates of total and rural population growth, whereas the urban growth witnessed the highest rate (68.47 per cent). Interestingly during the decade 1961-71, the rate of increase in rural and total population went up to 40.71 per cent and 46.62 per cent respectively as compared to their growth of 17.85 per cent and 23.96 per cent for the previous decade while the rate of urban growth increased to 68.47 per cent compared to 53.32 per cent for the previous decade (see Table 2.1). This shows that urban population growth has been very rapid by comparison with either rural or the total population. The most rapid growth has been recorded in the final decade of railway development (1921-31), due to increased agricultural prosperity and the consequent growth of trade and commerce. Commercial activity attracted migrants to various new urban centres along the railway lines.

2.3 Degree of Urbanization

The degree of urbanization is defined as the proportion of population resident in urban places (Hauser 1965). Being predominantly an agricultural region, the degree of urbanization was very low until 1921 when 9.84 per cent of the Panjab's population lived in urban areas. But later on it gradually increased to the maximum rate of 24.47 per cent in 1971 (see Table 2.3). It shows that the trend of the degree of urbanization also corresponds with the railway development of the region, where the urban population increased at moderate rates during the railway development (1881-1931) and after that it began to accelerate in the last four decades (1931-71). This visual relationship suggests the hypothesis that the location of the towns is related to railroad expansion, while their increase in size is associated with road building in the region.

To test this relationship statistically in the Panjab as a whole and at the sub-regional levels, the growth and degree of urbanization is measured separately. The percentages of change for each sub-region are given in Table 2.3, to understand the regional patterns of urbanization in terms of the changes in the population (percentage) living

Table 2.2

NUMBER OF TOWNS IN DIFFERENT CLASSES
DURING 1881-1971

Year	Classes of Towns						
	I	II	III	IV	V	VI	Total
1881	1	2	5	8	25	19	60
1891	1	3	4	9	25	12	54
1901	1	3	4	9	30	16	63
1911	1	3	3	11	32	12	62
1921	2	2	6	9	35	17	71
1931	4	1	11	13	40	23	92
1941	4	4	11	26	53	21	119
1951	6	4	17	37	52	29	145
1961	7	7	26	43	69	22	174
1971	14	10	41	80	41	16	202

Key

A (Ist class) = 100,000 +
B (IInd class) = 50,000 - 100,000
C (IIIrd class) = 20,000 - 50,000
D (IVth class) = 10.000 - 20,000
E (Vth class) = 5,000 - 10,000
F (VIth class) = Below 5,000

Source: Census reports of the Panjab 1881-1971.

in urban areas.

Table 2.3 suggests that in Lahore division a rapid change in the percentage of urban population occurred earlier than elsewhere. However, the spread of urbanization in the Sargodha division during recent decades was extremely fast and so was the growth of percentage living in urban areas. Between 1881-1931 the percentage of urban population in Lahore increased from 11.67 to 20.05 per cent while in Sargodha it increased from 5.44 to 10.05 per cent. In Rawalpindi division growth was approximately the same as in Sargodha. On the other hand the towns of both of the southern regions of Multan and Bahawalpur (which in 1881 had almost the same percentage as of Rawalpindi and Sargodha respectively) did not grow at all. But during the period after 1931, the towns in Bahawalpur grew very rapidly, and by 1971 the urban population was slightly higher than that of Multan. It can be concluded that Lahore and Sargodha divisions have shown a gradual development in their urban populations throughout the periods since 1881, whereas the remaining regions were either stagnant or declining during the early periods but later while maintaining their relative positions, showed a rapid absolute change.

2.4 Size of the Towns

The pattern of urban growth discussed so far includes only the total urban population without considering its composition in terms of the size and number of urban centres. It gives an inadequate picture because the urban centres of the region vary greatly in size. To obtain a true picture, towns can be grouped into six classes (according to the "instantaneous method" of Davis 1968) which measures the population in all urban categories and traces the changes in each class without taking into consideration the individual cities that make a class.

To study the population characteristics, a symmetrical distribution of the towns into the six classes has been presented in Table 2.2. Throughout it is observed that large size towns are fewer in number as compared to small and medium size towns. Until 1911, there was only one Class I town (Lahore) but in the following decade Rawalpindi

Table 2.3

URBAN POPULATION AS PERCENTAGE OF TOTAL POPULATION
IN THE PANJAB AND ITS DIVISIONS

Year	Panjab	Rawalpindi	Sargodha	Lahore	Multan	Bahawalpur
1881	9.38	8.15	5.44	11.67	8.40	5.35
1891	9.12	7.53	9.58	11.61	8.13	5.54
1901	9.16	8.34	7.26	11.81	8.63	5.84
1911	9.17	8.36	6.63	13.45	8.32	4.75
1921	9.84	9.38	8.26	14.66	7.44	3.96
1931	12.17	10.31	10.05	20.05	8.70	4.39
1941	14.71	12.55	11.15	25.59	10.20	8.67
1951	17.22	15.47	14.56	28.64	11.79	9.80
1961	21.30	18.90	19.62	33.93	14.93	13.61
1971	24.47	23.68	23.06	37.14	16.10	16.83

Source: Census reports 1881-1971

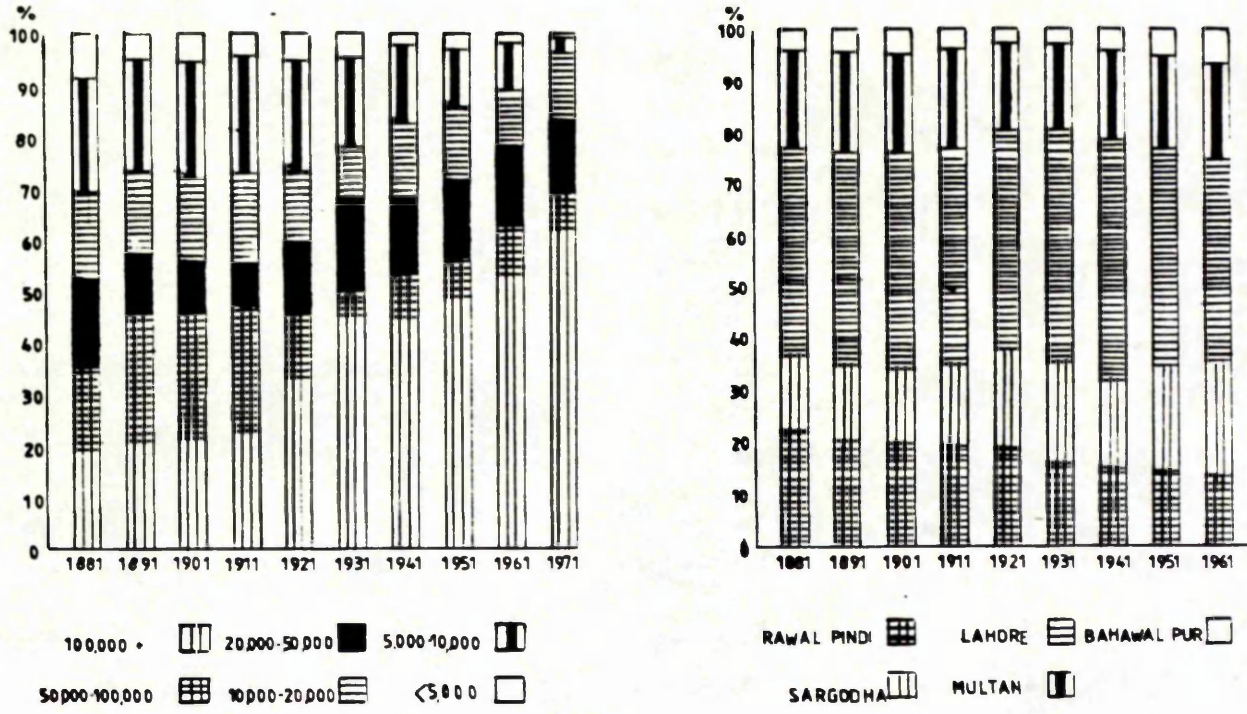
improved the status and was added in this class. In 1931, with the addition of Multan and Sialkot the number of towns in this class rose to four and finally this shot up to 14 in 1971, with a maximum increase during 1961-71. Wide variations in the numbers of small and medium towns (especially in V and VI Classes) are noticed from census to census, which is due to the promotion of towns from lower to higher classes, as a result of population increase. The Classes I, III and IV remained almost static until 1921 but the following decades (particularly 1961-71) witnessed a rapid change.

Looking at the proportion of population which has been accommodated in the different classes since 1881. Figure 2.1a suggests that in 1881, about one quarter of the urban population was accommodated in Class V towns which gradually decreased to 3.48 per cent in 1971. In the following decade (1891) the highest proportion shifted to Class II and remained until the addition of Rawalpindi as Class I city (1921) when the largest share of population was found in Class I towns. The figure brings out the increasingly important role of this Class (I) which in 1881 accounted for only 19.54 per cent of the total urban population while in 1971 it was responsible for 62.08 per cent of the total urban population, having 3,715 per cent more people in 1971 than in 1881. As with the addition of more and more people, towns grow and change their class - some increase in the highest Class I seems inevitable (see Figure 2.1a).

A sudden change in the proportion of the population in Class I towns also took place during 1921-31, when this proportion rose to 45.57 per cent in 1931 from 33.10 per cent in 1921. This occurred because of the upgrading of Multan and Sialkot, which at the same time was responsible for a significant decline in the proportion of Class II towns (from 13.43 per cent in 1921 to 3.48 per cent in 1931). On the basis of the above trends it can be concluded that the urban complex of the region has been increasingly dominated by large centres, with small centres growing more slowly. All the classes show wide contrasts in their trends through time recording their highest proportionate growth in different decades. It can be further classified by Table 2.5 which provides some interesting contrasts in the classwise percentage variation of urban population since 1881. It is evident that the highest rate of urban growth for Class I and III towns (ie. 100.7 per

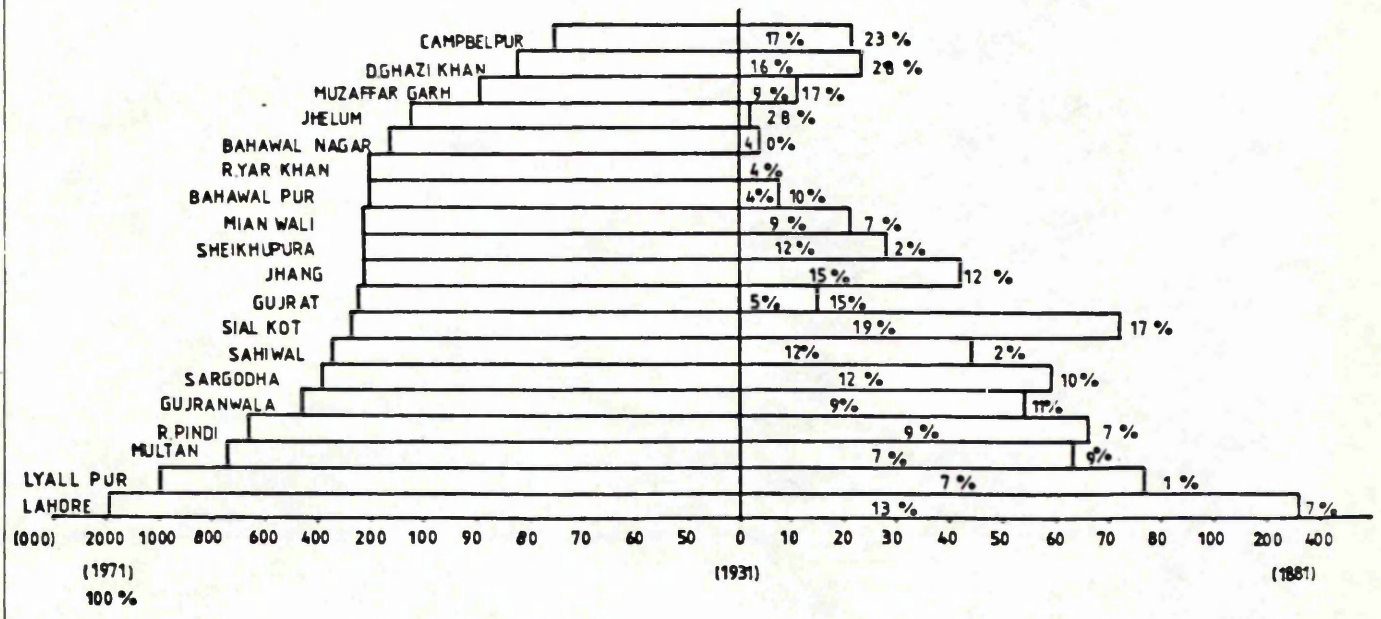
FIGURE 2·1

a. PERCENTAGE DISTRIBUTION OF URBAN POPULATION 1881-1971



b. DISTRICT LEVEL URBAN POPULATION CHANGE

(BASED ON 1931= 0)



cent and 125.3 per cent respectively) was in the decade 1921-31. The following decade (1931-41) witnessed a higher growth rate for the towns of Classes II and IV (ie., 337.3 per cent and 11.4 per cent respectively). This highest and unusual growth rate was due to the re-classification of the towns which can also be confirmed by the decrease of Class III during the same decade. The higher increase of Class IV (111.4 per cent) is due to the addition of towns, mainly in Lahore division. Similarly the higher increase of smaller Classes (V and VI) can be seen during the decades of 1951-61 and 1941-51 respectively (see Table 2.5). All this shows that the proportion of people living in different classes of towns has fluctuated from one decade to another. Similarly the increasing trend towards higher classes shows that the population tends to concentrate in the bigger urban units.

2.5 Tempo of Urbanization

To compare the tempo of urbanization in the region, the urban population has been divided into small (population below 20,000) and large (20,000 +) towns. The population of large towns increased by 66.5 per cent during 1951-61 while it increased by 80.65 per cent during 1961-71. On the other hand the population of smaller towns increased by 19.96 per cent and 25.66 per cent during the decades of 1951-61 and 1961-71 respectively. It shows an increasing tempo of urbanization for both types of towns, but it is comparatively faster for the larger towns. The table gives evidence of a slowing down of the tempo of the urbanization of smaller towns during 1961-71 compared to the earlier decades of 1931-41 and 1941-51. It shows that during earlier decades the increase of population in smaller and larger towns was higher and lower respectively than the last decades.

This contrast in the growth of smaller and larger size towns raises a number of questions regarding their link with the transport facilities of the region. Before making an attempt to understand the relationship between the degree of change and accessibility (absolutely and individually) it is important to look at regional changes of population between 1931 and 1971, with particular emphasis on population of the towns on the railway in 1931.

Table 2.4

ANNUAL GROWTH RATES
(Province and division level)

	1881 - 1931			1931 - 1971			1881 - 1971		
	Tot.pop.	U.pop.	U.cen.	Tot.pop.	U.pop.	U.cen.	Tot.pop.	U.pop.	U.cen.
Panjab	1.070	1.600	0.860	2.520	4.323	1.986	1.710	2.800	1.358
Rawalpindi Division	0.455	0.927	0.25	1.743	4.035	1.747	1.090	2.296	0.913
Sargodha Division	2.089 *	2.118 *	1.71 *	2.724 *	4.879 *	1.460	2.371 *	3.336 *	1.598 *
Lahore Division	0.782	1.878 *	0.67	2.347	3.937	2.243 *	1.475	6.566 *	1.369 *
Multan Division	1.281 *	1.361	0.77	2.703 *	4.292	1.689	1.910 *	2.653	1.177
Bahawalpur Division	1.089 *	0.656	0.58	3.259 *	6.800 *	4.581 *	2.048 *	3.343 *	2.337 *

* above the provincial rates of growth

Table 2.4a

	Population of 20,000 +			Population below 20,000		
Year	% of total urban pop.	% of total population	% change	% of total urban pop.	% of total population	% change
1931	68.0	8.3	-	32.2	3.9	-
1941	68.6	10.1	51.0	31.4	4.6	46.5
1951	71.7	12.3	46.9	28.3	4.9	27.0
1961	77.8	16.6	66.5	22.2	4.7	20.0
1971	85.5	20.4	80.7	16.5	4.0	25.7
1931-1971	-	-	567.6	-	-	180.5

Source: Calculated from the Census reports of the Panjab, 1881, 1931 and 1971

Table 2.5

DISTRIBUTION OF URBAN POPULATION AND
ITS DECENNIAL PERCENTAGE VARIATION
BY CLASSES OF TOWN SIZE 1881-1971

Year	I		II		III		IV		V		VI	
	A	B	A	B	A	B	A	B	A	B	A	B
1881	149	-	122	-	134	-	122	-	173	-	65	-
1891	177	19	203	66	98	-27	133	9	177	2	43	-34
1901	203	15	233	15	99	1	141	6	213	2	55	28
1911	229	13	251	8	80	-19	174	23	231	8	43	-22
1921	383	67	155	-38	142	77	171	-2	243	5	63	47
1931	769	101	59	-62	320	125	167	-2	287	18	86	36
1941	1138	48	258	337	338	6	353	111	367	28	72	-16
1951	1744	53	265	3	538	59	505	43	392	7	109	51
1961	2910	67	510	92	822	53	606	20	520	33	81	-26
1971	5699	96	655	28	1308	59	1141	88	320	-38	56	-31

A = Total urban population (000)
B = Percentage variation

It is generally believed that bigger urban concentrations are more relevant as these are growing faster than smaller ones. The statistics show that the proportion of large towns' population to total urban population has risen to 83.5 per cent in 1971 from 68.0 per cent in 1931 and the percentage of large towns' population to total population ie., the degree of effective urbanization has shot up from 8.3 per cent to 20.4 per cent in the same period (see Table 2.4a). As such, the rate of growth of small towns' population has been far short of the rate of increase in total population and also the large towns' population. Both the number and sizes of these towns have been increased. Similarly, the total increase during the period (1931-71) in the population of large towns (567.6 per cent) is much higher than the small towns' population (180.5 per cent).

2.6 Patterns of Urban Growth

This section examines the growth of urban population of the region from 1931 (the final stage of the railway construction) to 1971. This period witnessed a rapid change in urban population (444 per cent), which is higher than the changes of total population (170.3 per cent) and rural population (132.46 per cent). It will be observed from Table 2.6 that the growth of urban population is also higher in the sub-regions. Similarly, the number of towns increased from 92 (1931) to 202 (in 1971) with an increase of 120 per cent. The actual increase in number of towns is higher in Lahore (30) and Sargodha (22) divisions whereas the percentage increase in Bahawalpur (500 per cent) is exceptionally high due to the recent development.

The Classwise changes of the urban centres show a reduction in the number of towns in urban Class VI, whereas the highest increase can be seen in Class IV (67). Here the inter region variations are also interesting. The maximum increase in number of towns can be seen in Lahore followed by Sargodha division. The new towns are large, especially in Lahore and Sargodha.

It may tentatively be suggested that during the period each decade recorded a high degree of increase because of effective measures taken to control epidemics and also by stimulating the growth of market towns

Table 2.6

CLASSWISE INCREASE (1931-71) of:
(a) URBAN CENTRES,
(b) URBAN POPULATION (IN THOUSANDS), AT REGIONAL AND SUB-REGIONAL LEVELS.

Size Classes	Panjab		Rawal-pindi		Sar-godha		Lahore		Multan		Bahawal-pur	
	a	b	a	b	a	b	a	b	a	b	a	b
I	10	4930	2	705	3	1159	2	2301	2	631	1	134
II	9	596	1	70	2	121	2	135	3	196	1	74
III	30	988	5	148	7	247	4	95	9	260	5	237
IV	67	974	11	168	18	258	22	321	12	173	4	54
V	1	33	-3	-27	-3	-3	0	10	2	12	5	41
VI	-7	-29	1	2	-5	-20	0	-1	-7	-26	4	14
Total	110	7491	17	1066	22	1762	30	2861	21	1246	20	554
*Average	68.1		62.7		80.1		95.36		59.33		27.7	
% increase in towns	120.0		100.0		78.6		142.8		95.5		500.0	
% increase in population (total)	170.3		111.4		193.0		153.0		190.7		260.7	
% increase in urban population	443.5		384.8		572.4		368.0		437.2		1290.7	
% increase in rural population	132.5		80.0		150.6		98.9		167.1		213.7	

* Average increased population (000) per increased town

Source: Computed from the Censuses of 1931, 1971.

by the cash crops of irrigated areas. Apart from that not only has the network of roads been made far denser but also the regional disparities in the development of transport have been greatly reduced which resulted in the growth of a number of towns along lines in the form of collecting and distributing centres along with administrative, cultural and socio-economic functions. Similarly not only did the various regions experience tremendous differences in urban growth during each decade but also there were significant regional shifts in the patterns of urban growth.

2.7 Inter District Differentials

The annual growth rates of districts during 1931-71 varied from 9.61 (Rahim Yar Khan) in a newly settled district to 2.08 (Dera Ghazi Khan). Out of a total of 19, six districts showed growth rate higher than five per cent, whereas seven are with less than four per cent. It suggests though urbanization has picked up speed in the region during the 40 years, there are nevertheless large inter district differentials in the annual rate of urban growth. The co-efficient of rank correlation between the rates of urban growth since 1951 and 1961 comes out to be low, indicating no consistency in the pattern. The higher rates in the newly settled regions of Rahim Yar Khan and Bahawal Nagar (during 1931-71) give a misleading picture because of very low urban population in 1931.

Keeping in mind the urban population of the districts prior to 1931 and 1881, Figure 2.1b gives the district level urban population change based on 1931. It gives actual (population) as well as per cent changes for both periods (1881-1931, 1931-1971) on the basis of 1971 (100 per cent). The higher actual changes during 1931-71 can be seen in the districts with the major cities of Lahore, Lyallpur, Multan and Rawalpindi, whereas the group showing an increase of less than 100,000 people during the period 1931-71 includes the old, settled districts of Muzaffargarh, Dera Ghazi Khan and Campbelpur. These had a high proportion of urban population before 1881 (17 per cent, 28 per cent and 23 per cent respectively). Jhelum which had a higher proportion of its population (28 per cent) settled before 1881 remained almost static during 1881-1931 and showed an increase in more than 100,000

towns during 1931-71 (see Figure 2.1b). The districts with minimum old urban population (settled before 1881) are Bahawal Nagar, Rahim Yar Khan, Sheikhupura and Sahiwal, which have showed a higher increase in actual population during 1931-71. The districts with considerable actual change during 1881-1931 are Lahore, Lyallpur and Sialkot.

Finally it suggests that no district holds a proportion of changed population less than 50 per cent during 1931-71. This rapid growth of urban population can no doubt be attributed to an increasing rate of natural growth and rural urban migrations stimulated by improving the economy and multiplying the functions of towns. In earlier studies these changes have been mainly related with the irrigation and agricultural development (Malik 1963 and Hamid 1971) and very little attention has been paid towards transportation development. In this chapter the focus is to determine the degree to which particular types of urban developments were associated specially with various kinds and levels of achieved accessibility.

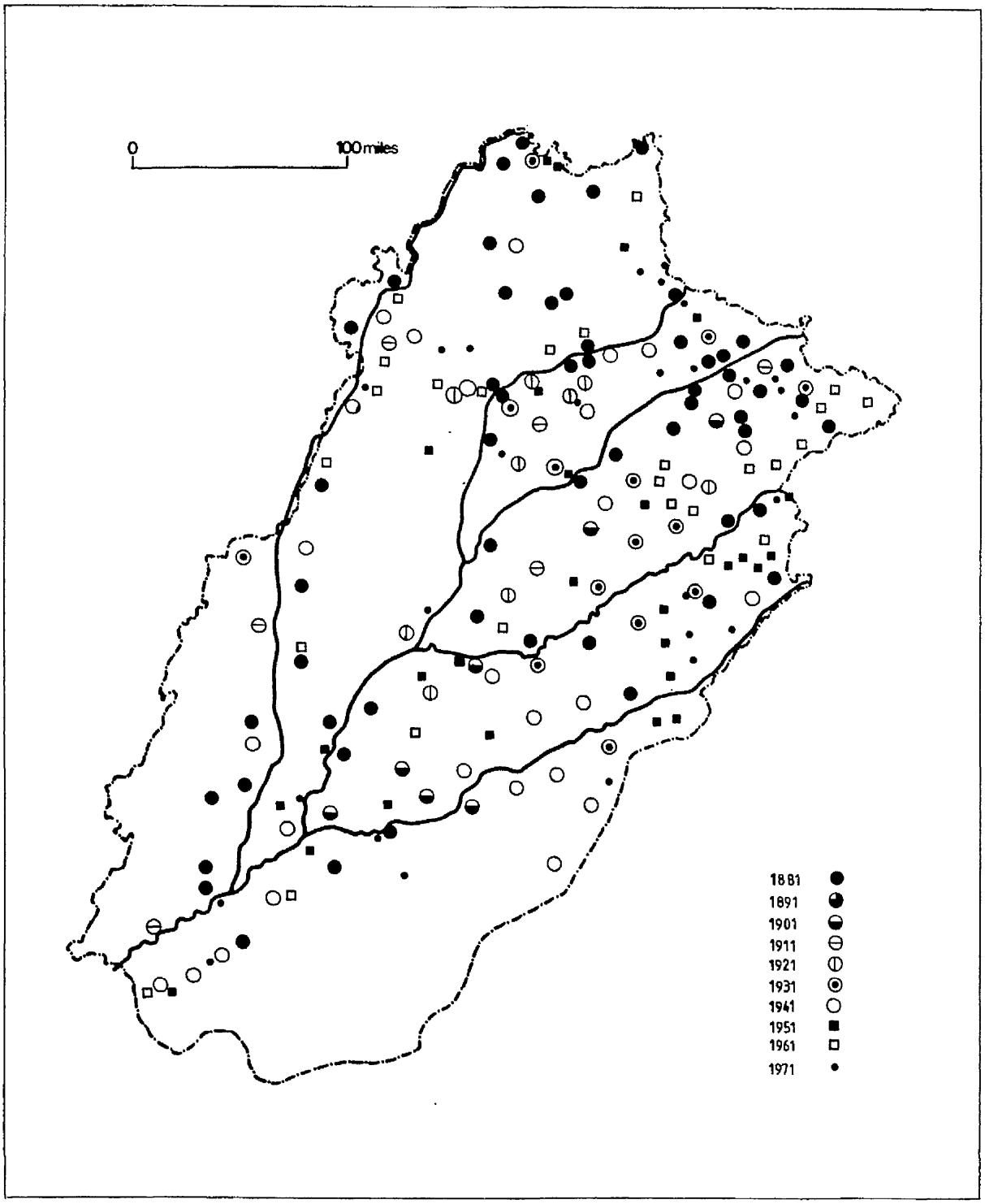
The observed regional contrasts of urban population change reflect similar variations in the change of urban centres. It further suggests that the framework of transport lines with which these centres are linked, have varied greatly in their existence capacities and frequency, through time. These changes for individual towns need to be recorded through decades; this has been attempted in the following section.

2.8 Growth of Urban Centres

In the preceding section an attempt has been made to look at the overall trends of urbanization since the first census of 1881. Although this trend appears to be uniform, in terms of the population of individual towns considerable contrasts can be expected because some of these towns have grown while others have declined, and a number of them have been created from new. On the basis of census data such changes can be identified by measuring the decadewise growth rates of individual towns. It will be useful to identify features associated with different trend rates of growth, with a view to provide parameters for a policy of guided urbanization.

FIGURE 2·2

AGE AND DISTRIBUTION OF TOWNS
[1881-1971]



The direct estimates of the growth are misleading because of the relationship between the size of a town and the expected variance of its growth rate. The scatter of growth rates is very wide for small places and relatively narrow for large places. To take account of these differences, Robson (1973) suggests a standardised measure of 'Z' scores or'standard scores' which express the growth rate of each town as a deviation from the average growth rate of the size group to which it belonged in any decade.

A decadewise pattern of growth during the period 1881-1971 is presented by a series of maps, where the places have been identified according to their growth rates above or below one standard deviation from the mean of their appropriate size groups are distinguished from towns which grew or declined by less than this.

For this purpose the study is limited to towns with population 5,000 + of the whole of the Panjab in 1971 (except for declining towns) only. Within each decade their relative growth is distinguished from: (i) the growth of the other towns in their size groups (I to VI); (ii) all towns (irrespective of their size).
It is measured on the basis of both percentage and actual variations. To identify the effect of the growth of the major cities on the smaller ones, the growth rates have also been computed by excluding them (major cities) from the analysis. The relative growth rates of the towns based on 'Z' scores can be divided into the six groups* (A - F) and are presented in Figures 2.41 - 2.45.

The examination of the maps suggests a prominent pattern of growth which differentiates one decade from another. For this purpose the period of relative growth rates for individual towns through which the system had evolved to reach its present conditions, can be divided into the following three stages of 30 years each:

i 1881-1911
ii 1911-1941
iii 1941-1971

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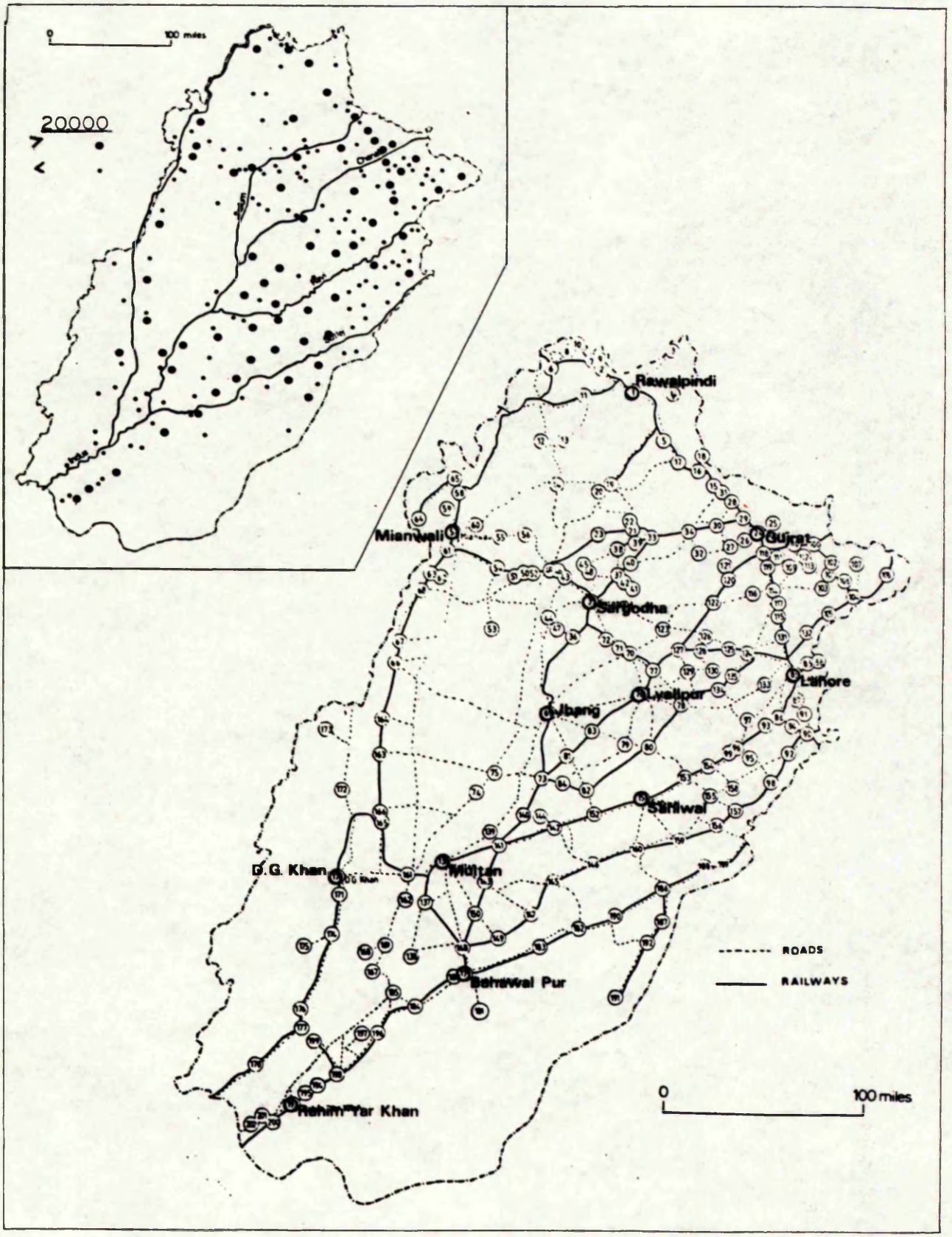
* A + > 2.00 | D - 0 to 0.99
B + 1.00 to 1.99 | E - 1.00 to 1.99
C + 0 to 0.99 | F > 2.00

FIGURE 2·3

KEY MAP FOR TOWNS 1971



KEY TO TOWN CODES 1972

1	Rawal Pindi *	52	Jauhar Abad
2	Wah Cantt.	53	Nurpur
3	Murree	54	Quaid Abad
4	Kahuta	55	Sakesar
5	Gujar Khan	56	Naushehra
6	Campbelpur *	57	Mianwali *
7	Hasan Abdal	58	Daud Khel
8	Hazro	59	Moch
9	Wah Cement Works	60	Musa Khel
10	Gurghashti	61	Kundian
11	Fateh Jang	62	Liaqat Abad
12	Pindi Gheb	63	Piplan
13	Khaur	64	Isa Khel
14	Tala Gang	65	Kala Bagh
15	Jhelum *	66	Bhakkar
16	Dina	67	Darya Khan
17	Kharakha	68	Kalur Kot
18	Mangla Cantt.	69	Jhang *
19	Chakwal	70	Chiniot
20	Bhaun	71	Rabwah
21	Pind Dadan Khan	72	Lalian
22	Khewra	73	Shorkot
23	Lilla	74	Ahmad Pur Sial
24	Gujrat *	75	Garh Maharaja
25	Jalal Pur Jattan	76	Lyallpur (Faisal Abad) *
26	Kunjah	77	Chak Jhumra
27	Mangowal	78	Jaranwala
28	Kharian	79	Samundri
29	Lalamusa	80	Tandlianwala
30	Dingah	81	Toba Tek Singh
31	Sarai Alamgir	82	Kamalia
32	Phalia	83	Gojra
33	Malakwal	84	Pir Mahal
34	Mandi Baha-ud-Din	85	Lahore *
35	Sargodha *	86	Raiwind
36	Sillanwali	87	Kahna Nau
37	Bhalwal	88	Padhana
38	Bhera	89	Dogri Kalan
39	Miani	90	Kasur
40	Phularwan	91	Lulliani
41	Kot Momin	92	Khudian
42	Lilliani	93	Kot Radha Kishan
43	Shah Pur Sadar	94	Raja Jang
44	Sahiwal	95	Chunian
45	Jhawarian	96	Pattoki
46	Shan Pur City	97	Bhai Pheru
47	Faruka	98	Kangan Pur
48	Kalra	99	Wan Radha Ram
49	Khushab	100	Sialkot *
50	Hadali	101	Pasrur
51	Mitha Tiwana	102	Chawindah

* District Headquarters (1971)

103	Kalaswala	153	Okara
104	Narowal	154	Renala Khurd
105	Badd Malhi	155	Pepalpur
106	Qilla Sobha Singh	156	Havaili
107	Zafarwal	157	Basirpur
108	Shakar Garh	158	Hujra
109	Daska	159	Pakpattan
110	Sambrial	160	Arifwala
111	Begowal	161	Muzaffargarh *
112	Bhopalwala	162	Khangarh
113	Jamke	163	Lieah
114	Gujranwala *	164	Kehror
115	Kamoke	165	Kotaddu
116	Qilla Didar Singh	166	Daira Din Panah
117	Eminabad	167	Alipur
118	Wazirabad	168	Jatoi
119	Gakhar	169	Shahar Sultan
120	Akal Garh	170	Dera Ghazi Khan *
121	Ram Nagar	171	Kot Chuta
122	Hafizabad	172	Taunsa Sharif
123	Pindi Bhatian	173	Vehowa
124	Sheikhupura *	174	Jampur
125	Chuharkana	175	Dajal
126	Khangah Dogran	176	Rajan Pur
127	Sangla Hill	177	Kot Mithan
128	Dhaban Singh	178	Rojhan
129	Shah Kot	179	Bahawal Pur *
130	Mananwala	180	Samasata
131	Muridke	181	Yazman
132	Narang Mandi	182	Hasil Pur
133	Sharaq Pur	183	Khair Pur Tamewali
134	Nankana Sahib	184	Ahmad Pur East
135	Warburton	185	Uch Sharif
136	Multan *	186	Bahawal Nagar *
137	Shuja Abad	187	Donga Bonga
138	Jalalpur Pirwala	188	Minchinabad
139	Kabirwala	189	Mandi Sadiqganj
140	Abdul Hakeem	190	Chishtian Mandi
141	Khanewal	191	Fort Abbas
142	Mian Channoo	192	Haroonabad
143	Jahania	193	Rahim Yar Khan *
144	Tulambah	194	Kot Samaba
145	Vehari	195	Trinda Sawai
146	Burewala	196	Liaqat Pur
147	Mailsi	197	Allah Abad
148	Lodhran	198	Khan Pur
149	Kehror Pakka	199	Chachran
150	Dunyapur	200	Sadiqabad
151	Sahiwal *	201	Ahmad Pur Lamma
152	Chichawatni	202	Sanjar Pur

* District Headquarters (1971)

a. 1881-1911

This was an era of much railway construction during which the basic net of the region was completed. This period also saw the beginning of change that brought the region from medieval times to modern with some pioneer attempts of Canal Colonies. There were 43 towns of different sizes in 1881 and there was no change in the numbers until 1911. By this time the settlement pattern was established in the north-eastern part of the region (see Figure 2,2) and most of the important centres were along the rivers. Away from the rivers the settlements were few and isolated. The sandy and dry areas were not settled. During this early phase of railway development two thirds of these towns were connected by railway.

During the first decade (1881-91) a total of 23 towns had a growth rate greater than one standard deviation above the mean. Two towns of Jhelum and Daska are included in 'F' group whereas Sahiwal shows the highest relatve growth rate (A). Thus 20 out of 43 towns were either declining, stagnant or growing with a very slow rate as compared to the others. During the next decade (1891-1901), the trend seems to be slightly different from the one noticed earlier. Only 18 towns were recorded above the standard deviation showing a slow growth rate. In this respect this decade seems to have been less favourable for growth of towns because of widespread epidemics. According to Davis (1951) this slow growth was not so much the direct result of a high mortality rate in the towns, but was due more to the people taking flight to the villages. Similarly the decade 1901-11 shows no change in number except the decline (E) of the further five towns which also reduces the average percentage change of the towns to 2.92 as compared to early decades of 1881-91, 1891-1901 which was 8.65 and 7.46 respectively.

b. 1911-1941

By the end of this period the number of urban centres rose to 80. So far, the railway lines have been extended into the heart of the agricultural regions, where the completion of each phase of the railway stimulated trade in that area and resulted in the growth of centres along it. The improved intensity of land use increased the surplus of food and commercial crops which 'led the cultivators to the

market' (Darling 1947). This gave birth to a number of new market ("mandi") towns.

The growth of urban centres during this stage shows that out of 51 towns during 1911-21, 21 are above the one standard deviation including four (Sargodha, Lyallpur, Sahiwal and Campbelpur) with high growth. By the end of this stage 1931-41, the number of towns with high growth rose to 14 whereas 11 towns declined rapidly. Among these two (Shorkot, Sangla Hill) were included in 'F'. Most of the towns with higher growth can be seen in the centre of the region which may be ascribed to the general development of agriculture and market towns under irrigation.

c. 1941-1971

This stage witnessed the rapid growth of those towns, which owed their existence to the growth of the network. As these towns grew more rapidly, the overall distribution of central places was substantially modified. It caused the elevation to urban status of former villages and also encouraged the gravitation of many existing centres to it. The construction of roads complementary to it by extending the service area and resulted in a number of small marketing centres in the central agricultural region.

The growth of towns in the beginning (1941-51) shows that 110 towns grew with an average of 37.3 per cent per town and out of these 42 had growth rates above one standard deviation. Ten towns, mostly old and on isolated railway lines, showed a declining trend (E) and the remaining towns grouped into 'D' category were either growing slowly or were stagnant. The next decade (1951-61) although shows no change in the per town average increase (per cent), but there were significant changes in the number of towns under varying rates. These changes were still more interesting in terms of their areal patterns. The number of declining towns classified 'E' decreased to four and a number of rapidly growing towns 'A' and 'B' rose to six and 11 respectively. During 1961-71 the distribution of the towns in the different classes is similar except 'C' where the towns rose to 47, showing a comparatively higher growth, which is also evident from the change of average increase (63.72 per cent).

The overall increasing trend of urban growth can further be seen from the ratio of towns between/above and/below the mean growth in those the respective decade. It is high during the early decade of 1881-91 (1.5) and low during 1951-61 (.41) when more than double the towns were below average. It reflects a rapid and high (percentage) relative change in the south and south eastern towns of Bahawalpur division (Bahawal Nagar, Chishtian, Harunabad, Khanpur, Bahawalpur, Burewala, Rahim Yar Khan and Sadiq Abad) which sprang up due to recent development. The urban pattern of these towns shows a predominantly linear pattern, stretched along the railway in recently irrigated tract. This period (1951-61) has the maximum number of towns having a growth rate higher than one standard deviation. This decade is significant because, on national level it has been a period of effective strides in the field of agriculture, industry, education and communication under the new regime installed in 1958 which showed their impact in the 1960s (Ahmad 1966). It is also evident from the highest average per town increase (63.72 per cent) during 1961-71.

For a final picture 'Z'-score permits comparison between the overall relative growth of the towns by their composite values for the decades. But, as the date of origin of these towns varies between the years 1881 to 1961 (see Figure 2.2), therefore it is difficult to assess the comparative position on such bases. It can only be looked at through the average scores (per decade) of the towns since their decade of origin (see Figure 2.5).

It shows that the areas of high growth are in the Panjab plains, where the spatial distribution of the towns is almost uniform and this part has undergone the major developments of agriculture, industry, roads and railway. This zone further extends towards Bahawalpur division where along with the recent economic development the border towns also grew due to the immigrants in 1947. In the north the growing trend of the towns can be seen around the Federal Capital.

The zones of slow growth or declining towns can be found around the centre. In the south western part where most of the remote towns of Dera Ghazi Khan and Muzaffargarh districts have been recording a very slow growth. In the north, the towns of mountainous districts of Jhelum, Campbelpur (and the mountainous part of Mianwali)

have also been showing a slow trend. Another similar trend can be seen in the eastern border towns of Sialkot and some old towns of Gujranwala district.

2.9 Relative Growth of Towns According to Their Sizes

This section attempts to analyse the relative growth of 163 towns of different sizes, having a population of more than 5,000 in 1961. It is based on the actual variations of the towns in the decades relative to their respective sizes.

a. Major Cities (100,000 +)

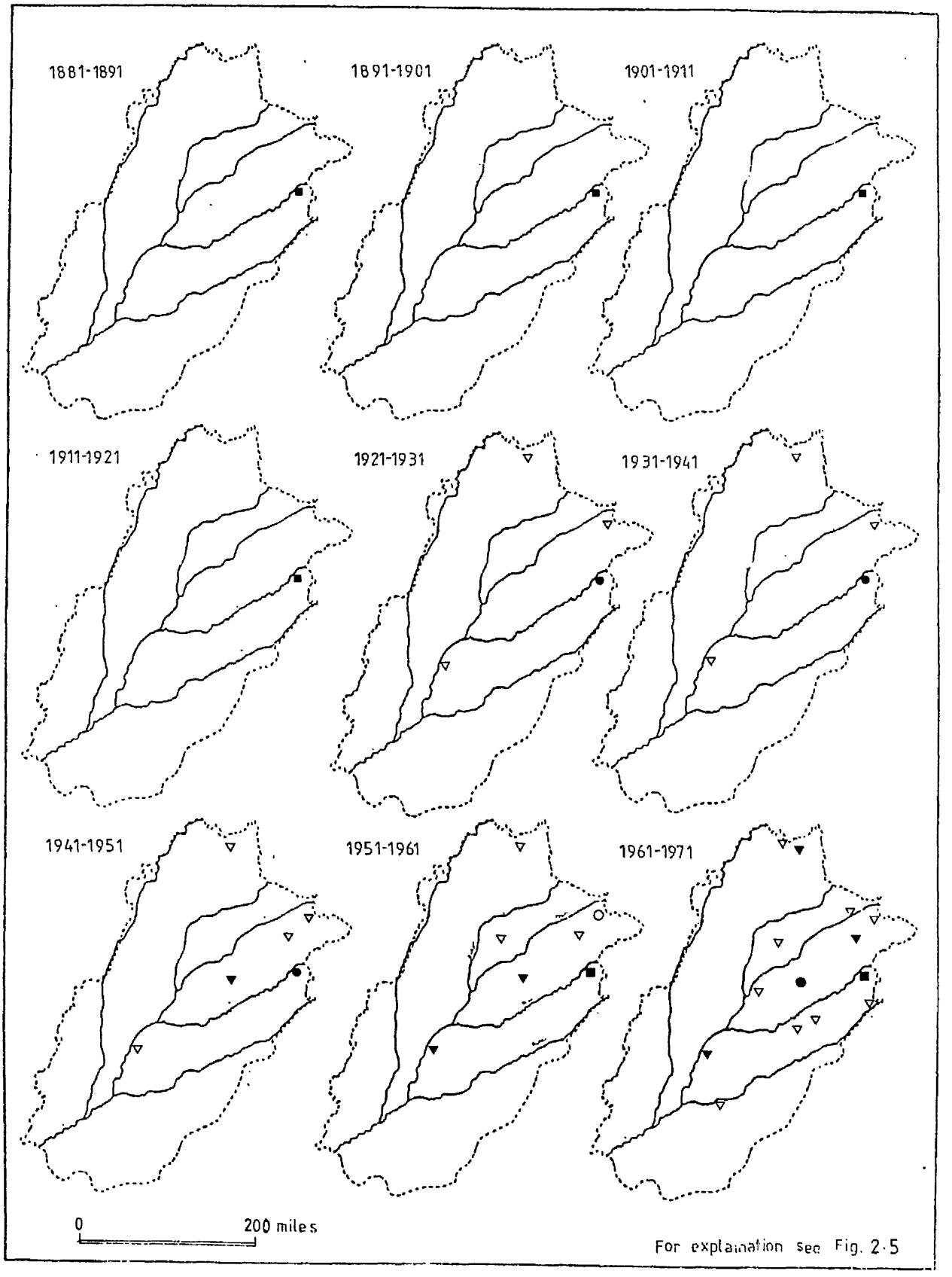
It includes a total of 14 in 1971. All have been towns since 1881, with the exception of Lyallpur, Sargodha, Okara and Wah Cantonment, which date from 1901, 1911, 1931 and 1951 respectively and have never showed a declining trend below 'D'. This consistent increase seems to be a result of the prospering agricultural economy based on canal irrigation. Interestingly Lyallpur and Sargodha rose from Class V towns while Okara was a Class IV town in 1931. The origin (in 1881) of the remaining ten cities of this class varies between Classes I (Lahore) and IV. Although these towns have recorded a gradual increase, there were fluctuations from decade to decade. In the early stage (1881-1911) Jhang, Sialkot and Gujranwala were declining to 'E' while Sahiwal and Lahore were rapidly growing (B+). The second stage (1911-41) witnessed the high growth of Lyallpur, Lahore and Gujranwala whereas Bahawalpur, Kasur, Sialkot, Jhang and Rawalpindi were slowly growing (see Figure 2.41).

b. 50,000 - 100,000

Out of ten only Jhelum, Dera Ghazi Khan, Kamalia and Chiniot are old (since 1881) and with the exception of one (Chiniot), all have shown a declining trend in four, three and one decade respectively (see Figure 2.42). On the other hand three new towns (since 1941) of Kamoke, Burewala and Rahim Yar Khan are rapidly growing, while the growth of Hafizabad, Sheikhupura and Khanewal never went below 'D' since 1921, when these were Class V towns. It shows that in this Class

Figure 2·41

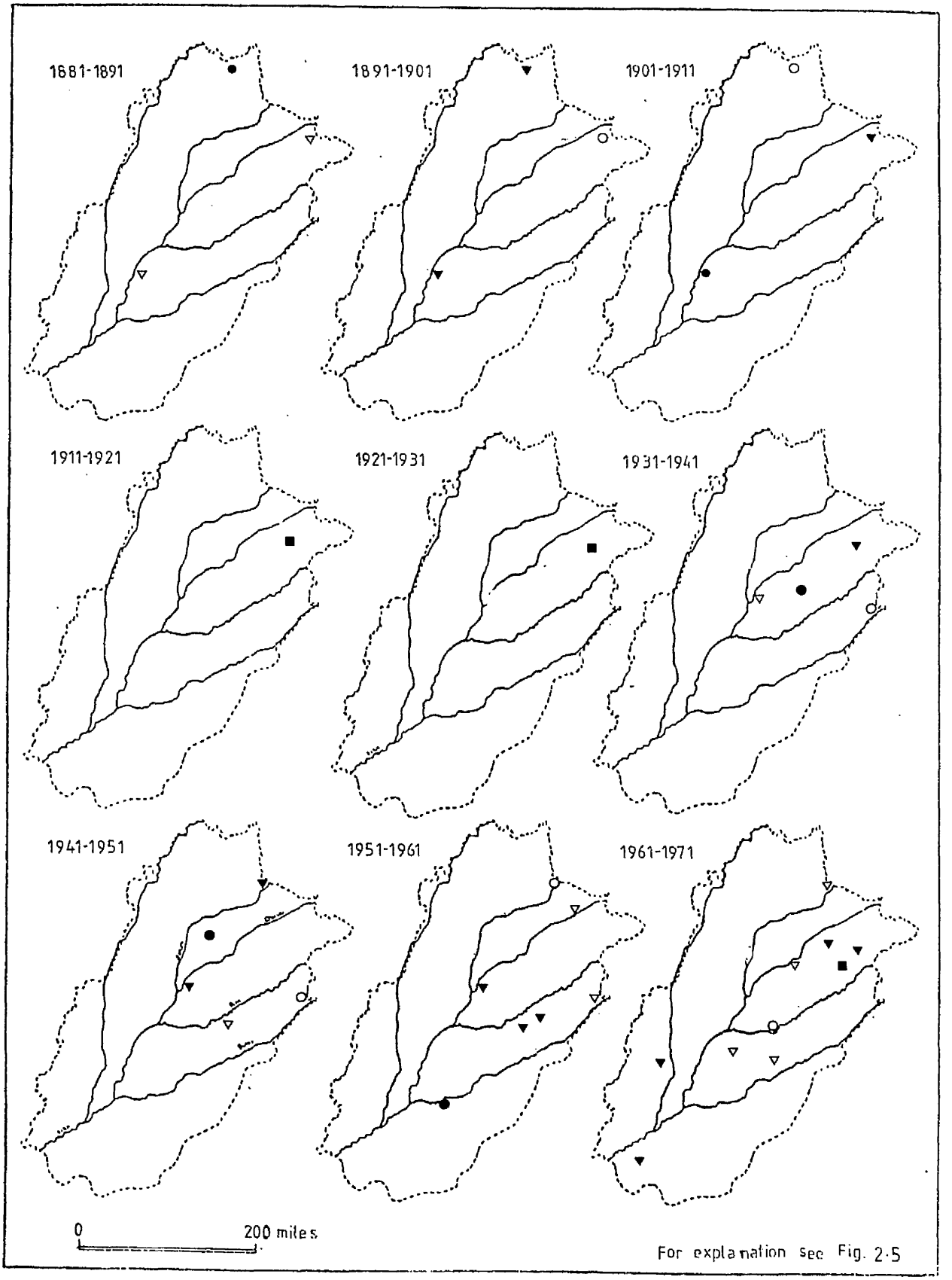
RELATIVE GROWTH OF TOWNS ABOVE 100,000 1881-1971



For explanation see Fig. 2·5

Figure 2·42

RELATIVE GROWTH OF TOWNS 50,000 – 100,000 1881-1971



For explanation see Fig. 2·5

Figure 2.43

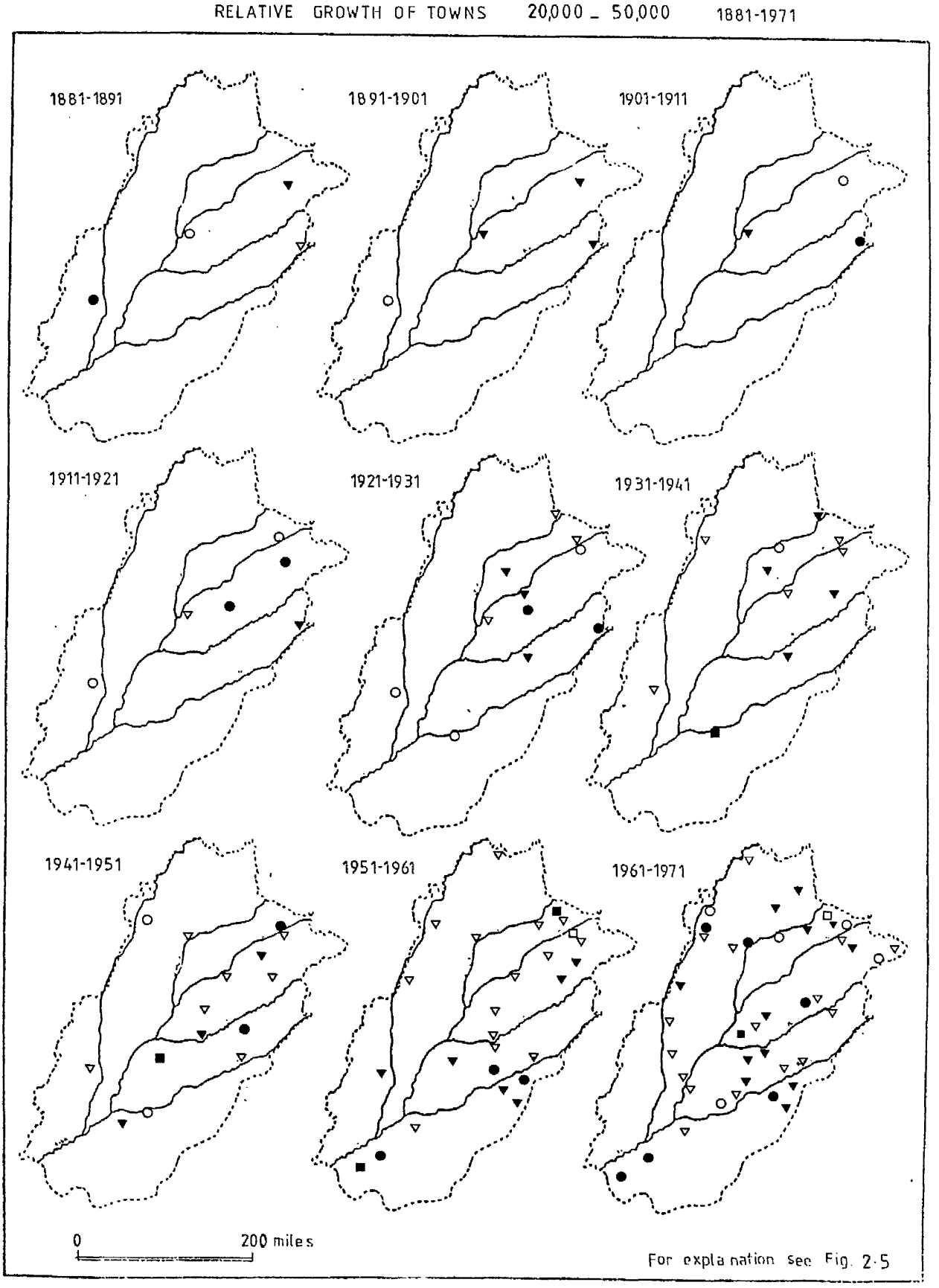

RELATIVE GROWTH OF TOWNS 20,000 _ 50,000 1881-1971
1881-1891
1891-1901
1901-1911
1911-1921
1921-1931
1931-1941
1941-1951
1951-1961
1961-1971
0
200 miles
For explanation see Fig. 2·5

Figure 2·44

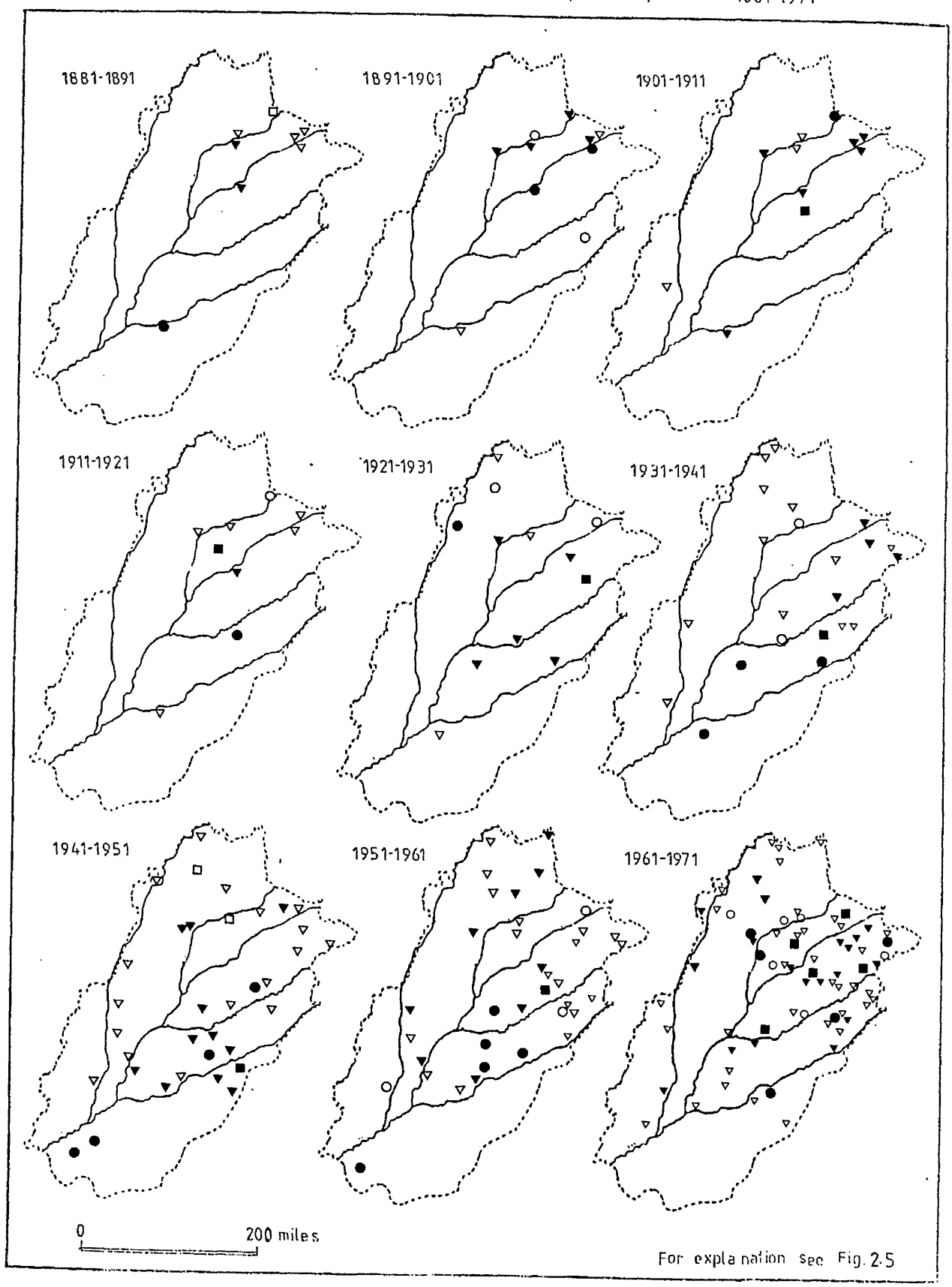
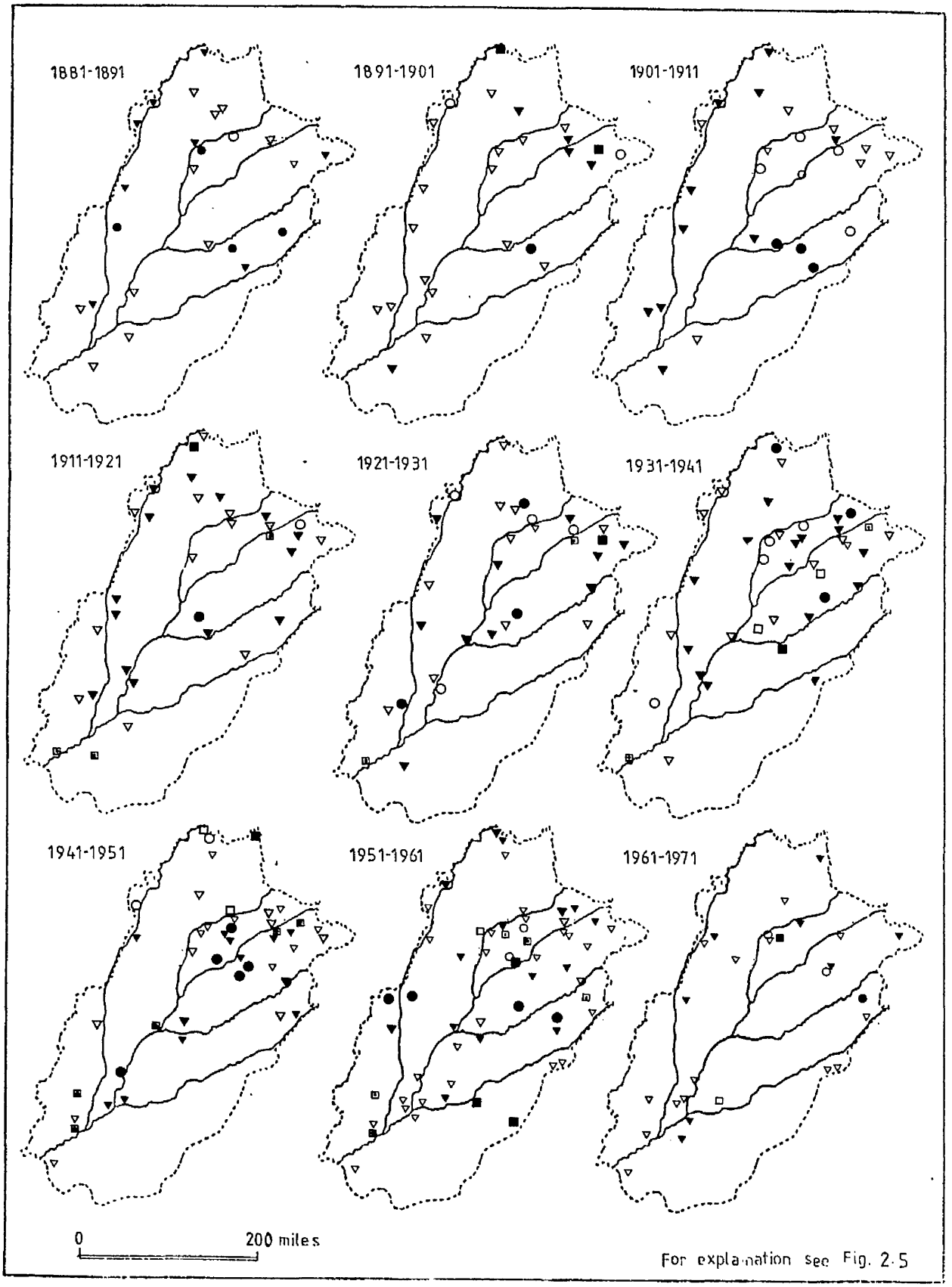

RELATIVE GROWTH OF TOWNS 10,000 _ 20,000 1881-1971
1881-1891
1891-1901
1901-1911
1911-1921
1921-1931
1931-1941
1941-1951
1951-1961
1961-1971
0
200 miles
For explanation see Fig. 2·5

Figure 2·45

RELATIVE GROWTH OF TOWNS 5,000 _ 10000 1881-1971



▣ fallen into lower category (<5,000)

Jhelum and Dera Ghazi Khan are either stagnant or growing very slowly because of their remote locations away from the Centre.

c. 20,000 - 50,000

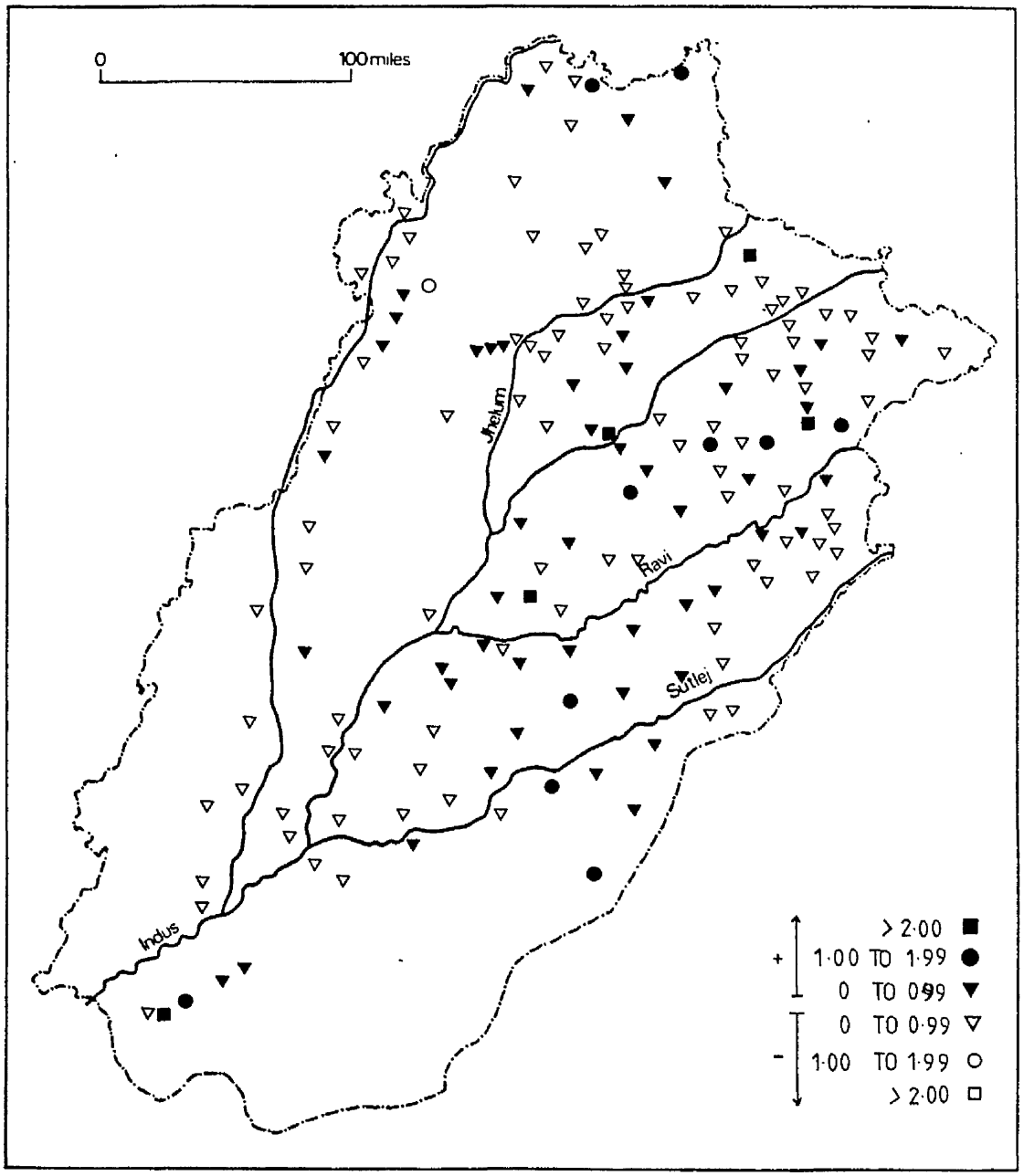
Until 1911, when the economy was mostly rural, the tendency was to reside in the smaller towns of Class V which were popular in serving as markets for rural localities. But later on with the development, this trend shifted towards the larger towns and some of these grew in the higher categories. Now this class includes 12 such old towns which have existed since 1881. Among these Daska, Chakwal, Khushab, Bhakkar, Pakpattan, Lieah, Ahmad Pur East and Khanpur have recorded a gradual and slow growth whereas Jalalpur, Bhera and Shujaabad have been recording an overall trend (see Figure 2.43). Among the new towns, high growth can be seen either in the towns of recently developing areas of the south and south east or in the central area's towns of Chichawatni, Vehari, Mian Channu, Gojra, Jaranwala, Mianwali and Mitha Tiwana. Most of the growing towns in this class have been administrative centres since their origin and have also acted as nodal trade centres for the better agricultural areas because of their favourable locations on the transport routes. It helped them to jump from Class V within a period of 40 years.

d. 10,000 - 20,000

This section classifies 71 urban centres of all ages. Most of these are new and only one sixth have been towns since 1881. All the old towns (before 1881) showed recorded growth more than one standard deviation below the mean throughout the period. Such towns provide the best examples to illustrate the negative effect of the railway by diverting the old channel of trade. Most of them like Jampur, Hazro, Pindi Gheb, P.D.Khan, Isa Khel and Kalabagh were important trade centres in the early decades and are now located on isolated lines. On the other hand most of the new towns of this class (Malakwal, Phularwan, Kot Momin, Hadali, Jauharabad, Rahwah, Lalian, Chak Jhumra, Kabirwala, Renala Khurd) are probably growing due to their favourable locations on main roads, railway or both. The remaining towns are included in the 'D' category of urban growth and are either stagnant or growing slowly (see Figure 2.44).

FIGURE 2·5

RELATIVE GROWTH OF TOWNS
1881–1971



e. 5,000 - 10,000

With the exception of a few old* declining towns (like Miani, Bhaun, Shahpur City, Ramnagar and Dajal) which have been in the same class since 1881, none of the towns in the class are older than 1941. The few old towns recorded a gradual relative growth until 1911, after which they continuously showed a declining relative trend and could not improve their status even in the present regime of rapid growth. Among the remaining new towns Kahuta, Dhaban Singh, Raiwind, Liaqat Abad, Zafarwal, Liaqatpur and Kalra are showing rapid growth while the category of slow growth includes Nurpur, Kalurkot, Khangah Dogran and Uch (see Figure 2.45).

f. Below 5,000 (Declining Towns)

The examination of the growth of the declining towns (which dropped from the higher Class V during the decades) reveals that there were no towns in this group during the early stage (1881-1911) when three towns Khanpur, Ramnagar and Rojhan entered the group in 1911-21. Later on Khanpur maintained the status and the group was joined by isolated river towns of Mithan Kot, Sambrial, Dajal and Ahmad Pur Sial in 1941-51, after which all these towns (except Rojhan) improved their status in 1961-71.

By classifying the overall position of the towns according to the districts, we see that the districts with growing towns are Rahim Yar Khan, Bahawal Nagar, Lyallpur, Sheikhupura and Sahiwal, whereas the districts having the towns with slow or stagnation process are Jhelum, Sialkot, Campbelpur and Dera Ghazi Khan. The remaining districts can be classified as the districts with towns of varying growth according to their location. To understand the locational pattern of these towns, the spatial distribution is discussed at the regional and sub-regional levels.

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* existed before the first census of 1881

2.10 Spatial Distribution

Contrasts in the degree of connectivity for the various districts are also caused by the pattern of location in the region. A close examination of the map (see Figure 2.3) shows some areas of concentration and others relatively empty. Historical inquiry reveals that the movements which have been directed along specific routes (rivers, railways and roads) have a great effect on the pattern of these settlements in the context of origin and destination which often exist at the junction of networks. These junctions have frequent association with distinctive clusters of human activities and vary according to the numbers, size, space and features. The characteristics of location distribution are related to points either with respect to a specific area (density) or with respect to each other. In the latter case, which is the main focus of the present analysis, the emphasis is placed upon the distance between the points (urban centres) in order to understand the influence of locations between the settlements, where each settlement has an equal chance of occurring at any position within the area.

The significance of spacing as one of the basic attributes of any spatial distribution can be examined statistically and then distinguished between the patterns of clusters, random and dispersed. In general the difference between all these three patterns of distribution is easy to understand as it appears from the settlement distribution map of the Panjab (displaying variety of distribution pattern between the sub regions) but in practice it is often difficult to distinguish between the degree of clustering or dispersion on the basis of qualitative estimates. Therefore, a strong need exists for a tool with which to describe urban settlement patterns in the regions of the Panjab. To identify this type of regional contrast a number of techniques have been developed, but the well used technique of nearest neighbour analysis outlined by Clark and Evans (1954) and exemplified by King (1962), makes it possible to describe any point pattern in terms of single statistic (Ru) on a scale ranging from 0 to 2.149. With the aggregation of all places at one point the value of 'R' would equal '0' with the completing random distribution of places R = 1 and if the pattern of the places was completely uniform 'R' would equal 2.15. In higher order patterns, the value of 'R' in a uniform distribution

increases slowly. It measures distance from an individual to its nearest neighbour irrespective of direction. In a clustered distribution these distances will obviously be low while an ordered pattern will exhibit relatively wide spacing between the points. It indicates the degree to which any observed distribution of points deviate from what might be expected if the points were distributed in the random manner within the same area. To compute the nearest neighbour statistic 'R' which is a ratio between Mean observed distances and expected mean distances, the following formula has been used (see Clark and Evans 1954).

$$R = \frac{\frac{\Sigma Y}{N}}{\frac{1}{2P}}$$

N = Number of settlements in the area.
Y = distance from each city (settlement) to its nearest neighbour
P = density of towns per unit area.

The analysis for the regional urban centres is carried on three different administrative units of the Panjab (as a whole), division and district level. By following the definition of towns according to the census of 1972, a total 202 towns were included without considering their population sizes.

2.11 Panjab and Division Level Nearest Neighbour Analysis

The Table 2.7a presents the statistic 'R' values along with the significance test* of critical values for the divisions and the Panjab as a whole. It reveals that the expected range in values for 'R' is apparent that the tendencies towards aggregate, random and uniform spacing of towns vary between the regions. Such contrasts are naturally expected in regions with contrasting physical and human sub-regions. According to the values of different sample areas,

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* Computed by formula $C = \frac{\bar{d}_{ob} - \bar{d}_{exp}}{SE\,\bar{d}}$

$$SE\,\bar{d} = \frac{0.26136}{\sqrt{nP}}$$

Table 2.7a

DIVISION AND PROVINCE LEVEL
NEAREST NEIGHBOUR ANALYSIS
(1971)

Division/ Province	No. of Towns	Area	Density	Distance Obs.	Exp.	R	c.values
Rawalpindi	34	11,206	.00303	11.32	9.08	1.25	2.75
Sargodha	50	17,095	.00292	9.68	9.25	1.05	0.63
Lahore	51	8,907	.00572	9.59	6.61	1.45	6.16
Multan	43	24,826	.00173	16.14	12.02	1.34	4.30
Bahawalpur	24	17,508	.00137	12.21	13.51	0.90	-0.90
PANJAB	202	79,542	.00254	11.61	9.92	1.17	4.63

the explanation follows per different units of measurement.

On Panjab level the pattern (of distribution) shows the approaching uniform distribution of urban settlements which is due to regional development allowing for economic, administration, social and physical features. Referring to division level 'R' values we can understand that there is only one region of Bahawalpur (division) where a clustered pattern is formed, which indicates a close spacing of distribution. This is mainly due to physical hindrance at other places for development of urban settlements in the region. Apart from that the physical factors seem to be largely responsible for the low scores in Bahawalpur where the arrangements of pairs of towns along rivers (Sutlej and then Indus) in otherwise largely uninhabited areas has produced linear clustering in the region.

The distribution in the remaining three divisions of Rawalpindi, Lahore and Multan approaches uniformity. The mainreason for this type of distribution seems to be the result of the development of agricultural occupance in the uninhabited areas, development of the market centres, industrial expansion and transport facilities for their respective hinterlands. The high scores in these regions are expected due to the low relief and uniformness of the land between the rivers.

The absence of a dispersed pattern in any region suggests that the overall spacing of the settlements in all the regions is relatively uniform. Lahore division followed by Sargodha have the towns located closer to one another, while Multan, being the largest in size has the towns with approximately average distance between them. On the other hand, expected mean distance, which reflects the relation of size and number of settlements in the region, is higher in the larger area regions of Bahawalpur while lower in smaller area regions of Lahore division. Similarly the northern regions of Lahore, Rawalpindi and Sargodha have lower YE values than the Panjab as a whole. This shows the higher concentration of urban settlements for demarcating the points while the southern divisions of Multan and Bahawalpur have higher YE values showing lower concentration of urban settlements.

2.12 District level nearest neighbour analysis

Taking a step further on district level, the pattern of distribution is more interesting. Table 2.7b gives the 'R' values for the 19 districts, which vary in size and number of settlements as well as their tendency towards aggregation. Three districts namely Jhelum, Sargodha and Jhang have a random distribution pattern, possibly due to physical and cultural features of urban development and particularly the influence of transportation routes. Four districts of Mainwali, Muzaffargarh, Bahawalpur and Rahim Yar Khan have a clustered pattern. All these districts have gone under the rapid change of irrigation and agriculture during the recent years. These have caused a number of new urban centres to grow on the main railway lines. Away from these most of the region is still uninhabited and the towns are distributed in the straight line (along railway lines and rivers). Except for Bahawalpur which lies along the River Sutlej and has similar reasons for clustering, all the three districts stretch along the River Indus, with their towns on straight railway lines running parallel to the rivers which help to produce linear clustering for the pairs of towns, which tends towards zero.

The remaining six districts of Gujrat, Lyallpur, Sialkot, Gujranwala, Dera Ghazi Khan and Bahawal Nagar have a distribution approaching uniform. In Lyallpur the pattern of transportation routes is in very close agreement with the arrangement characteristics of an hexagonal pattern of settlements where most of the towns appear to be associated with the intersection of more than two transportation routes.

Some observed ordered distances show a large deviation about the mean. The variations in the range of observations among the Panjab districts and among various orders within the same region, reflects the heterogeneity and relative isolation of many districts, therefore to differentiate the discrete groups or cluster of settlements on the basis of spacing, it is possible to classify them according to the distance of separation (Y_E) of the theoretical uniform distribution of the regular lattice, as a standard. The settlements located at the distance lower than 'YE' values are treated as one cluster while the settlements with higher than 'YE' distance within their respective district, are considered as dispersed centres.

Table 2.7b

NEAREST NEIGHBOUR ANALYSIS (1931 and 1971)

Regions/ Districts	A 1931 N	γ_{ob}	γ_{ex}	R	B 1971 N	γ_{ob}	γ_{ex}	R
Rawalpindi	2	25.00	15.89	1.57	5	20.20	10.06	2.01
Campbelpur	6	17.33	13.13	1.32	9	10.67	10.73	0.99
Jhelum	4	23.25	13.18	1.76	9	9.11	8.77	1.04
Gujrat	5	13.20	10.64	1.24	11	9.64	7.17	1.34
Sargodha	13	11.46	9.59	1.19	22	7.91	7.36	1.07
Mianwali	4	32.00	18.38	1.74	12	8.92	10.61	0.84
Jhang	5	19.00	12.87	1.48	7	11.57	11.02	1.05
Lyallpur	6	20.17	12.09	1.67	9	13.56	9.88	1.37
Lahore	4	20.25	11.24	1.80	15	9.27	6.08	1.52
Sialkot	6	10.00	9.27	1.08	14	7.78	6.08	1.28
Gujranwala	7	14.29	9.08	1.57	10	10.60	7.60	1.39
Sheikhupura	4	24.25	12.02	2.02	12	11.25	6.94	1.62
Multan	3	26.67	21.72	1.23	15	16.33	9.69	1.68
Sahiwal	4	25.75	16.22	1.59	10	16.40	10.27	1.60
Muzaffargarh	6	21.00	15.29	1.37	9	11.22	12.50	0.90
Dera Ghazi Khan	9	20.44	16.14	1.27	9	20.44	16.14	1.27
Bahawalpur	2	27.00	34.50	0.78	7	14.14	18.51	0.76
Bahawal Nagar	2	28.00	20.76	1.36	7	16.14	11.07	1.46
Rahim Yar Khan	2	25.00	23.57	1.06	10	8.10	10.61	0.76
PANJAB	94	18.82	14.54	1.29	202	11.61	9.92	1.17

Figure 2.6 shows the composite groups of concentration in the districts. The maximum concentration is observed in the districts of Sialkot, Sargodha, Rahim Yar Khan and Jhang, where more than half of their towns are located at distances lower than their theoretical expected mean distances ($\gamma\epsilon$), while the newly settled districts (in the Canal Colony) of Lyallpur and Sahiwal indicate a completely regular pattern with no town located at the distance of lower then the ' $\gamma\epsilon$ ' values of the overall district. These districts are then followed by Sheikhupura and Multan where hardly a few patches of concentration are found. It suggests that the distribution of urban settlements took place in the newly settled Canal Colony districts at a regular space. In the light of this regular distribution of the settlements, the higher scores of these districts are also expected on the indices of connectivity and nodal accessibility (which are to be measured in the next Chapter). The linear concentration along transportation routes is also found in the districts of Mianwali, Sargodha and Jhang where new settlements seem to have appeared (between the pre-existing centres on railway lines) with development of road transport.

Looking at the clusters around District Headquarters, which hold important positions in terms of political, economic and administrative activities, it is interesting to note that except for the six districts of Gujrat, Mianwali, Muzaffargarh, Dera Ghazi Khan, Bahawalpur and Rahim Yar Khan there is no District Headquarters town located to its nearest neighbour town, with the distance less than their theoretical distance ($\gamma\epsilon$). It suggests that the existence of the District Headquarters has been a barrier to the growth of new settlements in their hinterlands. The exceptions in this case can be explained due to either an already existing old town or an important transport node.

Similarly comparing the theoretical values ($\gamma\epsilon$) of the districts to the whole Panjab, there are ten districts having higher values while the remaining nine districts with lower ' $\gamma\epsilon$ ' values depict the higher concentration of urban settlements for demarcating the points. The districts with higher than the Panjab show lower concentration or wider spacing of urban settlements in their locations and are included in either the hilly districts of Rawalpindi and Campbelpur where the physiography does not permit the growth of settlements or the larger size districts of Bahawalpur and Dera Ghazi Khan having a smaller

number of towns as compared to their sizes.

A comparison between 'R' values of districts and 'R' values of the Panjab as a whole shows that there are 11 districts with higher values than the Panjab and suggest comparatively higher quality of approaching uniform or dispersed characteristics while the remaining eight districts show a more clustering pattern of distribution. Similarly ten districts have higher 'R' values and eight districts with lower than their respective divisions as a whole (see Table 2.7b). Only the district of Jhang has the same values of 'R' statistic of Sargodha division as a whole. This exhibits similar characteristics to Sargodha division as a whole with its central Jhang district, in respect of distribution pattern.

2.13 Hypothesis

After obtaining a descriptive position for the districtwise settlement pattern it is possible to apply a significance test to the analysis, to decide how probable it is that the observed arrangements of the points occurred by chance. The following hypothesis in this respect is tested through 'C' value statistic test*.

1. H_0 is that the pattern of settlement is similar to a pattern produced by the independent random location of each point or the observed arrangement is the result of points being located at random within the study region.

2. H_1 is that the settlements are distributed in a manner that is not random.

The last test therefore shows that the null hypothesis can be rejected according to the decided level of significance for the region of the Panjab as a whole and suggests that the arrangements shown in the region can be considered to be significantly dispersed '-001' level - a very high level of significance. For smaller units of divisions the null hypothesis can be rejected for Rawalpindi, Lahore and Multan showing a similar level of significance. On the other hand the divisions

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* It is based on the difference between d_{ob} and d_{ran} and is very similar in form to Studnets 't' test.

of Sargodha and Bahawalpur which show their approximation to a randomly generated distribution. It suggests that the pattern revealed is close to the distribution which would occur if each point was independently located and the result of 'chance'.

On the basis of test applied on district level pattern of distribution the null hypothesis is rejected at minimum 0.01 significant level, in the three districts of Lahore, Gujranwala and Bahawal Nagar, showing that the distribution might be expected to occur through chance variations less than once in a 100 (comparatively lower than the level for the Panjab as a whole), while in the districts of Rawalpindi, Sheikhupura, Multan and Sahiwal, the hypothesis is rejected at 0.001 level showing a chance variation less than once in a 1000 (a very high level of significance).

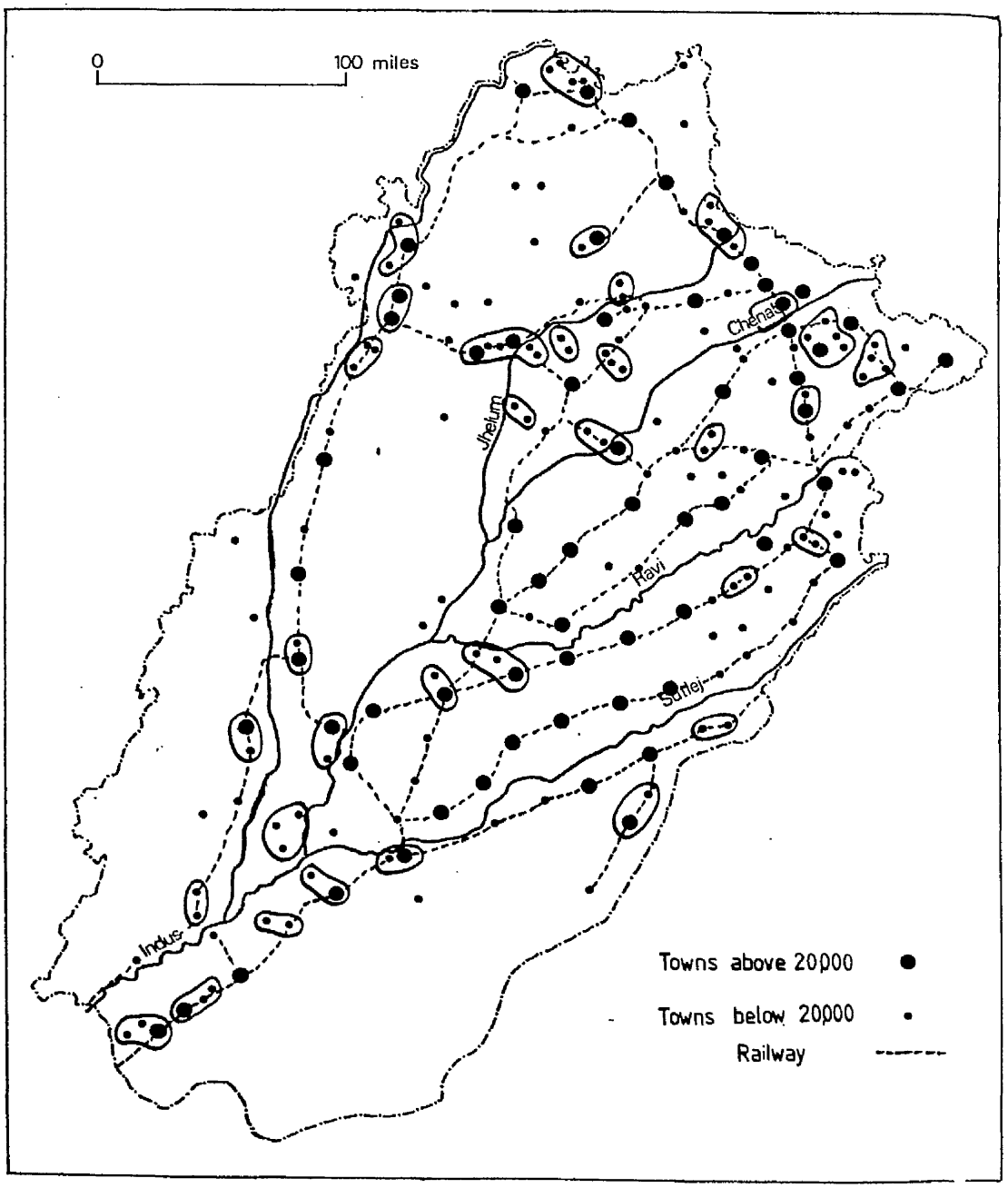
As this is the mathematical relationship and there is good reason to believe that the slight clusters and the blank areas in the pattern, although to be expected in a random distribution are partly the result of the influence of physical factors. It mainly includes the distribution of modes of transportation, service centres, market facilities, interlinking characteristics of urban settlements on their catchment areas and distribution of centres according to their economic and administrative activities as well as their relative accessibility in the region.

It is observed that the variations in physical conditions, economic potentialities and road rail densities in the region naturally result in marked contrasts between the distribution of towns at any one time, whereas some areas might exhibit a random pattern others might tend towards clustering or regular distributions. Similarly, the overall system can vary according to its 'R' values between the two different periods. The focus of this study is to understand the spatial changes in urban growth with particular reference to the period between 1931-1971, therefore to compare the spatial distribution of towns in the districts of the Panjab with an earlier date (1931) the nearest neighbour analysis has also been computed by the same procedure (while two towns were added in the two remote districts which had one town each in 1931). It was done to follow the rule that "the regions either should be empty or contain at least two towns", King (1962). This will

FIGURE 2·6

DISTRICT WISE URBAN CONCENTRATION

(According to 'rE' values)



be helpful in understanding the connection of 'spacing between towns' and with increasing urbanization, during the period of road development (1931-71) in the region.

Table 2.7b gives the 'R' values for all the 19 districts in 1931 ranging from a high tendency towards random 0.78 (Bahawalpur) to a pattern far more regular than the random 2.02 (Sheikhupura). Such contrasts are expected in a region with varying physical and human sub-regions. In 1931, a tendency towards a dispersion pattern is more prevalent as eight of these districts have dispersion values (more than 1.57). All these districts cover the northern half of the region. There are seven districts of Campbelpur, Gujrat, Jhang, Multan, Muzaffargarh, Dera Ghazi Khan and Bahawal Nagar, with approaching uniform characteristics, while Sargodha, Sialkot and Rahim Yar Khan had random patterns at that time (1931), only Bahawalpur district had the tendency towards a clustering nature. Practically, this pattern in Bahawalpur seems misleading because of its huge size and an addition of a town for the purpose of analysis. Apart from that the general pattern of 1931, clearly indicates a high tendency towards dispersion. With the application of the test the null hypothesis is rejected at a significance level of 0.01, for the districts of Jhelum, Mianwali, Lyallpur, Lahore, Gujranwala, Sheikhupura and Sahiwal showing that their distributions were expected to occur through chance variations less than once in a 100 (an acceptable level of significance). The districts showing a tendency towards the dispersion during this period are (in order) Multan, Rawalpindi, Sialkot, Gujrat and Bahawal Nagar while Sahiwal and Dera Ghazi Khan show no change. A high changes from dispersion to random and clustered pattern are significant in the districts of Mianwali and Jhelum and then followed by Muzaffargarh, Jhang and Sheikhupura. It shows that there has been a general decrease with increasing urbanization. Table 2.7b suggests that the values for 1931 are widely scattered between very high tendencies towards a regular pattern as compared to the tendencies towards clustered distributions. The array of values for 1971 shows a rather general shift towards random and aggregation. It seems that increasing urbanization has produced an urban pattern for more random than either clustered or hexagonal. It also reflects the increasing number of processes affecting urbanization in the region.

To understand the stability of the pattern during this period, in this study the concept of stability is taken to mean a settlement pattern for which the values of 'R' do not vary by more than 0.20 during the period; the pattern is unstable when the variation in 'R' is greater than 0.20. There are seven districts which in spite of an increase in the number of settlements have the stable pattern, while Dera Ghazi Khan has no change in the number of settlements. The maximum stability in the pattern of the distribution can be observed in the districts of Sahiwal and Bahawalpur, followed by Gujrat, Sargodha and Bahawal Nagar, showing minimum changes in their 'R' values but maximum change in the number of settlements. It reflects that in these districts the change in γ_{ob} was according to the γ_{exp} change and the growth of settlements was smooth with spacing similar to that of 1931. The general pattern of the whole of the Panjab region is also stable and shows a tendency from uniform to random during the period of 1931-1971.

Changes in 'R' values for particular districts are quite interesting. For example in the district of Jhelum and Mianwali the tendency for high change from dispersion to random reflects the construction of roads which have become new modes for settlement development. Similarly the change in Lahore district from dispersion to uniform is a reflection of road development, to connect the main city of Lahore to the other regions, through the district. Sometimes in the vast areas the forces of urbanization cause depression or show a tendency towards random instead of concentration. In the case of Multan district, it is observed that the thinning-out of the urban pattern (1.23 to 1.68) is due to agriculture and road development, which have changed the small settlements into urban centres with comparatively wider spacing. Similar trends are noticeable in the districts of Bahawal Nagar, Sialkot, Gujrat and Rawalpindi.

Finally it is concluded that the overall pattern of the region is stable and the discussion suggests that all sub-regions are not subject to the same spatial forces. This analysis of spacing and changes between 1931-1971 is useful for the subsequent study as it reflects the changing forces of urbanization in the region.

Chapter 3
HISTORICAL DEVELOPMENT OF TRANSPORT NETWORKS

3.1 Introduction (Background)

The backbone of the region's transport system is a broad gauge railway network which, from the start, has had its centre at Lahore. It is a system of main lines, one in each of the five parallel river 'doabs', interlinked and stretching from the coast to the Afghanistan frontiers. The main line leads to Karachi with another separating it and leading to Quetta (Baluchistan). Supplementing the railways, a road network covers the same ground on a roughly similar pattern, most of it concentrated, again, in the populous parts of the Indus Basin (see Figures 1.1 and 2.3).

The history of the development of the rail network goes back to 1844, when the proposals for railway construction in India were mooted in England. The East India Company, which then ruled the Sub-Continent, gave contracts to British Companies through a system of guaranteed returns, under which two small railway lines were made near Calcutta and Bombay. Lord Dalhousie emphasised the importance of railway construction in India, in his famous minutes of 1853. He recommended a system of trunk lines connecting the interior of each presidency with its principal ports. He favoured construction through private companies under the supervision and control of government. Consequently, between 1854 and 1880 contracts were entered into with eight companies and according to Malik (1962) the first portion of the railway line of the Panjab (Pakistan) was opened on 10-4-1862 between Wagah and Lahore and by the end of August 1870, Lahore was connected with Multan.

The maximum rail network construction took place before 1930 (see Figure 3.1a) and after that the main attention was given to the construction of roads to feed the railway. After partition (1947) the roads dominated the railways on district or division level (in the region) as in other less developed Countries. As Hodder (1971) writes

"In less developed countries the railway, for long the major stimulus to economic development and symbol of Colonial economic power over many areas, are gradually being replaced and extended by less expensive and more flexible road networks". In the Panjab this dominance of roads is due to the following advantages as compared to the railway:

i. Roads provide a great flexibility of service since numerous routes and destinations are possible.

ii. The road network offers directness and the possibility of door to door communication.

iii. Speed and cost over short distances is more favourable than that of the railway.

iv. Roads offer maximum access along their line side and have maximum scope for intervening opportunity.

v. Roads provide better frequency and efficiency over short distances.

3.2 Road Development

Although the history of road development in the region goes back to the Mughal period, the main era of road construction was initiated by the British Government, with the creation of the Public Works Departments (PWD) both in the provinces and at the centre. The earlier constructed roads were badly neglected in addition to being inadequate and the government's efforts led to the revival of the Grand Trunk Road, linking Peshawar with Delhi and Calcutta. This road has been the great highway for armies, traders and travellers from Central Asia and Europe. Lying as it does in northern Punjab, this road was marked with a string of towns commanding river crossings or central positions on the 'doabs' (Trevaskis 1928).

Another relatively less frequented, but quite important trade route that traversed the region came from the north-west through Kabul in Afghanistan and passing through Bannu and Chiniot, converged at Lahore. Apart from these, there was no road in the region that could be used by travellers until the time of British rule. The inadequacy was badly felt by the British, as is evident by the administrative reports (1917-1918) of India. "Among the difficulties which hinder the process of Indian agriculture, despite the efforts of the Agricultural and Co-operative departments, may be mentioned the lack of good roads. Some

of the best agricultural districts in India are cut off from Trunk Roads and railways and are inaccessible for most of the rainy season". The report for 1919-1920 added, "The same rock upon which the Moghal Empire finally split still remains a formidable obstacle to the progress of modern industry. Unceasing efforts and expenditure upon a scale hitherto impossible will be necessary if the Communications of India are to be adequate for the requirements of the Country".

In 1927 a Committee known as the Indian Road Development Committee was appointed to consider the major problem of communications. The Committee was of the opinion that the development of the road system was desirable for the general welfare of the country as a whole and in particular for:

i. the better marketing of agricultural produce,
ii. the social and political progress of the rural population which will be advanced by the increased use of motor transport and
iii. as a complement to railway development.
(Administration Reports of India).

In the meantime, in December 1943, a road conference of Provincial Chief Engineers was held at Nagpur to chalk out a plan for road development in India. The Chief Engineers came to the conclusion that India must increase its road mileage by 400,000 miles over a period of 20 years (Vakil 1950). The plan had not yet reached the stage of implementation when partition took place. At the time of partition, the road mileage for the Panjab (Pakistan) was 2,694 miles of superior surface roads and only 410 miles of metalled roads.

3.2a Main Highways of the Panjab

Roads in the region may be classified into

i. National Highways
ii. Provincial Highways
iii. District Roads and
iv. Village Roads.

The National Highways connect large towns and cities while the Provincial Highways are the main arteries of commerce within each province and are connected with the National Highways. The district

roads connect the producing centres in the districts with the highways and railway stations. The village roads are mostly 'Kacha' tracks connecting village with village. In addition there are municipal roads which are under the jurisdiction of municipal bodies, corporations, municipalities, etc.

The main highways of the Panjab which were in existence at the time of partition, are briefly described below:

i. The Grand Trunk Road was constructed by Sher Shah Suri in the thirteenth century for strategic reasons connecting NWFP with Bengal. The section that lies in the study area starts from Attock and, passing through Rawalpindi, Gujrat, Jhelum and Lahore terminates at Wagah on the Indo-Pakistan border.

ii. The Second Trunk Road connects Lahore with Karachi (Sind) and runs right through the country from north-east to south-west. It is made up of several inter district roads and the section that lies in the study area starts from Lahore and, passing through the districts of Sahiwal, Multan and Rahimyar Khan crosses the border of the Panjab near Sadiqabad. Most of the time it runs alongside the Karachi-Lahore railway line and is never far from it. Its commercial importance is great since it connects the port of Karachi with the rich agricultural regions of the Panjab.

Apart from these, there were a few roads connecting the districts; these were inadequate. Because of this inadequacy, more attention has been paid to road development during recent decades.

According to the Census of 1972, there is hardly a town in the region which does not lie on a road or bus route while on the other hand, three large towns (of more than 20,000 population) are not connected by railway. The number of unconnected towns (by railway) increases in the lower classes of town.

As there are no pre-partition statistics available for the roads in the region, it is difficult to look at road development through figures. However, it is possible to look at the degree of road development since 1965 and this can be compared with the position at the time of partition. In this respect Table 3.1 indicates the degree of development by Pi index (see Appendix A) according to 'High Type Roads' and 'All Type Roads',

separately. It shows a systematic development in the road network, particularly in the high type roads. It suggests that the province of Panjab is making an almost continuous improvement in road transport as compared to railway, as a result of the advantages mentioned above (Section 3.1). The last but not the least important factor is the availability of data for roads (traffic flow and route length) according to the administrative divisions of the region while for railways, data are available according to the railway units which are different.

3.3 Growth of Rail Network

In this section an attempt has been made to look at the changes decadewise in the network development from its inception in 1862 to the present. The measurement of these sequential changes will be useful in examining their impact on the growth of urban centres in the region as a whole and its subdivisions. It is important to look at these changes because the network may be seen as causes as well as effects. The addition, modification and elimination of a route may bring some changes in the accessibility of places relative to one another, and may also be a cause of the growth and decline of some places. So far a number of investigations have dealt with the interaction between urban centres and transport development. One of the most important studies is that of Gauthier (1968), who contends that a high degree of interdependence exists between the development of transport systems and the spatial pattern of urban economic growth. This (above mentioned) study for the period of 1940-1960 has provided some support for the argument that transport improvements are the leading factors in the development process and suggest that there will be an increase in the number of urban centres which derive functional/economic benefits from changes in their network accessibility.

Another study is worth mentioning for its historical treatment of the interaction between transport development and urbanization. Taaffe, Morrill and Gould (1963) were the first to construct a model which represents a generalised description of transportation network development through time in under developed countries. The model was based largely on data concerning Ghana and Nigeria, although they also examined the network expansion process in Brazil, Kenya, Tanganyika and Malaya. It has been found to be applicable to other developing areas.

This spatial model of transport network development has proved to be a valuable help in its understanding and has been widely applied. It emphasises the role of urban concentration where several coastal nodes with superior locational and political advantages grow faster than other centres less well endowed. This model of sequence of transport growth recognizes four stages in what is really a continuous process to obtain a clear understanding of the sequence of changes. Attempts have been made to build mathematical models to simulate continuous network development in a more realistic fashion. Kansky (1963) and Morrill (1965) have tried to reproduce the location patterns of railway routes as they developed over time dealing with areas of Sicily and Central Sweden respectively. The model of Taaffe et al (1963) has subsequently been applied to the seaports of New Zealand for the period 1853-1960 by Rimmer (1967).

Medvedko (1967) described the following four phases in the network evolution, with the help of graph theory indices introduced by Garrison (1960) and Kansky (1963). He suggests that it is possible to specify typical phases in network evolution after arranging these patterns according to the historical sequence of events and working within the framework of topology.

Phases	β	π
A Chain	$\frac{v-1}{v}$	1
B Chain with Branches		$\frac{v-1}{d}$
C First ring structure	1	>1
D Lattice	>1	>1

Phase 'A' signifies the emergence of a chain of pioneer centres in a previously uninhabited area and phase 'B' starts when the branching of the Chain begins. Phase 'C' starts when the branches grow progressively longer and eventually meet each other and finally, a lattice arises out of the Chain (Phase D). All these phases of the network can be recognized with the help of 'β' and 'π' indices mentioned above.

Similarly Taaffe and Gauthier (1973) have suggested four stages of network development for planai graphs. To identify the changes in spatial structure of the network and the degree of change, they have suggested alpha (α) and gamma (γ) indices and the values of these indices are meaningful only when considered in terms of the limit of network connectivity. All these indices have been used in this study to analyse the structure of the transport network and trace the relationship between urban growth and transport development in the region. As the elements of change to be analysed are not very recent innovations, it is difficult to trace something on a micro level, without looking at the changes which occurred in previous decades in the transportation networks as well as in the urban growth of the region. For this reason a clear understanding of the sequence of changes is necessary and it is important to trace the development of the transport networks through time and to relate the changes in urban growth to the changes in the patterns of network accessibility as it provides grounds for further research.

3.4 Methodology

The structure of the railroad network in the Panjab and its effectiveness are analysed since its beginning in 1862 to the present, by using some of the techniques of network analysis. So far it has been concerned with the extent of examining the relationship between network structure and geographic characteristics up to a lower order political unit. The region under study can be divided into further small units as Kansky (1963) has suggested,to differentiate three basic units of observation denoting 'C', 'S' and 'c' for countries, states and counties respectively. He has further suggested classifying the rail and road systems separately by denoting PRR (for railroad subgraph of the whole transport network) and 'PHWY' (for highway subgraph). For further sub-division of a smaller political unit it may be denoted as 'PRR^{2nd}' and '$PHWY^{2nd}$' which means a railroad and highway network of the third order political units respectively. So the network under study will be analysed up to 'PRR^{2nd}'. To look at the micro scale of the network through time, only a partial (railroad) system will be considered and a highway system will be included in the present study of the recent

years (1971).

As far as it is concerned with the political sub-division of the region, the whole country (Pakistan) is divided into four provinces Panjab, Sind, Baluchistan and North West Frontier Province. The province under study (Panjab) is sub-divided into five divisions of Rawalpindi (1-4), Sargodha (5-8), Lahore (9-12), Multan (13-16) and Bahawalpur (17-19), (see Figure 1.1). Except for Bahawalpur, all these divisions are further sub-divided into four districts each, while Bahawalpur contains three districts. The micro level analysis of the transport network through time will be useful not only to describe the structure of accessibility and to analyse the accessibility surface, but also as a basis for further examination of the relationship between such structural patterns of accessibility and patterns of urban change in the system. The results of this analysis will be useful for further examination of the relationship between transport and urban development. It is also useful because the evolution of transportation networks occurs not only at the macroscale of nations and large regions, but also at the micro or urban scale. In cities that developed over the course of many centuries, ie. in Europe and Asia, the road pattern has sometimes evolved from an initial series of trials through a system of ancient paved roads, to a complex network of modern freeways (Moryadas 1975).

Being an analysis of a micro region certain limitations are placed on the choice of nodes, routes and area.

i. In respect of the system taken into consideration only a partial system of railroads has been considered for historical analysis since 1862, and the road network has only been analysed for recent years (1971).

ii. The period has been divided into seven decades up to 1930 and after that a big interval of 45 years was taken as there was no significant development during that time. This gap will provide a useful basis for the comparison of the development of the road network with the rail network. The results will be helpful to understand the common theme of the dominance of road over railroad in under-developed countries in the recent phases. Taaffe et al (1963) have said that the evolution of the transportation system in under developed

countries has shown a steady rise in the importance of road traffic, which first complements the railroad, then competes with it and finally overwhelms it.

So this big gap of poor development in the rail network of the Panjab points to an important pioneer role of railways in the establishment of a transport infrastructure in the region, and more attention is now frequently paid to roads.

iii. Being a historical analysis of a micro region it is difficult to trace the changes of political units in terms of area. For this purpose the existing area of the units has been considered throughout.

iv. The next important thing to be clarified is the terminology and stability of definitions in the study. The use of graph theory as a method of transport network analysis has received considerable attention, introduced by Garrison (1960) and elaborated by Kansky (1963); network analysis now has a wider significance in geography as a whole (Haggett and Chorley 1969). Graph theoretical analysis provides, perhaps the only precise means of analysing the total accessibility and linkage within the network and represents a significant step forward in the analysis of transport patterns (Ward 1969).

As differing terminology has been used to describe these elements, points and nodes are now commonly referred to as vertices and routes or lines as edges (Chorley and Haggett 1969, Taaffe and Gauthier 1973, Hay 1973). Apart from this there are differences in the definition of nodes in the different studies. In some, only towns are counted as nodes while road and rail junctions without towns are ignored. For example, in the case of Sardinia (Italy) Kansky (1963) considered only the intersections or junctions originating and terminating points as vertices while in the case of Sicily (Italy) the vertices selected are towns. Similarly in other studies (Kissling 1969) etc. the vertices are selected from towns on the basis of population size. Therefore it is necessary to be clear about the definition and stability as most topological measures are calculated from the relation between the edges and vertices. As the study involves comparison between time period and regions, it is essential that the definition should be stable from one region to another. In this regard both the definition of nodes mentioned above are followed and compared.

In the first instance the intersections/junctions including end points are treated as nodes at the regional and sub-regional levels. Similarly the second definition of nodes is adopted which includes the urban centres according to the definition of the Census 1971. Most of these centres have a population of 5,000 and above, and are located on a rail network. Apart from these centres, the railway junctions (which are not classified as urban centres according to the Census 1971) are also included being the originating and terminating points. These definitions have been followed for the historical analysis throughout the period. The comparison of these two different definitions gives a clearer picture of the network.

For the recent years, the analysis of both the rail and road networks has been done separately by changing the definition of nodes according to the population size of 10,000 +, 20,000 + and 50,000 +.

v. It is important to be clear about the route development and track development. In this study only the route length has been considered by ignoring the double lines (if any).

vi. For the purpose of this study all the maps have been converted into topological shapes showing nodes and routes through decades (see Figures 3.2a and b).

vii. By applying topological indices, the measurement of the structural properties of the rail network (PRR) as a whole, and sub-rail networks (PRR^{2nd}), is derived through decades.

3.5 Province Level Topological Structure of Rail Network

According to the Census of 1971 there are 202 towns with a population of 5,000 + (with some exceptions). Out of these 137 towns are connected with the railway system, while all of these towns are connnected with the road system of the region. Apart from these towns there are nine junctions which are not considered as towns according to the Census of 1971. So this study includes a total of 146 vertices (137 towns + 9 junctions) for the year 1971, and all of these are on the rail network. By taking junctions and end points as vertices, there are 51 vertices for the same period, with a ratio of about 1/3, which shows that every third node in the region is either a junction

or an end point.

In the analysis of the changing pattern of transport it is necessary to distinguish between development and growth. Development includes changes in the nature of transport mode or in the service which it provides, while the growth involves the extension of an existing mode of transport and its associated services (Fullerton 1975). Development is usually accompanied or followed by growth but growth may occur in the absence of significant development. In the case of the Panjab, we are mainly concerned with the growth of the rail network but also have to look at its development.

Before the advent of the railway in 1862 the only source of transport and communication for both people and goods, was the rivers of the region (see Figure 2.2). The main route of this traffic was from the Panjab to Sukkar and then Karachi a natural port, where hundreds of tons of cereals, linseed, sugar, saltpetre and indigo was sent by these rivers. In 1855-56 the water traffic was greatest on the Sutlej, next on the Jhelum, then on the Indus and last on the Chenab and Ravi. According to the registration of boats at the junction point of Mithan Kot (DG Khan District) on the Indus, the traffic of goods was not less than 700,000 maunds or 35,000 tons per annum (Admin. Report 1855-56). During these years it was estimated that four-fifths of the total traffic was towards the South. There is a big variation in the speed according to the seasons, directions and Channels (rivers). Similarly, there were variations in the accessibility of the commodities to and from the various ports of the region. The speed of transport in those days was very slow and was dependent on the season, particularly in the region where floods and drought were common and famine conditions prevailing in one region could not be alleviated by the surplus of another. For these purposes, there was a great need for a more efficient and cheaper means of transportation.

Figure 2.2 shows the distribution of towns which were important trade centres in the region until the opening of the railway. The towns of Pind Dadan Khan and Wazirabad enjoyed a busy trade and industrial centres by having boatbuilding and repair yards. Now, except for two, Ram Nagar and Pindi Bhatian, all of these towns are connected

by rail. The analysis of these towns through time, will give a good picture of the relationship between transportation and the urban growth in the region. It will also be helpful to understand Gauthier's (1968) statement that 'the change in network structure may have an effect on economic development and it can produce serious changes in the pattern of interval accessibility for many of the urban centres of the network,' which will be discussed in the next chapter.

This inefficiency in the transportation was seriously felt by the authorities and a number of proposals were discussed during 1855-56. It was presumed that 'all the quantity that pertains to the Sutlej, the Ravi and the Chenab and a part of that belonging to Jhelum, will be diverted to the Amritsar and Multan Railway; and if the Railway up to Peshawar should have been established, then almost all the traffic of Jhelum and much of Indus would proceed to Lahore and thence down the rail to Multan' (Admin. Report 1855-56).

The idea was encouraged by a great increase in the number of passengers and income (amount) between the cities of Lahore and Amritsar, with the opening of a new road in 1856. It was hoped that a similar passenger traffic would doubtless spring up between Lahore and Multan, and, it may be added that the route via Karachi would be frequented by pilgrims to Mecca. It took some time to finalize and the first railway in Pakistan was opened in May 1861 (105 miles).

In the case of Pakistan (as a whole) the pre-1861 position can be compared with the first phase of the ideal typical sequence suggested by Taaffe, Morrill and Gould (1963). Along the coast were small natural ports each with an equal chance of development, but the concentration of activities was on one of them, Karachi. The position of the Panjab can be related with this model to some extent but fits with Lachene's (1965) model. The first stage of the model indicates the scattered distribution of the population and low level of economic activity distributed more or less uniformly throughout the region. The basic difference between the Lachene and Taaffe models lies in the environment postulated rather than in the mechanism of network growth (Chorley and Haggett 1969). As the region of the Panjab has a mid-continental situation with a sparsely populated territory and has no coastal situation, its pre-

railway stage is a good representation of the first stage of Lachene's model.

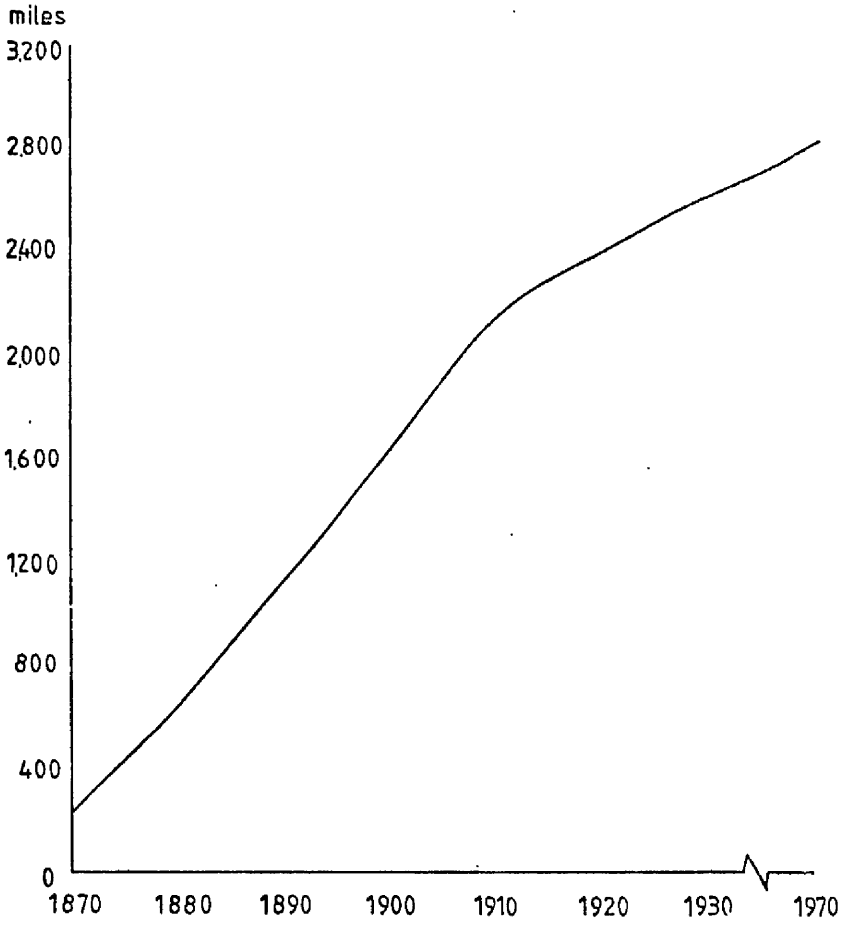
Railway network length from 1862-1975 has been shown in Figure 3.1a. The line is very smooth up to 1910, which shows the peak of the development of the network of the region. By this time 76.91 per cent of the existing network's length was completed while only 23.09 per cent was completed during the rest of the 65 years. The decade showing maximum route development of the existing network is 1900-1910, in which 19.28 per cent length was increased. Now an attempt will be made to look at this period in detail and analyse it with the help of topological indices. Similarly, the gradual development in length of the network has been shown (see Figure 3.1b) and these maps have been converted into topological form for the decades showing nodes as towns (see Figure 3.2).

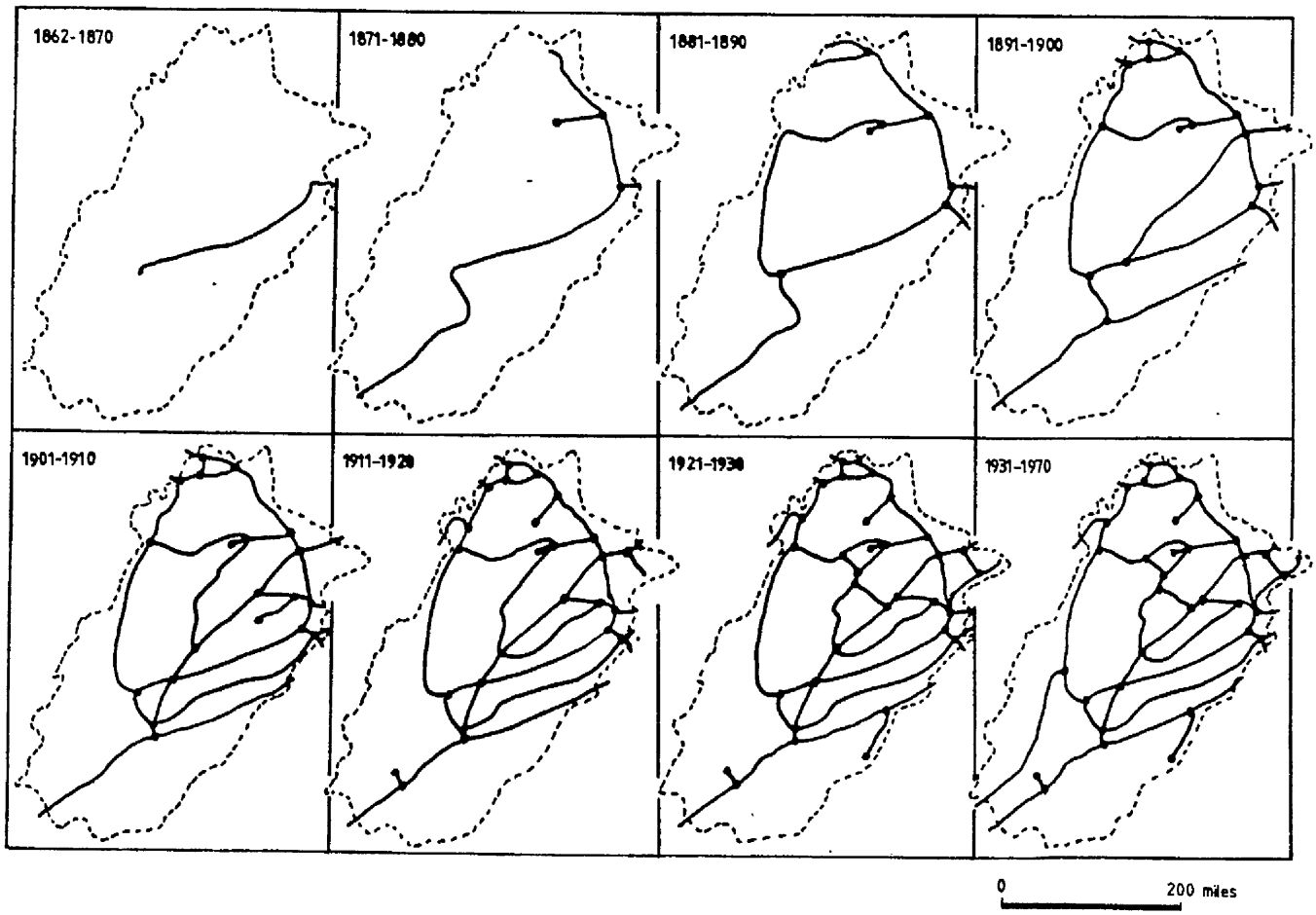
3.6 Stages of Connectivity

a. 1862-1870

With the encouragement of road connection between Lahore and Amritsar, the authorities decided to link these centres with rail net and as a result of that the first railroad was opened in the region under study on 18-4-1882 between Lahore and Amritsar. (A portion of 15 miles is still with Pakistan.) The main purpose was to divert the river traffic through the railway to the seaport of Karachi via Multan, Sukkar and Kotri. After three years of this connection another important trade and historical centre, Multan, was linked with Lahore and Amritsar after opening a 208 mile line on 24-4-1865, which was later extended six miles to Muzaffarabad on 21-7-1870. During this period a total of 229 miles length of route in the region was completed and it covers 8.14 per cent of the length of the existing network of the region and, similarly only 8.9 per cent of the existing nodes (towns) were connected. As it is a straight line without junctions so the β, index which measures the ratio between junctions and their edges, is very low 0.50, while the β measuring the ratio between towns and links is 0.923 at this stage (see Table 3.1). The γ index which measures relative linkage connectivity is 36.36 per cent for towns linkage and

FIGURE 3·1 GROWTH OF RAILWAY NETWORK 1862-1970





the 'γ' index showing increasing linkage between all points is 2.77 for the same network. As it is the initial stage of the development in which the total mileage of the network is the highest but the capacity of the individual link segments is quite low (Lachene 1965). Therefore the rest of the measures like 'μ', 'α' etc. are either poor or unable to give anything at this stage. As the edges and the diameter is the same, so the 'π' index which measures the degree of development is minimum (1.00) at this stage. But the Theta index or length per node (town) is 17.61 miles which suggests a reasonable distance between the urban centres. Similarly the η index is 19.08 miles (see Table 3.1) for the network constructed so far and the score is very low as compared to Algeria and Italy in the same period 1870 and 1875 respectively. The score for Algeria was 68.75 miles while for Italy it was 31.80 miles (Kansky 1963).

b. 1871-1880

During this decade the route length of the region increased from 229 miles to 665 miles with a maximum percentage growth as compared to the rest of the decades (see Table 3.1). This increase represents the completion of projects started in the last decade or before. Figure 3.1b shows that during this decade the north end of the region was connected to the south, parallel to the rivers and the Grand Trunk Road. Already connected line up to Multan was extended to Lodhran and was opened on 1-7-1873. Meanwhile the line from Karachi to Kotri was extended up to Saugi (near Rohri). Exactly five years after the extension of Multan-Lodhran, the Lodhran section was extended to Karachi and was linked at 'Saugi' on 1-7-1878, when Amritsar was connected with Karachi through the big trade centres of Lahore and Multan. Meanwhile the lines to connect Karachi and Peshawar which were under construction were opened soon after the completion of the link between Lahore and Karachi. The first portion between Jhelum and Lahore was completed and opened for traffic on 6-10-1878 while the extension up to Rawalpindi was opened about two years later on 1-10-1880. In this way, by the end of 1880 the extreme north of the Panjab was connected with the main port of Karachi.

Meanwhile another section Lala Musa to 'Mandi Baha ud Din' was opened on 1-1-1880 and extended to Miani (on 10-4-1880) which was the then depot for salt export. But it is important to note that with the extension of the railway to the Khewra salt mines across the river, the salt trade has almost left it and its glory has departed (Shahpur District Gazetteer 1917).

Before looking at the topological structure we will look at the principal motives for building the lines of penetration in the region. Taaffe, Morrill and Gould (1963) have pointed out three most important motives which have been active in the past in their study and are also expected in the historical development of transport networks of the developing countries. Among these the first desire is to connect an administrative centre on the sea coast with an interior area for political and military control while the second desire is to reach areas of mineral exploitation and the third desire to reach areas of potential agricultural export production. In the light of the cases examined, they have concluded that among all these motives the political motive has been the strongest.

These motives can easily be approximated in the case of the Panjab and can be named as multi purpose developments. The priority to link the main centres of trade with Karachi port and then building the branch lines on 'doabs' (the area between two rivers) alongwith the development in irrigation,points to the third desire or motive mentioned by Taaffe and his colleagues, while the establishment of cantonments at strategic points such as Wazirabad, Lahore, Jhelum and Gujrat from which reinforcements could easily be supplied in the event of an invasion or an internal disturbance (Spate 1968), points to the political motive.

Figure 3.1b shows a smooth increase in the length of railway during this decade. The length completed during the decade is 15.51 per cent and the total route length completed so far went up to 23.66 per cent of the existing route length. In other words we can say that about one-fourth of the route length was completed up to 1880 in the period of the early 18 years. By this time 30.14 per cent of the existing nodes (towns) were connected for which the β' index increased from 0.923 to 0.977, very close to 1.00. The stage of the network corresponds to

Table 3.1

RAILROAD DEVELOPMENT OF THE PANJAB 1862-1970
(Topological and metricated indices)

Indices	1870	1880	1890	1900	1910	1920	1930	1970
R.L. (miles)*	229	665	1158	1620	2162	2401	2616	2811
% increase	-	190.4	74.1	39.9	33.4	11.0	9.0	7.4
e (T)	12	43	77	97	124	137	151	157
v (T)	13	44	77	94	117	129	140	146
P	1	1	1	1	1	1	1	1
μ	0	0	1	4	6	9	12	12
α(T) %	0	0	0.7	2.2	3.5	3.6	4.4	4.2
β(T)	0.92	0.98	1.0	1.03	1.06	1.06	1.08	1.07
γ(T) %	36.4	34.1	34.2	35.1	35.9	35.9	36.5	36.34
$\acute{\gamma}$(T) %	2.77	9.95	17.59	22.45	28.70	31.71	34.95	36.34
η(T)	19.08	15.46	15.24	16.70	17.43	17.52	17.32	17.90
Theta (T)	17.61	15.11	15.24	17.23	18.48	18.61	18.68	19.25
D (T)	12	39	45	30	29	29	29	29
Dm (T)	229	604	673	523	523	523	523	523
e (J)	1	5	16	26	40	50	60	62
v (J)	2	6	16	23	33	42	49	51
α (J) %	0	0	3.7	9.7	13.1	11.4	12.9	12.4
β (J)	0.50	0.83	1.0	1.13	1.21	1.19	1.22	1.21
γ(J) %	0	41.7	38.1	41.3	43.0	41.7	42.5	42.2
$\acute{\gamma}$(J) %	0.7	3.4	10.9	17.7	27.2	34.0	40.8	42.2
η(J)	229	133	72.4	62.3	54.1	48.0	43.6	45.3
D (J)	1	3	6	7	9	11	12	13
Theta (J)	114.5	110.8	72.4	70.4	65.5	57.2	53.4	55.1
R.D. (A)**	0.25	0.84	1.46	2.04	2.73	3.03	3.30	3.55
R.D. (T.P)***	0.03	0.08	0.13	0.16	0.20	0.20	0.19	0.07
R.D. (U.P)****	0.37	0.87	1.39	1.71	2.15	2.07	1.55	0.31

*Route length

**Route density per 100 square miles

***Route density per 1,000 total population

****Route density per 1,000 urban population

Table 3.1α

DEGREE OF ROAD DEVELOPMENT (1947 - 1977)

Year	A	B
1947	4.49	5.19
1965	9.00	11.40
1966	9.30	11.54
1967	9.70	10.68
1968	9.82	10.58
1969	9.99	10.80
1970	10.22	10.83
1971	10.38	10.60
1972	10.52	11.03
1973	10.66	10.99
1974	10.68	11.31
1975	10.95	11.62
1976	10.83	11.51
1977	11.47	11.71

A = Pi index based on 'High Type Roads' (include the surfaces of black top, concrete and macadam)

B = Pi index based on 'All Type Roads' (also include 'Kacha' roads).

Source of data: Chief Engineer, Highways, Panjab, Lahore.

Phase B (Chain with branches) of Medvedko's (1967) Four Typical Phases Model or exactly presents the initial stage of Lachene's (1965) model with the highest length in route but low capacity of the individual link segment. The 'β' index for junctions is showing a big increase (from 0.50 to 0.83) as compared to 'β' index for towns. It suggests that there was a large increase in the intersections of the network. Similarly 'γ' gamma index which measures the number of routes between places as a percentage of the maximum possible number of routes, shows an increasing score of 41.67 per cent for the networks showing junctions but a decreasing score from 36.36 per cent to 34.12 per cent for the network showing towns as nodes (see Figure 3.2a). So this index shows a low connectivity in both cases. The π index which is related to length and intersections has gone up to 1.10 from a minimum score of 1.00 in the last decade. Similarly the 'γ' index which measures the increasing connectivity and is related to the increasing number of edges, has increased with the increase of vertices in the network. The Theta index, which measures the ratio between nodes and length, has decreased in both cases (see Table 3.1). As the network is still in Chain form or in its initial stage, so the alpha index (α) and cyclomatic number (μ) are weak to measure.

c. 1881-1890

During this decade the length of the route increased from 665 to 1158 miles with an increase of 493 miles about 17.54 per cent of the total existing network. The percentage increase in this decade is the highest among the previous decades. By the end of 1890 about 41.20 per cent of the total existing length was completed and 52.74 per cent of the nodes (towns) of the existing network were connected, while the percentage of the junctions (nodes) connected so far is much less. It is 31.37 per cent and there are still 68.63 per cent to be completed. Similarly the 'γ' (gamma index) which measures the changing connectivity of the network and is related to the increase of edges, is lower (3.40 per cent) for the junctions and is higher (9.95 per cent) for the network showing towns. This variation in the indices for two types of network suggests that the network is not congested and the nodes and links are increasing in the same ratio (see Table 3.1). With the completion of a circuit, the network has entered into Phase C (First

Ring Structure) of the Medvedko (1967) model or the second stage of the Lachene (1965) model as the 'β' Beta index and 'μ' cyclomatic number have become one and the 'π' Pi index has reached 1.72 (>1) according to the requirements of the models. As there is very low connectivity and circuity, therefore the 'α' alpha index shows a very low score (see Table 3.1). The gamma index has decreased for the network showing junctions only while it has increased for the other network. It suggests that the edges between junctions is not increasing in the same ratio as these (edges) are increasing between towns. Theta index has increased and suggests that the increase in the route length is higher than the increase of towns in the region in this decade, as compared to the previous one.

During this decade an extension of 493 miles took place with the opening and completion of 12 sections from 1-1-1881 to 15-3-1890. Among these sections about 123 miles of railroad was built on the hilly northern area of the region. After linking Rawalpindi with Karachi it was important to connect Peshawar, the main trade centre of the NWFP, with Karachi. For this purpose a line of 46 miles was extended to Lawrencepur on 1-1-1881, and just after that in April 1881 a link between Golra (Rawalpindi) and Khushhalgarh was opened (see Figure 3.1b). The line which was extended to Miani during the last decade went to Bhera and another section was opened to Khewra Salt mines in January 1883. The purpose of this section was to bring the salt by rail instead of by river. As the main line was not sufficient to carry the salt to the south, it was essential that another line along the Indus river be built. So the project was started during the decade, to connect the salt mines with Sher Shah via Kundian and Bhakkar, at the same time it would divert some of the river traffic from the river Indus to the railroad. This section was completed in 1887 and was finally opened with the completion of the Sher Shah Bridge on 1st February 1890. Among the important towns of the region were Sialkot and Ferozepore which still were to be connected. As they were not very far from the main line, Sialkot was connected in January 1884 with a link between Sialkot and Wazirabad, which was then extended to Suchelgarh on 15-3-1890. Similarly Ferozepore was connected in June 1883 by a link between Raiwind and Ferozepore.

This decade enjoyed the maximum linkage of the towns (22.60 per cent). The comparison of decades (see Figure 3.2a) suggests that by this time most of the pre-railway trade centres had been linked by rail and it will be interesting to examine the changes in these towns along with the changes of connectivity, in the next chapters.

d. 1891-1900

By the end of this decade the route length rose from 1158 miles to 1620 miles with an increase of 39.89 per cent and showing a percentage of 57.63 of the completed length so far and connecting 64.38 per cent of the towns (of the total as on 1975) with 61.78 per cent completed links. The increase in the cyclomatic number from one to four and a comparatively big increase in the edges as compared to vertices (in both types of network) suggests that the network has been changed to a well connected graph for which the alpha index has shown a good increase. Among the matricated indices, the decreasing theta in the case of junctions and increasing in the case of towns, suggests that the intersections have increased among the already built lines, as compared to the nodes on the new lines. In the same way, the length along the topological diameter which was increasing, has decreased and indicates the spread of the network. An increasing difference between the number of edges and the topological diameter is evident . The sudden increase in 'Dm ' indicates some addition of short cut routes (see Table 3.1).

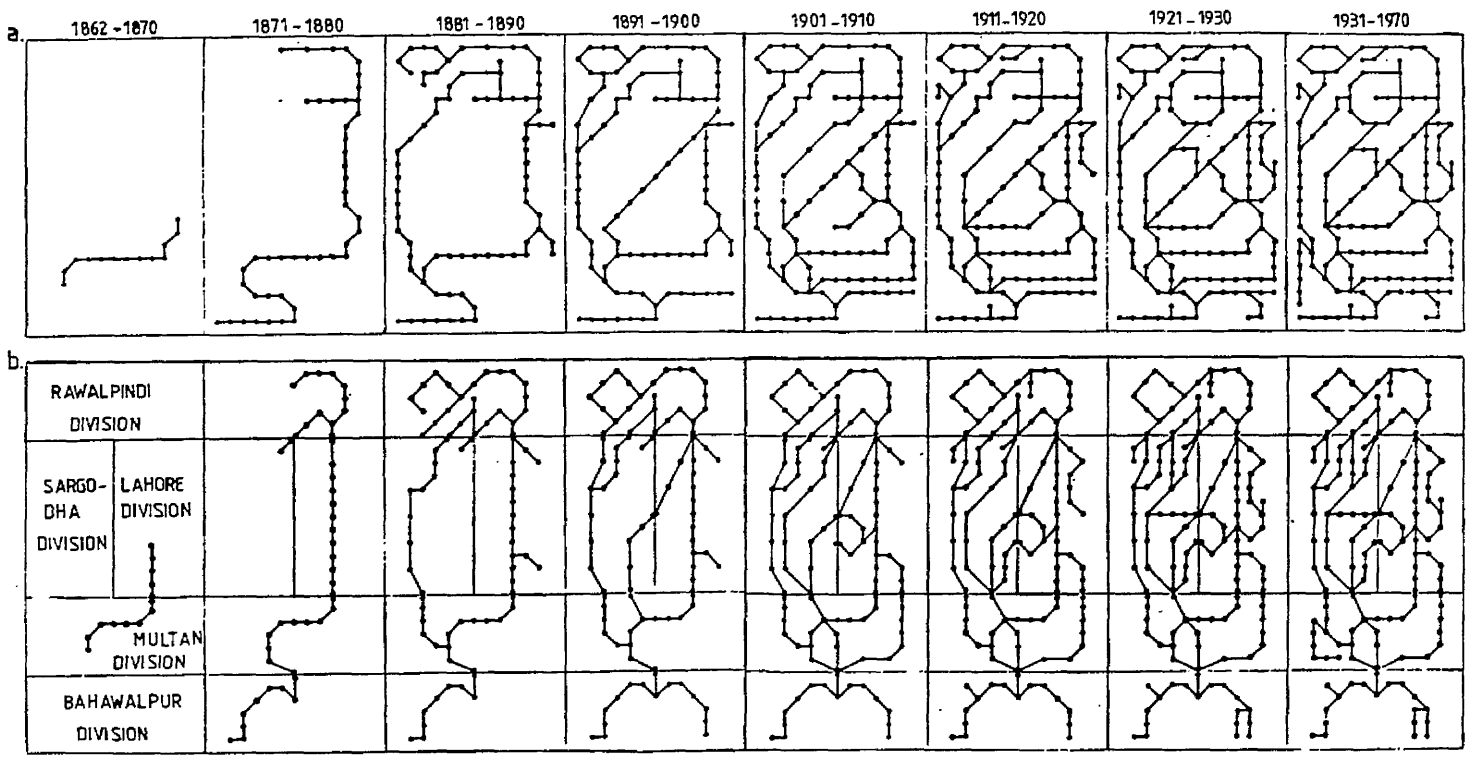
All these properties of the network given by topological and matricated indices can be confirmed by looking at the development of these sections in detail during the decade. The records show that a total of 462 miles in length divided into five sections was opened in eight different stages during this decade. Now more attention was being paid to reducing detours and connecting the main line by possible short-cut routes for which the main task was bridging the rivers. The geographic effects of virtually unregulated spread of railways up to this decade may be seen in Figure 3.1b where the network was still somewhat similar in shape to that of the rivers network (see Figure 1.1) where approximately all the lines are parallel to the rivers and the same position remained up to 1930. In this case it seems that all the

FIGURE 3·2

STAGES OF NODE CONNECTIONS

1862 - 1970

(TOPOLOGICAL)



a. PANJAB LEVEL

b. DIVISION LEVEL

detours were reduced according to the importance. When Peshawar was linked with Karachi, it was a long distance by main line. At the beginning of this decade a section between Kundian and Mari Indus was opened on 15-3-1892; this was extended from Daud Khel to Campbelpur via Jand and Basal on 1st April 1899 (see Figure 3.1b). The opening of this section gave rise to the 'α' (alpha index) and 'μ' (cyclomatic number) and the network entered the 'D' Phase of Medvedko's (1967) model. Meanwhile another attempt was made to connect Khanewal with Wazirabad to reduce another detour. The first position of this link between Wazirabad and Hafizabad was completed in August 1895, extended to Lyallpur in February 1896 and later on connected with Khanewal on the 16th April 1900. Apart from this another important link between Bhatinda and Sama Sata was completed in November 1897; from this line about 155 miles between Sama Sata and Qasimwala is still in the Panjab (Pakistan).

e. 1901-1910

It is clear from Figure 3.1a that in this decade the peak of growth in route mileage in the region was reached. More than three quarters of the existing route length (2811 miles) was completed up to the end of this decade. This period has great significance in the history of the region and particularly in the Indus basin when in 1905 the Government approved the Triple Canal Project and the three canals, Upper Jhelum, Upper Chenab and Lower Bari Daab, were designed to take off from the western river and with the development of irrigation, there was a need to build a railway between these newly irrigated areas. All the new railway lines were opened in this area during this decade (see Figure 3.1b). During this time some of the new sections were opened in the doabs (areas between two rivers) of the newly settled canal colonies of Sargodha (Shahpur), Lyallpur, Kheikhupura and Sahiwal. Most of the sections were opened along the rivers or between the rivers so avoiding the building of bridges (see Figure 3.1b).

During this period a total of 542 miles route length was added to the network, which is the highest since its inception (see Table 3.1). The already extended link to Malakwal was further extended to Sargodha

on 1st April 1903. On 14th May 1906, after construction work which took three years, it was connected to Shorkot. Meanwhile with the building of 213 miles of line (which was completed on 6th July 1910), Kasur was linked with Lodhran. The main aim of this line was to cross the fertile region between the Ravi and the Sutlej. As there was a huge traffic on the Multan - Lodhran section a short cut (chord) link between Khanewal and Lodhran was opened in April 1909 and the traffic was further reduced by the opening of a link between McLeod Ganj Road and Ferozepore in February 1906. Some further developments were made with a connection between Shahdara and Sangla Hill and an extension between Sheikhupura and Jaranwala on 18th November 1909.

The network developed so far presents a good picture of the third stage of Lachene's (1965) model or Phase D of Medvedko's (1967) model where the 'β' and 'η' indices are above one (see Table 3.1). The table shows that 'μ' (cyclomatic number) of the network has increased to 8 which suggests a good increase in the circuity of the network. Similarly, 'α' (alpha index) has also increased. Gamma index (γ) which measures the number of routes between places as a percentage of the maximum possible number of links suggests in both cases that the ratio of the increase of edges is higher than the vertices. The theta index (which measures the ratio between length and vertices) has increased in the case of towns while it has decreased in the case of junctions. It further suggests that the towns have not increased as much as the junctions showing that the new links originated or terminated from/in the already existing lines; this intersection in the already existing links has increased 'μ' in the network. No change in the length of topological diameter suggests the spread of the network, which can be confirmed by π (Pi index) that has increased to 4.13 (see Table 3.1).

f. 1911-1920

This period of the route length was not as important as in the previous decades. Probably more attention was paid to irrigation development. The total length increased during this decade was 293 miles which included the opening of small sections ranging between seven and 39 miles, except for one which was extended from Jaranwala

to Shorkot on 2nd May 1911 (with a total length of 88 miles). The other small sections are Khanpur to Chachran and Mari Indus to Bannu which were completed between 1911 and 1913. Similarly the opening of the sections between Manda - Bhaun and Sialkot - Narowal, took place between May 1911 and January 1916.

By the end of this decade 88.4 per cent of the nodes (towns) were connected by the network. In the case of junctions all the indices show a decrease except μ, α, γ, π, and D. In this case the decreasing 'β' suggests that the ratio of increase in junctions is much more than the links, but in the case of towns it is the reverse. The gamma index in this case is decreasing for the same reason. The eta index (η) which measures the ratio between the edges and the length is decreasing for the first time, the reason being that the number of edges has increased while the increase in the length is not so. It presents a dense shape to the network (see Table 3.1). In the case of the network showing towns all the indices are increasing. The comparison between the two types of the same network in this decade suggests that at the initial stages the scores of the matricated indices like eta and theta for the network showing junctions only is high and decreases as the network develops, while these indices for the network showing towns are also higher at the beginning and keep on decreasing until the develop-- ment of a circuit, after that they increase again.

g. 1921-1931

Although this decade does not show much change in the route length, it is important for network development. In this decade the scores of topological indices show an increase while the matricated indices (except π) related to the length show a decline, which suggests that there were no developments on the new areas but that the developments were made in the existing surrounded network with the linkage increase. It can be confirmed with the increase of 'μ' from 9 to 12 and the alpha index of 12.90 per cent for junctions and 4.36 for the network showing towns. Similarly the 'β' and 'γ' indices have shown an increase in both cases. The unchanging length in the diameter suggests the spread of the network where the Pi index has reached to 5.00 (see Table 3.1).

h. 1931-1970

Although this period of four decades does not show any significant change in the topological indices of the region, however, a considerable decrease in RD (UP) identifies a dramatic increase in urban population during this period (see Table 3.1). On the other hand, the lowest increase (7.4 per cent) in the route length of the rail network indicates the important role of road development in urban growth during the period. In this respect it will be helpful to look at the historical background of road construction in the region, with particular emphasis on post partition development.

3.7 Changing Structural Parameters

The historical growth of route length discussed so far gives a good picture of the network development which was accompanied by changes in its topological properties. These topological indices were compared within the decade, alongwith metricated indices and was clear that all indices did not show regular change over the period. In this section it will be interesting to compare these indices and to find a more detailed picture of the structure of the transport network through time. This comparison will be useful in identifying periods of greatly increased connectivity and development and other periods in which this development showed little significant change. It will provide meterial for tracing the relationship between changes in network development and changes in urban growth in the region, through accessibility.

As has already been mentioned the transport system of a region can be grouped into 'RR' (Railroad) 'HWY' (Highways) etc. which represent the partial system of the network. In this case we are dealing with the RR network. Similarly the definition of vertices, being the most important property of the network, can change the values. Any junction of the edges can be defined as a vertex (Chorley and Haggett 1969). However, in a study of transport networks urban centres are commonly the foci of the transport system and therefore urban centres are regarded as vertices in the topological analysis (Taaffe and Gauthier 1973). It is further suggested that the scale of analysis has a bearing on the size of urban centres which can both logically and practically

be treated as vertices. In this case as the study is mainly concerned with the urban growth, it is necessary to follow the second approach but some of the indices show a big difference in the values of different approaches. For this reason both approaches have been followed and the comparisons between indices and then between the approaches will be useful in the examination of the structure through time.

For this purpose the network which consists of junctions only as vertices will be denoted as RR(J) and the network which consists of urban centres (5,000 and above population, with some exceptions according to Census 1972) and the junctions (if not included as towns) will be denoted as RR(T). In the case of the boundary crossing edges in RR(J), the adjusted measures introduced by Kansky (1963) are followed.

The difference between these definitions can be examined from Table 3.1. This difference is not so clear in the topological indices as it is in the metricated indices. Similarly 'β' which measures the ratio between edges and vertices shows much difference of RR(J) and RR(T). It suggests that there is a good relationship between the topological indices irrespective of the definition of vertices and the values obtained by metricated indices are much affected with the change of the definition of vertices (see Table 3.1). In this case metricated indices are weak to measure at the initial stage of the network but are very useful later on (Kansky 1963).

Looking at the growth of route length through the period we see that it is smooth until 1910 and after that there is a short decline (see Figure 3.1a). It suggests a maximum development up to that period, which can be confirmed by looking at the net increase in the period under study which identifies two decades 1881-1890 and 1901-1910, where maximum route length was added. Similarly the net percentage increase of edges is high until 1910, which is recognized as a period of maximum development in route length.

3.8 Topological Changes

Though the basic purpose of all these topological indices is to measure connectivity, however, it is important to distinguish the types

of connectivity for which individual measures are useful. All these four measures of 'μ', 'α', 'β' and 'γ' indicate different aspects (of connectivity), of 'absolute circuit', 'relative circuit', 'simple linkage' and 'relative linkage' connectivities respectively. In this section an attempt has been made to understand the changing pattern of connectivity through period with the help of these indices.

According to the graph theory 'circuit' is the end product of evolution through path and tree stages. Two parameters of circuity ie. 'μ' and 'α' have recorded no change until 1890, when a sudden change can be noticed from tree to circuit and then identifying the period of great increase (1890-1910) in circuity. After a minor increase in 1920, another significant change between 1920-30 indicates the complexity of the network.

The Beta index closely monitors the changes for both RR(J) and RR(T) from path through tree to circuit in 1890. In the case of RR(T) it is smooth until 1910 and after identifying a very minor change between 1910-20 it is again smooth until 1930 and indicates only decline between 1931-70, while in the case of RR(J), the index has recorded a decline between 1910-20 (see Table 3.1). It suggests that during this period (1910-70) there was much increase in the edges between towns while there was not sufficient increase in the edges between junctions. It can also be confirmed by the declining trend of $\eta(J)$ during the period. A comparison between the net increase of e'J' and v'J' (see Table 3.1) shows that between 1910-20, there was much decline in the percentage of edges as compared to the vertices. This indicates that during this period the ratio of the edges connecting already existing nodes is higher than the edges creating new nodes, while the decline during 1931-70 is due to the links of new nodes.

In the case of RR(J) the values for the initial stage can not be produced, as there were only two vertices in 1870 while in the case of RR(T) there are more than two vertices. A set of fluctuating results can be determined for 1880 onward. These particularly emphasise the ups and downs of connectivity measure for 'β' and 'γ' values, despite the fact that there are no rail closures and one might expect the measures to increase the value as new lines are built. The main reason

for the declining connectivity measures is that they are relative to the number of points which exist at that time. In the case of RR(J) there are two declines, one in 1890 and the other in 1920 (see Table 3.1). The beta index is independent of the number of vertices and is mainly concerned with the increase or decrease of edges. In this case the number of edges did not increase according to the ratio of vertices or, in other words, the ratio of the actual edges in the network is much lower than that of the maximum edges required in the network for these periods.

To look at the gradually increasing connectivity we consider all points that were finally brought into the network for each date, (in the case of RR(J) it is 51 and in RR(T) is 146) and 'γ' (which measures the increasing linkage among all points at every date) records a consistently increasing trend (see Table 3.1). It is a useful measure because all values are relative to the final network rather than to their own particular set of connected places.

The diameter which is the topological length of the longest path of the graph indicates the development of the network and keeps on increasing as a straight line(unless junctions are built). Its increase in the first stages of 1870-80 and 1880-90 indicate the length without branches, while its sudden decline between 1890-1900 indicates complexity or short cuts and its static position shows either no development at all or development in the branches.

Chapter 4
TEMPORAL RELATIONSHIPS

4.1 Introduction

In the previous chapter a number of network measures proposed by Kansky (1963) were applied in the regional transport system. The basic concern of this chapter is to examine the utility of these measures, by applying them to empirical evidence, and to express numerically a hypothesized relationship between structure of transport network and urban development in the region of the Panjab. It is generally hypothesized that areas with high urban development have well developed railroads and highway networks of complicated structure and dense network pattern, while conversely, less developed regions have simple transportation networks.

The introduction of modern transportation technology in the region between the 1880s and the present has been closely associated with political, social and economic transformation which occurred in the region during the past 90 years. Among these the more spatially evident phenomena in the evolution was the rise of urban growth. A number of interactions between the transportation system and urban development are discussed in the study, among which important aspects for particular attention are:

i. The relationship between the localization of transport facilities and the spatial elements of the urbanization process.

ii. The role of specific transportation factors in the evolution of urban form and activities.

iii. The interdependence between transportation network flows and the development of urban systems.

Coming to the first aspect, here the main purpose is to answer the following fundamental questions relative to the relationship between the structure of transport network and urban growth in the region of the Panjab.

1. Is there a relationship?
2. What is the strength of the relationship
3. What is the form of the relationship.

After accepting the hypothetical relationship between the set of numerical values expressing the level of urban development and the set of numerical values indicating the degree of transportation development would indicate the utility of network measures as indices of degree of transportation development. In this chapter we shall concentrate on this task and measure the temporal relationship between indices of urban characteristics and indices of the transportation network, then the magnitude and areal variations of this relationship.

One section of this chapter examines the nature of the relationship that may be predicted between connectivity and urban development in the region and the adequacy of the techniques available for the analysis. This study started with the implications of connectivity and then turned aside to have a look into the temporal growth of the railway, which had assumed a particular predominance in the transport system of the region and had acted as a major initiator of development and modernization since 1881. Similarly the historical data of the region allows a study of the temporal growth of the urban system for the same period. After obtaining a clear understanding of the sequence of changes of the transport network through time, it will be interesting to relate the changes of transport structure with the changes in urban growth, as all the elements of change which are analysed are not recent innovations.

The second section of this chapter presents an analysis of the patterns of relationship through time particularly between 1881-1931 and 1881-1971 with an addition of four recent decades, and then discuss the temporal organization of transport and urban change on the State, division and district level.

The third section of the chapter examines the spatial relationship between structure of transport and distribution of urban population alongwith several other related parameters which have both direct and indirect influences on urban growth. The spatial patterns of these changes reflect the interaction of a number of different factors like irrigation and agriculture which have played a vital role in the urban growth. In the agricultural areas the centres have served both as a

point of production and of marketing. The relationship between agricultural changes and urban growth will not be examined in detail in this chapter which is mainly focused on the examination of the relationship between structure of transport networks and urban as well as population growth.

4.2 Techniques

For this purpose there is need to compare sets of data in terms of the extent to which a change in one is or is not reflected by a change in the other set. It implies that the individual items of both sets of data co-exist either in time or space, such that the possibility of the relationship of the changes can be considered. In the case of this study, both sets are temporal for which an index is required to measure association and changes in direction (+ or -). In this respect initially co-efficient of correlation (r) has been selected to measure a temporal relationship between the variables. At this stage it is useful because it can be used safely with small samples ($N < 10$), and is a useful method of comparison.

Similarly the co-efficient of Determination (R) helps one to judge the strength of the relationship between two interval scale variables. It is equal to the square of the correlation co-efficient and is the best measure of the goodness of fit of the regression equation because it tells exactly what proposition of the variation in one variable (Y) we have explained by the regression equation of 'Y' on 'X' as being due to the influence of 'X'. Having determined the form and significance of the relationship between the structure of the transport network and urban growth in the region, (with the help of correlation co-efficient and significance tests), it is important to measure its strength. For this purpose a good measure is an estimate of the proportion of the total variation in 'Y' that is associated with variation in'X' which can be measured with a co-efficient of Determination, and indicates the proportion of total variation in the dependent variable that is associated with or explained by the variation in the independent variable.

In the case of spatial relationship analysis sometimes the

correlations mentioned above are not equally useful as these are parametric statistics and before they can be used the requirements necessary for any parametric test must be met (ie. distribution of population must be normal). Therefore we have a Spearman's rank correlation co-efficient a well-tried alternative, having the characteristics of a distribution free test. It gives a co-efficient closely approximating to the product moment, having a power efficiency of about 91 per cent with the co-efficient of correlation. There are two methods that could be used in this study for the purpose of district level spatial analysis. One of these uses an application of Spearman's (γ) and the other Kendall's co-efficient of concordance 'W'. Among these the former will be used for the variables of two while the latter is useful if there are more than two variables.

With the use of these techniques we can assess the relationship between two variables or in other words we can say that this correlation is one way of deciding the relationship between two factors, but in many situations our interest lies with more than two. In this case, alongwith the relationship between transport and urban growth there are a number of other factors like administrative functions, facilities for health and education, industries etc., which cannot be ignored. So one of the difficulties encountered in this case is that of having to assess the influence of each of a number of factors in a particular situation. In the district level analysis we are particularly interested to know the extent to which the correlation between two variables is influenced by a third. Partial correlation is a method of dealing with three variables, in which the co-efficient correlation of two of them can be tested unaffected by the influence of the third, which is controlled. This technique is only used at the final stage of the analysis to determine the effect of other factors on the urban development.

To take the analysis a stage further by calculating the value that might be expected for one set of data if some given value occurred in the other set. In this study an attempt has been made to explain the relationship between the two sets of data with the help of regression as it is equally valuable as a descriptive device to illustrate the form of the relationship between the two variables. This technique will particularly be used in the spatial analysis of the relationship

between structure of transport and a number of selected variables for the 19 districts of the region.

Finally to understand the relationship between the difference between mean and the standard error of this difference, the technique of 't' test has been used and the degree of significance of the difference has been assessed by the tables and graphs.

4.3 Methodology

The essence of the present study is to extract trends from both spatial and time series data and find out the answer to some fundamental questions relating to the structure of transport networks and urban development in the region. The methodology adopted in this chapter is to correlate these variables through time for both periods 1881-1931 in the first instance and then a total of 90 years, 1881-1971, to find the difference in the degree of relationship. This correlation is at Province, division and district level.

After that the present structure of transport networks including rail and road will be correlated on district level for the purpose of spatial analysis. After establishing it, the basic aim is to ask what other factors are involved and to what extent they are amenable to analysis. The most notable of these are administrative, economic and the facilities of health and education. The effect of these factors will be analysed by Partial Correlation.

The period for temporal relationship between changes can be divided into two 1881-1931 and 1881-1971, with the addition of the four decades 1931-1971. The year of 1931 can be used as a yardstick as there is no significant development of the rail network after that and in this way it examines the change in relationship with the road development which mostly took place after 1931. This temporal relationship is further examined up to division and district levels.

4.4 Panjab Level Temporal Relationship

Several points of interest emerge from an examination of the correlation co-efficient relating to the variables of temporal growth of urbanization and structure of transport network. For this purpose 16 variables relating to the different aspects of urban growth have been correlated with ten topological and non-topological indices related to the structure of transport network in the region of the Panjab. A detailed introduction of all these indices has been given in the previous chapter. In this analysis all these indices calculated from the decade wise changing structure of rail network, have been used as the dependent variable (Y) turn by turn and are correlated with some demographic/urbanization measures of development as independent variable (X). The reason for selection of decade wise period for the indices is the availability of the demographic data (with which the relationship is measured).

Keeping in mind the limitations of both overall structure of the study and the data, only demographic changing parameters, particularly related to urban development have been considered for the analysis of this temporal relationship, while some of the non-demographic parameters relating to the economic conditions of the region have been taken for spatial analysis. Among the demographic changing parameters, total population is important to measure its relationship with the structure of the rail network. Before proceeding to the urban population, first we will look at the relationship between the change in total population and the change in the development of rail network, with the help of the indices calculated for this purpose.

Table 4.1 shows the simple correlation between the population change and the structure of the rail network. The correlation co-efficient between total population and degree of development (π) for this temporal period of 1881-1931 is +0.947 and for 1881-1971 is +0.661 and the co-efficient of determination for both of these periods is 89.68 per cent and 43.69 per cent respectively. A 't' test of the significance of the correlation co-efficient indicates that the observed relationship for both periods is significant at more than 95 per cent level, the minimum required for rejecting the null hypothesis. To make the study more interesting and comparable the relationship has been examined by

Table 4.1

PANJAB LEVEL TEMPORAL RELATIONSHIP

No.	Variables	a. 1881-1931										b. 1881-1971									
		A	B	C	D	E	F	G	H	I	J	Average (for A-J)	A	B	C	D	E	F	G	H	I	J	Average (for A-J)
1	Total population	x		x		x		x	x	x	x	.883	x							x	x		.556
2	Urban population								x			.762											.476
3	Percentage of urban population											.559	x							x			.531
4	Urban population of 20,000 +											.646											.456
5	Urban population below 20,000	x		x		x			x	x	x	.830	x							x	x		.535
6	Urban population in 100,000 +											.682											.455
7	Urban population in 50,000-100,000											- .133											.352
8	Urban population in 20,000-50,000											.447											.480
9	Urban population in 10,000-20,000	x		x	x	x	x	x	x		x	.837											.465
10	Urban population in 5,000-10,000	x		x		x		x	x	x	x	.901	x		x				x	x	x	x	.643
11	Urban population below 5,000											.362											.470
12	Total urban centres											.694	x							x	x		.596
13	Centres below 20,000											.746	x		x				x	x	x	x	.653
14	Centres above 20,000											.531											.474
15	Route density per 1000 population	x		x	x	x	x	x	x	x	x	.892											.269
16	Route density per 1000 urban pop.						x					.774											- .105

x significant over 95 per cent A = Pi Index B = Gamma Index, D = Alpha Index, F = Beta Index based on junctions C = Gamma Index, E = Alpha Index, G = Beta Index based on towns

H = Cyclomatic Number, I = Route Length, J = Theta Index

Note: Only significant relationships are given here; for detail see Appendix B1

the use of both types of topological indices ie.

i. Defining 'v' as junction (J)

ii. Defining 'v' as town (T)

Table 4.1 shows that total population has a positive relationship with all the indices. The highest association has been with the degree of circuity for the period of 1881-1931 and with route length for the whole period of 1881-1971. This association suggests some interesting points. The temporal change in total population is highly correlated with the change of indices of 'T' as compared to 'J'. In other words we can say that the changes in total population of the region are not as much correlated with the changes of rail network which have occurred due to an increase in junctions as the changes which have occurred due to an increase in the number of urban centres. Similarly, the positive and significant relationship between population growth and route length suggests that population growth took place along the lines (railway) not necessarily on the junctions.

To look at the relationship between connectivity and population change Taaffe and Gauthier (1973) suggest two measures of alpha and gamma, which measure the number of linkages within a network over and above those necessary to make a circuit. A significant correlation between population and α (T) suggests that there has been an equal increase in the alternative routes between vertices to increase the connectivity of the system between 1881-1931 while this association does not correspond to the relationship afterwards ie. 1881-1971 (as there is no significant development on the rail network during the recent four decades).

Similarly a significant correlation between population and γ (T) for the early period attests the relationship of population change to the change of number of edges in the network to the maximum possible number of edges for that period but this association for the rest of the period is positive but not significant as there is no increase in the edges after 1931 and the increase of edges on a new line between Kot Addu and Kashmore through Dera Ghazi Khan, has further decreased the value of the index. On the other hand the significant correlation between the change of population and three most important indices of η (degree of development), μ (degree of circuity) and route length, for both periods suggests that the degree of transport development

was higher than the degree of population growth up to the period of 1931 and for this reason the gap existed between the equal relationship of these variables; it was covered later on in 1931, when the changes occurred in the population growth but not in the rail network of the region. It can further be attested by examining the correlation of population with 'β (T)' which is useful measure of complexity and shows a significant association between the temporal increase in the population and the changing complexity of the transport system, which took place up to 1931 and after that this relationship remained positive but not up to the significance level.

The examination of the theta index, which measures the ratios between the length and vertices suggests a significant correlation up to 1931. It shows that all the topological indices related to the gradual change of edges and vertices are highly related to the changing pattern of population until the rail development period, while a non or semi topological element of 'π' and route length are highly correlated for both periods. Looking at the ever increasing index of 'μ' (cyclomatic number) which records abrupt changes in the system and a comparison between the degrees of relationship of gradual and abruptly changing indices suggests that the population change in the region has been gradual up to 1931 and it was accelerated in the last decades, therefore the association with the abruptly changing indices like 'μ' and 'π' is high as compared to the rest of the indices, which record the changes in the system gradually. This temporal relationship with gradual changing indices can only be seen to be significant at the early stage of development (see Table 4.1).

All these three topological indices of 'α'(J), 'β'(T) and 'α'(T) use the same basic component vertices and edges and they are strongly correlated in practice. In this case, for example, there exists a correlation between α (T) and β (T) indices for the ten temporal decades of 0.96 (co-efficient) and between α (T) and γ (T) indices of 0.95. Though they do not measure identical properties of the network, they are closely interrelated.

The urban population growth which was smooth until 1921 and accelerated afterwards, shows a positive association with the rail network indices for the period of study. It can be confirmed with the

examination of its significant correlation (0.892) with the abruptly changing index of 'μ' during 1881-1931 while during the whole period of 1881-1971 the change in urban population is highly related to the non topological parameter of route length (0.594), cyclomatic number (0.588), Pi index (0.581) and Theta index (0.539) than to the purely topological indices like β (T) (0.514), Gamma index (T) (0.494). A low degree of association of urban population change with the topological indices, compared with the non topological parameters, for the whole period of 1881-1971 indicates that the fastest urban growth took place at the end of the railway development or in other words we can say that the change in total population was followed by the change of urban population during the recent decades of 1931-1971 and that it started at the end of railway development. This relationship suggests at early stage rail development played a more important role in the change of total population than the change in urban population but at the later stage after the completion of the rail network the road development has a significant effect on the urban growth. In other words we can say that in the region of the Panjab, the centres created by railway development during the early 60 years were later on developed by the construction of roads during the last 40 years. This aspect of urban change will be discussed in more detail while looking at the spatial distribution of urban population and its relationship with road network connectivity.

The above mentioned fact can further be elaborated by taking the year of 1931 as a yard stick and to look at the percentage of both total and urban population before and after 1931. Out of the total 1971 urban population (100 per cent) about 81.6 per cent was attained between 1931-1971 and ten per cent between 1881-1971 and only 8.4 per cent before the study period of 1881. While the total population between 1881-1931 was 63 per cent and during 1931-1971 about 15 per cent and before 1881 there was 22 per cent of the total existed population in 1971. As there is a big difference between the percentages of urban population and total population for the different periods, therefore an equal degree of association for both (total and urban population) cannot be expected, with the structure of transport network, through the period.

In the light of these large variations in the existing percentages of total and urban population it will be interesting to explore further

the changes in these variables alongwith the degree of association of rail network. As urban population represents a portion of the total population, it is important to examine the degree of relationship between the changing structure of the rail network and changes in the percentage of urban population, through the period.

A correlation between percentage of urban population and growth of urban population as a whole (decade wise) for the period of 1881-1931 and 1881-1971 is 0.946 and 0.977 respectively. This correlation, where both variables are equally changing shows that it is comparatively more significant for the later period and it can be confirmed with the examination of the correlation of various topological and non-topological indices (see Table 4.1). With the comparison of this relationship for both periods it is interesting to note that this correlation is positive for the periods and the degree of association with abruptly changing indices is higher and more significant for the later period (1881-1971) while the association with gradually changing indices is not significant; it is the same with the change in the number of urban centres for which the correlation with the indices is not up to the significance level for the six early decades, while it is more significant for all ten decades. It also suggests that an increase in the number of urban centres took place in the later decades. It again clarifies the already mentioned statement that rail development played an important role in the creation of new towns, though they prosper later on with the road development. As we see that there are 65 towns with a population of more than 20,000 (Census 1971) and out of these 62 are on the rail network and similarly among the centres belonging to the lower class of population sizes, most are with railway stations. A big difference between the degree of correlation (for both periods 1881-1931 and 1881-1971) between the number of urban centres and the structure of the rail network, suggests that during the later stage of road development a number of newly grown towns were no more than village railway stations before 1931.

Before looking at the changes in the different sizes of the urban centres, we will first look at the relationship of the change in number of the urban centres with the transport indices. Taking the size of 20,000 population as a yard stick the number of urban centres can be divided into two classes:

i. Lower group includes the number of urban centres with a population

of less than 20.000.

ii. The upper group includes centres of more than a population of 20,000.

Table 4.1 shows that the correlation between the lower class of towns and the indices is positive for both periods but it is only significant for ten decades (1881-1971). On the other hand, the upper group of towns is positively correlated with the structure of the rail network with the equally lower significance level for both types of periods. In the light of these relationships it can be believed that alongwith the railway growth the centres of the lower group (mostly new and small market towns) did grow in number in the first six decades but not with an equal speed of railway growth/development. The gap in degree of relationship was covered during the four decades 1931-1971.

Instead of number of urban centres of these groups if we look at the population of the same groups (see Table 4.1) we can see that the population of towns below 20,000 has a comparatively significant and higher degree of relationship for the rail development period, as compared to the large towns (above 20,000) which indicates the change of population from rural areas to the newly settled towns on the railway lines. This relationship provides grounds to believe that in the decades of railway development the growth and development of new urban centres was following the rail development in the central newly settled regions of the Panjab. The urban population in these towns was changing rapidly as compared to the pre-existing towns of the region. In other words we can say that at the initial stage urban growth was a cause of railway development, as we can see a significant correlation between this variable and all the abruptly changing indices for the early as well as the later periods. A positive but comparatively low correlation between the urban population of the upper class and indices suggests that in early decades gradual urban change in this group did not correspond to the abrupt change in the railway development. But in the later stage the absence of the further development in the railway did correspond with its acceleration. It can further be attested with the examination of the similar correlation of indices and number of urban centres in this class.

In order to make this study more meaningful and interesting an attempt has been made to examine the relationship by further break down

of these two groups into three each, to trace a classwise detailed picture of the relationship.

From Table 4.1 it can be seen that except for the second highest class (50,000-100,000) all five classes are positively correlated with the indices of the transport network for the early period but with the addition of the last four decades the relationship is positive for all classes. On the basis of these scores it is found that in the six early decades the urban population between 5,000-10,000 size group is highly correlated with the structure of the rail network.

There were changes in order of these classes between the period 1881-1931 until the completion of the railway and then between 1931-1971. Among these classes IInd and Vth class remained the same in order while Ist and IVth went down and IIIrd and VIth came up. It shows that the growth of urban population in the lower classes had a close association with railway development until 1931.

Lastly two variables entirely related to the railway development are route density per thousand total population and route density per thousand urban population. The comparison of these variables with other variables discussed so far show that they are related to the structure at a very low level and it shows an expected decline in the periods. The correlation of these variables is positive with the indices for the six early decades but later on it is low, obviously due to no development in this respect.

To examine the relationship of individual indices and variables and to know which variable has been highly associated as compared to others, here an attempt has been made to plot the data according to the selected indices. Only four of these are selected for the comparison of the relationship through time and finally it will be concluded which measure is highly associated with the overall urban/population growth and similarly which variable of population has a high association with these measures.

Tables 4.1a and 4.1b show the changing relationship of 16 demographic variables with the topological indices for the six early decades and then the ten decades all together. The four selected indices present

the relationship with the degree of development (π) completion of circuits (μ) and purely topological ratios on the basis of towns (β(T)) and junctions (βJ). All these indices are positively correlated among themselves, and there is not much difference in the degree of relationship.

Most of these variables are significantly related to th 'μ' and π indices, which are abruptly changing indices in the system. Among these variables no. 1, 5 and 10 (see Table 4.1) were significantly related up to 1931 and on the basis of the same rail development three variables (3, 12 and 13) which were close to the significant level in the early decades crossed the significant level, with the addition of four recent decades. Similarly three other variables (7, 8, 11) were away from the significance level in the early decades but came closer later on. (see Tables 4.1a and 4.1b). It suggests that all these variables are related to the structure but with a variation of degree in the periods.

Now we will examine the composite degree of relationship for individual demographic variables with all the indices and then between individual indices to all variables, for the purpose of the exact position of the individuals in order of priority. Therefore the average scores for each variable have been calculated and are ranked for both periods. The changes in the ranks for the periods point out the effect of railway and road development on these variables. The maximum degree of change can be seen in variables no.15 and 16, which is expected and then in the five variables (3, 8, 9, 12 and 13).

In the same way the average scores of the measures used for transport structure clearly show that the measurements based on junctions as vertices do not give the exact picture of relationship up to significant level as is evident from Table 4.1, which shows no significant correlation for any demographic variable. It indicates that the temporal relationship of town based structure of transport and demographic changes is high with town based structure as compared to transport structure based on junctions.

4.5 Division Level Temporal Relationship

For this section of analysis four demographic/urbanization variables of total population, urban population, percentage of urban population and number of urban centres, have been selected to analyse the relationship with three non (route length), semi (η index), and Purely (β) topological indices of the rail network, which have been found useful in the previous discussion on state level analysis. This section is more interesting in terms of comparisons of relationship between divisions, variables and periods.

In this section an attempt has been made to examine the relationship in terms of degree of closeness and then its change with the addition of four recent decades and finally the variation of these degrees and changes between the divisions of the region, belonging to the different periods of development and this comparison leads to some detailed discussion about chicken and egg situation in the region.

The first set of simple correlations relate to the temporal development of the divisions relating to the decade wise change of railroad development to the change of urban development from 1881-1931 and 1881-1971 with the addition of a recent period of 1931-1971. An overall examination of these correlation co-efficients shows that high correlation exists between total population and the indices of rail network, mainly in the plains regions. A positive but comparatively low correlation values of Rawalpindi Division suggests that the physiography of the area was not suitable and favourable for railway development and which later on affected the population growth but on the other hand in the central regions this situation is the opposite; this can be attested by the examination of significant correlations for the early as well as the later periods. Among the co-efficients relating to total population with structure of the rail network are significant in all divisions except Rawalpindi, but the co-efficient relating to urban population is positive in all the five divisions but is not at significant level in the extreme north and hilly division of Rawalpindi and the extreme south division of Bahawalpur.

Further, it could be asked whether all these indices are related in equal degree, as the nature of measurement is different. Beta (β)

measures a topologically simple ratio between nodes and edges, Pi (π) the degree of development in terms of complexity while 'route length' is a purely non-topological measure. Table 4.2 shows that all these indices vary in degree for individual variables of change. It is interesting to note that some variables which are low with one measure are high with another. This indicates the structural variations in the sub regions in terms of complexity length and vertices. With the exception of Rawalpindi, all the divisions have minor variations in the degree of relationship between variables and indices. The variables of Rawalpindi division are highly correlated with π, route length and 'β' respectively. As all these indices represent the different nature of the structure, so a high correlation with 'π' and low relation with 'β' in Rawalpindi division suggests the complexity of the network with a little increase in vertices and a medium change in route length (index) of the region. The low degree of relationship of the changes in number of urban centres (index) with the index of route length indicates the route length which constructed at an early stage and similarly the lowest degree of correlation with 'β' shows a very minor change in vertices throughout the period in this region (see Table 4.2). This fact can further be attested with the examination of a very low rate of growth for urban centres in this region (see Table 2.4). The existence of significant correlation (0.935) between total and urban population for 1881-1931 require an equal degree of association between these two variables and indices only Pi index (π) show an equal degree while this relationship is low in the case of 'route length' and 'β'. It indicates that there was not a significant change or increase in the route length and in the number of vertices at the later stage of the period but the changes took place from a simple network to a complex one, with the addition of small routes. It can further be confirmed by the net increase in Rawalpindi Division which was high in 1881 and 1891, but later on it was very low.

The low relationship of the indices with the variable of 'number of urban centres' and comparatively high with 'urban population' suggests that in this region the expansion of pre-railway towns was more significant than the growth of new towns in the period of rail development.

Except for the 'percentage of urban population' the variables for

Table 4.2

DIVISION LEVEL CORRELATION

Region	Variables	1881-1931				1881-1971			
		β	π	L	Av.	β	π	L	Av.
1-RWP	Total population				.733				.460
	Urban population				.752				.424
	%age of urban pop.				.652				.498
	No. of urban cen.				.092				.412
2-SRG	Total population	x	x	x	.954	x	x	x	.753
	Urban population	x	x	x	.956				.587
	%age of urban pop.				.506	x	x		.663
	No. of urban cen.	x	x	x	.963	x	x	x	.856
3-LHR	Total population	x	x	x	.867	x	x	x	.636
	Urban population		x	x	.863		x	x	.617
	%age of urban pop.		x	x	.869	x	x	x	.771
	No. of urban cen.				.661		x	x	.650
4-MTN	Total population	x	x	x	.892			x	.642
	Urban population	x	x	x	.794			x	.541
	%age of urban pop.				-.560				.416
	No. of urban cen.				.729	x	x	x	.676
5-BWP	Total population	x	x	x	.921				.633
	Urban population				.474				.521
	%age of urban pop.				-.687				.532
	No. of urban cen.				.539		x		.688

x significant over 95 per cent

β = Beta Index
π = Pi Index
L = Route length
Av.= Average value of three indices

Note: only significant relationships are given here; for detail see Appendix B2.

the newly settled division of Sargodha are associated with the indices of rail network at a significnat level and with a very small variation in the degree of these indices with each variable. The highest relationship of total population can be seen with 'route length' 'β' and 'η' respectively (see Table 4.2). The highest correlation between 'route length' and total population in a newly settled region is expected as the development started at the same period. The growth in 'route length' was very low until 1881 and afterwards the gradual increase attests the significant relationship.

Similarly, a slightly low degree of association between total population and 'β' can be expected as well because at the initial stages of the rail development the region had a simple network for which both 'β' and 'η' remained low but later on in 1910-1931, the interconnection between the vertices, made the network complex and the indices high.

It shows a comparatively high degree of relationship with the urban population of the region (see Table 4.2). A significant correlation (0.911) between urban and total population for the same period confirms the fact.

A positive but comparatively low correlation between 'percentage of urban population' and indices of rail network seems due to the fluctuations in the percentage of urban population during 1891-1901, when the total population of the region showed a sudden increase and in spite of a gradual increase in urban population, its ratio came down. In this region it is interesting to note that a high degree of correlation (0.994) exists for three variables with three individual indices of rail network ie., total population with route length, urban population with 'η' and number of urban centres with 'β' (see Table 4.2). In other words it can be inferred that initially in the region route length (which is a non-topological index and does not indicate any complexity of the network) and the total population are accompanied by each other. Later on with the development of branch lines and interconnections the network becomes more complex and the degree of Pi index (η) increases, which corresponds to the urban population either in the pre-existing or newly settled towns. A high and significant degree of relationship (0.994) between the Beta index and 'number of urban centres'

for the period 1881-1931 indicate the growth of market towns along the railway lines during this period. A comparatively high growth of urban centres in this region for the same period confirms the fact (see Table 2.4).

All variables for the Lahore division, which includes both new and settled districts are related with the indices of rail network at equal degree except for two; one is the variable of number of urban centres which has a comparatively low degree of relationship with all the indices of rail network, the other variable with a low degree of correlation is 'urban population', with a poor relationship with 'β'. Here it is interesting to note that the association of 'β' is significant with total population but not with urban population (see Table 4.2). This low level of relationship of 'β' with both the variables (urban population and number of urban centres) indicates the dominance of the city of Lahore, which will be more clear in the district level analysis of the relationship.

The variables of 'urban population' and 'percentage of urban population' are related with the individual indices of rail network at an equal degree of relationship (see Table 4.2). It indicates the closeness of these two variables in terms of changes in the urban population of the region. Like Rawalpindi division, the structure of this region (Lahore division) is also highly correlated with Pi (π), route length and 'β' respectively.

In the case of Multan and Bahawalpur divisions, all the indices of rail network show very minor differences in the degree of relationship with the individual variables as these indices measure the changes of the region at the same scale. In the Multan division the variables of total population, urban population and number of urban centres are positively related with the percentage of urban population and are negative with all the indices. It shows that percentage of urban population did not change, probably due to an accelerating change in the total population of the newly settled areas of the region. A similar relationship can be found in the same variables of Bahawalpur division showing a higher growth rate in total population than the urban population (see Table 4.3). In Bahawalpur division, the higher association between 'number of urban centres' and indices of rail

network indicates the growth of new urban centres along the lines with less population.

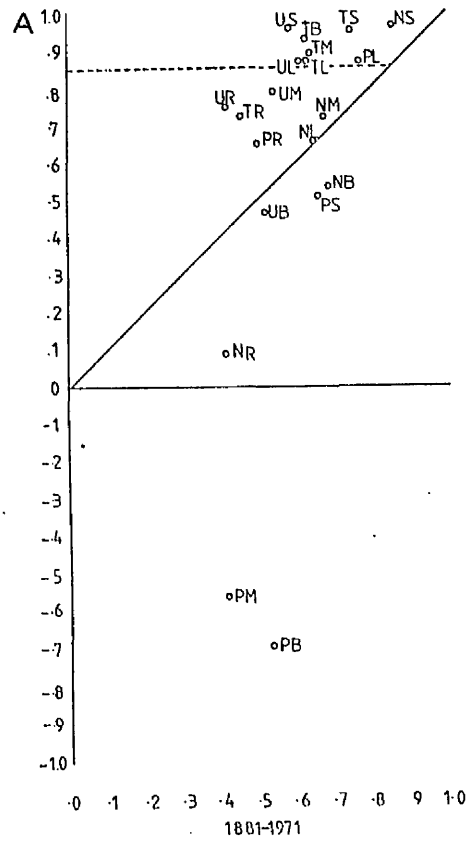
Coming to the conclusions in terms of individual indices here an attempt has been made to examine the number of variables according to their degree of correlation with the individual indices. For the sake of comparison the degree of relationship can be divided into the following four groups of critical values:

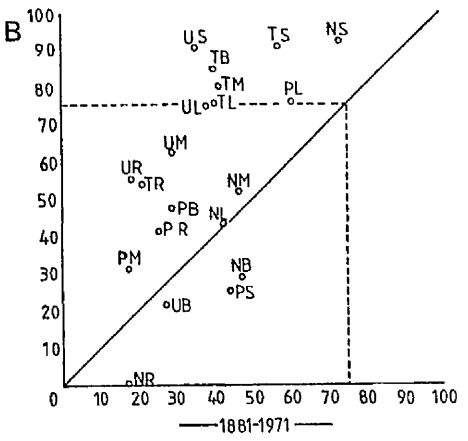
A $\pm$ 0.700 - 1.000 (a high degree of association)
B $\pm$ 0.400 - 0.700 (a substantial relationship)
C $\pm$ 0.200 - 0.400 (a low degree of association)
D $\pm$ $<$ 0.200 (a negligible relationship)

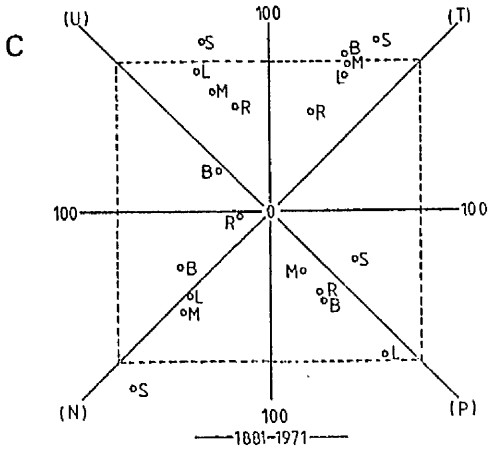
Taking all the variables together out of a total of 20 (four for each division) Pi index (π) is correlated with a total number of 13 variables at 'A' level, with six variables at 'B' level and with only one at 'C' level while the 'β' index is correlated with 11 variables at 'A' level (high degree of association), with eight variables at 'B' and with only one at 'C' level. The non topological index of 'route length' shows a very close association with 12 variables at 'A' level and seven and one variable at 'B' and 'D' levels respectively. It suggests that although all these indices show a variation in degree of association with individual variables, collectively they are very much correlated with one another. So for the purpose of the comparison of the degree of association between variables, regions and periods it will be useful to obtain the average scores of these indices to present the structure of the rail network as a whole.

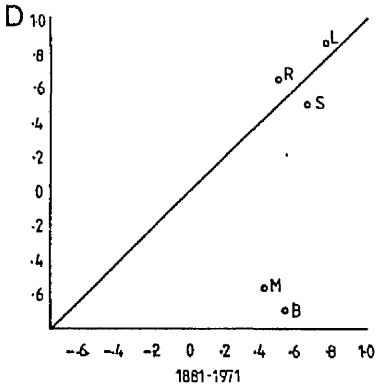
A division level correlation analysis with individual indices and then with average degree of total and urban population gives a clearer picture of the relationship (see Figure 4.1 F-M). The high correlation between total population and individual indices for individual divisions does not indicate any significant change in order of the divisions while correlating with the average scores of the indices (see Figure 4.1 L). Similarly a division level relationship of urban population does not indicate any significant change in order of the divisions (see Figure 4.1 G,I,K) by the correlation with average scores of the indices (see Figure 4.1 M). In other words we can say that if 'β'

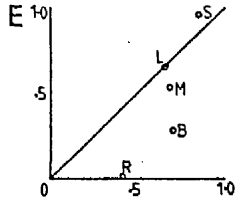
DIVISION LEVEL TEMPORAL RELATIONSHIP

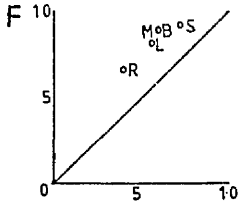


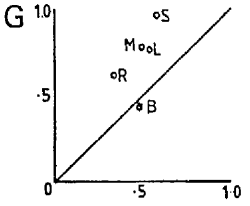


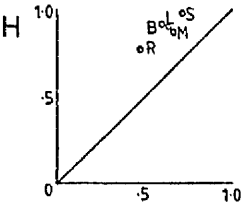


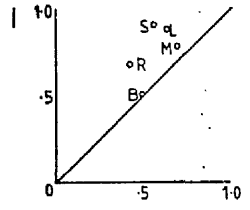


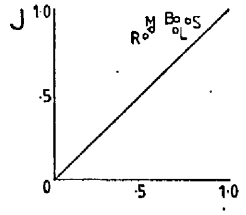


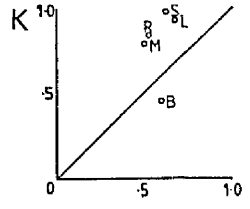


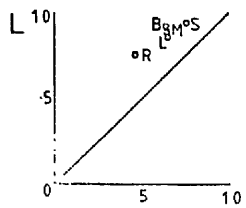


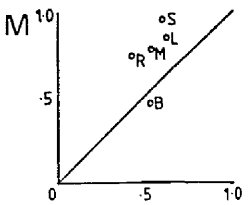












R=RAWAL PINDI DIVISION
S-SARGODHA DIVISION
L-LAHORE DIVISION
M-MULTAN DIVISION
B-BAHAWAL PUR DIVISION

T - TOTAL POPULATION
U - URBAN POPULATION
P - PERCENTAGE OF URB. POP
N - NUMBER OF URBAN CENTRES

indicates its high degree of association with urban population for Sargodha division and low for Bahawalpur division, it remains the same with π, RL, and finally with average scores of these indices (see Figure 4.1 F-M). The temporal relationship between total population and structure of rail network is significant in the central and southern divisions of Sargodha, Bahawalpur and Multan while a positive but comparatively low relationship can be found in the old settled divisions of Lahore and Rawalpindi.

Similarly the relationship between urban population and structure of rail network is again high for Sargodha division and then for Lahore, Multan and Rawalpindi divisions and this association is very low for Bahawalpur division, where urbanization is a recent phenomenon and in this respect the change in the ranks of divisions between total and urban population is expected. The dominance of Lahore division is due to the changes of urban population in the city of Lahore. This can be confirmed by the examination of a big variation in the degree of association between the variable of 'number of urban centres' and the structure of the transport network (see Figure 4.1 E).

A comparison between the degree of association of the variables 'U and N' (urban population and the number of urban centres) with the structure of the transport network for the various divisions, shows that the structure of the rail network of the old settled divisions of Lahore and Rawalpindi is highly correlated with the urban population but the correlation is low with the number of urban centres. This indicates the dominance and growth of the old cities of the region which were connected with the rail at the initial stage or the stage at which these cities were connected.

In the same way the degree of relationship between percentage of urban population and structure of transport network, vary for the divisions. It is high for the old divisions of Lahore and Rawalpindi and low for the newly settled areas of Sargodha, Multan and Bahawalpur divisions. A comparison between the degrees of relationship

i. between the structure of rail network and total population,

ii. structure of the rail network and percentage of urban population,

suggests that all those divisions whose structure of transport network is highly correlated with the total population show a low degree of

relationship between their structure of transport network and percentage of urban population. The structure for the newly settled divisions of Sargodha, Multan and Bahawalpur has a high association with the total population of these regions but has a low association with the percentage of their urban population (see Figure 4.1 D and L) and similarly the case for Lahore and Rawalpindi is opposite. This contrast further suggests that the change in urban population was smooth and regular in the old regions while it was abrupt in the newly settled regions. For example, the percentage of urban population has been fluctuating throughout the period, with the sudden growth of the total population in the new districts of Sahiwal, Lyallpur and Sargodha and with the decline in Bahawalpur. A negative correlation (-0.62) between total population and percentage of urban population will be helpful to confirm it.

So far we have shown the relationship between total 'explained' and 'unexplained' variations, but to know the variation without considering the effect of positive and negative variations to obtain a percentage value, all the average scores of the indices have been squared to calculate the co-efficient of determination which indicates the proportion of total variations in the dependent variable that is associated with or explained by the variation in the independent variable and the comparison of these 20 variables will be helpful to understand the relationship on the basis of percentage variation.

The percentage values or 'R' (co-efficient of determination) showing the relationship for the variables can be divided into three groups:

i. 75 per cent - 100 per cent
ii. 50 per cent - 75 per cent
iii. < 50 per cent

Among these the high class includes eight variables out of which four belong to the total population of the divisions and three out of eight are associated with Sargodha division. It suggests that among all the five regions Sargodha division has a comparatively high association with the structure of its transport network; and among these variables of the Sargodha division (tested so for) the 'total population' has been significant in association. After that the second most important and significantly associated variable for Sargodha

division is urban population.

A comparison between the correlation of the same indices and variables shows a number of changes for the two periods. A decrease in the degree of association between variables and indices is expected, but it is interesting to note that the changes in the variations of the degrees of association are not similar and all the negative associations have changed to positive. Most of these changes (from minus to plus) are significant in the divisions of Multan, Sargodha and Bahawalpur. The degree of relationship between total population and structure of rail network measured with 'β' shows a significant change for Bahawalpur, Multan, Rawalpindi and Lahore respectively and is comparatively low in Sargodha division for both periods. The case for urban population is slightly different where the low changes in the degree of relationship between urban population and 'β' can be seen in Lahore and Bahawalpur (see Figure 4.1 F,G). An increase in the correlation between urban population and 'β' can only be seen in Bahawalpur division, which indicates a later development in the urbanization of the region. In the case of the Bahawalpur division, there was much increase in the correlation between 'total population' and 'route length' and no change in correlation between 'route length' and 'urban population' for both periods support the idea and suggest that in this region (Bahawalpur division) the growth of total population and railway were equal during the first six decades and urban growth became equal four decades later, or in other words, both the urban population and railway network were not closely related due to unequal growth rates; later on, this gap was covered with the abrupt growth of the urban population. A similar situation exists in Multan division.

Looking at the relationship between total population and structure of transport network (average scores of π, β, RL) one sees that the total population of the newly settled divisions of Sargodha, Bahawalpur and Multan was closely related with the structure of their rail network at the early period when rail development was in process, but at the later stage the degree of relationship decreased for all the divisions at an equal difference ranging between -0.2 to -0.3 degrees (see Table 4.2 and Figure 4.1 L). This variation in the degree of association between two periods is high in Bahawalpur, Rawalpindi, Multan, Lahore

and then in Sargodha division respectively. An equal decline in the degrees of correlation (between total population and indices) of all divisions indicate that the total population of these divisions was equally associated with their structure of transport network for the later period.

Examining the relationship between urban population and structure of the rail network for the divisions, the change in periods highlights its importance in the case of Bahawalpur where a low degree of correlation increased with the change of period. It suggests that in the already settled regions the effect of association of railway development can be expected at the early stage, but in new areas of settlements it always follows. In the case of the rest of the divisions a negative change in the degree of association is similar. It is interesting to note that there exists a significant correlation between urban population and the structure of railway for the period 1881-1931, in the divisions of Sargodha, Lahore and Multan, but with the addition of four decades (1931-1971) this relationship comes down lower than significant level while the decrease of the relationship of the total population does not cross the significance level (see Table 4.3).

It indicates two points of interest:

i. The correlation between urban population and the structure of transport is comparatively stronger than the correlation of total population and structure in the region.

ii. The changes in the total population are much smoother than the changes in urban population.

It can further be supported by examining the growth rates of these regions which are higher for urban population, than the total population during this period (see Table 2.4).

The picture becomes clearer by looking at changes of the relationship between percentage of urban growth and structure of the rail network, for both periods. For the six early decades this relationship is only significant in Lahore division, which indicates that in spite of low urbanization at that stage the percentage of urban population in this region was equally changing. The second region with a high association is also an old settled region, that of Rawalpindi while among the new

settled divisions only Sargodha has a low positive correlation while Multan and Bahawalpur divisions show a strong negative relationship in this respect. It also supports the already mentioned statement that at the initial stages in the new areas total population has a close association with structure of transport network and due to the high pressure of rural population in the newly settled canal colony districts,the ratio of the urban population for the whole division became low. But with the addition of the four recent decades, the situation of the relationship has been changed (see Figure 4.1 D).

Lahore and Rawalpindi divisions show a very minor decrease in the degree of association between percentage of urban population and structure of rail network between the two periods, while a big increase in the degree of association can be seen in the case of Bahawalpur, Multan and Sargodha divisions. It suggests that at the early stage of development this variable was unable to change equally in the newly settled areas.

The fourth variable 'number of urban centres' has a significant relationship (with its structure of transport for the period 1881-1931) in Sargodha division where a number of new market towns were created during the period of rail development. This association is very low in Rawalpindi division. In this case the significant changes between two periods can be seen in the divisions of Bahawalpur, Rawalpindi and Multan (see Figure 4.1 E).

Finally to look at these changes through individual regions and variables for the periods, the squared values (co-efficient of determination) of the correlation of the variables has been given in Figure 4.1 C, where we can compare the degree of relationship between the two periods of 1881-1931 and 1881-1971, to see that the relationship of total population does not show any significant change (positive to negative or negative to positive) in any division of the region while the relationship (between variables and structure of transport network) of urban population indicate a change in Bahawalpur division, 'percentage of urban population' in Sargodha division and the correlation of 'numbers of urban centres' changes its degree of association in Rawalpindi and Bahawalpur divisions. It shows that variables of Lahore and Multan divisions have comparatively weak

association with this structure of transport network.

To understand more precisely the changes in relationship between the periods of 1881-1931 and 1881-1971, these can be compared with their annual rates of growth for the same periods (see Table 2.4). Here 15 out of the 20 variables have been selected and are compared after ranking. Among these variables two NR (number of urban centres of Rawalpindi division) and N$ are equally associated in both the periods while the three variables relating to the number of urban centres of the rest of the three divisions have a weak correlation for the early period but high for the whole 90 years. It suggests that the growth of the urban centres mostly took place after the completion of the rail network.

Similarly two variables of UB (urban population of Bahawalpur division) and NB (number of urban centres of Bahawalpur division) relating to the less developed region show a significant difference in the rates of growth between the periods indicating the later urban development of the region.

An examination of the comparison between correlation and annual rates of growth of the variable for both periods suggests that the degree of relationship of these individual variables with the structure of transport network, varies according to their annual growth rates for the period of 1881-1931 but for the period 1881-1971 the situation is the opposite.

4.6 District Level Temporal Relationship

For the purpose of district level analysis the 19 administrative districts of the Panjab are used as units, since all the statistical information gathered uses these units as the basis for data collection. As the topological indices are weak in measuring the small units through time, therefore, 'route length' of these units has been selected as a changing parameter for the measurement of temporal relationship with their total as well as urban population for the same periods of 1881-1931 and then 1881-1971. Initially the relationship is measured by correlation co-efficient for the period 1881-1931 and then to

Table 4.3

DISTRICT LEVEL CORRELATION

	Name of District	1881-1931		1881-1971	
		Route length with total population	Route length with urban population	Route length with total population	Route length with urban population
1	Rawalpindi	0.911 *	0.944 *	0.529	0.501
2	Campbelpur	0.578	0.526	0.382	0.373
3	Jhelum	0.349	- 0.195	0.456	0.358
4	Gujrat	0.586	0.648	0.495	0.463
5	Sargodha	0.981 *	0.636	0.700 *	0.588
6	Mianwali	0.831	0.783	0.518	0.430
7	Jhang	0.927	0.711	0.590	0.529
8	Lyallpur	0.907	0.895	0.552	0.452
9	Lahore	0.856 *	0.797	0.556	0.527
10	Sialkot	0.621	0.921	0.631	0.750 *
11	Gujranwala	0.453	0.502	0.355	0.365
12	Sheikhupura	0.772	0.653	0.760 *	0.569
13	Multan	0.078	0.767	- 0.092	0.483
14	Sahiwal	0.756	0.685	0.642 *	0.523
15	Muzaffargarh	-	-	0.892 *	0.843 *
16	Dera Ghazi Khan	-	-	-	-
17	Bahawalpur	-	0.637	-	0.338
18	Bahawal Nagar	-	-	-	-
19	Rahim Yar Khan	-	- 0.885	-	0.457

* significant 95 per cent

understand the percentage of total variation statistically explained by different units, the values have been changes to 'R' (co-efficient of determination). Out of these 19 units correlation values can only be measured for 14 districts and leaving aside the five less developed districts of Muzaffargarh, Dera Ghazi Khan, Bahawalpur, Bahawal Nagar, and Rahim Yar Khan where either the rail development took place later or population data are not available for individual districts since 1881.

Table 4.3 shows that the total population of the three districts of Rawalpindi, Sargodha and Lahore is related to their structure of transport for the early period, at significant level. The districts with a high correlation but below significance level are again the three districts of Sargodha division. It shows the early pressure of the rural population alongwith the railway development in the region. The high relationship in the upper districts of Rawalpindi is due to the early concentration of the population in the northern and north eastern districts of the Panjab where it was increasing relatively more rapidly than in the central and western districts. But with the opening of the lower Chenab canal in the Rechna Doab in 1899, a great impetus to population spread and growth was given to the central districts. A big difference of the degree of correlations between the two periods (1881-1931 and 1881-1971) for Rawalpindi and a lower difference in the case of Sargodha district confirms that a close relationship between population and transport network in Rawalpindi district is only due to its early concentration and railway connections. As the railway development took place at a comparatively later stage in the Central districts, so the relationship is moderate.

Coming to the relationship between urban population and transport network, it is higher in the old districts of Gujrat, Sialkot, Gujranwala and Multan as expected (see Table 4.3). It suggests that during this period the rural to urban movement was in the towns of old districts while in the new districts this process started late.

Chapter 5
THE REGIONAL STRUCTURE OF TRANSPORT NETWORKS

5.1 Introduction

In this section the regional structure of transport is also analysed with the help of graph theory based on edges and vertices. These are used to derive two closely inter-related properties of connectivity and accessibility. The former expresses the degree to which a network permits direct movements between its various nodes and is therefore a single aggregate measure relating to the structure of the network as a whole. Accessibility on the other hand is specific to individual nodes which are differentiated in terms of their locations relative to one another.

The essence of the present study is to quantify the network of linkages in the Panjab and to relate it with urban development. Therefore in the previous chapter a similar attempt was made to look at the temporal growth of railway (across a whole century), which is still the most important carrier for long distance goods and people, even though there has been tremendous competition from road haulage in recent years. This chapter examines the structure of existing transport networks and presents some initial results obtained from the study of rail and road transport systems which have evolved in the Panjab in the periods of 1871-1931 and 1931-1971, respectively. Then the analysis is focused to evaluate the effect of changes in these transportation networks of rail and road comprising route lengths of 2,811 and 6,979 miles respectively. Both of these networks link urban centres of all classes with one another as well as with their tributary areas.

Initially the analysis is focused to:

(1) measure structural properties of the rail network as a whole,

(2) measure the structure of the road network

(3) identify the changes in the network that follow railway construction. These changes which took place by the construction of roads between small towns as well as rural areas, will be useful to identify the changes in nodal accessibility which normally disrupt the existing pattern of spatial competition in the region.

5.2 Definitions

The places which are connected by the transport system of the region (particularly road network), range from an intersection (without urban centre) to a big city like Lahore. Thus to obtain a clear understanding of the connectivity pattern, it would be necessary to be specific regarding the definition of a vertex. As the urban centres can be grouped hierarchically according to their sizes, it will be more convenient to select these centres as vertices according to the scale of analysis. On the other hand, in a region like the Panjab, the importance of road intersections cannot be ignored as these have the effect of introducing new places with strategic locations in the economy and also in shifting the relative location of places already developed (Garrison 1960). But because of the problem of computing nodal accessibility these intersections cannot be included for relative accessibility but are only counted (as vertices) for absolute connectivity separately.

To look at the aspects of 'absolute' and 'individual' connectivity - The terms connectivity and accessibility are used throughout the study to describe the accessibility of the network as a whole and the accessibility of individual places respectively.

5.3 Connectivity

Analysis of the connectivity of transport networks of the Panjab and changes in the accessibility of urban places (during 1931-71) is conducted in two parts:

i connectivity of rail network

ii connectivity of road network

a. Rail Network

A connection to a first order vertex has a different effect on the system than a connection to a second or third order vertex, therefore the structural properties of the rail network are examined by adopting the following four definitions of a vertex:

i as the intersection of more than two links

ii as urban centres (according to the census of 1971) with the addition of those junctions which are not classified as towns.

iii towns with a population of 50,000 +

iv towns with a population of 20,000 +

Table 5.1a shows that the values of railway connectivity obtained through the topological indices for the whole region of the Panjab, vary according to the definition of vertices. All the structural properties of the network are measured by various indices, each of these is capable of describing different concepts, that cannot be captured adequately by one index. The general network characteristics show a low degree of (circuit) connectivity, particularly with the vertices of small size towns. A big variation in the degree of relative circuit connectivity evaluated by the alpha index (α)* shows a maximum contrast according to the size of vertices. It shows that the degree of connectivity of big urban centres becomes high due to a number of factors like favourable distribution within the region and the location of intersections, which helps to connect themselves through a high ratio (65.12 per cent) of fundamental circuits. This ratio decreases along with the size of vertices.

Beta index (which indicates simple linkage connectivity) follows a similar pattern of connectivity according to the size of the vertex. For larger urban centres the value of 2.12 shows that there is considerably more than the minimum number of edges necessary to link all centres (of the same size class) to the network. With the addition of 38 lower-size towns the degree of connectivity decreases (to 1.35) due to the increase of vertices on the existing network (mostly on the same edges), as it is evident from the decreasing value of 'Eta' and 'Gamma' where the decrease in 'per edge length' and 'maximum possible number of

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* For explanation see Appendix 'A'

edges' took place respectively (see Table 5.1). In the light of the values of different indices it is difficult to conclude a general picture of connectivity because it is not feasible to accept the result on the basis of any one defined vertex or on the basis of any one index. Therefore an average value of the Alpha (25.25) Beta (1.44) and Gamma (50.61) indices suggests that with the exception of relative circuit connectivity, the general pattern of railway connectivity is developed at an intermediate level. The low relative circuit connectivity is mainly due to the lack of the interconnections of the urban centres mostly located apart on parallel lines. Only 14 per cent of the towns (with a population of more than 20,000) have the intersections of more than two lines, while the ratio of the smaller towns is poorer in this respect. Similarly a higher Pi index (5.37) indicates a considerable amount of surplus in the network and the configuration confirms that more than the necessary number of links for minimally connected graphs are present.

b. Road Network

The structure of the road network is more important in the region, as it connects all the 202 towns (Census 1971). Most of these towns are the product of intersections and all the major urban centres are linked through them. Due to the important role played by these intersections in terms of exchange of goods, people and routes, all of them have been included as vertices while analysing the topological structure of road network in the region by the indices based upon the relationship between the number of edges and vertices. This section of analysis is carried out by adopting the following four types of vertices:

i Major urban centres (50,000 +)
ii Towns of 'C' group (20,000 +)
iii Towns of 'D' group (10,000 +)
iv Intersections (with more than two links)

While 'E' group is reserved for a smaller scale analysis of district level.

Table 5.1b presents the topological indices for the Panjab's road network. A close examination of the values of these indices, which have been measured on the basis of four different size nodes suggests that

Table 5.1

PROVINCE LEVEL PATTERNS OF CONNECTIVITY

(TOPOLOGICAL AND METRICATED INDICES)

With the changes in the definition of vertex.

(a) RAIL NETWORK

Indices*	Vertex defined as Intersections (all)	Towns and Intersections	Town size 50,000 +	Town size 20,000 +
E	62	157	51	84
V	51	146	24	62
μ	12	12	28	23
α	12.37	4.18	65.12	19.33
β	1.21	1.08	2.12	1.35
γ	42.18	36.34	77.27	46.67
Theta	55.12	19.25	117.12	45.34
Eta	45.34	17.90	55.12	33.46

(b) ROAD NETWORK

Indices*	Vertex defined as Intersections (all)	Town size 50,000 +	Town size 20,000 +	Town size 10,000 +
E	1033	65	121	245
V	634	24	65	145
μ	400	42	57	101
α	31.67	97.67	45.6	35.4
β	1.63	2.71	1.86	1.69
γ	54.48	98.48	64.02	57.10
THETA	11.00	290.79	107.37	48.13
ETA	6.76	107.37	57.68	28.49

E = Edges
V = Vertices
μ = Cyclomatic Number
α = Alpha Index
β = Beta Index
γ = Gamma Index

* For explanation of indices see Appendix 'A'.

the size of the vertex has a close correspondence with the degree of the connectivity of the network. The values increase from the smallest (intersection) to the largest (urban centres of 50,000 +) vertices. It suggests that the network provides more links to the larger centres than the smaller ones, whose presence between the larger centres reduces the overall connectivity. The high values of topological indices on the basis of the major urban centres indicate an above average degree of connectivity for the whole network. Its low values with smaller centres are due to their location on the edge connecting the major urban centres, where the appearance of the smaller towns increases the vertices but decreases the edges, required to maintain the same values. It is also evident from the 'Theta' and 'Eta' values, which are low with small centres and high with the major centres.

5.4 Changes in connectivity

A comparison between the connectivity of rail and road networks indicates big changes in the values, which are due to the super-imposition of the road network on the rail network in the region. Although the connectivity values of the road network are higher than the rail network on the basis of all the four nodal definitions, our interest is focused only on the values obtained through the (defined) vertices of 'B' and 'C' class towns, which hold an equal position on both networks.

As the overall connectivity of the region on the basis of major urban centres (50,000 +) as vertices, is above average for both rail and road networks, a high degree of change cannot be expected in this respect. The difference between the values shows that with the development of the road network in the region the 'Alpha' index rose (from 65.12 per cent to 97.7 per cent) with about 50 per cent change which is about 28 per cent with 'Beta' and 'Gamma' indices. A lower change in this size group reflects an equal importance of the centres in terms of connectivity on both networks. On the other hand the changing pattern on the basis of the smaller towns group (20,000 +) as vertices is different. Here the high changes are in relative circuit connectivity (136 per cent), while the changes in 'Beta' and

'Gamma' indices are 38 per cent and 37 per cent respectively. It indicates that this group of towns (20,000 +) had considerably more than the minimum number of edges necessary to link them to the rail network in 1931 and with the road development later on (1931-71). The road construction took place along the railway lines as well as between them (lines) to connect the already connected centres and caused a higher change in circuit connectivity rather than linkage. A low value of Alpha index (19.33 per cent) reflects the spread of these centres along the corresponding railway lines with intersections far apart as is evident from the high 'Eta' index (45. 34) for the railway network and the low 'Eta' index (6.76) for the road network. If these centres were connected to each other the 'Cyclomatic Number' would rise to 150 per cent. Thus the addition of a few links would have a major effect on the accessibility of the network.

5.5 Nodal accessibility (Relative)

Though connectivity indices provide useful aggregate measures to understand the spatial structure of the whole network under discussion, however, there are still many situations in which interest is focused on the accessibility of individual nodes relative to the network as a whole and also as the consequences of adding or removing a particular link. As the essence of the whole study is to explore the relationship between transport and the growth of urban population as well as urban centres, the changes in accessibility of individual centres could be an equally important factor in urban growth, along with the changes in connectivity of the whole system. In this case we are interested in the effect of changes in the network, that are due to the addition of road development in the region. For this purpose it is possible to measure the accessibility through a matrix, which will be useful to quantify the structural aspects of the network and to derive meaningful measures of accessibility for the individual network elements with respect to each other. Given a measure of the Shortest Path Matrix it is possible to calculate an index of accessibility by means of which urban centres can be ranked according to their accessibility relative to each other. As the limitations of the matrix do not permit the inclusion of all the urban centres in one

matrix, in this section the analysis has been restricted to the 62 main urban centres with a population of greater than 20,000. In order to compare and obtain a clearer picture of the accessibility, the size group has been further sub-divided by separating the centres with population of greater than 50,000. This major class of centres yields a total of 24 vertices or approximately five per division. With the exception of four districts (Campbelpur, Mianwali, Muzaffargarh and Bahawal Nagar) all the district headquarters are included in this class. Among these the districts of Gujranwala and Multan have three (each) while Rawalpindi, Jhang, Lyallpur, Lahore and Sahiwal have two (each) towns in this class.

According to the size of the towns the nodal accessibility is divided into:

i Accessibility between towns of 50,000 + population

ii Accessibility between towns of 20,000 + population

5.6 Accessibility between major towns (50,000 +)

According to the Census of 1931 there were only five towns in this size group but within a period of 40 years they increased five fold. Similarly this size group which has over 69 per cent of the total urban population of the region gives a change of more than 560 per cent in the last 40 years (1931-71). How far has accessibility been responsible for the rapid changes in this size group? This question is studied on the basis of the assumption that 'the changes in accessibility have a significant effect on the growth and size of the towns of this size group'. As the term 'accessibility' is used in a wider sense, therefore in this case the following few measures have been chosen.

a. Rail Network

For these major centres the analysis of the accessibility by railway network is applied to the system as it was originally completed* in 1931 and the original important rail centres are

*with the exception of Dera Ghazi Khan section completed later

identified. The scores of these centres are then compared with the scores of the accessibility completed in 1971, to evaluate the effect of road development on this group of towns during the period.

The values obtained through the matrix show that Sargodha and Khanewal have the highest scores of accessibility making them the most accessible centres to the rail network as a whole. These are followed by Multan, Lyallpur and Chiniot while the rest of the centres have comparatively low scores indicating their relative isolation from the overall network. Among these five top ranking towns, three have a population of more than 20,000, while the two, Chiniot and Khanewal, have less than 100,000 population. At the lower end of the scale are the peripheral towns like Rahim Yar Khan and the developing new towns of Kamoke and Okara. The position of Lahore is in the middle of the hierarchy (13th) due to its peripheral location in the region. Because of its central position among the group of larger towns of the north east its higher ranks on railway accessibility scale cannot be expected.

To investigate the rise and fall in the surface of accessibility, it would be possible to create a map with the help of isolines of accessibility based on the nearness of each one to all the rest (see Figure 5.1a). It shows a north-south pattern of accessibility and the contours become steeper towards the east where these towns are close spatially but are far apart topologically, due to the absence of the shortest paths.

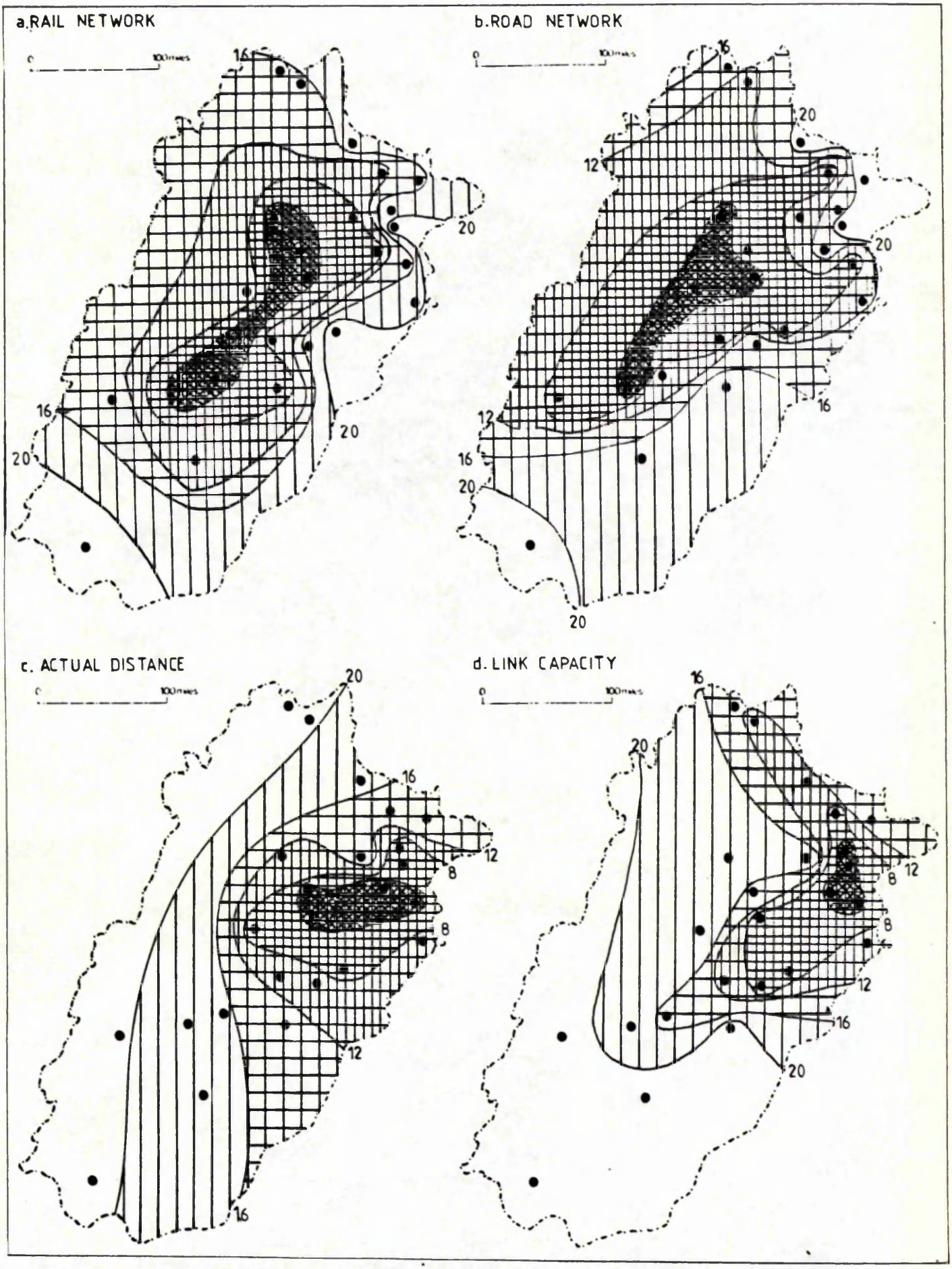
b. Road Network

Figure 5.1b shows that the high connectivity values measured by road network distinguish the urban centres of the central region, where early economic growth, especially in the field of agriculture took place. Most of these centres with high values of accessibility by road, had comparatively low ranks on the rail network. The increase of absolute network connectivity (measured by topological indices) resulting from the extension of the road network during 1931-71, predicts changes in the nodal accessibility. It shows that the accessibility of a number of urban centres increased between the period under discussion, while the accessibility index of certain other centres decreased in relative importance. A comparison between

FIGURE 5·1

NODAL ACCESSIBILITY OF MAJOR TOWNS

[50000+]



the ranks of these centres suggests that the development of the road network brought little change in the overall pattern of accessibility. With the exception of a few, the highest values remained focused on the centres of Lyallpur, Sargodha, Multan, Khanewal and Chiniot, while the lowest values can be found towards the periphery. However, when the accessibility scores of individual urban centres, after the extension of road networks is expressed as a percentage of corresponding values before it was added, certain trends become apparent. Among these the greatest increase has occurred either in the central nodes of Okara and Jhang (located in the centre of the lines) or the urban centres like Kasur located on isolated branches. These became a part of the circuit with road development.

As the pattern of accessibility is based on only the large centres it is expected that the addition of these towns will identify major changes with the comparison of rail and road networks. Similarly by ignoring the non-topological indices, the general and structural pattern of accessibility is not clear. To have a comparative and closer picture of these variations metricated indices have been included. The first is the flow of buses along the road network, while the second is distance* along the shortest path.

c. Link capacity

Topological and non-topological accessibility matrices give only a partial impression of the links connecting the major urban centres. In the topological analysis only the physical existence of the link was recognized, while in the metricated matrix the actual length along the shortest path was included. However, no consideration has yet been given to the variation of the links in terms of width and capacity, etc. Thus it is not possible to compare directly, for example, the link between Multan and Dera Ghazi Khan with that of one between Lahore and Kamoke, where the volume of motorised traffic per day in the first case is only 600 while in the second it is 7,000. Similarly the growth and accessibility of a town on the former link cannot be compared with that on the latter.

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* For ranks of towns see Appendix 'C_2'

It would only be possible to compare the accessibility of nodes within the region as a whole where all the links being analysed are of equal quality. As the main focus of the study is to trace the relationship between growth of towns and accessibility and both of these are influenced to some extent by the traffic flow, the distinction of the links in terms of flow capacity is important because flow of bus and rail passengers is used as an indicator of the number of people leaving their home area via public transport and orientation or destination in which they most often move. The possible number of origins and destinations for movement by bus (in the region) indicates the spatial organization. In general, bus route capacity should be a good indicator of the actual numbers of people moving along each route.

However, despite this limitation it is possible to compare the accessibility of various nodes by weighting the links according to the units of traffic flow per day. This would be worked out from the lowest capacity along the link which would work as a bottle-neck. Following the rule of population potential* we can make the assumption that the distance along the link will act as a resistance and dividing the capacity of the link by the distance, the values for the places can be obtained. The larger the values, the more accessible are the places at each end of the link.

This kind of measure is useful in the region like the Panjab where the flow per link has a big variation. On the basis of the flow data an index of accessibility has been calculated** for buses only, which are the main means of communication both for people and for goods between the towns of the region. All these centres are ranked according to their scores on this scale (see Appendix C_2).

To obtain a comparative understanding of the pattern of accessibility (between the major centres) through four different matrices, the results are presented as a series of surfaces depicted by isolines

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* which is based on the notion that the impact of one location on another depends on the factors of their relative population

** For matrix see Appendix 'D'

drawn in Figure 5.1 (a-d).

Figure 5.1a shows the pattern of rail accessibility between the major urban centres. A striking feature is the core of accessibility stretching along the main central line between Multan to Sargodha (through Chiniot and Lyallpur) from which runs a dominant axis or ridge descending gradually towards the periphery. The next highest level of accessibility appears in the north east, focusing on Sheikhupura due to its central position on three lines. Because of the concentration of the major centres in the north east, the overall surface of accessibility declines particularly for Kamoke, which is located between two major cities.

A comparison between Figures 5.1a and 5.1b suggests a noticeable change in the surface of accessibility, brought about by the road development. The core of the accessibility has shifted slightly towards the west due to the maximum centrality of Jhang by road network. Similarly among the changes towards the periphery, the increase in the accessibility of Okara and Sahiwal is noticeable. Their changes indicate the interconnectivity between the major centres. It is also evident in the case of Lahore, Gujrat and Dera Ghazi Khan which, inspite of their peripheral location, are included in the second highest zone of accessibility.

The pattern of accessibility obtained through the distance matrix is quite different from those of topological. Figure 5.1c shows that by including the actual distance along the Shortest Path, the zone of highest accessibility has shifted towards the east and focuses upon Lyallpur, Lahore, Sheikhupura and Chiniot and then it decreases towards north and south. The increase in inaccessibility towards the south is gradual as compared to north. It seems to be due to a comparatively high concentration of major urban centres and the location of Hafizabad on an isolated link. On the other hand the remoteness of the 'Thal Desert' has caused the zone of high inaccessibility including the whole western part of the region from Rawalpindi to Rahim Yar Khan, where no big town is located. It is expected that the general pattern of accessibility (and particularly in this zone) will be more clear in the subsequent part of the analysis, when the accessibility between smaller size groups of the towns is measured.

The pattern of accessibility through 'link capacity' indicates a shift of accessibility further east along the main highways and identifies a triangle of high accessibility (Lahore, Sheikhupura and Gujranwala) which could be travelled within three hours by bus (see Figure 5.1d). The isolines of decreasing accessibility then gradually move along main routes connecting the three major urban centres of Lyallpur, Rawalpindi and Multan, to the highest accessibility zone. Among these two Hafizabad and Burewala located away from the highways on low capacity links have low scores and interrupt the gradual decline of accessibility. The maps show a general relationship between traffic flow and urban growth (as predicted) where the areas of heavy bus usage are located in the districts of high density and are also high in the hinterlands of main cities particularly in the districts of Lyallpur, Sahiwal and Lahore, as these are blessed with irrigation. It is likely that the inter regional flow of people and goods throughout will accelerate greatly, enhancing the economic advantages of these promising areas.

On the basis of the results provided by various measures it is possible to obtain a final picture of accessibility (for the towns of this size group) reflecting their average accessibility on the basis of rail, road (networks), distance and link capacity. All these centres are classified into the quartiles according to their average scores.

1st Quartile

Lyallpur, Chiniot, Lahore, Sheikhupura, Jhang, Sargodha

2nd Quartile

Gujrat, Kamalia, Multan, Okara, Khanewal, Gujranwala

3rd Quartile

Hafizabad, Kasur, Sahiwal, Kamoke, Rawalpindi, Burewala

4th Quartile

Sialkot, Wah Cantonment, Jhelum, Dera Ghazi Khan, Bahawalpur, Rahim Yar Khan.

5.7 Inter relationship

A number of interesting points emerge from the study of the accessibility, the important are the inter relationship of these matrices.

A general association of all these four matrices is assessed through Kendall's Co-efficient of Concordance 'W' (Yeates 1968) which yields a correlation of + 0.42 with a significance level of 95 per cent. This suggests that all the rank order of centres on one matrix, is similar to some extent to than on the other matrices. The rank order difference between topological and metricated matrices (distance and topological) is identified by Spearman's Rho of + .274 (80 per cent significant. It suggests that though the topological pattern of accessibility is similar to the pattern by distance, but still there are a number of residuals which need to be identified. Gujranwala, Kamoke and Sheikhupura appear to be the towns with good accessibility on distance matrix (see Figure 5.1c) while they are ranked lower on the topological scale due to their central location in terms of distance and absence of direct links by rail respectively. In such cases the actual distance alsong the shortest path provides higher accessibility scores than the topological, as there is a tendency for central locations to be the most accessible.

On the other hand Multan, Dera Ghazi Khan, Rawalpindi and Wah Cantonment have low scores on distance but high on the topological scale. It is because of their peripheral location as well as the absence of major urban centres in the western part (of the study area) where only Sargodha enjoys topological centrality. It shows that in spite of the distance inaccessibility of these peripheral towns, structurally they are well connected with each other and the rest of the system as a whole.

A high degree of correlation between distance and road network accessibility compared with that between distance and rail network accessibility suggests that these towns are better connected by roads than they are by railway as the shortest path distance along the roads is less than by railway. This appears to suggest that the roads have provided better short cuts between the towns.

In spite of the different locations of the major cities like Lahore, Lyallpur, Multan and Rawalpindi, all these have higher scores on road network matrix than the rail network. Similarly a high correlation of town size with road accessibility (+.274) than rail accessibility (+.07) confirms that inter connections (by roads) of the towns already

situated along the railway lines have increased the overall accessibility. A positive correlation of (+.289) between population growth (1961-71) and the accessibility by 'link capacity' shows that the towns of 50,000 + connected by high traffic flow links had a high growth rate during 1961-71 while on the other hand a low correlation (0.094) of growth with size indicates that growth rate is high in the towns irrespective of size. This relationship appears to suggest that the recent development in the transport and accessibility is more effective in the growth and expansion of new towns than the old (pre 1931) ones *. Kamoke one of the new towns ranks highest on both growth rate and metricated accessibility scale but is lowest on population size. A higher correlation of distance (acc) with road acc. (+.276) than with rail acc, (+.157) suggests a road's 'short circuiting' the railway which was more effective in urban growth. It is also evident from a negative significant association between flow and rail accessibility (-.260) suggesting that (towns inaccesible by rail have become accessible by (road traffic flow. It reflects the fact that smaller towns which lie along the routes leading to the biggest cities have also a high accessibility as they are conveniently situated. The same is also true for places lying along the main railway lines with a big number of express trains running.

A significant correlation between distance accessibility and accessibility by link capacity (+.578) shows that the towns which are more centrally located with a relatively nearer position to all others, are also well placed in terms of minimum link capacity. In other words the towns with nearer location in terms of distance are also located on the links of high bus flow. It also reflects the important role of distance in changing the accessibility.

All this discussion identifies the importance of road accessibility in changing the major urban centres, which are concentrated in the eastern part of the region. As most of the new urban centres are in the small size group, therefore the scale of the analysis shifts to the lower size towns, to explore the relationship in detail.

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* It is also evident from a minor effect of size (0.280) which controlled partially.

5.8 Towns with population 20,000 +

a. Rail Network

With the exception of Daska, Jalalpur and Bhai Pheru, all the towns in this size group are connected with the railway system. This class includes a total of 62 towns and except for Dera Ghazi Khan (which was connected later on), all these towns have been located on the railway system since 1931, by which time 93 per cent route length had been completed. However, the road network has developed substantially since 1931. The subsequent analysis not only measures the present day comparative accessibility of these centres to the road and rail networks but also indicates the changes in relative accessibility of the towns brought about by the development of the road network.

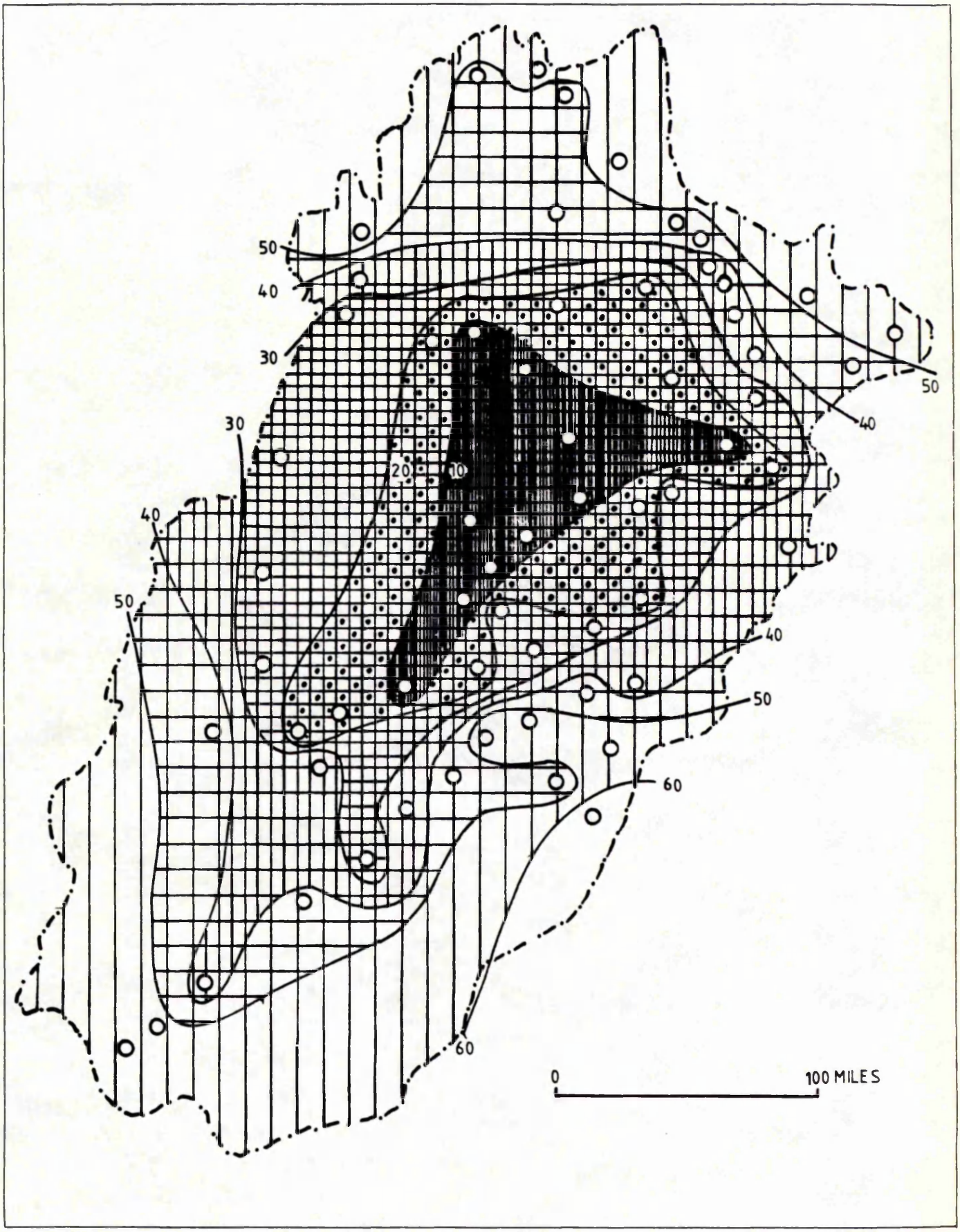
Using the 'Shimbel index' the values for 62 centres have been obtained and are ranked in order. Sargodha the most accessible among 'B' class towns continues to maintain its highest position in accessibility among these towns as well. Similarly, Khanewal, Lyallpur and Chiniot are also included among the top ten urban centres. Among the newly included towns Shorkot, Jhang, Khushab, Bhera and Sheikhupura have high scores. As all of these are located in the central agricultural region of the Panjab; the completion of the railway network in 1931, strengthened the focusing of the railway network on Sargodha and Lyallpur. This is shown even more clearly when towns of 20,000 to 50,000 (population) are included in the analysis.

Figure 5.2 shows the overall topological pattern of accessibility in the region. It illustrates the belt of high accessibility in the centre of the region which stretches in a narrow shape from Bahawalpur in the south becoming wider towards the north with an extended strip to the east. The belt covers most of the main towns lying in the agricultural region between the rivers Jhelum and Ravi. The slope of decreasing accessibility suddenly steepens towards the north and south, while the pattern is very gradual towards the east and west, particularly the north east where a minimum number of towns are located along the main railway line. The mountains in the north account for the sudden decrease in accessibility. In the south Bahawalpur is the focus of the sub-network and there is no direct connection between south east and

FIGURE 5·2

RAIL AND ROAD ACCESSIBILITY RANKINGS

(Towns 20,000+)



central region. This accounts for the steep decline in accessibility from the centre to the south east, despite the fact that Bahawalpur itself has relatively high accessibility for its peripheral position. In this situation there is no chance of high scores on the shortest path accessibility for the towns located to the south of Bahawalpur, as all of these are connected with the centre, through Bahawalpur. Another reason for low accessibility of these northern and southern towns is their location near the border of the Province where these are strongly oriented to places outside the region. This situation is more significant in the northern towns of the region (which are well connected to the towns of the North West Frontier Province) than the south while the eastern towns are not affected at all.

The pattern of contours also shows that even in the central region accessibility is not uniform. It is steepest in the west and gradually decreases towards the east. The reason lies in the expansion of the network in the east, where the important and old city of Lahore is located, while in the west the backward area like the 'Thal desert' remains relatively undeveloped. Another interesting contrast in the slope of decreasing accessibility is visible in the south east, where on one hand the towns of Vehari and Burewala, though located near the centre of the region, are less accessible* than the comparatively distant town of Chishtian which has easy access on one shortest path (through Bahawalpur).

b. Road accessibility

The specific problem posed here is that of measuring the accessibility of the same places as those measured on the railway network in terms of their accessibility by road. On the basis of the difference between the two measures it can be hypothesised that the evolution of the transport network would result in an unequal increase in the accessibility of individual places through time. It would also be expected that the overlapping of road network on the already existing rail net, would increase the accessibility of old towns and create new intersections in the region which would have the effect of

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* Because of middle location on railway line

introducing new places with strategic locations in the economy and changing the relative importance of locations of the places which had already been developed.

Following a similar procedure, the relative accessibility has been obtained through the matrix and the towns are ranked according to their scores on this scale (see Table 5.4). For the understanding of the variation in accessibilities of the towns, a histogram of Associated Numbers has been presented as well.

Figure 6.1a shows the variation in the topological distances* from one vertex to each of the other vertices. One fourth of the vertices have higher Associated Numbers (AN) than the average, while there are only three with the maximum value (9). It shows that the proportion of the least connected and peripherally located urban centres is comparatively low. Most of the towns have the maximum number of links necessary to be interconnected - in this case, seven. Four places, Jhang, Chiniot, Lyallpur and Gojra have the lowest shortest path distance and are able to reach other places of the system with the least number of links while Jalalpur, Lalamusa and Harunabad require the maximum number of steps to achieve the same contact.

Although the detailed pattern of nodal accessibility is different from that obtained through Associated Numbers (AN), the core of accessibility is similar. The features illustrated by the maps show the circular nature of the isopleth (a feature that can be expected from this type of parameter). A different pattern will emerge at different levels of analysis. Cities at each level are the foci of different numbers of routes in various regional and sub-regional clusters of towns. The importance of such places in terms of their accessibility could be identified more clearly at sub-regional level analysis. This will be discussed in detail in Chapter 6.

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* Distance in this context is the number of intervening edges between two vertices measured along the shortest path regardless of the actual mileage involved.

c. Time Accessibility

There are a number of possible ways in which the quality of links could be measured. Distance, flow, cost and time are such measures which could theoretically be studied. None involves change in the basic structural relationships, but data are not readily available for all such possible measures. In this section 'time accessibility' is discussed as one illustration of the changes to the topological indices of accessibility. It is based on time units along the shortest path in respect of time either by rail or road. To some extent time reflects distance and the difficulty of movement as well. On the basis of score, the towns are ranked in order and for comparison the surface of accessibility has been explained on the map (see Figure 5.3).

Looking at the accessibility of individual centres, Lyallpur appears as the most connected centre with maximum routes radiating from it to different parts of the region from where one can reach it more quickly and efficiently. It is followed by the centres of Sargodha and Jhang on both topological and time accessibility scales. As compared to these three centres (located in the centre on main roads) the accessibility of the major city of Lahore is significantly low on topological matrices because of its peripheral location but interestingly due to its highest administrative, industrial and urban status it is well connected to the region by an efficient transport system which ranks it high on 'time accessibility' scale.

Chiniot, which compared with Lyallpur and Sargodha is a small town, also appears as one of the most accessible towns of the region. This is because of the radiation of a number of routes and its location at a bridging point (see Figure 2.3), where three important regional centres* are connected. Its location puts it high in both topological and time accessibilities scales. The high accessibility in the central zone is seen even more clearly in the surrounding towns of Okara, Sahiwal, Gojra, Jaranwala, Sheikhupura, Shorkot and Khushab, which are also well connected to the rest of the network, either directly or

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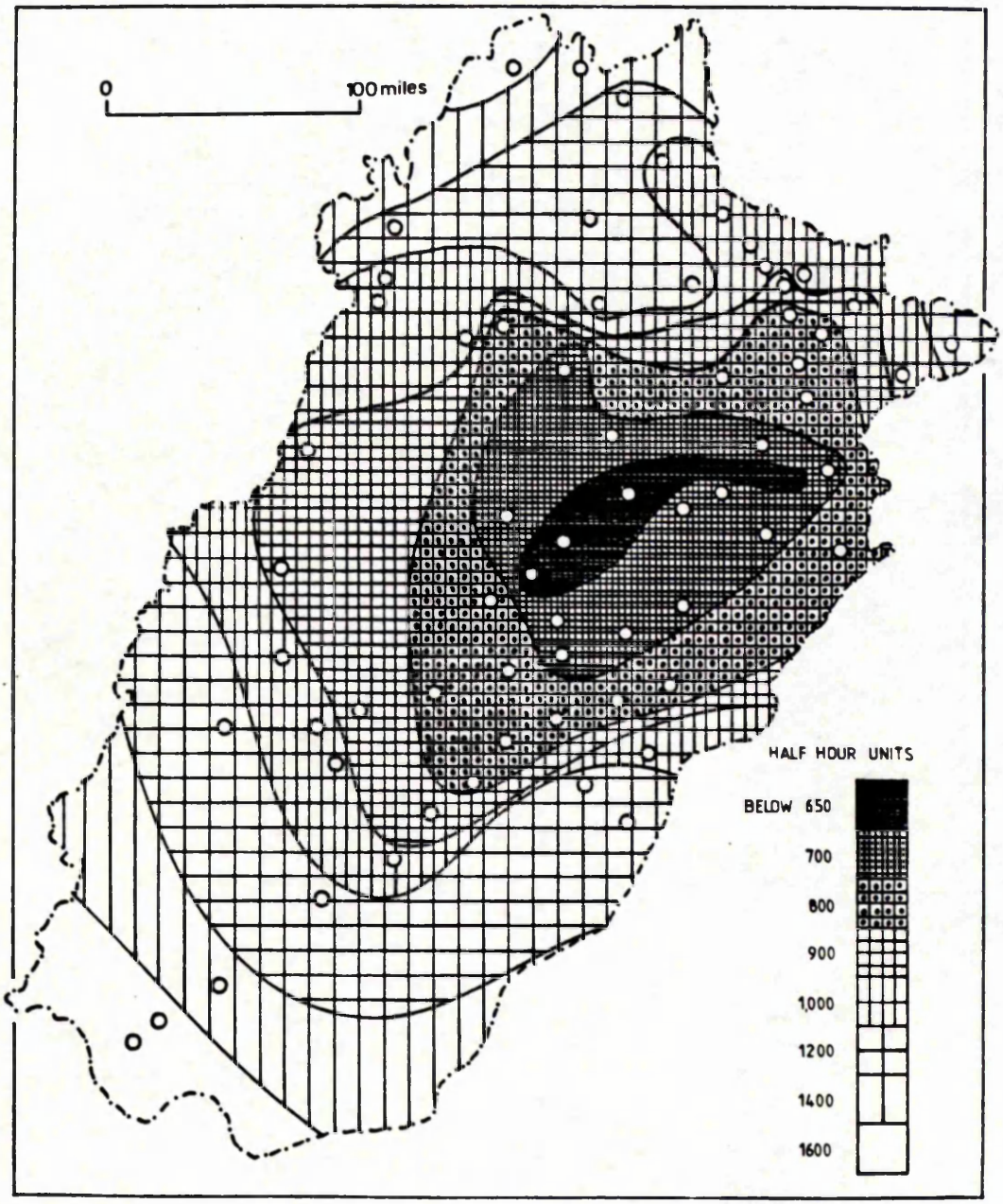
* Lahore, Lyallpur and Sargodha

FIGURE 5·3

TIME ACCESSIBILITY 1971

[TOWNS WITH POPULATION 20,000+]



through the central zone of high accessibility. Among these the towns of Lyallpur and Sahiwal districts (Jaranwala, Toba Teksingh, Kamalia, Gojra, Sahiwal, Okara and Chichawatni) are ranked higher along the 'time accessibility' scale than the topological scale. This reflects their central location along the main efficient and frequent transport routes which connect these places to the rest of the centres with a minimum detour of distances. Secondly most of these places are surrounded by a number of small towns in the agricultural plain region which have direct connections (with these places). These links provide a maximum number of alternative routes with maximum distance and time along the shortest path. On the other hand the towns of Khushab, Mitha Tiwana and Shorkot have topologically higher accessibility ranks than on time. This seems due to their location in comparatively remote areas where the vertices are located apart and are connected by less efficient routes. Sheikhupura located along main and frequent routes has equal scores on both scales but being a railway junction it holds comparatively higher rank in railway accessibility. All this appears to suggest that the nature of the region has also affected the accessibility. Although the degree of accessibility is low in the peripheral centres of Rawalpindi, Jhelum, Gujrat, Sialkot, Multan and Bahawalpur, yet these have originated a number of routes. Because of their high scores on 'link capacity' matrix (between major centres only), their high scores on accessibility can be predicted in the sub-regional networks (Division and district level and are measured in the next Chapter). A similar prediction can be made in terms of border towns like Campbelpur, Sadiq Abad etc., which are well connected to the smaller neighbouring towns as well as with the towns outside the region.

A large number of towns show poor accessibility on all the indices and grouped as remote towns as only a few routes radiate from these. The best examples are Daud Khel, Shakargarh, Kehror, Ahmad Pur East, and Harunabad. Kasur, being a neighbour of Lahore, enjoys high accessibility on time matrix but low topological accessibility is due to its adverse location.

This general discussion suggests that a high degree of accessibility on all three matrices is shared by central large towns on main routes, while only a small proportion goes to peripheral towns.

5.9 Areal Distribution of Accessibility

The series of maps (see Figures 5.2, 5.3) shows the relative accessibility of the towns (20,000 +) by topological (rail and road) and metricated (time) accessibility. The general pattern reaches a high level in a broad belt between Sargodha, Lyallpur and Jhang and attains its maximum around Lyallpur. The zone of high accessibility extends west to east, nearly coinciding with the agricultural belt. This includes the Canal Colony districts. The north-south axis of high accessibility clearly indicates the uniformity of railway lines and major roads running alomst along the rivers, through the agricultural belt. The decrease towards the periphery is not uniform, as a result of various factors such as physiography or the effectiveness of irrigation.

The variations in the pattern of overall accessibility reflect areal differences in population, settlements, economic activities, movement of people and goods between the regions. In regions like the Panjab, where roads are comparatively more important than the railway, accessibility also provides a useful indication of the tempo of human activities in the areas served by road transport.

In this section the level of accessibility of individual centres will be compared within the region and attempts will be made to understand the causes of the differences that exist. Finally, a number of generalizations will be formulated about the factors affecting the pattern of accessibility in the region.

Figures 5.2 and 5.3 give an average impression of both topological and non topological accessibility. Away from the central core of high accessibility the figures show a slope of decreasing accessibility. In the north it shows a low level of transportation and in the west, the Thal desert is also characterised by low accessibility. A major peak around Lyallpur reflects the size and central position of the city. The peak then extends to the homogeneous regions of Sahiwal and Sheikhupura where intensity of farming and surplus agricultural production favour high accessibility, while in the south low rainfall and population are unfavourable factors. The presence of significant industrial activities is evident through a ridge of high accessibility

extending towards Sheikhupura and Lahore, in spite of their peripheral location towards the border.

One of the most important features of the accessibility is its similarity to the distribution of population densities. The region shows the association according to the pattern predicted by Kolars and Malin (1970). The districts with a high density of population lie within the central core of accessibility while the peripheral districts of Dera Ghazi Khan, Bahawalpur and Campbelpur have low densities of population. Similarly, the regions with high densities of urban population are along the contours of high accessibility while low densities of urban population are along the contours of low accessibility.

With the addition of the 'time accessibility' measure, a major change in the accessibility of towns along the Lahore-Rawalpindi route is noticeable. This change reflects the efficiency of transport which is related to various factors like the width of roads, urban concentration, industries and the level of technology. In urban areas travel of all sorts, including journeys to and from work, is more common than in rural areas. Another reason for change in accessibility is the nature of economic activity in the hinterland of major industrial and urban centres, where an increase in local traffic accompanies an increase in the general intensity of human activity. The correspondence between accessibility isolines and rail and road links show an equal level of accessibility between the towns. The southward extension of the region of high accessibility is a result of the presence of two relatively accessible towns - Okara and Khanewal. These towns which were created by the railway, had their accessibility enhanced by the development of the road network. Thus, while the growth of the rail network was a vital factor in the origin and development of many towns in the region, it is the expansion of the road network that has produced a more recent contribution in accessibility. This aspect of the analysis will be clearer at the smaller scale.

Finally, an understanding of the level of accessibility requires considerations of the population, its distribution, density and other characteristics, including the nature of basic human activities along with the level of technology and standard of living in the region. Apart from that, the physiography and level of urbanization also directly

affect the areal distribution of accessibility in the region.

5.10 Changes in Accessibility (1931-1971)

The changes in the accessibility of urban centres (20,000 +) through time can be assessed with the help of rail and road network analysis. To compare the changes directly between the towns, these have been measured by the following three procedures:

i ranking of urban centres
ii calculating the percentage of accessibility
iii calculating a relative accessibility index

The difference between the mean Associated Number (MAN) for the road network (6.89) and for the rail network (11.0) suggests that road development has increased the accessibility of the region by reducing the number of links in the shortest paths between the towns. On the other hand a comparison of the ranks of towns in terms of their rail and road accessibility suggests comparatively little change in their relative accessibility brought about by the extension of the road network. (The correlation co-efficient for ranks of towns on the rail against ranks on the road network = 0.53.) However, when the accessibility of each urban centre is expressed as a ratio* of the corresponding values of the rail and road networks, certain trends become apparent. The hierarchy established by these ratios is used to identify the changed general pattern of accessibility, while the ranks based on percentage values of both rail and road networks are compared as residuals to assess the change for individual centres.

The map (see Figure 5.4) shows the changes in the surface of accessibility. The region has been divided into six parts, where a line of equal ratio (1.00) quickly distinguishes between 'gain' and

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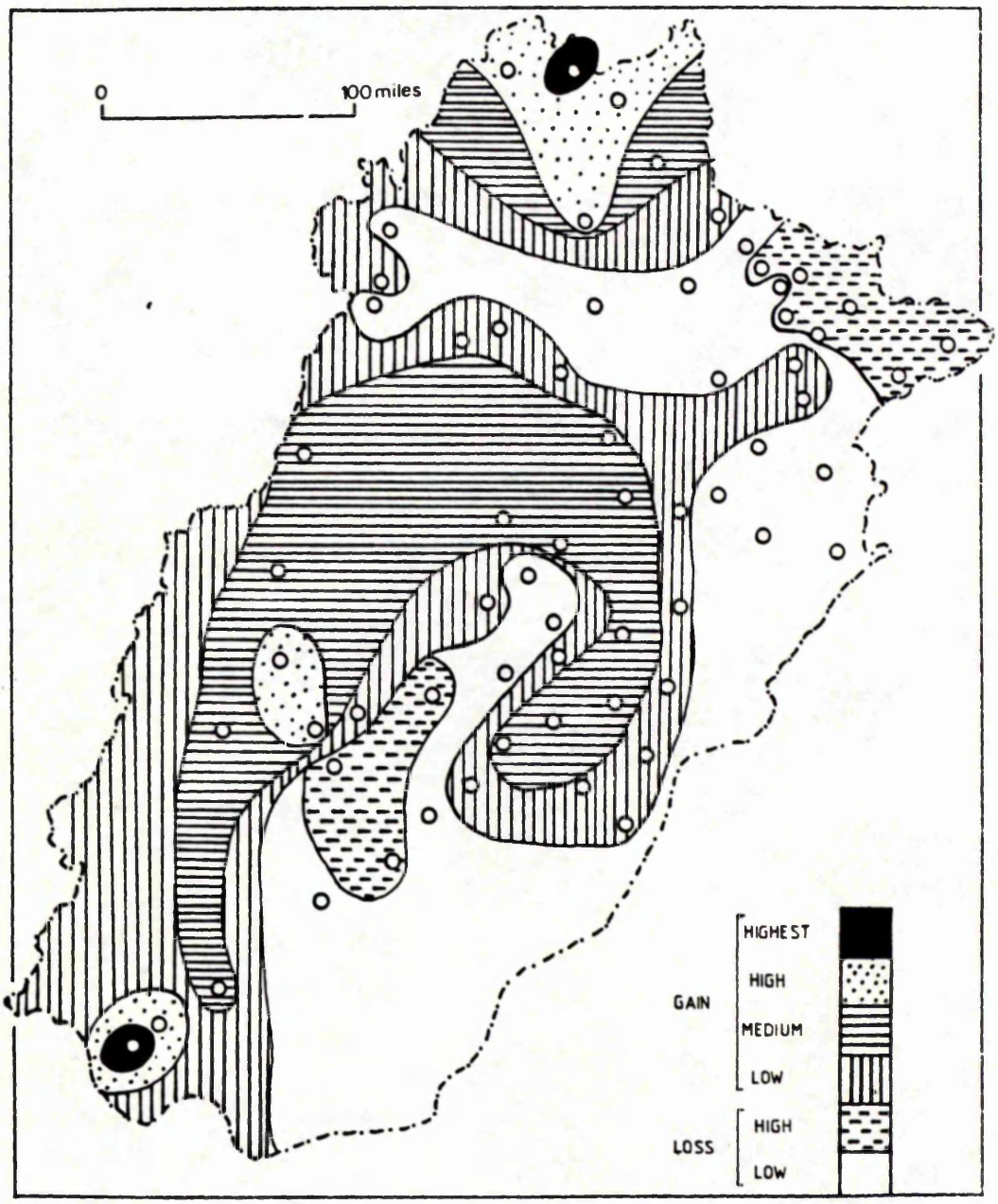
* The accessibility of urban centres to the road and rail network was calculated by converting the accessibility index (Ai) for individual towns to a percentage of the accessibility of the network as a whole. In order to express high accessibility on a high positive figure, the accessibility percentage for each town was subtracted from 100. This gave indices for each town on the rail and road networks, which allowed their direct comparison.

FIGURE 5·4

CHANGES IN NODAL ACCESSIBILITY OF TOWNS

1931-1971



'loss' (positive and negative changes respectively) in the accessibility which occurred after road extension. The areas of positive change have been further sub-divided into four; highest, high, medium and low. Similarly the areas of negative change have been identified by the high and low relative loss in accessibility. Looking at the positive side of the changes, a striking feature which emerges from the map is the identification of three peaks. Two of these are located in the extreme north and south, while the third one is in the centre between Multan and Dera Ghazi Khan. The north peak of the high changes includes four towns of Wah Cantonment, Rawalpindi, Chakwal and Campbelpur. It illustrates the increasing level of road development in the north and indicates that this part is no longer isolated from the rest of the region. These changes are almost certainly due to the link between Chakwal and Khushab, through the 'Salt Range' which reduces the distance along the shortest path and provides direct connectivity with the system. The importance of this link can be further assessed by examining the high values of route ratio (between rail and road distances) between the towns of Chakwal, Khushab and Sargodha. Similarly, the high changes in the south and centre are due to the major link between Muzaffargarh and Sadiq Abad. It provides the shortest path connectivity not only to the neighbouring towns but also to the whole system, which is connected with the major seaport of Karachi, through this link.

The remaining zone of medium change, stretches across the central plain and then extends to the south along the main routes. As it includes the central towns with high accessibility in both rail and road networks, therefore in this region only a medium range of changes can only be expected. The zones of negative changes lie in the north east mainly, including the old well connected towns.

5.11 Hypotheses

The hierarchies of urban centres (20,000 +) established on the basis of different indices of accessibility and urban development differ from each other reflecting the interaction of a number of factors. But keeping in mind the functioning economic position of the region, a number of regularities can be expected in terms of

regional development. For example, the road development would be expected to have made the larger size towns the most accessible. Similarly, one would expect any very accessible town to be in a strong position for economic and population growth. It is a 'chicken and egg' situation; does accessibility encourage growth and create large towns at accessible locations or does a large town influence the growth of the network and create an accessible location?

In the rapidly changing region of the Panjab one can also expect that the improvement in accessibility of regional centres will necessarily influence their rate of growth or, in other words, the changes in accessibility may disrupt existing patterns of spatial competition in the region and have an effect on relative rates of urban growth. It could be assumed that new towns have an even clearer association with accessibility and the changes in accessibility which took place due to the growth of the road network during 1931-71.

With a number of similar questions in mind regarding the relationship between accessibility and urban development, the following hypotheses are put forward to examine in the light of the data available on the Panjab's urbanization and rail and road networks.

i Accessibility is a significant factor in urban growth and has a significant impact on the size of towns.

ii Road accessibility is more significant on the growth and development of new towns than the old.

iii Changes in accessibility of urban centres corresponds with their growth rate.

iv The growth rates of new towns are more influenced by the addition of new links than the improvement of links in terms of efficiency.

5.12 Relationship

Various types of accessibility measurements have been discussed in the previous section. These can now be related to patterns of development in the 20,000 - 50,000 urban size class. The following indicators are chosen:

i Population size 1971

ii Population change 1961-71

iii Population change 1931-1971
iv Age of the towns*
v Road accessibility 1971
vi Rail accessibility
vii Time accessibility 1971
viii Changes in accessibility between rail and road

The first four have been used as indicators of urban development while the remaining four reflect accessibility. In the first stage of analysis the degree of association is measured by simple correlation (between the indices of accessibility and urban development) which is an index of the 'closeness of fit' (see Table 5.2). In the second stage these simple correlations are tested by controlling other variables within the data set, with the attempt to pick up the genuine from the spurious relationship and isolate the truly significant relationships (see Table 5.3).

a. Population size

Many interesting points emerge from an examination of the correlation co-efficients relating the variables of change to the population size of the towns. It shows a strong relationship between their size and their relative accessibility by both rail and road networks. Interestingly, the relationship of 'town size' with road accessibility is comparatively stronger than with the rail accessibility. It suggests that the road network provides a higher degree of relative accessibility to the larger urban centres, than the rail network. It also reflects the comparatively high inter-connectivity of these centres by the shortest possible road routes. Similarly the strong relationship of urban size with road accessibility is also found with time accessibility, indicating a greater frequency of rail and road transport between the major cities. An examination of the association of 'time accessibility' with rail and road networks separately, shows that the towns having high accessibility scores on the rail network index are also characterised by a higher degree of 'time accessibility'. This

* It has been computed since the first (estimated) census of 1871 according to size and date. If more than one town appears in the list of towns in the same decade, they are arranged in order according to their population.

Table 5.2

SIMPLE CORRELATION MATRIX

Variables	1	2	3	4	5	6	7	8	9	Total
1 Town size	x									1.588
2 Road acc.	.287	x								3.078
3 Rail & Rd. acc.	.290	.886	x							3.473
4 Time acc.	.217	.500	.612	x						2.270
5 Pop change 1961-71	.035	.208	-.112	-.047	x					1.902
6 Rail acc,	.161	.535	.890	.610	-.275	x				3.469
7 Acc change	.092	.388	-.263	-.128	.315	-.461	x			1.961
8 Pop change 1931-71	.060	.017	-.092	.002	.583	-.208	.224	x		1.854
9 Age of Towns	.446	.257	.328	.154	-.327	.329	-.090	-.668	x	2.599

1. Town size 1971
2. Road accessibility 1971
3. Rail and Road accessibility 1971
4. Time accessibility 1971
5. Population change 1961-71
6. Railway accessibility 1931
7. Accessibility change 1931-71
8. Population change 1931-71
9. Age of towns since 1881

suggests that the patterns of topological accessibility measured on the rail network in 1931, were directly comparable with patterns of 'time accessibility' in 1971. Thus towns which were already characterised by high accessibility to the rail network in 1931 benefited further from improvements to the road network in the following period. A similarly significant correlation between 'town size' and 'age of the towns' shows that with the increase of urban population the old towns are still dominating the 'size' with the gradual growth of population.

A lower degree of correlation of 'town size' with the changes (during 1931-71) in accessibility and population, (+.092 and +.060 respectively) shows that during the period high changes in both accessibility and population took place in the towns irrespective of their sizes and association of these changes has no significant effect on the association of town size and accessibility (see Table 5.2). The effect of 'age of town' on the relationship of 'town size' with all the three types of accessibilities is clear by the noticeable decrease in the degree of assocaition when the influence of the third variable 'age of town' is eliminated by partial correlation, where it has the maximum effect on the correlation with railway accessibility followed by road and time accessibilities respectively. Table 5.3 suggests that in the case of many old towns, the accessibility (particularly railway) and 'town size' are uncorrelated, where it reflects either the old and large towns of Rawalpindi, Lahore, Kasur, Sialkot, Gujranwala and Multan with low accessibility on the railway network or the old and accessible (by rail) towns of Bhera, Khushab, Chiniot, Lieah and Muzaffargarh with comparatively smaller sized populations. Similarly the effect of accessibility on the correlation of 'size' and 'town age' is also clear through the decrease in the size or value of the relationship by controlling with all three types of accessibilities, shows the greater importance of road accessibility as compared to rail and time accessibilities. It reflects the important role played by road development (accessibility) in recent years in establishing the population size hierarchy similar to hierarchy according to 'age of the towns'.

Table 5.3 shows that the growth rate of the urban centres during 1931-71 has a positive correlation with the accessibility change during the same period. It reflects a similar hierarchy of towns on both indices, but on the other hand the growth rate (1931-71) has 99.9 per

cent significant negative correlation with 'age of town' which shows that the ranking of towns according to their growth rate will tend to be the reverse of ranking according to the 'age of town' and a strong negative co-efficient of correlation must be expected between 'age of towns' and accessibility.

All this appears to suggest that the changes in accessibility between 1931 and 1971 took place in the new towns of higher growth rates, where population and accessibility changes are inter-related. This relationship reflects the fact that most of these towns were located along the parallel but unconnected railway lines. These towns were least accessible by rail to other centres in the region as well as to those towns which were closest to them geographically but were on a different line. The effect of road development on changes of the accessibility of these towns is due to the roads short circuiting the railway. This is evident from the network itself (see Figure 2.3). Examination of the rail : road distance ratio for these towns shows high values for Sahiwal, Bahawal Nagar, Arifwala and Chichawatni (of between 5 and 8.6). These are followed by Chakwal, Khushab and Sargodha. This situation also corresponds to the predicted pattern of connectivity on the basis of variation on the alpha index between rail (19.33 per cent) and road (45.6 per cent) networks (see Table 5.1).

The relationship of growth rate (1931-71) varies with all the three types of accessibilities. The relationship is weakly positive with topological road accessibility and strongly negative with topological rail accessibility. It is almost absent in the case of 'time accessibility', indicating that with the change in mode of transport and road development. the towns having a high railway accessibility in 1931, showed a low growth rate during the period, whereas the new towns with poor railway accessibility showed a high growth rate in their population (as evident from the relationship of 'growth rate' and 'age of towns' : $r = -.668$). This reflects the fact that towns with high railway accessibility in 1931, showed high changes neither in accessibility nor in urban growth afterwards, whereas the changes in accessibility due to road development are interrelated with recent urban growth.

The absence of significant correlation co-efficients, which either indicates a lack of relationship or randomness, is equally important

Table 5.3

SIMPLE AND PARTIAL CORRELATION CO-EFFICIENT RELATING:

(i) Town size 1971 (ii) Urban population change 1961-71 (iii) Urban population change 1931-71 (iv) Age of towns (v) Rail and Road Av. accessibility 1971

With the variables of change.

	Control Variables	RD ACC	RL ACC	TIME ACC	CHANGE IN ACC.	AGE OF TOWN
I	γ (Town size 1971)	.287	.161	.217	.092	.446
	Pop. change 1961-71	.286*	.177	.219	.081*	.460
	Pop. change 1931-71	.286*	.178	.217	.081*	.654
	Age of town	.199*	.017*	.168*	.148	
	Road acc.		.009*	.088*	-.022*	.402*
	Rail acc.	.241*		.152*	.190	.422*
	Time acc	.211*	.037*		.124	.428*
	Change in acc	.274*	.230	.232		.458
	Rail & Rd. Av. Acc.	.068*	-.222	.052*	.182	.388*
	γ (Pop change 1961-71)	.208	-.275	-.047	.315	-.327
II	Town size	.207	-.284*	-.055*	.327	-.383*
	Pop change 1931-71	.244	.499	-.059	.232*	.103
	Age of town	.320	-.187	.004	.366	
	Road acc.		-.467*	-.178*	.260*	-.402*
	Rail acc	.437		.158	.220*	-.260
	Time acc	.268	-.393*		.312*	-.324
	Change in acc	.098*	-.154	.034		-.316
	Rail & Rd. Av. Acc.	.667	-.387*	.027	.298*	-.309
	γ (Ur. pop change 1931-71)	.017	-.208	.002	.224	-.668
III	Town size	-.001*	-.221*		.220*	-.778*
	Pop change 1961-71	-.131*	-.061		.052*	-.622
	Age of town	.188	.017		.221*	
	Road acc		-.257*		.220*	-.696*
	Rail acc	.155			.147*	-.649
	Time acc	.018	-.264*		.226	-.676*
	Change in acc	-.077*	-.121			-.667*
	Rail & Rd. Av. Acc.	.046	-.278*		.208*	-.678*

γ = Simple correlation
* = Showing effect
γ = Significance level: 95 per cent .25
99 per cent .325

Table 5.3 Continued

	Control Variables	RD ACC	RL ACC	TIME ACC	CHANGE IN ACC	AGE OF TOWN
IV	γ (Age of town)	.257	.329	.154	-.090	
	Town size	.150*	.291*			
	Ur.pop change 1961-71	.352	.263*			
	Ur.pop change 1931-71	.361	.261*			
	Road acc		.234*			
	Rail acc	.101*				
	Time acc	.210*	.300*			
	Change in acc	.318	.325*			
	Rail & Rd. Av. Acc.	-.076*	.090*			
V	γ (Rail & Rd. Av. Acc.)	.886	.890	.612	-.263	.328
	Town size	.876*	.893	.587*	-.304*	.232*
	Ur.pop change 1961-71	.935	.867*	.611	-.241	.310*
	Ur.pop change 1931-71	.891	.894	.615	-.250	.360
	Age of town	.878*	.877*	.601*	-.248	
	Road acc			.421*		.224*
	Rail acc			.191*	.364	.082*
	Time acc	.847*				.299*
	Change in acc					.317*

in the case of time and road accessibilities. This absence of correlation between time accessibility and urban growth (1931-71), indicates that the towns ranked higher on the time accessibility scale do not show a high growth rate during the period. On the other hand a stronger positive correlation of +.208 between road accessibility and urban growth during 1961-71, suggests variations in the patterns of urban growth during different decades. A decrease in the correlation of recent growth rate (1961-71) with time accessibility shows that the ranks of the towns according to recent growth (1961-71) are more similar to the hierarchy of the towns established topologically, than the hierarchy by time accessibility. It further suggests that the recent higher growth rate in new towns is more closely associated with the topological pattern of road accessibility than with time accessibility or, in other words, in the growth of new towns the existence of a topological road link is more important than the efficiency of the link, which plays an important role in the growth of towns which existed previously. Similarly, it can be expected that the chances for the growth of new towns are higher by new linkage than on the link with heavy traffic flow. This aspect will be further elaborated and examined on the small scale of the study by including most of the new towns.

This variation of relationship of urban growth with road and time accessibilities reflects a number of facts:

Most of these are new towns located away from main routes (connecting cities) where the efficiency of transport is less, while the major cities are connected by direct non stop routes taking less time.

As the administrative functions dominate in the region the district headquarters (which are mostly old towns) have easy accessibility. Some of the new towns, in spite of their inaccessibility by road, are quickly available by railway. The relationship of rail accessibility is negative with recent urban growth (1961-71) and 'age of towns' but it is positive with accessibility change (1931-71). It indicates that some of the accessible towns on the rail networks have been left aside from the roads and due to this diversion in the channel of trade, these are showing low growth while new towns have gained a lead on them. Further analysis of partial correlation clarifies the situation of the relationship between accessibility and urban growth. It is observed

that with the influence of rail and road accessibilities controlled, the value of correlation between changes in population accessibility (during 1931-71) is reduced and this indicates that much of the apparent correlation between the variables depends on the correlation of each with rail accessibility, followed by road accessibility. The correlation between road accessibility and recent growth, reduced dramatically with the control of accessibility changes (see Table 5.3). It reflects the importance of these changes (due to road development) on the relationship. Similarly the decrease in association of rail accessibility and recent urban growth brought about by the control variables shows a high influence of road and time accessibilities which reflects their important contribution to the pattern of recent urban growth. A significant correlation between population change (1961-71) and 'accessibility change' is also affected by road accessibility (see Table 5.3).

In the Table 5.2 the totals of the columns of the variables give an indication of the general amount of relatedness of all the nine variables between each and every other variable. The higher the value the more generally related is the variable. In this case the variables of topological accessibility are highly related and are then followed by 'size of towns', 'time accessibility' and 'accessibility change', while the ramaining three are least correlated. It reflects to some extent the impact of accessibility on the patterns of urban development and shows that the indices of accessibility are more closely interrelated than the indices of urban development.

Finally in the light of these inter relationships between accessibility and urban growth, it can be concluded that the strongest association exists between the construction of road facilities in the region and the development of activities in urban centres which have been benefited by the resulting improvement in network accessibility. The development of the activities will be further analysed in the subsequent section of district level analysis. On the basis of the interrelationships between changes of 1931-71 in both urban population and accessibility, it is concluded that a high increase of urban population took place in the established centres which were newly created as service centres for developing agricultural areas. Similar questions could be asked regarding the recent changes in the pattern of

Table 5.4

RANKING OF TOWNS (20,000+) ACCORDING TO ROAD ACCESSIBILITY

(excluding three towns which are not connected by railnet)

R	Name	R	Name
1	Jhang	32	Dera Ghazi Khan
2	Lyallpur	32	Kundian
3	Chiniot	32	Kamalia
4	Sargodha	35	Campbelpur
5	Shorkot	36	Wah Cantonment
6	Muzaffargarh	36	Khanpur
7	Gojra	36	Nankana
8	Khushab	39	Rahim Yar Khan
9	Kot Adu	40	Bahawalpur
10	Mitha Tiwana	40	Gujrat
11	Bhakkar	42	Sadiq Abad
12	Ohara	43	Burewala
13	Jaranwala	44	Arifwala
14	Sheikhupura	45	Kasur
15	Multan	46	Vehari
16	Toba Teksingh	47	Jhelum
17	Lieah	48	Kharian
18	Mandi Bahaodin	48	Shujaabad
19	Hafizabad	50	Mailsi
20	Sahiwal	51	Kehror
21	Khanewal	52	Ahmad Pur East
22	Chichawatni	53	Bahawal Nagar
23	Mian Channu	53	Chishtian
24	Lahore	55	Gujarkhan
25	Mianwali	56	Wazirabad
26	Pakpattan	57	Narowal
27	Chakwal	58	Daud Khel
28	Bhera	59	Lalamusa
29	Gujranwala	60	Sialkot
30	Rawalpindi	61	Harunabad
31	Kamoke	62	Shakargarh

urban growth on smaller scales, which are discussed in the next Chapters.

Chapter 6

DIVISION LEVEL PATTERN OF CONNECTIVITY

6.1 Introduction

In the previous chapter the regional transport system was measured at the state level. This represents the most general level of analysis. Here the analysis moves to a lower level. This is necessary because some factors which operate at the regional level are not relevant at a more local scale. Equally, it is important to identify those factors which play a part in the relationship between urban growth and accessibility at the local scale (Kansky 1963). In this chapter an attempt is made to identify these factors.

According to Berry (1972), the sub regional centre of high population potential acts as a centre for the "diffusion of development impulses to the less developed areas within a region (and) is a function of access to the growth centre".

Furthermore, a number of reasons can be outlined for the sub-division of regions and the inclusion of smaller size towns in this study:

1. The regional level of analysis only gives an impression of the broad pattern of connectivity. In a region like the Panjab, which is not only dynamic but also heterogeneous, the variations in connectivity between developed and less developed areas, and particularly between peripheral and central sub regions, cannot be identified.
2. At the sub-regional level it is possible to identify the pattern of accessibility including the smaller towns in the analysis. In a complex network these may play a crucial role in the overall pattern of connectivity.
3. Most of the smaller towns lie away from the main routes and it is not possible to transfer indices from the regional scale directly to the lowest level analysis. It is necessary to analyse the importance

of smaller towns at the sub-regional scale, where the role is greatest, because not only are the smaller centres much less important to the regional level transport system but at the regional scale it is impossible to measure the pattern of accessibility to the smallest town.

4. All these sub-regions share varying socio-economic characteristics and exhibit contrasting road development patterns, which are surprisingly comparable.

Finally to test the effect of the level of analysis a total of 145 towns have been included as vertices for the analysis of connectivity and nodal accessibility in the five political divisions, at the first stage. This analysis is then shifted to the district level transport networks to measure the absolute and nodal accessibility of all (202) towns of the Panjab.

6.2 Connectivity

Table 6.1 a-c presents the information on the basis of three types of vertex (towns with a population of 20,000 +, 10,000 + and road junctions only) for all five political divisions of the Panjab. With the increased number of smaller size vertices, the values of topological indices are bound to decrease, as illustrated in Table 6.1 a-c. However, the general ranks on the topological scale remain similar to the pattern where only the larger centres were included. On the topological scale, high connectivity is found in Sargodha and Multan divisions followed by Lahore and Rawalpindi. Bahawalpur is the least connected division when measured on the basis of large vertices (towns of 20,000 +).

This order is changed for the Gamma index (based on road junctions as vertices) on which Sargodha division ranks lowest (see Table 6.1c). This indicates that in Sargodha there are sufficient links to connect the major towns but the ratio of links between the road junctions is low. This is probably due to the lack of minor bridges across the rivers. In contrast, Lahore division maintains high scores for its small size towns because of its compact shape. Bahawalpur division has the lowest connectivity scores on all topological indices,

Table 6.1

DIVISION LEVEL PATTERN OF CONNECTIVITY

BY TOPOLOGICAL AND METRICATED INDICES.

(a) v = Town with population of 20,000 +

Indices*	Rawalpindi	Sargodha	Lahore	Multan	Bahawalpur
Edges	15	32	21	30	8
Vertices	11	16	13	17	8
Cyclomatic Number	5	17	9	14	1
Alpha Index	29.41	62.96	42.86	48.27	9.09
Beta Index	1.36	2.00	1.61	1.76	1.00
Gamma Index (%)	55.55	76.19	63.64	66.67	44.44
Theta Index (Act)	132.63	103.37	93.30	95.59	124.62
Theta Index (EQ)	187.27	146.37	142.86	137.70	171.75
Eta (Act)	97.26	52.69	57.76	54.17	124.62
Eta (EQ)	137.33	73.19	88.43	78.03	171.75
Road length (Act)	1459	1686	1213	1625	997
Road length (EQ)	2060	2342	1857	2341	1374
Total pop. ('000)	5671	8980	9795	9508	3553
Urban pop. ('000)	1343	2071	3637	1531	598
Total pop. per route mile	4089	5326	8075	5851	3564
Urban pop. per route mile	920	1228	2998	942	600
Ai (accessibility)	29.3	33.0	25.0	49.0	20.0
I.T.Circuity (%)	293	220	210	307	279
% change in Acc.	53.66	44.00	61.29	55.22	55.56
Topological diameter	7	5	4	7	6
Area (sq. miles)	11,206	17,095	8,907	24,826	17,508
Density (per sq. mile)	506	525	1100	383	203

(b) v = Town with population of 10,000 +

Indices*	Rawalpindi	Sargodha	Lahore	Multan	Bahawalpur
Edges	32	70	62	53	13
Vertices	25	38	37	32	13
Cyclomatic Number (μ)	8	33	26	22	1
Alpha Index (α)	17.77	46.48	37.68	37.29	4.76
Beta Index	1.28	1.84	1.67	1.66	1.00
Gamma Index	46.38	64.81	59.05	58.89	39.39
Theta (Act)	58.36	44.37	32.78	50.78	76.79
Theta (EQ)	82.40	61.63	50.19	73.16	105.69
Eta (Act)	45.59	24.08	19.56	30.60	76.69
Eta (EQ)	64.39	33.46	29.95	44.17	105.69
Ai (accessibility)	102	138	120	137	50
ITC (%) (Ai)	425	373	333	442	417
Change	47.30	39.05	50.63	47.76	43.24
Topological diameter	11	8	7	12	10
Mean Ass. No.	8.12	7.10	5.54	8.87	8.00

* For explanation of Indices see Appendix 'A'

Table 6.1 continued

(c) v = Road Junctions only

Indices *	Rawalpindi	Sargodha	Lahore	Multan	Bahawalpur
Edges	175	235	208	270	113
Vertices	125	143	124	162	80
Cyclomatic Number	51	93	85	109	34
Alpha Index	20.81	33.06	34.98	34.17	21.94
Beta Index	1.40	1.64	1.68	1.67	1.41
Gamma Index	47.42	35.55	56.83	56.25	48.29
Theta (Act)	11.67	11.79	9.78	10.03	12.46
Theta (EQ)	16.48	16.38	14.98	14.45	17.17
Eta (Act)	8.34	7.17	5.83	6.02	8.82
Eta (EQ)	11.77	9.97	8.93	8.67	12.16

* For explanation of Indices see Appendix 'A'

reflecting the linear pattern of the towns which are located far apart within a large region, and which shows only one circuit with larger towns (20,000 +).

On the basis of the wide contrasts in the topological and metricated indices* (see Table 6.1 a-c), a number of predictions regarding the pattern of nodal accessibility can be made. It is predicted that the overall pattern of nodal accessibility in all these five regions will differ. Where regions have high topological connectivity scores they will have their towns well connected within the region and then to the whole system. It is also expected that the nodal accessibility will show a closer relationship with urban growth, in the regions with high topological connectivity scores.

6.3 Nodal Accessibility

Using Shimbel's Matrix, the nodal accessibility has been computed** for all regions separately and their nodal values are compared within the regions. In Rawalpindi division Chakwal, connected with 70 links to all 24 towns is the most accessible town, while Gurghashti is the remotest. Similarly, Jhang, Sheikhupura, Khanewal and Chishtian are the most accessible towns of Sargodha, Lahore, Multan and Bahawalpur divisions respectively (see Table 6.2). All these accessible towns vary according to age, size function and growth. This suggests that their high accessibility within the region has different origins. Similarly, the only common characteristic that the least accessible towns have seems superficially to be their remoteness. The lack of a systematic relationship between accessibility and other urban characteristics might suggest that the patterns of interrelationship which were shown to exist for the larger towns do not hold at this lower level. This question may be clarified further by studying the nodal pattern of accessibility at division level.

Table 6.1b shows that there are some interesting contrasts between

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* See Appendix 'A' for definitions and measures

** For matrices see Appendix 'G'

the regions in terms of nodal accessibility. The 'Ai'* varies from 50 (Bahawalpur) to 138 (Sargodha) showing a varying amount of average topological edges covered from one node to all others in the network. Though the higher values reflect the lack of direct shortest paths between the nodes in the network, mostly due to their remote location, at this level of analysis this difference cannot be compared because of the variation in the number of vertices.

To obtain the overall connectivity of the nodes in their respective regional networks, these contrasts can be further distinguished by the Associated Number which measures the accessibility of a vertex to its most distant vertex in the network. Figure 6.1c explains the position of the regions in terms of the variations in the number of edges needed to connect their most distant vertices within the respective networks. The Associated Numbers are marked along the horizontal axis and the height of the various columns indicate the frequency for each Associated Number in the five regions, which gives a general impression of the amount of variation in the accessibilities of the vertices of the networks. The frequency distribution for Multan indicates the existence of a larger number of topological edges between distant vertices, whereas the frequency distribution for Lahore is high on the Associated Numbers of smaller towns. The Mean Associated Numbers for Lahore division (5.54) suggest a comparatively high level of accessibility. It is then followed by Sargodha (7.10). The remaining three regions with a Mean Associated Number of more than 8.00 can be classified as regions of low level accessibility. In a region where the towns are well inter-connected. a higher population change can be expected. By comparing the accessibility of the towns within the region, a number of factors seem to be contributing collectively towards the accessibility scores of these towns. Among these the most important are the administrative functions, size, age and population change of the towns. To sort out their collective influence, the indices of nodal accessibility make possible the testing of a number of hypotheses in which accessibility is interrelated with the variables of change.

(i) Population changes are related with the accessibility and this

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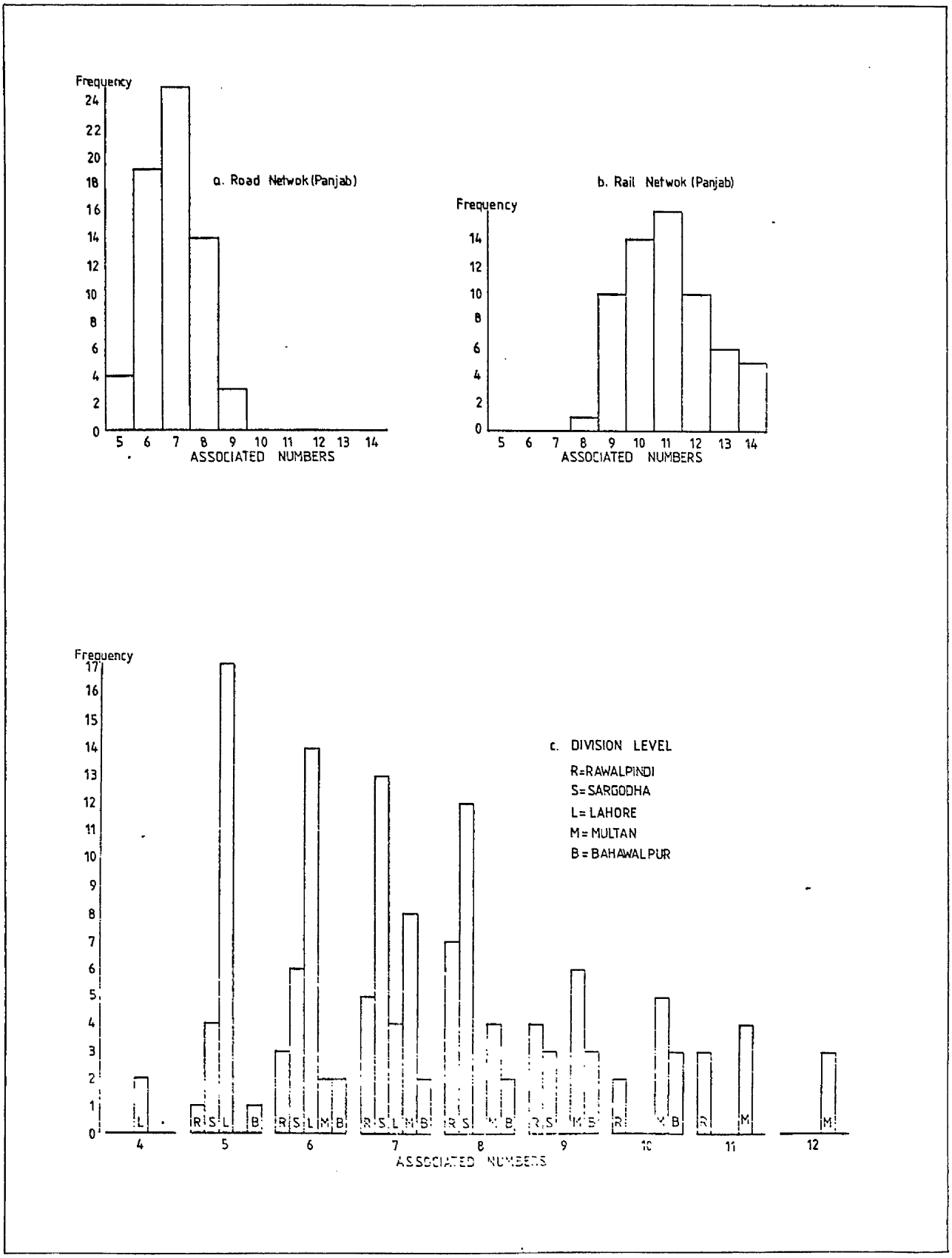
* Ai = Per vertex average accessibility of the network

Figure 6·1

FREQUENCY OF ASSOCIATED NUMBERS IN ACCESSIBILITY MATRICES (1971)



relationship is more significant in the regions of higher level accessibility.

(ii) Accessibility has a significant impact on the relationship between population size and change.

(iii) Accessibility is not equally related with the variables of change in all regions.

The analysis of the larger towns in the previous chapters suggested that there is a significant relationship between structure of transport and a number of variables of urban growth. However, it has been shown above that superficially these relationships do not appear to hold for the smaller towns. The subsequent analysis tries to see how far such a superficial judgement is valid.

6.4 Comparison

Although the nodal accessibility of each town can be compared within the region, it is not possible to compare directly the nodal accessibility of a town in one region with that of a town in another region, because the regions differ in size and number of centres. To derive comparability between the regions the accessibility indices of each node has been standardised* by the Index of Topological Circuity (ITC), first modified and used by Bradnock (1976).

The values of ITC are given in the brackets of Table 6.2. These values are useful to compare the accessibility of the towns within the regions and also with the towns of other regions. The internal contrasts can be assessed by the percentage variations of the most and least accessible towns within the region. The maximum variation in Lahore is 50.63 per cent (see Table 6.1b), showing that its most accessible town of 10,000 is connected by almost half the number of edges than that of its most remote one. In Sargodha the ratio for the

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* by converting them into a percentage of the minimum number of links necessary to connect each node directly with all the other nodes.

$$ITC = \frac{Ai}{Ai\ min} \times 100$$

Ai = Mean Acc

Ai min = -1

Table 6.2

DIVISION LEVEL NODAL ACCESSIBILITY OF TOWNS 10,000 +

RAWALPINDI DIVISION

Rank	Name	Acc	(ITC)	Rank
1	Chakwal	70	292	9
2	Gujarkhan	77	321	34
3	Rawalpindi	79	329	42
3	Dina	79	329	42
3	Khewra	79	329	42
6	Talagang	83	346	54
7	Jhelum	89	371	72
8	Fateh Jang	90	375	75
9	Malakwal	91	379	76
10	Pindi Gheb	93	387	81
11	Mandi Bahaodin	95	396	88
12	Wah Cantonment	97	404	97
12	Kharian	97	404	97
14	Murree	102	425	104
15	Lalamusa	103	429	106
16	Campbelpur	104	433	108
16	Dingah	104	433	108
18	Pind Dadankhan	106	442	112
19	Hasanabdal	108	450	117
20	Gujrat	122	508	127
21	Hazro	125	521	129
22	Lilla Town	129	537	133
23	Jalalpur	145	604	137
23	Kunjah	145	604	137
25	Gurghashti	148	617	140

SARGODHA DIVISION

Rank	Name	Acc	(ITC)	Rank
1	Jhang	91	246	3
2	Jauharabad	93	251	5
3	Sahiwal	108	292	9
3	Khushab	108	292	9
5	Hadali	113	305	17
5	Sargodha	113	305	17
7	Bhakkar	115	311	20
7	Lyallpur	115	311	20
9	Chiniot	117	316	27
10	Piplan	118	319	30
10	Darya Khan	118	319	30
10	Toba Teksingh	118	319	30
13	Gojra	119	322	35
14	Shorkot	122	330	46
15	Ahmad Pur	126	341	49
16	Lahan	132	357	60
16	Sillanwali	132	357	60
18	Mianwali	133	359	64
19	Rabwah	134	362	65
19	Jhaurian	134	362	65
21	Mitha Tiwana	135	365	68
22	Kundian	138	373	73
23	Samundari	141	381	77
24	Tandlianwala	143	386	79
24	Bhalwal	143	386	79
26	Chak Jhumra	145	392	82
27	Kamalia	146	395	86
27	Pirmahal	146	395	86
29	Jaranwala	147	397	89
29	Kot Momin	147	397	89
31	Daud Khel	164	443	114
31	Bhera	164	443	114
33	Moch	166	449	116
34	Musa Khel	167	451	119
35	Lilliani	177	478	123
36	Phularwan	179	484	125
37	Kalabagh	197	532	132
38	Isa Khel	233	630	144

Table 6.2 Continued

Rank	Name	Acc	(ITC)	Rank
LAHORE DIVISION				
1	Sheikhupura	80	222	1
2	Gujranwala	88	244	2
3	Lahore	89	247	4
4	Muridke	103	286	7
5	Mananwala	104	289	8
6	Pasrur	105	292	9
6	Chuharkana	105	292	9
8	Daska	108	300	14
8	Warburton	108	300	14
10	Kamoke	110	306	19
11	Qilla Didar-singh	112	311	20
11	Nankana Sahib	112	311	20
13	Narang Mandi	113	314	25
13	Sharaqpur	113	314	25
15	Bhai Pheru	114	317	28
16	Eminabad	117	325	36
17	Gakhar	118	328	39
17	Kot Radhakishan	118	328	39
17	Rajajang	118	328	39
20	Lulliani	119	331	47
21	Kahna Nau	120	333	48
22	Sangla Hill	123	342	50
22	Narowal	123	342	50
22	Bado Malhi	123	342	50
25	Pindi Bhattian	128	356	59
26	Hafizabad	129	358	62
26	Shahkot	129	358	62
28	Wazirabad	131	364	67
29	Sambrial	132	237	70
30	Sialkot	134	372	73
31	Chawinda	137	381	77
32	Jamke	141	392	82
33	Chunian	143	397	89
33	Pattoki	143	397	89
35	Kasur	147	408	99
36	Akalgarh	148	411	102
37	Shakargarh	158	439	111

Rank	Name	Acc	(ITC)	Rank
MULTAN DIVISION				
1	Khanewal	96	311	20
2	Mian Channu	97	313	24
3	Multan	99	319	30
4	Vehari	102	329	42
5	Jahania	107	345	53
6	Chichawatni	109	352	56
6	Kabirwala	109	352	56
8	Burewala	110	355	58
9	Muzaffargarh	113	365	68
10	Mailsi	114	368	71
11	Dunyapur	122	394	85
12	Sahiwal	123	397	89
12	Tulamba	123	397	89
14	Abdul Hakeem	124	400	95
15	Arifwala	125	403	96
16	Shujaabad	127	410	101
17	Kehror	128	413	103
18	Dera Ghazi Khan	134	432	107
19	Kot Addu	135	435	110
20	Jalalpur	137	442	112
21	Lieah	140	452	120
22	Pakpattan	141	455	121
23	Okara	144	464	122
24	Taunsa	160	516	128
25	Jampur	162	523	130
26	Depalpur	167	539	134
27	Renala Khurd	170	548	135
28	Havaili	175	565	136
29	Vehowa	190	613	139
30	Rajanpur	102	619	142
31	Hujra	195	629	143
32	Basir Pur	201	648	145

Table 6.2 Continued

Rank	Name	Acc	(ITC)	Rank
BAHAWALPUR DIVISION				
1	Chishtian	32	267	6
2	Khairpur	38	317	28
3	Hasilpur	39	325	36
3	Bahawalpur	39	325	36
5	Ahmad Pur East	42	350	55
6	Khanpur	47	392	82
7	Harunabad	49	408	99
8	Bahawal Nagar	51	425	104
9	Trinda Sawai	54	450	117
10	Donga Bonga	58	483	124
11	Fort Abbas	60	500	126
12	Rahim Yar Khan	63	525	131
13	Sadiq Abad	74	617	140

most accessible town : the least accessible town is 39.05 per cent : 60.95 per cent. This aspect could be further clarified by the range of accessibilities between the most and least accessible towns of the regions. This difference on ITC scores within the region identifies a considerable contrast in this respect. Except for Lahore division, where the range is 217 per cent and shows comparatively better inter-connectivity, none of the regions has the difference in accessibility between most and least accessible centres less than three times. The maximum difference can be seen in the Sargodha region (384 per cent) showing that the centres are comparatively least inter-connected with their division level transport system. It reflects a number of reasons, like the east to west central location, where these towns are better connected to the towns of other regions, than its own through the linear pattern. Another important reason is that the area stretches along three rivers and lack of bridges puts a tremendous pressure on certain links, and the range between most and least accessible towns is increased by the towns in remote areas. These differences will be widened further by the district level nodal accessibility of the region.

The range between most and least accessible centres, which reflects their degree of interconnectivity follows the pattern of nearest neighbour analysis (see Table 2.7a). The range is low in the region of Lahore (217 per cent) where the spatial distribution is clustered (1.45), whereas in Sargodha with a comparatively dispersed spatial distribution, there is a high range (384 per cent).

A considerable contrast also appears while comparing the regions in terms of the hierarchies of their towns, established on the basis of accessibility within the region and to the whole system. Looking at the tenth most accessible town* of each region, we find that its position varies from region to region on 'ITC' hierarchy to the whole system. The least accessible position of the tenth town can be seen in Bahawalpur (124th) followed by Rawalpindi (81st) and Multan (71st) while it remains high in Lahore (19th) and Sargodha (30th). It suggests that the most accessible centres in Sargodha and Lahore regions are also

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* Because the number of towns varies from 13 (Bahawalpur) to 38 (Sargodha) and the tenth town in the hierarchy can be found in all the regions (see Table 6.2).

the most accessible to the whole transport system. On the other hand, the towns which have high accessibility within their regions in the remaining divisions are not accessible to the whole system. Even the most inaccessible town of Lahore region (Shakargarh) holds a comparatively high position (111) in the whole transport system. The least accessible towns of the remaining regions also include the five least accessible towns (ranking between 140-145) of the whole transport system. It reflects the fact that in spite of the location of the remote towns of Lahore along the Indian border they are well connected to the whole (Panjab level) transport system, whereas the remote towns of other regional networks are also remote to the whole system.

6.5 Correlation Analysis

The correlation co-efficients are obtained for the five sub-regions of the entire region and these are based on the four sets of data of the regions:
(i) Accessibility (ii) Age of the towns since 1881 (iii) Population size of towns (1971) (iv) Population change between 1961-1971. Initially the degree of association is measured by simple correlation where these variables are related turn by turn; it is then followed by partial correlation to eliminate the effect of one or more other variables, which may be inter-related. Both values for simple and partial correlations are presented in Table 6.3. The degree of correlation between the variables varies considerably from one area to another and similarly from one variable to another in the regions.

Accessibility is computed by the shortest path matrix and does not include any metricated index. It reflects direct accessibility between the centres of supply and distribution of the regions. The examination of the correlation co-efficients relating accessibility to the variables of change, show a number of contrasts in the sub-regions. The correlation between accessibility and age of the towns is high in Sargodha and Bahawalpur divisions while it is near zero in the remaining three sub-regions. It appears to suggest that in Sargodha and Bahawalpur the pattern of high accessibility tends towards old towns. Although this correlation is high in both regions, and they are of similar size, the correlation between accessibility and size of the towns shows a

Table 6.3

PARTIAL CORRELATION BY DIVISION (TOWNS 10,000 +)

Control Variables γ	Rawalpindi	Sargodha	Lahore	Multan	Bahawalpur
12	-.055	.262*	-.065	.049	.596*
12.3	-.128	.091	-.154	-.143	.746
12.4	.022	.339	-.019	.045	.370
12.34	-.063	.170	-.056	-.131	.650
13	.341*	.418**	.111	.417*	.008
13.2	.358	.348	.178	.435	-.559
13.4	.283	.379	.039	.420	-.208
13.24	.312	.246	.064	.435	-.600
14	.284	.240	.325*	-.021	-.503
14.2	.280	.323	.320	-.004	-.004
14.3	.207	.150	.304	-.060	-.534
14.23	.175	.207	.271	-.017	.267
23	.185	.451**	.559**	.403*	.610*
23.1	.217	.390	.571	.421	.754
23.4	.280	.547	.615	.370	.620
23.14	.285	.481	.616	.387	.767
34	.285	.260*	.231	-.178	-.325
34.1	.209	.181	.207	-.186	-.371
34.2	.352	.424	.380	-.047	.439
34.12	.281	.351	.347	-.050	.528
24	-.265	-.239	-.145	-.342*	-.841**
24.1	-.260	-.322	-.131	-.341	-.780
24.3	-.337	-.413	-.340	-.300	-.844
24.13	-.320	-.433	-.311	-.294	-.791

γ = Correlation

1 = Accessibility between the towns of resp. divisions

2 = Age of the towns since 1881

3 = Size (population) of the towns 1971

4 = Population change (1961-71) in percentage.

* 90% sig. only simple
** 99% sig. correlation

considerable contrast between them. This relationship is highly significant in Sargodha indicating high accessibility in large towns but very low association in Bahawalpur. This association is also high in Rawalpindi and Multan (see Table 6.3). By correlating accessibility with population change (1961-1971), only Lahore shows a significant relationship while Sargodha and Rawalpindi show a low but positive relationship, indicating that high accessibility is related to the population change during the last decade in the regions where the towns are well inter-connected. On the other hand Bahawalpur and Multan (with low inter-connectivity) have low and lowest negative correlations respectively.

The correlation of accessibility with the variables of urban development shows some interesting contrasts in all the regions, where except Sargodha, which shows significant correlation of accessibility with both 'town age' and 'town size', no region shows a significant correlation of accessibility with more than one variable. This shows that accessibility is significantly related with 'size', 'town age' and 'population change' in three, two and one sub-regions respectively. It suggests that except for Lahore and Bahawalpur divisions which have more random characteristics in terms of relationship between accessibility and size, the pattern of high accessibility in the remaining three divisions, closely corresponds with the 'size of the towns', where the towns with larger populations have also high scores on accessibility.

A significant correlation between 'town size' and 'age of the town' in Sargodha and Lahore followed by Multan and Bahawalpur divisions, shows that except Rawalpindi, the towns of all the regions are still maintaining their population size according to their age. The relationship of 'size' varies with each variable in all the regions. In Lahore and Bahawalpur the correlation between 'size' and 'accessibility' is very low (see Table), but it is very high between accessibility and town age. However, while accessibility is positively correlated with population change in Lahore it shows a negative correlation in Bahawalpur. This suggests that in both regions most of the larger size towns are old and have low accessibility but the population change during 1961-71 is high in these towns of Lahore but low in Bahawalpur.

'Change of population ' (between 1961-71) is significantly related in all the regions but with different variables, showing varying characteristics of the towns and also a number of factors responsible for the Change during the period. In Lahore it is related with accessibility, in Sargodha with 'size' and in Rawalpindi it has an equally positive (with low significance) relationship with accessibility and size. On the other hand, in Multan and Bahawalpur it has a negative correlation with 'town age'. It suggests that the 'changes of population' in all regions are not due to the same factors. This dissimilarity of the regions is also apparent from the correlations of the variables separately. In Rawalpindi the highly positive inter-correlation can be seen between 'size', 'accessibility' and 'population change' respectively, while 'age of the town' is negatively correlated. In Bahawalpur the indicators of high positive association is 'age of the town' followed by 'size' and 'accessibility' whereas 'population change' is not positively correlated with any variable (see Table 6.3). In Sargodha the significant correlation can be seen between 'size', 'accessibility' and 'town age', showing that the old towns are comparably larger and more accessible, while the recent changes are not higher in these towns, as the 'age of the town' is negatively correlated with population change. Such types of anomaly are further examined through partial correlation analysis.

a. Rawalpindi Division

Table 6.3 shows that the highest positive correlation in the division is between 'accessibility' and 'size of the town', which is reduced with the control of 'population change' but remained unaffected by controlling with 'town age'. It shows that in this region much of the apparent correlation between 'accessibility' and 'town size' depends in part on the correlation of each with 'population change', while 'town age' has no noticeable effect on this correlation as it is also evident from the second order partial correlation co-efficient (+.312) that has reduced only due to population change (which has an equal degree of association with 'accessibility' and 'size'). When the factor of accessibility is controlled, the correlation between 'town size' and 'population change' is reduced. This shows the significant effect of accessibility on this relationship. On the other hand, the second order control of both 'accessibility' and 'town age', shows a

very slight decrease in the correlation, while it increases with the control of 'town age' alone. This indicates that the recent changes in the population of the larger towns are positively affected by the 'accessibility' and not by their age. Very little effect of 'town age' can be noticed on the relationship of 'accessibility' and 'population change' but its decrease with the control of 'size' is more significant. A further decrease (+.175) with the influence of both 'age' and 'size' shows that the association between 'change' and 'accessibility' is influenced by both variables of 'size and 'age', but the former has a more significant effect on the relationship.

A comparatively weak association between 'size' and 'age' (0.185) is not affected either by 'accessibility' or by 'change' and has obtained an even more statistically significant position (.285) by the control of both. This identifies the strength of 'size' and 'age' in the region. Similarly on the negative correlation between 'age' and 'change' the effect of 'size' is more significant than the effect of 'accessibility', where, with the control of 'size' the correlation becomes increasingly significant (see Table 6.3).

b. Sargodha Division

Among these four variables the impact of accessibility in the region can be observed on the inter-correlation of all the remaining three variables. The most significant impact can be observed on the negative association of 'age' and 'change' where the first order partial control of accessibility makes it statistically more significant (-.322) and with the addition of second order partial control of 'size' the correlation further moves down (-.433). It shows comparatively more influence of 'size' than 'accessibility', on the relationship. Furthermore, the impact of accessibility on the correlations of 'size' with 'change' and 'age' is also evident and is more effective than the second order partial controls of 'age' and 'change' respectively.

The effect of size on the inter-correlations of the variables becomes apparent by examining Table 6.3. It is equally great on the correlations of 'age' with 'change' and 'accessibility', showing comparatively little impact on the correlation between 'accessibility' and 'change'. The impacts of 'change' and 'age' are only evident on

the correlation between 'accessibility' and 'size', and show a poor response towards the remaining sets of correlations.

By comparing the first and second order partial correlations, the significantly increased second order partial (.481), clarifies the position in terms of relationship which represents the correlation co-efficient between 'age' and 'size' for towns haveing both the same accessibility and 'change' during 1961-71. By excluding the variable of accessibility the first order highest partial correlation (.547) represents the relationship between 'size' and 'age' for the towns having the same population changes. On the other hand the low partial correlations (which are not very close to linear, either in general or within the categories of test variables), are + 0.091 and + 0.170 for the first and second order respectively. Both of these represent the correlation co-efficients between 'age' and 'accessibility' of the towns in the region, but they show with different impact.

The weakness or absence of significant partial correlation between 'accessibility' and 'age' with the control of size, suggests that in spite of the high population change (during 1961-71) in the new towns, the old towns are larger and are more accessible in the region.

To identify the comparative importance of the variables, comparisons between the first order partial correlation are made. The value of $r_{13.4}$ (.379) as compared to $r_{34.1}$ (.181) indicates the importance of accessibility as compared to population change but the strength of $r_{23.1}$ (.390) shows less importance of accessibility than the size of the town $r_{12.3}$ (.091).

c. Lahore Division

With the exception of correlation between 'size' and 'age' all the sets of correlations present a different picture. The effect of accessibility can only be observed on the correlation between 'size' and 'change', while 'size' has a great impact on the correlations of 'change' with 'accessibility' and 'age'. The introduction of the controls of 'accessibility' and 'change' increase the strength of the correlation between 'size' and 'age', whereas the introduction of 'age' and 'size' reduce the strength of the correlation (.271) between

'accessibility' and 'change'. This shows the impact of both variables and represents a rather weak association between 'accessibility' and 'change' for the towns having both the same 'age' and 'size'. On the other hand the increased correlation (.616) represents a stronger association between 'size' and 'age' for the towns with similar accessibility and population change. Interestingly, this strength of relationship did not change when accessibility was excluded (see Table 6.3).

The value of $r14.3$ (.304) as compared to $r13.4$ (.039) reflects the greater importance of population change as compared to the size of the towns, while on the other hand a comparison between $r23.4$ (.615) and $r34.2$ (.380) suggests that in the region the variable of 'age' is comparatively more important than population change.

d. Multan Division

Table 6.3 shows that only two variables of 'change' and 'size' have reduced the co-efficients to insignificance as a first order partials and the accessibility does not show any significant impact in this respect. The increase in the strength of the correlation between 'accessibility' and 'size' appears with the control of 'age', reflecting the similar scores (of towns) and indicating no change in the strength of relationship with the addition of 'population change' (+ .435) as a second order partial control, and which is itself negatively connected with 'age' (- .342). A similar association (- .341) with the control of accessibility shows that the negative relationship between 'age' and 'change' is unaffected by accessibility, but the addition of 'size' as a second order partial control moves the correlation towards further insignificance (- .294). It shows that in spite of high population changes in new towns, the accessibility is high towards the larger towns, which are mostly old (.403).

The strength of the partial correlation of $r13.4$ (.420) as compared to $r14.3$ (.060) indicates the much greater importance of the 'size' as compared to 'population change', in the region.

e. Bahawalpur Division

This region shows some interesting contrasts in the relationships particularly the control of the variable of 'age' which has dramatically changed the strength of the correlation because of its highly significant association with population change (- .841) and the controls of 'accessibility' and 'size' do not show any clear impact. With the control of 'change', the decrease in the correlation between 'accessibility' and 'age' (+ .370) shows the effect of 'change' while with the addition of 'size' as a second order partial control, the correlation becomes more significant (+ .650) representing stronger correlation co-efficient between 'accessibility' and 'age' for the towns with both similar size and population change (see Table 6.3).

The impact of 'change' on the correlation co-efficient between 'accessibility' and 'size' is shown by the increased co-efficient obtained when the variable of 'change' is controlled (from .008 to - .208) when 'age' was included as the second control variable the correlation went up to a significant level (- .600), which represents an inverse linear correlation between 'accessibility' and 'size' for the towns having a similarity in both 'age' and 'population change'.

Finally, to distinguish the effect of individual variables on the correlation of the remaining pairs of variables, the regions are compared. Table 6.3 shows that the influence of each variable on others, varies from one region to another. The impact of 'size' on the remaining correlations is evident in all the regions. On the correlation between 'accessibility' and 'age' ($r12.3$)* 'size' has a considerable effect in Multan, little effect in Rawalpindi and a negative impact in Bahawalpur. Similarly, in cases of $r14.3$ and $r24.3$ the impact of size is more clear in Sargodha and Lahore respectively, while it is negative in Multan. It shows that the changes in the regions are not subject to one factor alone.

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* 1 = Accessibility
2 = Age of towns
3 = Size of towns
4 = Population change 1961-71

Looking at the impact of 'change' on the correlations it appears that in cases of r12 and r13 it is significant in Bahawalpur and is low or totally absent in the remaining regions, while in the case of r23, only Multan has a positive influence. It suggests that the correlations in both Bahawalpur (r12, 13) and Multan (r23) depend in part on the correlation of each with population change.

The impact of accessibility is positive on 34 in all the regions but the remaining correlations (r23 and r24) are influenced by accessibility only in Sargodha region. This reflects its importance in the association of 'size' and 'change' and the comparatively more important role of accessibility played in the Sargodha region. The effect of 'town age' is only significant on r13 in Bahawalpur region, whereas no region shows the impact of 'town age' on the correlation between size and 'change (r34). It indicates a weak association of the variable in all the regions except one, where it is inversely correlated with 'population change' at a highly significant level (see Table 6.3).

Among these four variables it is possible to identify the influence of (correlations of) one pair on another. Except for Rawalpindi, where r14 shows the maximum negative impact on r23, in all the remaining region r12 shows a negative impact on r34. On the other hand, positive influence varies between the regions. In Rawalpindi, the pair of variables, which show the greatest influence is r23 in Sargodha and Lahore r13, whereas in Multan and Bahawalpur are r34 and r24 respectively. This reflects the regionwise importance of the variables, which play an important role in reducing the strength of the correlation between the remaining pairs of variables, in the respective regions.

The use of the second order partial controls for all regions, changes the strength of simple correlation for all six pairs of variables, showing both negative and positive impacts, which are not similar in the regions either in values or in number of pairs. The pairs showing positive impact vary from one (in Bahawalpur) to five (in Rawalpindi) with two, three and four (pairs) for Multan, Lahore and Sargodha respectively.

6.6 District Level Nodal Accessibility

In Table 6.4 the values of ITC for the individual nodes show accessibility to their own district level network expressed in terms of the degree of the circuity of its shortest path connections with all the other nodes in the network. Here the nodal ITC values are compared within the districts especially to understand the extent to which the towns with important functions, hold their position in terms of accessibility . To understand the accessibility in terms of location and efficiency of these towns within the districts, the two non-topological matrices of 'distance' and 'time' are also included.

Looking on the basis of the average scores of all the three types of accessibilities, it is found that in nine (out of 19) districts, the district headquarters is the most accessible town, and except for the district headquarters of Lahore and Jhelum (ranking sixth and seventh respectively), all the remaining district headquarters are among the four most accessible centres. These include the districts of Gujrat, Sargodha, Lyallpur, Sialkot, Sheikhupura, Multan, Sahiwal and Dera Ghazi Khan, where the most accessible towns are either tehsil headquarters or the old railway junctions (like Lalamusa, and Raiwind). They have better internal accessibility than their respective administrative headquarters. Similarly only one fourth (19) of the tehsil headquarters are not among the five most accessible centres. This reflects the fact that within the districts the towns with administrative functions are most accessible as compared to other non-administrative centres. The remaining non-administrative, most accessible centres are mostly found in the districts of Mianwali, Lahore and Sheikhupura, where these are well connected and hold comparatively central locations in their respective districts.

To understand the extent to which new towns are ranked in terms of accessibility in their respective districts, it is possible to identify the position of new towns added in 1972. Out of 28 new towns only nine are included among the five most accessible centres of their respective districts. It shows that very few of the new towns enjoy a clear advantage of accessibility and most of these are remote to their own network (see Table 6.4).

Table 6.4

DISTRICT LEVEL RANK ORDER NODAL ACCESSIBILITY
OF THE TOWNS INCLUDED IN THE CENSUS OF 1972

			ITC
(i)	Rawalpindi District		
	1	Rawalpindi	100
	2	Kahuta	150
	2	Gujarkhan	150
	4	Wah Cantonment	175
	4	Murree	175
(ii)	Campbelpur District		
	1	Campbelpur	150
	2	Hasanabdal	225
	2	Hazro	225
	2	Pindi Gheb	225
	5	Fateh Jang	237
	6	Khaur	287
	7	Talagang	300
	8	Wah Cement Works	325
	8	Gurghashti	325
(iii)	Jhelum District		
	1	Chakwal	187
	2	Kharakha	200
	3	Khewra	212
	4	Bhaun	237
	5	Dina	250
	6	Mangla Cantonment	262
	7	Pind Dadankhan	275
	8	Jhelum	337
	9	Lilla Town	362
(iv)	Gujrat District		
	1	Lalamusa	180
	2	Kharian	200
	2	Phalia	200
	2	Mandi Bahaodin	200
	5	Gujrat	220
	5	Dingah	220
	7	Sarai Alamgir	240
	7	Kunjah	240
	9	Mangowal	260
	10	Malakwal	290
	11	Jalalpur	310
(v)	Sargodha District		
	1	Shahpur Sadar	238
	2	Shahpur Shahar	257
	3	Bhalwal	271
	4	Sargodha	276
	5	Khushab	286
	6	Jhaurian	295
	6	Kalra	295
	8	Sahiwal	310
	9	Jauharabad	343
	10	Bhera	352
	11	Lilliani	357
	12	Kot Momin	367
	12	Phularwan	367
	12	Sillanwali	367
	15	Naushehra	376
	15	Sakesar	376
	17	Faruka	395
	18	Hadali	414
	18	Nurpur	414
	20	Miani	448
	21	Quaidabad	486
	22	Mitha Tiwana	490
(vi)	Mianwali District		
	1	Mianwali	227
	1	Kundian	227
	3	Liaqat Abad	255
	3	Piplan	255
	5	Daud Khel	273
	6	Moch	291
	7	Kalurkot	300

Table 6.4 Continued

	Mianwali District Cont.,	ITC
8	Musa Khel	318
9	Kalabagh	345
10	Darya Khan	373
11	Isa Khel	436
12	Bhakkar	464
(vii)	Jhang District	
1	Jhang	167
2	Chiniot	183
3	Garh Maharaja	200
4	Shorkot	217
5	Rabwah	233
6	Ahmad Pur Sial	283
7	Lalian	317
(viii)	Lyallpur District	
1	Samundari	125
2	Lyallpur	137
3	Tandlianwala	150
4	Kamalia	162
4	Gojra	162
6	Toba Teksingh	175
7	Jaranwala	187
7	Pirmaha;	187
9	Chak Jhumra	212
(ix)	Lahore District	
1	Lahore	193
2	Raiwind	214
2	Pattoki	214
4	Bhai Pheru	221
5	Kahna Nau	236
6	Kasur	243
6	Rajajang	243
6	Lulliani	243
6	Kot Radhakishan	243
6	Chunian	243
11	Khudian	257
12	Padhana	286

	Lahore District Cont.	ITC
12	Dogri Kalan	286
14	Wan Radharam	307
15	Kanganpur	350
(x)	Sialkot District	
1	Pasrur	169
2	Sialkot	177
3	Qilla Sobhasingh	208
3	Zafarwal	208
3	Daska	208
6	Chawinda	215
7	Narowal	231
7	Sambrial	231
9	Jamke	246
10	Kalaswala	262
11	Begowal	269
11	Bhopalwala	269
13	Bado Malhi	277
14	Shakargarh	323
(xi)	Gujranwala District	
1	Gujranwala	167
1	Akalgarh	167
3	Hafizabad	211
3	Qilla Didarsingh	211
5	Eminabad	233
5	Wazirabad	233
5	Gakhar	233
8	Ramnagar	256
9	Pindi Bhattian	300
10	Kamoke	322
(xii)	Sheikhupura District	
1	Sheikhupura	155
2	Chuharkana	173
2	Mananwala	173
4	Shahkot	191
5	Nankana Sahib	218
6	Dhaban Singh	227

Table 6.4 Continued

	Sheikhupura District Cont.	ITC
6	Shareqpur	227
8	Warburton	236
8	Kangah Dogran	236
10	Muridke	245
10	Narang	245
12	Sangla Hill	300
(xiii)	Multan District	
1	Multan	171
2	Khanewal	179
3	Jahania	193
4	Vehari	207
4	Kabirwal	207
6	Mailsi	214
6	Dunya Pur	214
8	Mian Channu	221
9	Shujaabad	229
10	Lodhran	236
10	Kehror Pakka	236
12	Abdul Hakeem	243
13	Burewala	286
14	Talamba	293
15	Jalalpur Pirwala	300
(xiv)	Sahiwal District	
1	Okara	167
2	Sahiwal	178
2	Depalpur	178
4	Havaili	189
4	Pakpattan	189
6	Basir Pur	211
7	Renala Khurd	222
8	Hujra	233
8	Arifwala	233
10	Chichawatni	267
(xv)	Muzaffargarh District	
1	Muzaffargarh	163
2	Khangarh	175
3	Shahar Sultan	215

	Muzaffargarh Dist. Cont.	ITC
4	Lieah	225
4	Daira Din Panah	225
6	Kehror	237
6	Kot Addu	237
8	Ali Pur	287
8	Jatoi	287
(xvi)	Dera Ghazi Khan District	
1	Jampur	212
2	Kot Chota	225
3	Dajal	300
3	Rajanpur	300
5	Dera Ghazi Khan	312
5	Kot Mithan	312
7	Taunsa	325
8	Rojhan	400
9	Vehowa	412
(xvii)	Bahawalpur District	
1	Bahawalpur	167
2	Samasata	183
3	Khanpur	217
4	Ahmad Pur East	233
5	Yazman	250
6	Hasilpur	300
7	Uch Sharif	317
(xviii)	Bahawal Nagar District	
1	Bahawal Nagar	167
2	Donga Bonga	183
2	Chishtian	183
4	Harunabad	200
5	Minchinabad	217
6	Fort Abbas	283
7	Sadiq Ganj	300
(xix)	Rahim Yar Khan District	
1	Chachran	156
2	Rahim Yar Khan	178
2	Sadiq Abad	178
2	Khanpur	178

Table 6.4 Continued

Rahim Yar Khan Dist. Contd.		ITC
5	Alah Abad	200
6	Trinda Sawai	222
7	Kot Samabah	233
8	Liaqatpur	256
8	Ahmad Pur Lamma	256
8	Sanjarpur	256

The ITC values show some interesting contrasts between the districts in the extent to which there is similarity in the 'nodal accessibility' of the districts. In Mianwali and Gujranwala districts two centres share the highest degree of accessibility, whereas in the remaining districts one node enjoys the clear advantage. A comparison between the most and second-most accessible centres shows a pronounced difference in the accessibility, which is high in northern districts of Campbelpur and Rawalpindi (75 per cent and 50 per cent respectively) and low in Sialkot and Multan (8 per cent) and among the other districts no one has more than 22 per cent.

Similarly the range of accessibility obtained through the differences of ITC scores between the most and least accessible centres (in the districts) can be compared between the districts to assess the overall degree of connectivity within district level transport systems. The low range is found in the districts of Rawalpindi (75 per cent), Lyallpur (87 per cent), Sahiwal (100 per cent) and Rahim Yar Khan (100 per cent). It is then followed by Muzaffargarh (124 per cent), Multan (129 per cent), Gujrat (130 per cent) and Bahawal Nagar (133 per cent). None of these districts shows a difference in accessibility between the most and least accessible centres of much greater than twice, showing a comparatively higher degree of overall inter-connectivity of the towns in their respective district level transport systems. On the other hand the high range of 200 per cent or more can be found in the districts of Dera Ghazi Khan (200 per cent), Mianwali (237 per cent) and Sargodha (252 per cent).

It may be concluded that in the district level analysis the relationship between accessibility and administrative functions is very clear. The relationship of accessibility with the remaining functions (at the same scale) is analysed in the next chapter.

Chapter 7

DISTRICT LEVEL PATTERN OF CONNECTIVITY

7.1 Introduction

In previous chapters some concepts of accessibility were discussed and applied to the Panjab and division level transport networks. This may stand in its own right as an introductory and very partial discussion of the transport network and it lays the foundation for the analysis of micro level change. The remainder of this thesis examines in greater detail the nature of the relationship between accessibility and the pattern of urban change. The development of standardised indices of network structure and of nodal accessibility does make possible the testing of hypotheses in which socio-economic changes are related to the local (district level) structure of transport network and urban accessibility. Having analysed the structure of district level transport networks in this chapter, a number of hypotheses are operationalised in both Chapters 7 and 8.

7.2 The Hypotheses

Earlier discussion suggests that the changes in the region are due to the interaction of various important factors. Despite a wide contrast in the spatial patterns of socio-economic change, a number of spatial regularities may be ecpected in the region of the Panjab. For example, the changes in connectivity brought by road development during 1931-71, have played an important role in the economic development of the whole of the Panjab and particularly the areas with recent agricultural development. The addition of road linkage in an agricultural region increases the complexity of the network. It provides the possibility for goods and services to enter a region which will then contribute to the social complexity of that region. The likelihood is great that businessmen will establish themselves where facilities for transportation

are good. It also encourages the branches of different institutions like entertainment, commercial and administrative. This increases its attractiveness to the population of other regions which in turn, leads to high growth rates of both total and urban populations. People are also attracted by regions characterised by a high level of administrative complexity and having a high level of social organization with the ability to provide the major facilities, which may not be available from the less differentiated regions. Similarly, agricultural markets and commercial establishments provide intra regional competition and the availability of a large variety of goods and services in various parts, and, lead to inter and intra regional traffic and interaction.

With these points in mind the following general hypotheses may be advanced:

i. higher changes in connectivity (1931-71) positively affect recent economic and agricultural development,

ii. route surplus is a significant factor in the growth of major towns as well as the growth of total and urban population;

iii. the administrative functions contribute towards higher connectivity and traffic flow;

iv. the efficiency of traffic flow has a significant relationship with socio economic and industrial functions.

7.3 Topological Structure (1971)

The district level topological structure can be divided into:

A. Urban connectivity of the districts

B. Nodal connectivity of the districts

A. Urban Connectivity

Table 7.1a shows the topological indices of the accessibility for the districts of the Panjab dealing with a total of 202 vertices (towns) or approximately 11 per district. The number of vertices varies from 5 (Rawalpindi) to 22 (Sargodha) showing a considerable contrast between them. All these districts have more than the minimum number of edges to make a minimally connected network. All the districts

have at least one circuit except for Dera Ghazi Khan and Bahawalpur, which are extremely simple with a one branch network and having no close set of lines. It is mainly due to the backwardness of the districts where most of the road length is parallel to the rail and most of these vertices are equally connected by both rail and roads. This difference can be identified while comparing 'nodal' and 'urban' connectivity for these districts. In the other central districts where most of the road length is not parallel to the railway, roads play an important role in connecting the towns on rail with the towns away from the railway, and it makes the connectivity values for the district high. This gradual road development evolved from a simple path to a tree and then to a circuit network. As the circuit is merely the end product of an evolution through path and tree stages, therefore, the existence or absence of a circuit has much importance in the connectivity.

Looking at this in terms of absolute circuit connectivity the networks of Multan, Sargodha and Sheikhupura districts possessing more circuits have a greater degree of connectivity than the others and the greater the degree of completeness between vertices and arcs, the higher is the level of connectivity. At the comparatively lower end are the other central districts of Lyallpur, Mianwali, Sialkot, Lahore, Muzaffargarh and Sahiwal with five to ten circuits. This measure gives a general idea about the connectivity of the districts.

For the purpose of understanding the relative circuit connectivity of these districts the existing percentage of the possible numbers of fundamental circuits has been calculated by the alpha index (α) (see Table 7.1a).

At the top of the scale there are only three districts of Lyallpur, Sheikhupura and Multan possessing more than 50 per cent of the possible numbers of fundamental circuits, identifying two districts of Sargodha and Lyallpur from their values measured on the 'μ' scale. The district of Sargodha has a high number of circuits due to its vertices while Lyallpur has less vertices but higher 'α' values indicating more compactness of its network than Sargodha. The low values of relative circuit connectivity for the rest of the districts is due to the various factors of physiography, shape, remoteness and obstacles like rivers and mountains but the parallel rail and road lines are most important. In

Table 7.1a

DISTRICT LEVEL TOPOLOGICAL INDICES OF THE PANJAB

	District	v	e	μ	d	α	β	γ	E	Pi	Th	$\acute{E}$	$\acute{Pi}$	$\acute{Th}$	A	B
1	Rawalpindi	5	5	1	2	20.0	1.00	55.5	96	7.05	96	117	8.62	117	250	250
2	Campbelpur	9	11	3	4	23.1	1.22	52.4	33	3.90	41	46	5.34	56	225	275
3	Jhelum	9	12	4	4	23.1	1.33	57.1	25	3.09	33	33	4.14	44	225	300
4	Gujrat	11	15	5	5	29.4	1.36	55.5	21	4.58	29	27	5.81	36	220	300
5	Sargodha	22	34	13	7	33.3	1.55	56.7	17	5.06	26	23	6.83	35	314	486
6	Mianwali	12	20	9	4	47.4	1.67	66.7	21	2.85	34	30	4.18	50	300	500
7	Jhang	7	7	1	5	11.1	1.00	46.7	56	3.39	56	69	4.15	69	140	140
8	Lyallpur	9	17	9	3	69.2	1.89	80.9	18	3.91	34	30	6.58	58	300	567
9	Lahore	15	20	6	5	24.0	1.33	51.3	10	2.17	14	18	3.75	23	300	400
10	Sialkot	14	20	7	5	30.4	1.43	55.6	18	5.12	26	24	6.72	34	280	400
11	Gujranwala	10	11	2	5	13.3	1.10	45.8	26	4.14	29	36	5.71	39	200	220
12	Sheikhupura	12	22	11	4	57.9	1.83	73.3	16	4.48	30	23	6.39	42	300	550
13	Multan	15	28	14	5	56.0	1.87	71.8	18	4.44	34	29	6.96	54	300	560
14	Sahiwal	10	14	5	4	33.3	1.40	58.3	26	4.46	37	39	6.55	54	250	350
15	M.Garh	9	14	6	4	46.1	1.56	66.7	29	3.10	45	37	3.94	58	225	350
16	D.G.Khan	9	8	0	7	0	0.89	38.1	41	1.49	37	65	2.27	58	129	114
17	Bahawalpur	7	6	0	5	0	0.86	40.0	55	3.50	47	77	4.87	66	140	120
18	Bahawal Nagar	7	7	1	5	11.1	1.00	46.7	40	2.99	40	63	4.67	63	140	140
19	R.Y.Khan	10	13	4	4	26.7	1.30	54.16	30	4.58	38	38	5.95	50	250	325

e = link between two vertices
v = towns according to the census of 1971
μ = e - v + P
α = (/2v - 5) 100
β = e/v
γ = (e/3v - 2) 100
E = Road length/e
Pi= Road length/dm
Th= Road length /v
A = v/d 100
$\acute{E}$ = Rail and road length/e
$\acute{Pi}$= Rail and road length/dm
$\acute{Th}$= Rail and road length/v
B = e/d 100

Table 7.1b

DISTRICT LEVEL TOPOLOGICAL INDICES

	Districts	v	e	μ	α	β	γ	E	Pi	Th
1	Rawalpindi	45	59	15	17.6	1.311	44.4	8.13	7.05	10.67
2	Campbelpur	26	36	11	23.4	1.385	47.4	10.19	3.90	14.11
3	Jhelum	23	28	6	14.6	1.217	41.8	10.61	3.09	12.91
4	Gujrat	31	44	14	24.6	1.419	48.4	7.18	4.58	10.19
5	Sargodha	47	71	25	28.0	1.510	51.1	8.05	5.06	12.17
6	Mianwali	35	61	27	41.5	1.742	59.2	6.77	2.85	11.80
7	Jhang	28	30	3	6.0	1.071	36.6	13.10	3.39	14.03
8	Lyallpur	33	58	26	42.6	1.757	59.8	5.33	3.91	9.36
9	Lahore	37	59	23	33.3	1.595	54.1	3.46	2.17	5.51
10	Sialkot	36	59	24	35.8	1.639	55.7	6.25	5.12	10.25
11	Gujranwala	20	33	14	40.0	1.650	56.9	8.67	4.14	14.30
12	Sheikhupura	31	47	17	29.8	1.516	51.6	7.53	4.48	11.42
13	Multan	41	61	21	27.3	1.488	50.4	8.44	4.44	12.56
14	Sahiwal	52	94	43	43.4	1.808	61.0	8.41	4.46	7.11
15	Muzaffargarh	39	65	27	37.0	1.667	56.5	6.29	3.10	10.49
16	D.G.Khan	30	42	13	23.6	1.400	47.7	7.88	1.44	11.03
17	Bahawalpur	33	40	8	13.1	1.212	41.2	8.32	3.50	10.09
18	Bahawal Nagar	19	28	10	30.3	1.474	50.9	10.03	2.99	14.79
19	R.Y.Khan	28	37	10	19.6	1.321	45.1	10.40	4.58	13.75

v = Road Junction

this case it may be hypothesised that "the greater the parallel rail and roads length in the region, the lesser will be the percentage of the possible number of fundamental circuits".

A Spearman's Rho of +0.727 (significant level of 99 per cent) between the alpha index and the percentage of parallel rail and road length (shortest path) of the edges, confirms the fact that all the roads built parallel to the already existing rail network, might have increased the efficiency of networks in terms of time and frequency, but has not increased the relative circuit connectivity. On the other hand, the development of roads not parallel to the railway line, has increased the values of the network by connecting the already unconnected towns or vertices.

The districts showing the highest values of connectivity on the alpha index (α) are Lyallpur (69.2 per cent), Sheikhupura (57.9 per cent) and Multan (56 per cent), have the lowest percentage of parallel roads of zero per cent, 2.4 per cent and 4.2 per cent respectively. On the other hand all the districts with a high percentage of parallel roads are Dera Ghazi Khan (52 per cent), Bahawalpur (71 per cent) and Bahawal Nagar (78 per cent) having very low connectivity values.

As the alpha index does not measure the connectivity of simple networks (without circuits) which makes the comparison of the connectivity values between these districts difficult as we have two districts of Bahawalpur and Dera Ghazi Khan having simple networks. For this purpose the Beta index (β) can measure the tree and other very simple networks on the basis of 'the more edges a network possesses in relation to a certain number of vertices, the higher its level of connectivity'.

The values obtained on the Beta index for these districts range from o.86 (Bahawalpur) to 1.89 (Lyallpur) indicating a marked contrast between well developed and backward districts.

All 19 districts of the region can be divided into four main groups according to their degree of connectivity measured through 'β'.

The first group closely round (β) beta index of about 0.90 consist of those districts where the network is only partially connected. It

includes two comparatively less developed and distant districts of Bahawalpur and Dera Ghazi Khan.

The second group having 'β' values close to unity and with entirely simple connections (1.00 - 1.29) includes the districts of Bahawal Nagar, Jhang, Rawalpindi, Gujranwala and Campbelpur. All these districts are located away from the centre except for Jhang and Gujranwala which have low values mainly due to their shape.

Similarly a third group exhibits the beginnings of the development interconnections including six mostly old settled districts of Rahim yar Khan, Jhelum, Gujrat, Lahore, Sialkot and Sahiwal. All of them have a long history of urbanization but most changes have taken place in recent decades. These districts have the 'β' values between 1.30 - 1.40 indicating their developing position in terms of connectivity.

Finally the fourth group consists of the districts with advanced interconnections which include the Central newly settled districts of Muzaffargarh, Sargodha, Mianwali, Sheikhupura, Multan and Lyallpur which have gone through a rapid change of development in terms of roads, to take : agricultural produce to the markets.

Table 7.1a shows that all the district level networks have the minimum number of edges (ie. one less than the number of vertices) needed to link together all the vertices of the network. After looking at the connectivity of absolute circuits, relative circuits and simple linkage, we are also interested to look at the linkage connectivity according to the number of vertices of the respective districts. Due to the variation in the number of vertices the networks do not give the same values by measuring with different indices. For example, the networks of Sargodha and Sahiwal districts have different values for 'μ' but the same for 'α' index (33.3 per cent) which are again different while measured with 'β' and 'γ' indices. A similar contrast can be seen in the values of the networks of Campbelpur and Jhelum districts where the number of vertices and alpha index values are the same (23.1 per cent)but the values for the other indices are different due to the difference in the number of edges. This shows the importance of the edge in the network.

Here the main concern is to compare the district level networks by the ratio of the existing edges to the maximum number of edges possible in that network. For this purpose the values are measured by 'γ' (gamma) index, which gives the range values possible, from 0 to 1 or 0 to 100 per cent if changed into percentage. The higher the index the greater is the connectivity of the network.

Table 7.1a shows that out of 19 districts there are only five that have a gamma index of less than 50 per cent in ascending order Dera Ghazi Khan, Bahawalpur, Gujranwal, Jhang and Bahawal Nagar; none of these districts has more than ten vertices (towns) and therefore consist of very small networks. The three districts of Dera Ghazi Khan, Bahawalpur and Bahawal Nagar are located away from the centre of the region and come under the later phase of the development while Gujranwala district holds the central position and is well connected to it neighbouring districts as well as to the whole of the Panjab. The shape and good connectivity to the rest of the whole network has reduced the possibility of cross linkages within the districts of Jhang and Gujranwala. This can in the case of Gujranwala, be supported further by examining and comparing the 'γ_T' values and 'γ_J' values* which are 45.8 per cent and 56.9 per cent respectively. The difference indicates that in the network the ratio of edges connecting road junctions is higher than the ratio of edges connecting the towns.

In this case the position of Jhang district is slightly different. In spite of its central position the low degree of linkage connectivity is due to the presence of two rivers the Jhelum and the Chenab which make the internal interconnections difficult. Apart from that the shape of the region is an important factor effecting the degree of connectivity. The lowest values of Jhang district on the 'Shape index' (see Chapter 8) provide grounds to believe that along with other factors the shape of the region has a significant effect on the degree of connectivity.

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* γ_T = Gamma Index based on v = town

γ_J = Gamma Index based on v = Junction

On the other hand the district of Lyallpur is classified as having a delta configuration according to Taaffe and Gauthier's (1973) structural indices. As much as 80.9 per cent 'γ' values indicate that the district has a high proportion of its possible routes linking places directly and also a high proportion of possible complete circuits (α = 69.2 per cent) which indicates its advanced development in the transport networks.

Among the other districts with high connectivity indices on the 'γ' scale are the newly settled districts of Sheikhupura, Multan, Muzaffargarh, Mianwali and Sahiwal, located in the doabs. These are characterised by the recent development of roads.

So far we have seen the district level pattern of connectivity with the help of four indices ($\alpha, \beta, \mu, \gamma$) separately. In spite of a close degree of correspondence between the indices the whole picture of connectivity for a district cannot be obtained by one measure due to a variation in the vertices. Apart from that these measures do not identify the same concept of measurement.*

It is clear from the above discussion that the connectivity of these districts cannot be compared by one measure, as we are interested in all four concepts of connectivity* to understand the exact picture of district level connectivity. Therefore it is possible to put these values in the composite connectivity scores by computing z-scores of four indices for town based connectivity of the 19 districts of the Panjab. On the basis of CCS the Panjab has been divided into the four groups of connectivity and is plotted on the map (see Figure 7.1).

It shows that with the exception of two districts Gujranwala and Jhang, a higher degree of district level connectivity can be found in the central doabs (interfluves) of the region where obstacles like

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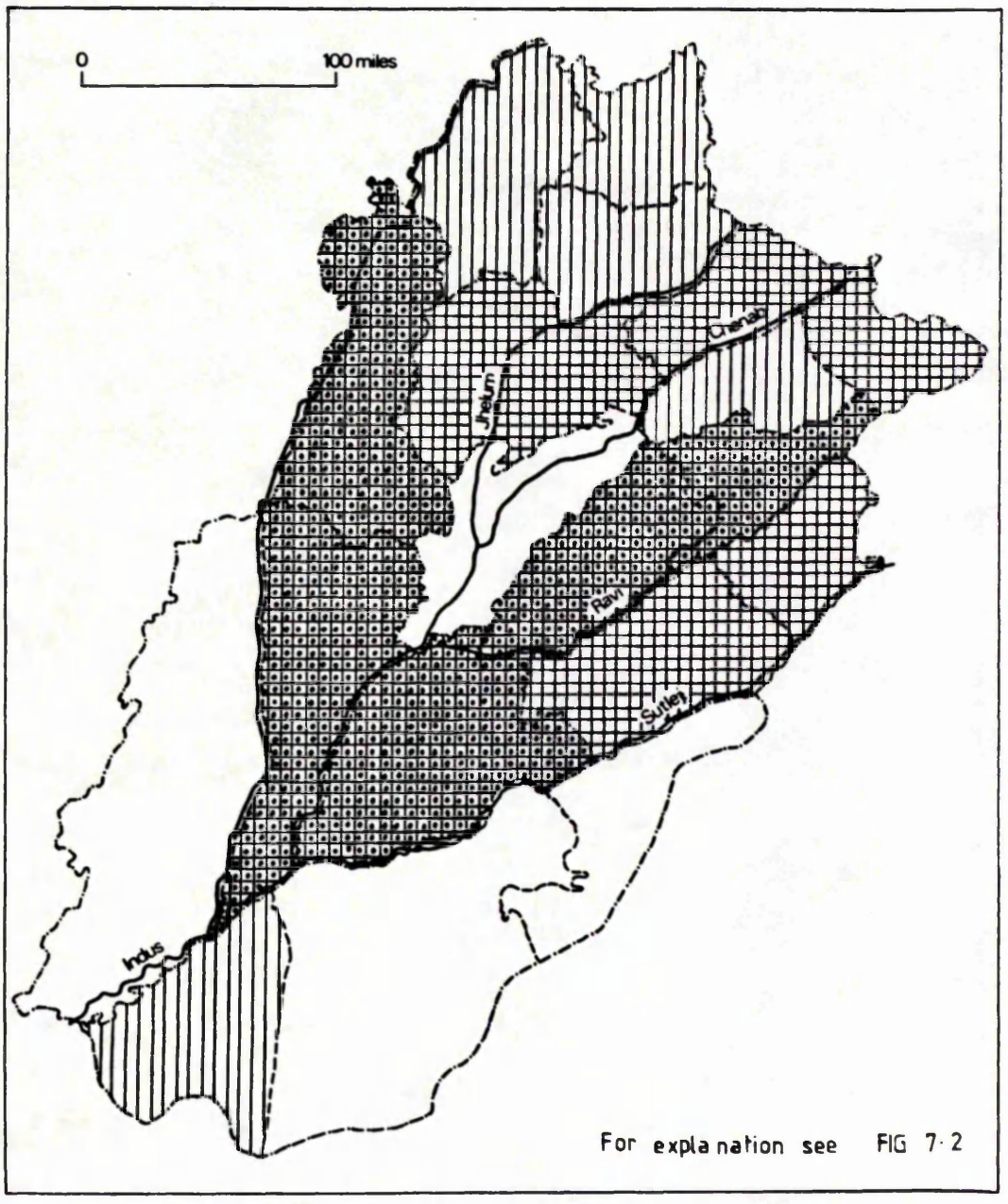
* 1. Cyclomatic number measures only absolute circuit connectivity.
2. Alpha Index measures relative circuit connectivity.
3. Beta Index gives the values of simple linkage connectivity.
4. Gamma Index measures relative linkage connectivity.

FIGURE 7·1

DISTRICT WISE CONNECTIVITY
1971

[COMPOSITE CONNECTIVITY SCORES OF TOPOLOGICAL INDICES]



mountains do not exist and rivers only pass along the boundary of these districts which do not reduce the degree of connectivity, with a few exceptions. The degree of connectivity declines toward the northern hilly districts of Campbelpur, Rawalpindi and Jhelum including a small number of vertices (towns) and hills which decrease the degree. Among the central districts, Gujranwala holds a central position in the region but due to the location of its towns, some on the straight rail and road line and others on the border, it has a comparatively low value on internal connectivity. As most of its towns are along the rivers which reduce the possibility and need of cross linkage and make the degree of connectivity low within the district but high within the region of the Punjab which can be seen in the previous analysis of the whole region. A similar reason of central location of Jhang district puts it in the lowest Quartile along with the other major reasons of rivers and shape. For the other southern districts of Bahawalpur, Bahawal Nagar and Dera Ghazi Khan, the low degree of general connectivity is expected, as all of their towns are on one straight line along the rivers.

B. Nodal Connectivity (v = J)

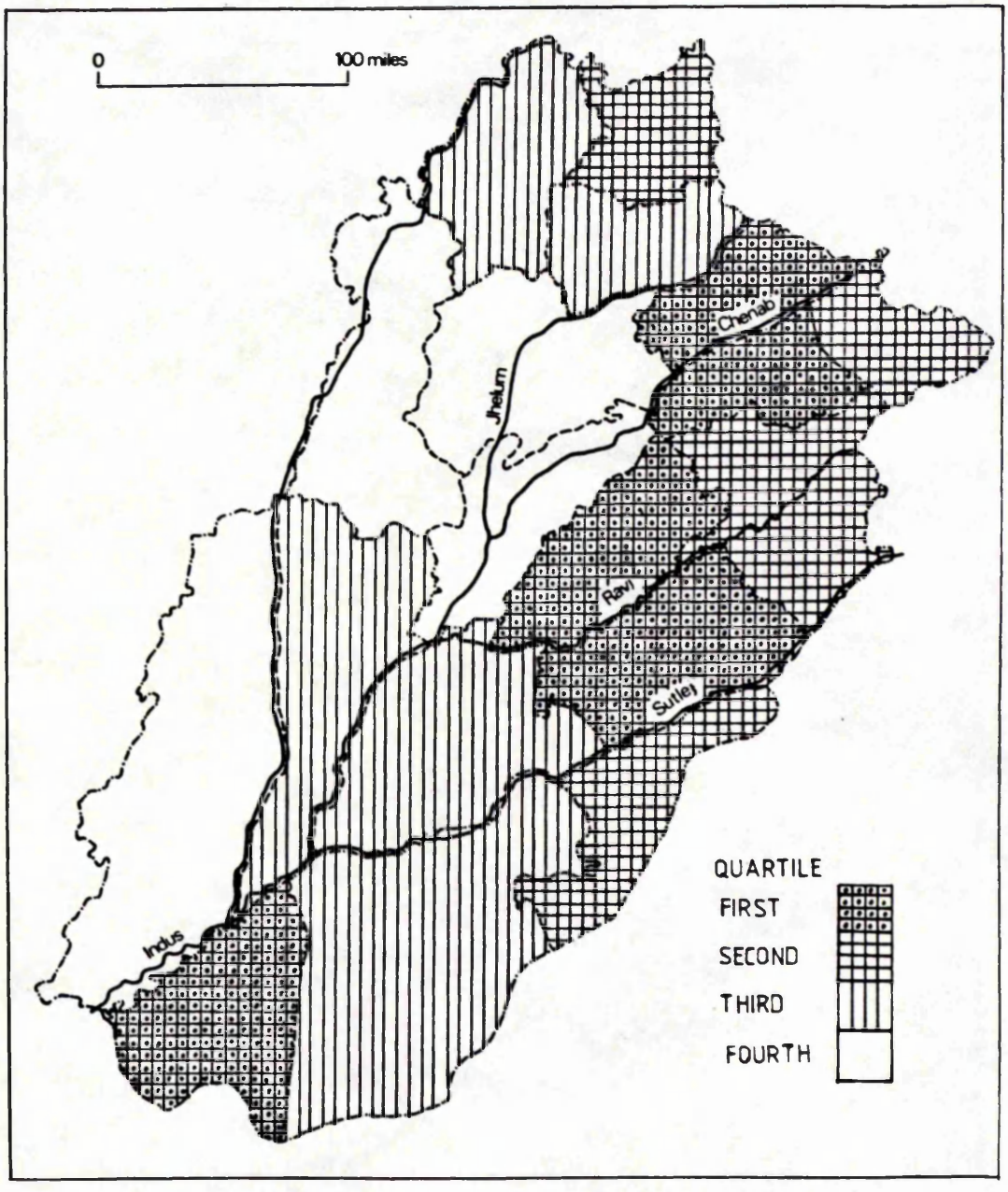
In this section the topological structure of the district level connectivity has been measured by the same indices with the change in definition of vertex from 'town' to a node (junction), which generally provides the base for a new town. Referring back to the main aim of the study, that is to find the relationship between the structure of transport and urban growth which includes the increase of population in old towns as well as the growth of new towns during the period of road development (1931-1971).

Generally railways are the primary modes of national connection, while roads serve primarily to interconnect regional town systems. In this study, which focuses on the district level pattern of connectivity, the road network is considered to be the most appropriate mode of interconnection. Therefore, here we are also interested to note the district level effect of road development on the degree of connectivity and urban growth. It is possible to compare these values with the values of connectivity obtained from the urban (v = town) connectivity as it

FIGURE 7·2

DISTRICT WISE NODAL ACCESSIBILITY 1971

BASED ON COMPOSITE SCORES OF TOPOLOGICAL, DISTANCE AND TIME ACCESSIBILITY.



was based on both modes of transport (rail and road), while nodal connectivity is only based on road netowrks. Apart from that the analysis is important to find the answer to one of the fundamental questions posed by the study ie. does accessibility encourage growth and create new urban centres at the accessible locations in the districts where nodal accessibility (v = J) is high or does the presence of old towns influence the growth of the network and make nodal (junctions) connectivity high?

7.4 Comparisons

For this purpose the analysis of the connectivity based on junctions as vertices is useful to explore the idea and its comparison with the connectivity of towns will provide grounds for the study of urban growth which is the focus of the remaining chapters. In this part we are mainly concerned to

1. look more closely at the pattern of connectivity in the districts.
2. to differentiate between connectivity values obtained on the basis of nodes and towns.
3. to understand the degree of correspondence between the indices and degree of connectivity for individual districts.
4. to test the district level relationship between the connectivity of junctions and connectivity of towns which is helpful to trace the effect and importance of road development in the region.
5. to know the district level degree of correspondence between the connectivity of urban population (through urban centres as vertices) and the degree of connectivity of rural population (to urban centres through nodes/road junctions).

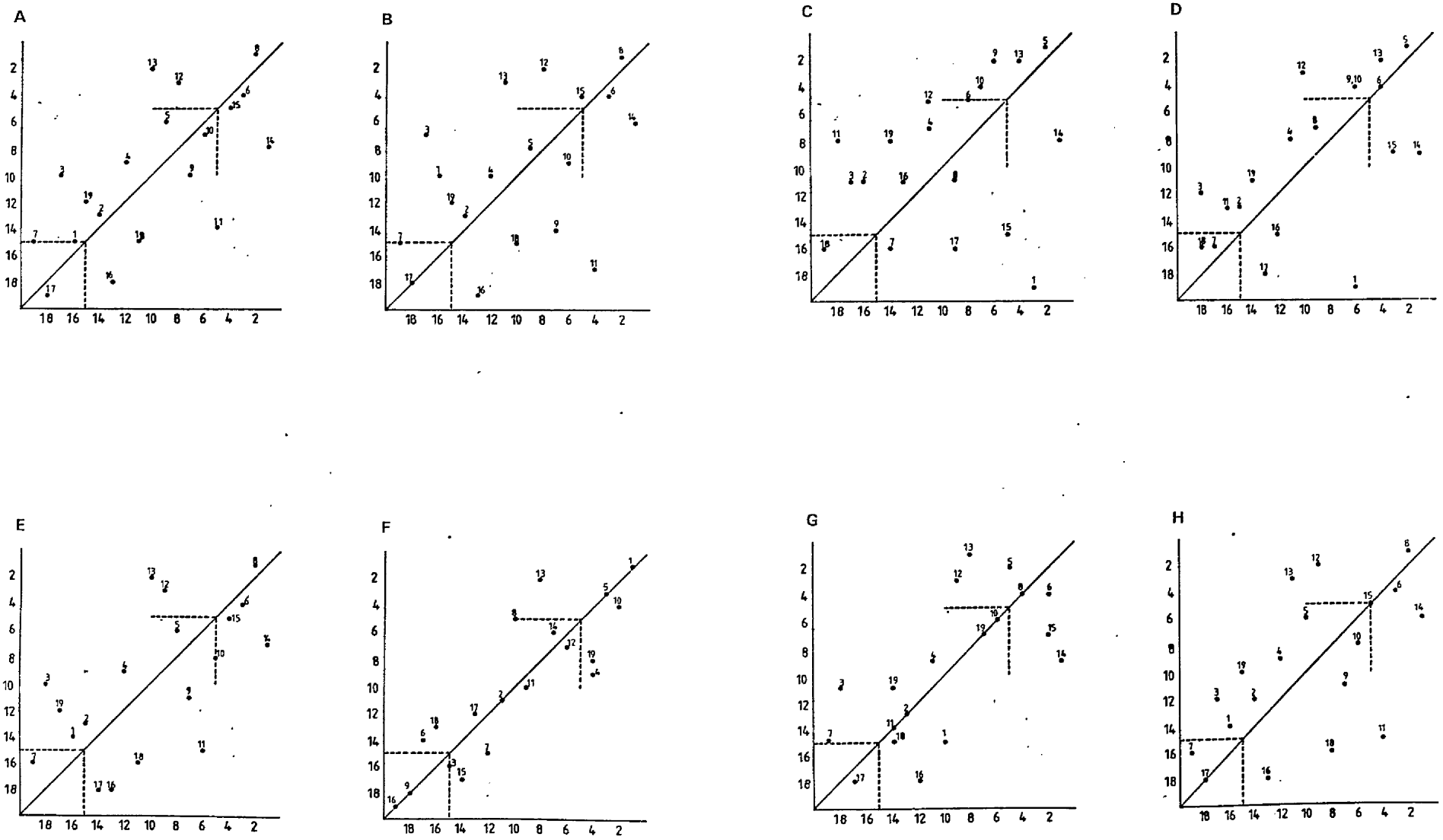
Table 7.1b shows topological properties for the district level connectivity based on 634 vertices (nodes/junctions) and 1033 edges with an average of 33 and 54 per district respectively or about nine vertices and 14 edges per tehsil. According to the figures of 1972 an average of 40 villages are served by each node. The number of vertices varies from 19 (Bahawal Nagar) to 52 (for Sahiwal). Similarly the values for absolute circuit connectivity (μ) range from 3 (Jhang) to 43 (Sahiwal) showing a marked contrast between them.

The minimum number of nodes for each district is at least double the number of towns, showing that each town of the district like Gujranwala and Sargodha is served by two nodes, while the towns of Jhang, Lyallpur, Muzaffargarh, Sahiwal and Bahawalpur have the proportion of four to five nodes per town. The highest proportion can be seen in the district of Rawalpindi. This seems to be due to the presence of Islamabad, the capital of the country, which is connected with a number of roads. In the same way the degree of circuit connectivity (μ) on the nodal scale is much higher than the connectivity measured on the urban scale (towns as vertices). The increase in cyclomatic number ranges from two (Jhang, Jhelum) to 38 (Sahiwal) showing a maximum change in all central districts (except Jhang) where this connectivity plays a more important role in connecting the non-urban population to the urban centres than the centres themselves. In other words, we can say that in these districts (with high nodal circuity) the non-urban population has also easy access to the urban centres where a high change of population in pre-1931 towns and growth of new towns can be expected .

A comparison between the number of vertices measured on both the nodal and urban scales, shows that each district has at least twice as many nodes as urban centres identifying a big variation in the nodal-urban ratio of the districts, like Gujranwala and Rawalpindi where the nodal-urban ratio ranges from two to nine respectively. It is generally expected that the districts with a high number of urban centres have many nodes but a poor degree of co-efficient correlation (0.40) between the number of nodes and urban centres; this does not confirm it due to variation in the characteristics of the districts (see Section 8.8). This general pattern of relationship can further be explained by rank scatterdiagram (see Figure 7.3c) which identifies the residuals from the central line by hierarchy of the districts in terms of both towns and nodes. It shows only six districts rank higher with number of nodes than the towns. Out of these, the districts of Lyallpur and Jhang lie within the band of 95 per cent confidence level indicating their almost equal position in terms of both nodes and towns, while the remaining four districts of Sahiwal, Muzaffargarh, Bahawalpur and Rawlapindi (hilly) have higher ranks in nodes than towns due to the common reason of recent road development in all districts except Rawalpindi which has good roads due to its being, including the Federal Capital of Islamabad.

Figure 7.3

DISTRICT WISE COMPARISON BETWEEN INDICES



On the other hand, out of the remaining 13 districts only four located away from the 95 per cent confidence level band show their high ranks in terms of urban centres and low in nodes. This includes two central industrial districts (Gujranwala and Sheikhupura), one from the northern hilly area (Jhelum) and the other the extreme southern district of Rahim yar Khan, all with different urban characteristics which are beyond the scope of this chapter and will be discussed in Chapter 8 (8.8).

For smooth and equal connectivity values between nodes and towns the same type of location for ranked districts is expected in Figure 7.3d which compares the number of edges between nodes and towns but a close examination of Figures 7.3c and 7.3d show a contrast in the position of different districts which can be identified by (i) ranking the districts according to nodal and urban connectivity values measured by the same index and the residuals can be traced with the help of a rank scatterdiagram (see Figures 7.3a, 7.3b, 7.3g, 7.3h). (ii) comparing district-wise values of nodal connectivity with urban connectivity measured by the same index.

In this case it is only possible for the indices of linkage connectivity (β and γ) as the two southern districts have no circuit connectivity on urban scale, while on the nodal scale the values of absolute circuit connectivity are 13 and eight for both districts. Similarly, the values of relative circuit connectivity (α) for these remote districts of Dera Ghazi Khan (23.6 per cent) and Bahawalpur (13.1 per cent), suggest that the networks of these districts do not possess the fundamental circuits in the shortest path distance between the towns, as these are located in a straight line along the main rail or road.

A close examination and comparison of the index on Tables 7.1a and 7.1b shows that the higher values of (i) nodal connectivity (rather than urban connectivity), Pi index more than one and values of Km (per square mile route density), for these two districts point to a surplus network away from the towns, which serves the rural population through nodes. In other words, this surplus route of these districts helps the remote rural population to connect with the towns (along the rivers).

Among the rest of the districts the 'α' values difference between

nodal and urban connectivity is higher on the nodal scale in the six districts of Gujranwala, Bahawal Nagar, Lahore, Sahiwal, Sialkot and Campbelpur. It shows that in these districts the simple junctions (nodes) possess a higher percentage of their possible fundamental circuits than the town's. It seems to be due to various factors like

i. more than one road/connection between two towns
ii. dispersed urban settlement pattern
iii. new development in the peripheral areas of the district.

On the other end the networks of the four central canal colony districts of Multan, Sheikhupura, Sargodha, Lyallpur and Jhang have a comparatively high urban connectivity, probably due to the fact that a large proportion of these nodes in these districts (except Jhang) are towns. It is beyond the scope of this chapter to identify these centres according to origin and growth, which is the focus of the subsequent study.

Figure 7.3g gives a general idea of the changes in district level absolute circuit connectivity based on both nodes and towns. A Spearman's rank correlation (0.712) for all the districts shows a close relationship between the nodal and urban circuits. In Figure 7.3h the relationship is close as well but slightly different. This is due to change in the residuals of Gujranwala and Bahawal Nagar, which have low ranks on the 'μ' scale as compared to the other districts, but due to their minimum number of vertices, the nodal relative circuit connectivity has shown a big change.

Despite the slight instability of some of the indices discussed above, the general pattern of circuit connectivity for both nodal and urban networks is clear. A similar pattern for these networks can be predicted on linkage connectivity scales (β and γ). A comparison of the values measured with 'β' for both nodes and towns, shows that only five districts of Multan, Sheikhupura, Jhelum, Lyallpur, Rahim yar Khan and Sargodha have higher urban connectivity than the nodal connectivity indicating that in these districts the ratio of urban centres to edges is higher than that of the nodes to edges. This is due to a number of factors which are analysed below:

i. either the nodes could not occur due to fewer inter-connections
ii. or, the nodes changed into new towns
iii. or, the inter-connections took place only between the already

existing urban settlements of the districts. The answer to all these questions can be obtained through the analysis of metricated indices in the next chapter.

Finally to get a complete picture of the nodal connectivity, the values for each district obtained through four topological measures ($\mu, \alpha, \beta, \gamma$) are scored for the purpose of a comparison between urban and nodal topological structures (see Figure 7.3e). On the nodal scale these districts can be divided into four groups of high, medium, low and lowest nodal connectivity (see Figure 7.1). It shows that the highest nodal connectivity can also be seen in the newly settled central districts, including two western districts of Mianwali and Muzaffargarh where the development is still in progress under TDA (Thal Development Authority). The second group of medium connectivity includes the districts where the main network is between the old towns but the nodal connectivity is higher due to good road development. A comparison of these scores between nodal and urban composite connectivity scores shows close correspondence in some cases, while in others there are contrasts which need comments after the analysis of metricated indices (see Section 8.8).

7.5 Changes in Connectivity

The district level changes in connectivity are achieved by studying the structure and development of the rail and road networks since 1931. The present day degree of connectivity has been analysed (see Section 7.3) in two phases: (1) a topological analysis between the towns as vertices including both rail and road networks; (2) on the basis of road junctions dealing only with the road network, which mainly began to evolve in the 1930s. Before that the road network either did not exist or was not designed for motor use and the railway was one of the main means of communication both for people and goods.

The values of connectivity for the rail network in 1931 have been calculated and the changes for a period of 40 years measured* (see Table 7.2). A high percentage of changes can be seen in the districts of

*At that time the capacity of the individual railway lines did not differ much from one another, therefore while comparing the changes all the connections will be assigned equal weight.

Table 7.2

DISTRICT LEVEL CHANGES IN CONNECTIVITY 1931 - 1971

	Districts	A	B	C	D	E	F	G
1	Rawalpindi	20.04	33.31	55.55	55.55	0	1.00	0
2	Campbelpur	46.46	25.70	23.81	52.38	28.57	2.19	120.00
3	Jhelum	112.80	105.76	23.81	57.14	33.33	2.40	140.00
4	Gujrat	58.59	38.87	22.22	55.55	33.33	2.50	150.00
5	Sargodha	67.02	56.94	21.67	56.67	35.00	2.61	161.50
6	Mianwali	87.85	75.03	26.67	66.67	40.00	2.50	150.00
7	Jhang	66.67	40.02	20.00	46.67	26.67	2.33	133.35
8	Lyallpur	116.00	108.15	33.33	80.95	47.62	2.43	142.87
9	Lahore	49.61	34.63	20.51	51.28	30.77	2.50	150.00
10	Sialkot	63.43	42.84	19.44	55.55	36.11	2.86	185.90
11	Gujranwala	28.35	14.58	25.00	45.83	20.83	1.83	83.32
12	Sheikhupura	105.85	92.52	26.67	73.33	46.66	2.75	175.00
13	Multan	87.00	82.25	33.33	71.79	38.46	2.15	115.40
14	Sahiwal	96.08	75.00	20.83	58.33	37.50	2.80	180.00
15	Muzaffargarh	95.00	50.00	19.05	66.67	47.62	3.50	250.00
16	D.G.Khan	-	-	-	-	-	-	-
17	Bahawalpur	7.50	-10.00	26.66	40.00	13.34	1.50	50.00
18	Bahawal Nagar	16.69	15.52	40.00	46.67	6.67	1.17	16.68
19	R.Y.Khan	51.69	34.08	25.00	54.17	29.17	2.17	116.68

A = Percentage connectivity change in Beta Index (1931-1971)
B = Percentage connectivity change in Gamma Index (1931-1971)
C = γ' (1931 by assigning vertices as in 1971)
D = γ (1971)
E = Actual change (1931-1971) between γ and γ'.
F = Ratio between C and D
G = Percent change (1931-1971) between γ' and γ.

Lyallpur, Sheikhupura, Jhelum, Sahiwal, Muzaffargarh and Mianwali. The districts with medium change are Multan, Sargodha, Jhang, Sialkot, Gujrat and Rahim Yar Khan while on the lower end of the scale come the remaining peripheral districts of north and south.

The changes recorded on pure road network scale are not very different. These changes are comparatively high in the districts where recent economic growth, especially in the field of agriculture, is in progress and (these districts) also provide a high connectivity to their rural population. It mainly includes the districts of Mianwali, Muzaffargarh and Bahawal Nagar. In contrast the districts of Multan, Lahore, Sargodha and Campbelpur, which had comparatively high connectivity at the end of 1931, did not show much change. Jhelum which had the lowest values in 1931, improved its road connectivity in the present day network as a result of the recent short cut road connections, between the central districts of the Panjab and The Federal Capital of Islamabad.

Between 1931 and 1971, the road network of Panjab developed on a regional rather than on a district basis. The connections considered important were widened and improved, irrespective of the districts they passed through, and by 1971 the network was composed of primary and secondary connections. Secondly as the number of vertices for both periods varies, therefore the beta index which only records ratios, does not give as clear a picture as can be obtained by looking through the relative linkage connectivity 'γ' as it records the changes with the increase or decrease of number vertices, that exist in that period of time. Instead of comparing the separate values on this index, it can be more conveniently produced by considering all points that were finally brought into the network for 1971 by setting for all descriptions even in 1931, to calculate '$\acute{\gamma}$' (see Table 7.2). The difference between 'γ' and '$\acute{\gamma}$' indicate changes and consequently we are able to see a consistently increasing trend. It is clear that the number of points we are interested in, comprise the total number finally brought into the network (1971). Thus '$\acute{\gamma}$' is based on finally connected points (towns 1971) rather than the number connected in 1931. In this case this measure is useful because all values are according to the change in the number of vertices and are relative to the final network rather than previously connected places. The districts can be divided into four groups of high, medium, low and lowest changes in

connectivity (according to the maximum possible edges of their vertices).

i. High (above 40 per cent) changes include the new districts of Lyallpur, Muzaffargarh, Sheikhupura and Mainwali.

ii. Medium changes (30 - 40 per cent) include the districts of Multan, Sahiwal, Sialkot, Sargodha, Jhelum, Gujrat and Lahore.

iii. Low (20 - 30 per cent) changes can be seen in the districts of Rahim Yar Khan, Campbelpur, Jhang and Gujranwala.

iv. Lowest changes comprise the districts of Bahawal Pur, Bahawal Nagar and Rawalpindi.

A comparison of these changes at different scales shows that the values of connectivity differ for a number of reasons:

i. The scale of already (1931) developed network; if the network is already well developed a lesser degree of change can be expected, as is the case of Lahore, Multan and Sargodha.

ii. An increase in the number of vertices also affects the changes in connectivity as it is evident from Rawalpindi, Jhang and Gujranwala.

iii. 'Increase of the edges alongwith the vertices' also contributes to the changes of connectivity. The increasing edges of Lyallpur district can be compared with that of Campbelpur as both of these have equal increase in number of vertices. High changes took place due to increase of edges between the already existing vertices.

It will be interesting to note that the changes for Muzaffargarh, Mianwali and Lyallpur were the highest (see Table 7.2). They had the maximum number of towns on railway network in 1931, and later on developed their connectivity by road. On the other hand the districts showing low changes in connectivity during the period (Bahawalpur, Bahawal Nagar and Rawalpindi) either did not change their number of towns or the existing towns could not get more links to increase the degree of connectivity.

Connectivity could be further examined by weighting these vertices according to their links to evaluate the ratios (Iota index). The highest values on this index also identify the same districts of Lyallpur, Sheikhupura, Mianwali and Muzaffargarh with the vertices originating maximum number of links while on the lower end of the scale are Bahawalpur, Bahawal Nagar and Jhang. Finally, a significant (98 per cent) Spearman's Rho between iota index and changes in connectivity concludes that the districts where towns were already connected

with more links have higher changes in connectivity than those with new towns (not on railway).

Chapter 8
DISTRICT LEVEL METRICATED INDICES

8.1 Introduction

Keeping in mind the variations of the districts in terms of area, population and number of urban centres it is difficult to rely on topological indices for a true picture of connectivity for the districts, as it is expected that metrication of topological indices will change the ranks of the districts on their accessibility scale. This is expected mainly owing to the variation in the spacing of the towns which (on spacing index) varies from 41.75 (for Bahawalpur) to 13.71 (for Lahore and Sialkot). This suggests that there is a wide contrast in the distances between vertices due to the different sizes of their districts ranging from 9587 square miles (Bahawalpur) to 2022 square miles (in Rawalpindi). In this respect the comparison of the shortest paths (topological) between the districts could be misleading. A similar range of variation in total population as well as in urban population can be seen in the districts of the region (see Table 8.1). Ignoring these contrasts, particularly in terms of area, population and distances, makes the comparisons between the districts far more difficult. However, the application of metricated indices will make comparison between the districts possible.

8.2 Pi Index

This measures length per unit of diameter and changes its values according to the surplus of routeways within the region. It is very similar to the topological indices of alpha and gamma which change their values according to redundant routes. As the higher numerical values along this index reflect higher degree of development therefore the northeastern districts of Rawalpindi, Sialkot, Sargodha and Gujrat show more complicated road networks while the districts of Bahawal Nagar, Mianwali and Dera Ghazi Khan have low values. The

Table 8.1

DISTRICT LEVEL METRICATED INDICES 1971

	District	A	U.P	T.P	Dm	Km	L/u	L/p	C	Al	S
1	Rawalpindi	2,022	772	1,755	68	3.45	1,317	2,995	263	6.0	0.509
2	Campbelpur	4,418	123	983	94	8.26	245	1,958	223	17.3	0.452
3	Jhelum	2,772	167	1,048	96	7.00	420	2,633	245	16.0	0.523
4	Gujrat	2,264	280	1,885	69	5.65	698	4,701	50	22.2	0.407
5	Sargodha	4,775	495	2,094	113	6.18	641	2,712	329	74.3	0.540
6	Mianwali	5,403	236	1,098	145	8.91	389	1,812	598	22.5	0.322
7	Jhang	3,401	288	1,549	116	7.07	599	3,220	52	13.7	0.237
8	Lyallpur	3,516	1,052	4,240	79	6.76	2,023	8,154	47	13.3	0.390
9	Lahore	2,216	2,421	3,772	94	6.27	6,858	10,685	217	35.3	0.475
10	Sialkot	2,067	383	2,338	72	4.27	791	4,830	104	30.6	0.506
11	Gujranwala	2,312	590	2,049	69	5.87	1,497	5,200	41	21.0	0.551
12	Sheikhupura	2,312	242	1,636	79	4.58	479	3,240	62	21.7	0.282
13	Multan	5,630	880	4,012	116	6.98	1,090	4,971	77	32.0	0.473
14	Sahiwal	4,224	385	2,809	83	7.76	708	5,164	78	18.6	0.505
15	Muzaffargarh	5,613	120	1,554	132	10.77	230	2,983	11	17.8	0.247
16	Dera Ghazi Khan	9,359	146	1,134	229	18.03	281	2,184	294	24.9	0.257
17	Bahawalpur	9,587	225	1,073	95	20.71	486	2,317	52	14.3	0.397
18	Bahawal Nagar	3,428	168	1,078	94	7.81	383	2,456	65	13.1	0.288
19	Rahim Yar Khan	4,493	205	1,402	84	9.00	410	2,804	37	19.0	0.570

A = Area (in square miles)

U.P = Urban population (in thousands)

T.P = Total population (in thousands)

Dm = Length of topological diameter (in miles)

Km = Area per mile of route (rail + road)

L/u = Number of urban people per mile of route

L/p = Number of people per mile of route

C = Degree of circuity

Al = Mean accessibility index

S = Shape (Range .06-.93)

values for the rail networks are different. A 99.9 per cent significant correlation (Kendal) between the pi index based on road length and route length (rail + road) indicates that addition of rail length in the districts does not change the ranks, with the exception of a few like Lyallpur, Multan, Gujrat and Rahim Yar Khan where the surplus shows a significant change with the addition of rail length. This change has moved the ranks of Lyallpur and Multan higher due to their minimum percentage of parallel running rail and roads (0.5 per cent and 4.2 per cent respectively) where the railway length helps to increase the surplus. On the other hand a lower movement of the ranks of Gujrat and Rahim Yar Khan is due to their maximum percentage of parallel roads (36 per cent and 45 per cent respectively) which does not contribute to the increase of surplus. While comparing the degree of development with route length it will be interesting to note that a Spearman's Rho of + .443 between actual road length and pi index indicates a lower degree of significance than that of + 0.684 (99.9 per cent significant) between equivalent road length (on the basis of ten feet standard width) and pi index. This suggests that though there is a positive relationship between the degree of development and route length, yet the surplus of the roads is higher in the districts, where the roads are wide. Similarly a correlation of -.585 (significance level .005) between spacing index and pi index suggests that the districts with sparsely located vertices have a lower degree of development and vice versa. It seems reasonable to expect that the shape of the district will differ in its degree of development. To test this all the districts were measured through the simplest technique which relates properties of the area to the properties of a circle of equal area (Haggett 1965), to compare with the pi index. A positive correlation of 0.519 (significance level .012) suggests that the shape has a significant effect on the pi index and the districts with compact shape have higher route surplus than the districts with less circle-like or compact shape.

Table 8.2 gives the values for the degree of relationship (Spearman's Rho) between pi index and selected variables which have a comparatively high relationship with the pi index based on both rail and roads than roads only. This indicates that the addition of rail route length as a surplus favours a stronger relationship of pi index with these variables. The correlation is positive with total population and rather

Table 8.2

RELATIONSHIP BETWEEN PI-INDEX AND SELECTED VARIABLES (1971)

Variables		Pi index (roads)	Pi index (rail + road)
1	Total population	0.375 (0.057)	0.495 (0.016)
2	Urban population	0.379 (0.055)	0.549 (0.008)
3	District level urban population change (based on 1931=0)	0.396 (0.047)	0.553 (0.008)
4	Urban population in towns more than 20,000 +	0.358 (0.067)	0.517 (0.012)
5	Number of urban people per square mile	0.471 (0.021)	0.540 (0.009)
6	Number of urban people per mile of route	0.393 (0.048)	0.500 (0.015)
7	Percentage of registered industries	0.395 (0.047)	0.506 (0.014)
8	Average population size of new towns (1931-1971)	0.422 (0.036)	0.537 (0.009)
9	Average population size of new towns (1931-71) on rail	0.434 (0.032)	0.488 (0.018)
10	Percentage of urban population of new towns (1931-71)	0.369 (0.061)	0.490 (0.016)
11	Arrival of wheat in Mandies	0.304 (0.104)	0.515 (0.013)
12	Number of hospitals	0.409 (0.041)	0.559 (0.007)

Note: Figure within brackets indicates significance level.

stronger with urban population and shows the strongest attitude towards the change of urban population after 1931. This is to be noted that per square mile density of urban population is more strongly correlated with the pi index than with per mile route density. Looking in terms of urban population size of the districts a varying degree of positive correlation between pi index and urban population (20,000 +), average population of new towns (1931-1971), new towns on rail and percentage population of new towns, suggests that the districts with the new towns (during 1931-1971) have a higher degree of development than those of larger size towns, and with those where the average population size of new towns on rail is higher. Finally a higher degree of correlation with the arrival of wheat and number of hospitals indicates the association of degree of development with agricultural produce and health services.

8.3 Theta Index *

This is a ratio of the network as a whole to its vertices, and expresses the function of an average vertex in terms of route length, freight, volume and traffic flow (Kansky 1963). In this study it is used to illustrate the difficulties of comparing district level network (which covers very different sized areas) in terms of route length and traffic flow. The ratios can be subdivided further according to the definition of the properties, ie, vertex, length and flow.

i Per town road length
ii Per town route length (rail + road)
iii Per node road length
iv Per town traffic flow (car units)
v Per node traffic flow (car units)

Per town road length ratios vary according to the size and number of urban centres in the districts. Smaller networks with a large number of urban centres (Lahore and Sialkot) have a low score while the large networks with small numbers of urban centres (Rawalpindi and Jhang) have high scores. These scores conform to the predicted pattern of

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* For detail see Appendix A

district level high accessibility (between towns) being measured by high indices. Sargodha with a large network (ranking first on actual road length) has a low score on the theta index, where it reflects a very large number of vertices. Similarly, Bahawal Nagar (one of the smallest networks) also has a high theta index score but in this case the index reflects the large area and very small number of vertices which are far apart and the road mileage in relation to the number of vertices is correspondingly great.

Per town route mileage ratio or theta index based on both rail and road length is very similar to that of the scores per town road length ratio, which is confirmed by a positive Rho of 0.936 (99 per cent significant). It shows an equal distribution of rail mileage according to the vertices and indicates a major influence of road length as compared to rail maileage, on the theta index.

With the addition of rail mileage an increase in per town route length is expected, but the change in terms of scores is very small and too small to disturb the ranks. The decrease in the scores can be noted in the districts with small networks of Campbelpur, Muzaffargarh and Rahim Yar Khan, while the increasingly large networks are Multan and Lyallpur districts (ranking first and second respectively on rail net length).

With per node route length ratio, the pattern is very different due to varying town-node ratios in the districts. The values are high in the less developed district of Bahawal Nagar, Campelpur and Dera Ghazi Khan, while low in the districts of Lahore, Sahiwal, Lyallpur and Sargodha which provide comparatively more transportation linkage to their hinterlands and rural population and, where the pattern of internal high accessibility can be predicted.

In a developing region like the Panjab, it is expected that the larger the centre the more linkage and facilities it will provide to its hinterlands and other smaller urban centres. Therefore three underlying factors are assumed to influence the index of transportation network within a region; structure, length and function. To compare the districts according to the functions of their vertices it is

possible to weight the networks according to their traffic flows. These distorted ratios between the total network and their vertices will be useful to identify the variations of the districts in terms of traffic flow carried by their vertices (towns). According to Zaidi (1968) flow pattern depicted in terms of the volume of traffic is certainly a superior index to the efficiency of transportation and communication facilities.

8.4 Traffic Flow

The picture, depicting per vertex traffic for the districts, is interesting. The most striking feature is that the districts, located along the main roads, Lahore to Rawalpindi and Lahore to Lyallpur via Sheikhupura, score high ranks. Rawalpindi in spite of its peripheral location (with a low number of towns) secures the leading position because of the Federal capital of Islamabad. It is followed by Lahore district, which is due to the large population and functional complexity of Lahore city. These districts are then followed by relatively more densely populated and economically prosperous districts of Lyallpur and Sheikhupura. The position of Jhelum district is high in the districts of the first quartile. This is because of the neighbouring position of Rawalpindi and Islamabad which helps Jhelum to secure the highest rank in terms of traffic flow. Jhelum district plays the same role in connecting Islamabad with the region as Sheikhupura plays for Lahore. Both of these cities (Islamabad and Lahore) with peripheral location in the north and east are connected with the centre through their neighbour districts of Jhelum and Sheikhupura respectively. Most of the towns of these districts enjoy the highest ratio of traffic flow, due to their location on the main route. High score values can be predicted for these towns on general'nodal accessibility', and particularly on 'time accessibility' scale because high traffic flow through intersections reflects the efficiency of the network.

A comparison of theta index (traffic flow) between the districts shows that the values are high in the small network (districts) of wide roads with main cities (Rawalpindi, Lahore, Gujranwala) while the large size districts with small towns (Bahawalpur, Bahawal Nagar, Dera Ghazi Khan and Mianwali) have low scores. Among the four southern

and peripheral districts (of Bahawalpur, Bahawal Nagar, Dera Ghazi Khan and Rahim Yar Khan) the position of Rahim Yar Khan comes up (ranks eighth) strikingly in the index. This seems to be because of its extreme southerly location (see Figure 1.1), with a main route through it, connecting the Panjab with the seaport of Karachi. A high frequency of truck flow helps the district to secure a high rank on this index. The importance of this link will be further highlighted through eta index, in the next section.

A significant (99.9 per cent) correlation between per town and per node traffic flow ratios, suggests a similar pattern of the districts. Finally, to test the assumption that structure of transportation network is a reflection of the network's traffic flow pattern, the hierarchies of the districts based on per town route length and per town traffic flow are compared. A positive but low correlation (+.233) suggests a big contrast in the hierarchy of the districts in terms of length and width of the links and the traffic they carry. Rawalpindi with the highest traffic flow ratio has the lowest scores on route length ratio and on the other hand Sialkot with a high route length ratio has a low traffic flow ratio. The districts with small changes in the hierarchy can be noted as Lahore, Multan, Bahawalpur, Gujranwala, Sahiwal and Muzaffargarh. These contrasts are due to width of roads (ratio between actual and equivalent roads) which is more significantly correlated with traffic flow ratios (+.614) than the route length ratios (.235), which *gauge low*.

8.5 Eta Index

This is also a ratio measure and is used to compare the districts. In the topological indices edges represent just the physical connection irrespective of the distance or any type of weight but in the region edges vary according to their qualities (such as length, width, location and particularly the flow they carry along). This variation makes the comparison very difficult. Eta index is a ratio indicating the position of average edge in terms of its quality. This expresses the relationship between the transportation network as a whole and its routes as individual elements of the network. On the basis of these ratios it is possible to compare the districts. As the values of this index totally depend

upon the definition of the 'vertex', the inclusion of more nodes in the network gives lower values. Therefore both the definitions have been adopted in this analysis (ie. edge between 'towns' and 'nodes'). A positive but weak correlation (+.553 sig. .008) between both definitions suggests a variation in the pattern, which is due to a considerable contrast between the ratios of the number of nodes and towns in the districts, like Rawalpindi, Muzaffargarh and Dera Ghazi Khan on the one side (high ratios) while Jhelum,Sargodha and Multan on the other have lower ratios of nodes. The values obtained on this index are different as by theta, but the hierarchy of the districts suggests a similar pattern of accessibility.

A transport network can be thought of either as a system of routeways (channel of movements) or a system of traffic flow moving along these channels. The channels are measured by connectivity while the movement itself can be described by traffic flow and its density. The integration of the people within the Panjab region can be measured by examining the extent to which the transportation networks are utilized. This analysis has been limited to the road transport system of the region. The road networks of the districts are mainly used by both types (non motorised and motorised) of traffic. Among the non-motorised traffic bicycles and animal drawn vehicles are important means of transportation (for people and goods respectively) for the distances of approximately ten miles. With the exception of a few routes, the railways, after playing an important pioneer role in the establishment of regional transport infrastructure, have been dominated by the steady rise of the road traffic in the whole of Panjab.

To understand the importance of road networks in terms of the traffic carried by their links, the traffic flow has been measured by eta index at district level. It gives a close picture of the average movement in the districts by briefly examining the modes of both motorised and non motorised transport systems separately.

a Non Mototised Traffic

As the spatial distribution of overall traffic flow among the districts of the Panjab is characterised by wide variations; a number

Table 8.3

RELATIONSHIP BETWEEN TRAFFIC FLOW (ETA INDEX)
AND SELECTED VARIABLES, (1971)

Variables	Motor cycles	Motor cars	Buses	Trucks	Car Units
1 Area	-.451 (.027)	-.663 (.001)	-.602 (.004)	-.410 (.041)	-.538 (.009)
2 Total population	.581 (.001)	.498 (.015)	.593 (.004)	.371 (.059)	.549 (.008)
3 Urban population	.549 (.008)	.456 (.025)	.593 (.004)	.300 (.106)	.498 (.015)
4 Density	.707 (.001)	.644 (.002)	.733 (.001)	.393 (.048)	.595 (.004)
5 Number of urban people per square mile	.652 (.002)	.683 (.001)	.735 (.001)	.433 (.033)	.630 (.002)
6 Percentage of urban population (total population)	.323 (.089)	.421 (.037)	.438 (.031)	.323 (.089)	.442 (.029)
7 Actual increase of total population 1961-71	.552 (.008)	.514 (.013)	.596 (.004)	.431 (.033)	.584 (.005)
8 Width of roads	.681 (.001)	.407 (.042)	.623 (.003)	.513 (.013)	.619 (.003)
9 Number of urban people per mile of route	.655 (.002)	.560 (.007)	.689 (.001)	.399 (.046)	.575 (.005)
10 Percentage of industries	.830 (.001)	.570 (.006)	.685 (.001)	.424 (.036)	.573 (.006)
11 Spacing of towns	-.618 (.003)	-.644 (.002)	-.636 (.002)	-.364 (.063)	-.446 (.028)

Note: Figure within the bracket indicate significance level.

of factors seem to be responsible for the distribution of non motorised traffic. Among the most important are the physiography, irrigation and agriculture as well as the size of the roads. The physiography of the districts has an important bearing on the scores of the index (for non-motorised traffic) which are lower in the hilly districts and high in the eastern and central districts (see Figure 8.3) where the agricultural produce is transported to the markets. A significant correlation (+0.567) between the eta index for non motorised traffic and the arrival of wheat in the markets confirms the fact. Similarly, high scores for short distance movement of the people can be expected in the districts with high ratios of urban population and industrial-ization, as it can be examined by the difference of relationship. The degree of relationship between eta index scores for bicycles and percentage of registered industries (+ 0.705) is higher than the relationship of the index with urban density (+ 0.43), which suggests that the ratio of industries has a comparatively great influence.

Finally on the basis of the units for non motorised traffic it is concluded that the belt of high score districts extends from Lahore to Lyallpur and then up to Gujrat in the north. The low score zone lies in the west from Rawalpindi to Dera Ghazi Khan through Campbelpur, Mianwali and Muzaffargarh which includes either hilly area or desert with an absence of industries, urbanization and markets as compared to the western part of the region. The zone corresponding to comparatively poor physical, commercial and administrative entities is expected to show a good response with the new development of roads particularly in the districts of Mianwali and Muzaffargarh.

b Motorised Traffic

By the motorised traffic flow we encompass not only a range of transported commodities but also the energy flow that leads to the creation of tensional networks (Haggett 1969). This section deals with the modes of transport which move the people and goods for a distance of more than ten miles. The district level eta index measured for the separate modes of motorised transport will be helpful to identify the districts according to the flow carried by each link, which can then be compared to understand the importance of those links

(which were difficult to assess by the simple non-metricated indices). Apart from that, coming to the main focus of the study, which is to measure the relationship between structure of transport networks and urban growth in the region, this analysis is employed because it is useful to test the following assumptions:

1. The flow along the links itself changes the value of a link and therefore the pattern of the shortest path.

2. The flow along the links will lead to re-evaluation of the locational advantages of vertices within the network and in the longer term, to consequent changes in the land use and traffic generation.

3. The flow along the links will affect the locational accessibility in terms of time and cost on local, sub-regional and regional links.

The modal variations in the districts* reflect a number of reasons. These are mainly due to variations in the locational structure of different complementary activities, their type, location and intensity. Apart from that, the geographic pattern of various population units and economic characteristics have important implications for these variations. The complementarity of urban sub-areas is the most important factor in traffic movement. The north eastern districts which provide good locations for activities in the urban areas have high scores, while the peripheral districts with poor activities have low scores.

Looking at the individual modes of transport according to the activities the pattern of motor cycles movement, which are either used within the city or for a short distance, is similar to that of non-motorised traffic, covering the same zones on the top and bottom of the scale. The hierarchy of the districts established by motor cars is different and reflects their dominance either in highly urbanized districts with big cities or the districts lying on the way to cities. The pattern follows the main highways of the region. The high peaks of the flow are evident in Rawalpindi due to Islamabad. They decrease down to the south from Gujranwala, Lahore and Sheikhupura to Lyallpur, and then further down to the districts with poor economic health.

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* The ranks of the districts according to the eta index scores measured by various modes of motorised and non-motorised traffic are given in Appendix J.

Our major concern is with public transport by trucks and buses which were more or less restricted to serving routes within a particular district. However, since 1959, that restriction was removed and now they are free to operate throughout Pakistan. The basic aim of these modes of transport is to provide a reliable and efficient transport service adequate to meet the economic and social requirements of the movements of goods and people. These may be considered in the following two groups which vary according to volume, origin and destinations, distances and cost.

1. movement between major centres of production and consumption
2. distribution and local movements between the major economic centres and the near and far hinterlands.

The spatial distribution of bus flow assessed by eta index suggests that the higher scores are in the districts with good spacing of towns and economic activities. As the origin and destinations of truck movement are spread throughout the country, the pattern of movement on this scale is not smooth. Apart from that the irregular distribution of the districts in terms of size and location create variations (particularly the use of bridges) for the long distance movement, at the district level. It shows that the spatial distribution of traffic flows among the Panjab districts is characterised by wide variations as a result of contrasts in the different structural dimensions: demographical, occupational, industrial and functional. It will be interesting to identify these dimensions according to their relation with the individual modes of traffic flow, measured by the eta index. This relationship has been measured with Spearman's Rho and is presented in Table 8.3. The Table shows the extent of the relationship between the per link average ratio of traffic flow (eta index) and some selected variables under discussion.

For smaller units like districts the flow of motorcycles is a useful medium to demonstrate the analysis of linkage pattern of the region. They are used for a small scale distance, therefore the picture of relationships obtained through this mode of transport gives a clearer idea than the others which are mostly used for inter-district movement. The flow ratio of motor cycles shows a high degree of relationship with the distribution of industries. This pattern is then followed by the densities of total population. It

indicates that this mode of transport is more concerned with the location of activities in the urban areas. An inverse correlation with area and spacing of the towns suggests that motor cycle flows are high in the small and complex districts.

As the road network is mostly used by passenger and goods transport (buses and trucks) and the ratio of private cars is comparatively less, a slightly different picture can be expected for motor cars. An examination of the relationship between motor car flow and other variables shows that it is highly associated with smaller size, complex and densely (urban) populated districts, while the flow of buses (which serve rural populations as well) is more significantly related to the population density (rural and urban) and the distribution of industries (see Table 8.3). Being a major and scheduled means of communication the flow of buses in the various districts gives a useful idea about the frequency of bus services. An inverse and significant relationship of bus service with area and spacing of towns highlights important facts ie., the increase in the distance between the stations results in fewer and fewer trips. This is because the increase in distance affects the cost of transportation which can be avoided by minimizing trips. In some cases it has been observed that the routes are served by only one or two trips and generally the daily requirements of the people of those areas are met through short trips. Apart from that, trip generation is further characterised by the socio-economic characteristics of the people of the region. The districts with high urban and total population densities have a good frequency of bus services, as is evident from the degree of correlation between the bus flows ratios and the variables of urban population densities (see Table 8.3). Similarly, the relationship of bus flows with distribution of industries (+.683) suggests that large numbers of workers in secondary and tertiary activities directly affect the generation of trips as they increase the level of movement. These activities add income to the industrial urban centres and these towns encourage further generation of trips, which makes the overall ratio of bus flow in the district high. A high correlation between flow and densities of population is simple to explain as the flow is affected by land use intensity. It describes the functional size or importance of a tract and intensity is measured in terms of per unit area where greater densities are likely to generate more trips than

the lower densities. So it is concluded that the bus flow ratios follow the pattern of density of population.

As the movement of trucks is not scheduled and is considered as intra regional rather than inter regional flows, the spatial pattern of truck flow in the districts is very different from that of buses. Its comparatively low correlation with all the variables can be explained by its long distance and independent movement, particularly between the Panjab and Sind (Karachi), as is evident from the high rank of the southernmost district (Rahim Yar Khan) of the Panjab which is crossed by all the trucks moving between the Panjab and Sind. Similarly in this respect, it is clear that the districts through which the seaport of Karachi is connected by district routes which have high eta index scores for truck flows. Multan and Jhang are the best examples of this type of flow. The internal flow of the region is dominated by the industrial belt including Lahore, Gujranwala and Sheikhupura. Jhelum and Rawalpindi play an important role in passing the flow (through their networks) between the North West Frontier Province and the Panjab and then on to Sind Province. The position of Gujrat district remains lower as most of the flow coming from the north and the North West Frontier Province is distributed in Jhelum district.

Finally it is concluded that despite the slight instability of some of the modes, which the above discussion suggests, the general pattern of traffic flow is clear. The districts can be ranked and grouped according to the car units (see Figure 8.3). The overall resulting pattern shows that the networks with the highest traffic flows, are those located on the major highway between Lahore and Rawalpindi (except Gujrat) and then Lahore to Lyallpur all of which have considerable industrial and economic activity. On the other hand the districts with the lowest scores are Mianwali, Bahawal Nagar and Dera Ghazi Khan and these also have low scores on economic activities. These final scores of the traffic flow highlight the pattern of internal accessibility in terms of transport efficiency.

The examination of the general pattern of district level accessibility obtained through topological and metricated indices, suggests that there are regional contrasts in the overall pattern. It is beyond the

scope of this chapter to look at the regions for this in detail. However, some of the more important reasons should be outlined as they are pertinent to the subsequent discussion. But before that there are some more common factors which play an important and intermediate role between the relationship of connectivity and urban growth. It will be useful to look at the districts from as many angles as possible, thus some more indices of shape, efficiency and circuity have been included.

8.6 Shape

A big variation in the connectivity can also be expected due to the variation in the shape of the districts, therefore it is useful to keep in mind the shape of these districts while comparing in terms of connectivity. The shape* index is also important as it can affect certain graph theoretic measures (Kansky 1963). The index is obtained as per Haggett's (1965) formula for the districts.

The shape of the districts can be identified according to the three theoretical lattices based on a triangle (0.42), square (0.64) and hexagonal (0.83). It is evident from the table 8.1 that all these districts have values lower than the square and hexagonal shapes. Among these, the districts of Rahim Yar Khan, Gujranwala, Sargodha, Jhelum, Rawalpindi and Sialkot have higher (than a triangle) values, while on the lowest scale there are Jhang, Muzaffargarh and Dera Ghazi Khan.

8.7 Efficiency Index

Earlier discussion reveals that a large central place should have better connectivity within the region. Similarly in a region like the

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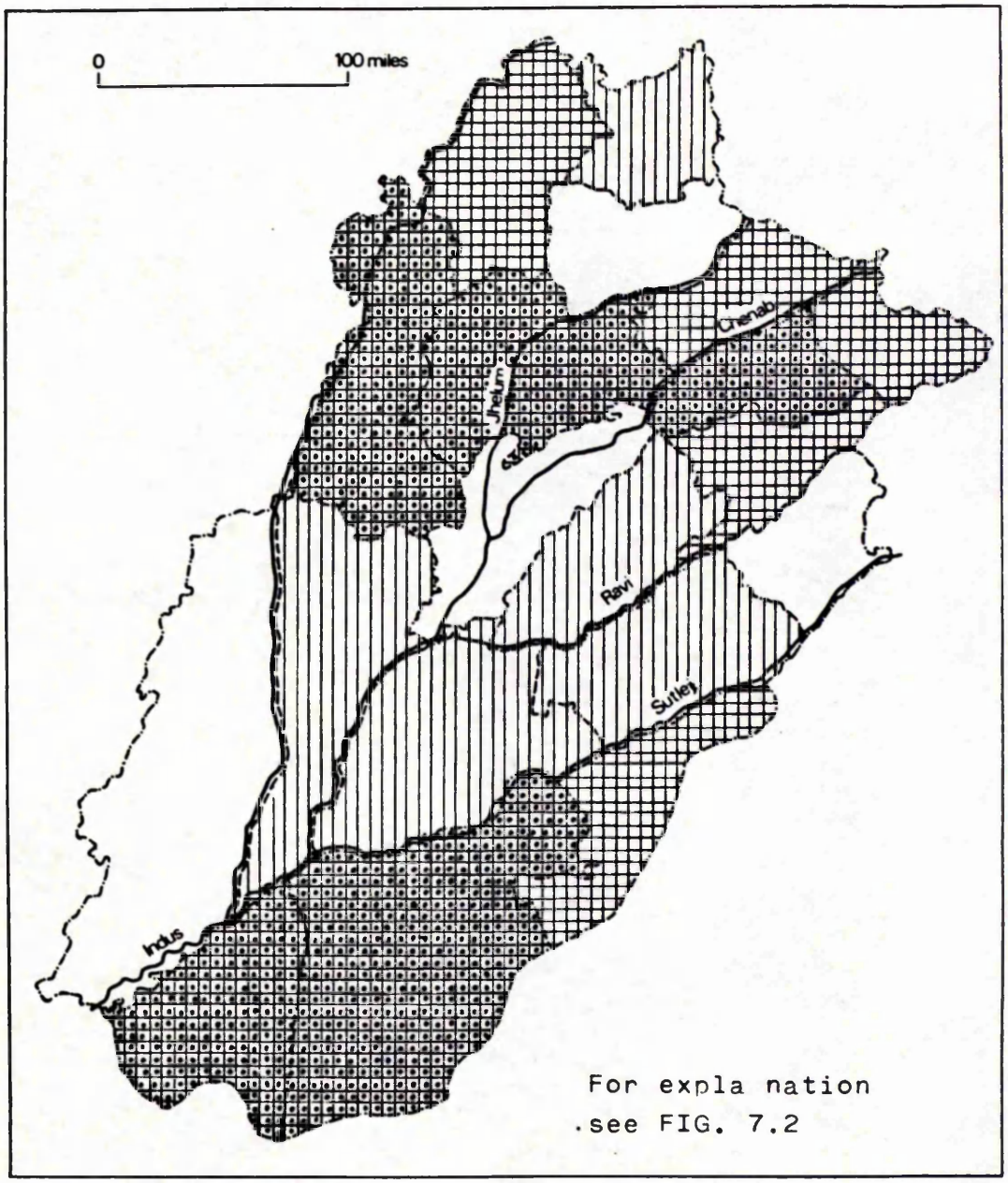
* The shape index for individual districts has been adopted where the index for a district (A) may be expressed as the ratio of the area of that district (A) to the area of the circle with the longest axis, 'L' as a perimeter, R^2 so that 'S' = A/R^2 or 1.27 A/L^2. Here constant value 1.27 is so adjusted that the circle could have an index of 1.00 with ranging value down towards 0.00 showing circular and elongated shapes respectively.

FIGURE 8·1

EFFICIENCY OF DISTRICT LEVEL NETWORKS
1971



Panjab, where district headquarters hold a central position (among its towns) in administration and exchange of socio-economic activities, it is to be expected that these should have a higher efficiency within their respective district than any other town. Smeed (1968) measured the average length of journey from the suburbs to the C.B.D. for different types of street plan in towns with the same area and found that the values ranged as follows:

0.70	$A^{\frac{1}{2}}$
0.87	$A^{\frac{1}{2}}$
1.70	$A^{\frac{1}{2}}$

indicating efficient, inefficient and highly inefficient road plans. The mean value for realistic case studies was $d = 0.87\ A^{\frac{1}{2}}$. This shows the efficiency of the road network by the average distance (d) travelled on some imaginary and real road networks in terms of the area within a boundary (A). Its values range according to the location and distribution of the points. The same method has been used to measure the efficiency of the routes:

i from towns into the district headquarters of the respective district.

ii relative efficiency for the individual headquarters (nineteen) within the regional road network.

Among the district level networks the road plan efficiency ranges from 0.318 (Bahawalpur) to 0.976 (Jhang), reflecting the size, location of the headquarters in the district, distribution of the towns, and degree of the network connectivity. According to the scale the four districts of Jhelum, Jhang, Lahore and Dera Ghazi Khan are classified as inefficient road plans (see Figure 8.1). Except for Dera Ghazi Khan which has towns located far apart, the three districts have low scores due to the location of the respective D.H.Q. within the district and the irregular shape of the whole district (Jhang particularly). Their positions in the whole network show that all of these are most efficient among the D.H.Qs on a Panjab level. The highest values for Bahawalpur within the district are misleading because the network is spread over the whole district (while much of it is desert) and the towns are in a linear position along the border. Therefore its values should be around its neighbouring districts of Bahawal Nagar and Rahim Yar Khan if one consider a smaller portion of its area around the network. This consideration can increase the inefficiency

of Dear Ghazi Khan which also has a sufficient area away from the network. It suggests that in the region the administrative function is dominant and most of the D.H.Qs have highly efficient road plans. Looking at the larger scale, there are only six peripheral D.H.Qs: Rawalpindi, Campbelpur, Dera Ghazi Khan, Bahawalpur, Bahawal Nagar and Rahim Yar Khan, which can be classified as inefficient.

8.8 Circuity Index*

This measures the relative location of a network's individual elements and is a measure of a network's overall character. It assesses the difference between the existing transport system and an imaginary transport system which contains routes connecting all vertices by the shortest possible paths (Kansky 1963). The application of this index is useful for the districts of the Panjab because of their contrasts in terms of physiography and obstacles like rivers etc., which lead to zig zag routes and create 'detours' in the network. The index shows high scores (low values) in the networks with flat plain areas and no obstacles, while it is low in the networks with winding or indirect roads between the centres (see Figure 8.2). It will be very useful to identify such factors which are responsible for detours and decreases in the overall connectivity of the network. A comparison between circuity index and efficiency index will be interesting to assess the efficiency of the whole network with reference to its district headquarters, as these two indices are the reflection of route length and area respectively.

The scores for the index range from 11.26 (Muzaffargarh) to 597.89 (Mianwali) reflecting a considerable contrast between the detours of the districts. The districts with plain areas have high scores on this index, these include Rahim Yar Khan, Gujranwala, Lyallpur and Gujrat (see Figure 8.2). On the lower end of the scale are the districts either with mountainous regions (like Rawalpindi,

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*It is expressed by the formula:

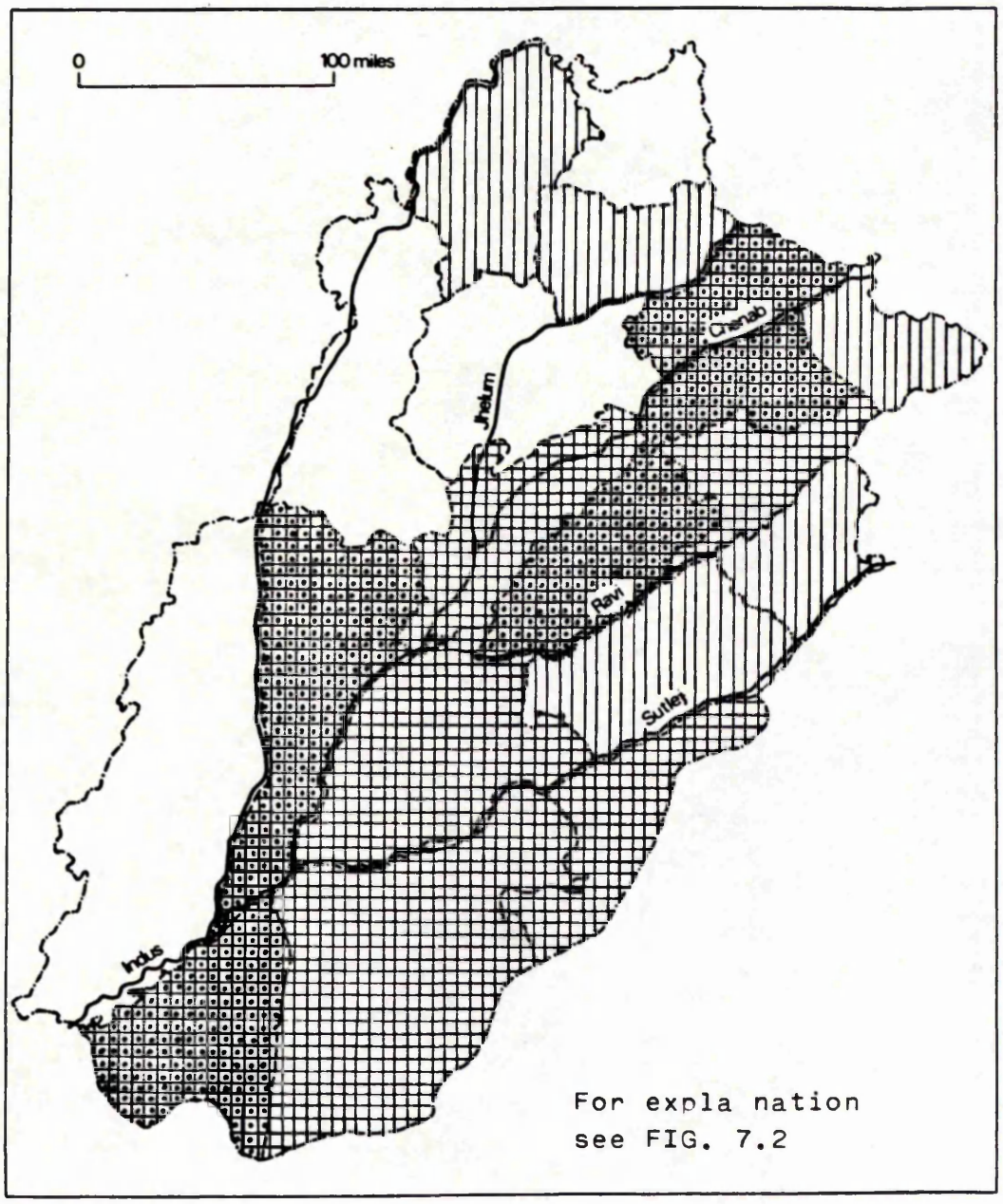
$$C.I. = \sum_{l=1} (E - D)^2$$

E = existing route length;

D = desire line length; v = vertices

FIGURE 8·2

DEGREE OF CIRCUITY 1971



Jhelum, Campbelpur), or the districts divided by rivers with a shortage of bridges over them (Sargodha and Mianwali). One most interesting contrast in the scores of Muzaffargarh and Mianwali (with the highest and lowest respectively) is due to the varying distribution pattern and role of the River Indus, which cuts Mianwali district and divides its towns on both sides with only one connection through a bridge in the extreme north resulting in a maximum detour, while Muzaffargarh has a straight line pattern with a minimum difference from the desire line.

A comparison between the efficiency index and the circuity index for Mianwali district (it ranks third and nineteenth respectively) distinguishes between the indices and suggests that the district has an overall high detour owing to its towns being devided by the river, while the central location of Mianwali town (D.H.Q.) near the bridge favours its efficient road plan, as it provides equal efficiency for all the towns to the D.H.Q. A similar contrast is evident in Sargodha which is divided by the River Jhelum with only one bridge near Khushab. It has a comparatively higher efficiency (ranks fifth) because a major portion of its towns are around the D.H.Q, than circuity (ranks eighteenth) because of a comparatively high ratio between actual and desire line distances due to the river. Campbelpur is also a hilly district, but with towns centrally located it shows a similar contrast between efficiency and circuity indices where it ranks sixth and fourteenth respectively. On the other hand, the districts of Lyallpur, Jhang and Muzaffargarh have opposite hierarchical orders as these are located in the plain areas and high scores on circuity can be expected. All these districts have high scores on circuity index but due to their D.H.Qs being in central locations (which makes it difficult to reach them from all towns of the district with equal efficiency) it has low scores on efficiency index.

8.9 Comparison *

Throughout the study it is important to notice the great disparity among the districts in respect of their sizes. The smallest is

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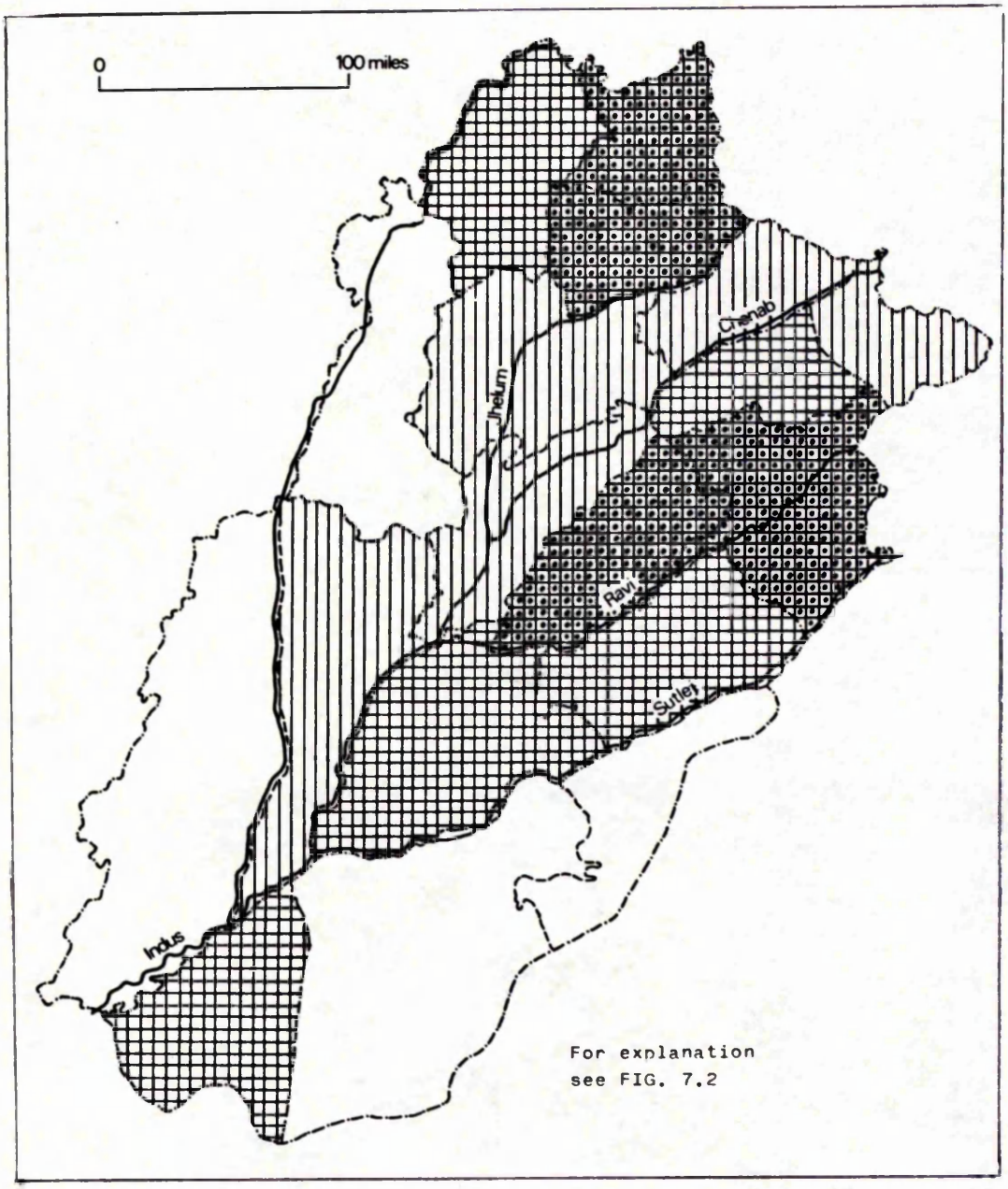
*The district level socio-economic indices are given in Appendix 'K'.

FIGURE 8·3

DISTRICT WISE PER VERTEX TRAFFIC FLOW

1971

[BASED ON CAR UNITS]



Rawalpindi (2,022 square miles) while the largest is Bahawalpur (9,587 square miles), almost five times the size of the former. In a region like the Panjab where the disparity is prominent in respect of relief, climate, soil, vegetation, agriculture and mineral resources, it has been felt that in many cases the district boundaries are no longer suited nor do they coincide with the regional units. Apart from these the other factors like irrigation, industrial development and means of communication also vary from one district to another. As our major concern in this section is to distinguish among these factors , those which are more closely associated with the district connectivity and accessibility (measured on both topological and metricated scales), an attempt has been made to compare and comment on the districts according to their relative positions with respect to varying characteristics.

Referring back to the composite connectivity scores of the districts, we find that the group of districts on the lowest scale which are least well served by their local transport networks include Dera Ghazi Khan, Bahawalpur, Jhang and Rawalpindi. The contrasts in these districts are due to various reasons. The huge districts of Bahawalpur and Dera Ghazi Khan rank first and second in size and are sparsely populated (with 112 and 122 persons per square mile respectively). Bahawalpur is a part of the vast Indus plain without hills and mountains. On the basis of settlement patterns the district can be divided into three zones of Riverain, Colony and Cholistan, which are inhabited by old settlers, new settlers (Abadkars), and nomads respectively. The Riverain zone is along the River Sutlej with some urban centres, Bahawalpur being the largest, followed by Ahmad Pur East and Hasilpur. With the immigration of new settlers there occurred an agricultural revolution with canal irrigation and the spread of agriculture which in turn led to the growth of already existing towns of Bahawalpur and Hasilpur (more than 100 per cent change during 1961-1971). As most of the district is still desert and as all the urban centres are in a straight line along the river, the difficulty of the desert is among the factors ensuring that only the minimum number of routes necessary to link these centres would be constructed, and this has contributed to the districts low scores on all the connectivity indices. Apart from that the size of this district is the main factor contributing to its lower scores on the metricated indices measured

by unit area. The characteristics of Dera Ghazi Khan district are similar in terms of size and distribution of old settlements, as well as traffic flow but are different in terms of period of rail development, width of roads, urban population growth and ratio, efficiency of road network between the towns, degree of circuity and accessibility etc., which Bahawalpur ranks comparatively higher than Dera Ghazi Khan. For both of these districts the overall reason for low scores on all the indices is size, peripheral location, low degree of urban and industrial development. In addition to that the vertices are spread almost in a line through both districts and minimal network is adequate.

Among the other districts with low connectivity scores are the northern districts of Jhelum and Rawalpindi with varying characteristics. Rawalpindi, the smallest district in size, is a mountainous tract with poor agriculture. Until the introduction of British rule, it was sparsely populated with about five per cent urban population according to the first estimates of 1871. Rawalpindi became a cantonment of considerable size (first occupied in 1849) and shortly afterwards the headquarters of the division. Meanwhile as soon as the city was connected with the railway it sprang into importance and grew like a mushroom. The subsequent development of the district as a hill resort for europeans seeking to avoid the hot weather, saw the development of towns like Murree. Due to the difficult terrain the district did not show any change in the number of urban centres until 1952, when Kahuta and Wah Cantonment grew up with populations of more than 5,000 people. Accompanying these changes in urban growth, the shift of the Federal Capital made it the second largest urbanized district in the Panjab and in 1971 almost 44 per cent of its population was classified as urban out of which 80 per cent is in the city of Rawalpindi/Islamabad, 14 per cent in Wah Cantonment and only six per cent in the rest of three towns. It shows a big concentration in the district and particularly in the twin cities of Rawalpindi and Islamabad,which along with the difficulty of terrain are important factors ensuring that only the minimum number of routes necessary to link the urban centres (with district headquarters), would be constructed. This plays an important role in lowering its scores on all the topological connectivity indices (which are mainly concerned with number of vertices). On the other hand, the district ranks high on simple metricated indices related to the area:per mile of route, width of roads, traffic flow (eta index)

and per square mile freight carried. Having a small number of vertices and an efficient transport system it ranks high on nodal accessibility scores, particularly measured on shortest path and time scale, while on the other hand, its comparatively lower scores on distance accessibility scale are due to its rough terrain where the obstacles increase the ratio of actual distance along the shortest path particularly between Rawalpindi and Murree.

Jhelum district is slightly bigger than Rawalpindi in size (2,772 square miles) is sparsely populated with a very low percentage (16 per cent) of population living in nine towns. Out of these four have the status of towns since 1881 and according to the Census of 1971, these four towns contain 70 per cent of the total urban population of the district. This indicates a change in the number of urban centres since 1881. It is due to a number of characteristics among which the most important is poor agriculture caused by low ratio of cultivated area. Apart from that because of low rainfall the district is characterised as sub-mountainous, salinity stricken and highly eroded. This is also an important factor in pushing the people to join the armed forces or settle in other main cities of the country. Its low rank (13th) on spacing index suggests a dispersed settlement pattern and their location on the border of the district make these settlements more accessible to the towns of other districts as compared to their connectivity within the district. It is expected that the pattern of connectivity for these towns will be clearer when the nodal accessibility on division and province level is examined. Apart from that the low percentage of rail and road length (3.6 per cent and 4.0 per cent respectively) shows that the district has very few routes. It is due to its physical characteristics as well as poor economy and sparse settlement pattern which make the construction of rail and road routes uneconomic. It concludes that all these factors are more or less equally responsible in ranking the district low on connectivity indices.

The fourth district with low connectivity scores is Jhang, which is by contrast a central district. Its scores resemble those of Jhelum in size, density, area, per mile of route, percentage of railway length, degree of circuity but differ in terms of shape, and spacing of the settlements which suggest some different reasons for its lower

connectivity. It is partly as a result of the fact that the two rivers Jhelum and Chenab pass through the district by making a 'Y' shaped junction in the centre and divide the district into three long parts stretching from north to south. The limited number of bridges puts a tremendous strain on road network development, therefore the roads tend to run parallel to the rivers and water courses rather than cut across them. In view of the high cost of constructing a bridge, parallel roads are cheaper and easier to maintain. In this way the division of the district by the rivers not only reduces the degree of connectivity but also results in a high degree of detours, which indicates a low degree of efficiency between towns of the district. All these factors favour low scores for the district. The location of Jhang city on the west of the rivers between two bridges gives it predominantly central location, as it connects all the eastern towns to the central canal colony districts of the region. This centrality enhances that of the city to the wider network of the whole region of the Panjab and makes it a nodal point on a divisional, provincial as well as national level. Because of the irregular shape of the district Jhang city is better connected to the towns of its neighbouring districts (particularly Lyallpur) as compared to its own towns. In terms of the traffic movement only 11.5 per cent of truck traffic and 12.7 per cent of bus traffic operates within the district while the operation percentage between Jhang and Lyallpur is 44.4 and 32.9 respectively. In this way taking the River Chenab as a boundary, its eastern part in Jhang district resembles Lyallpur district, a highly developed district of the region. It is therefore anticipated that the nodal accessibility of Jhang city will be clearer and significant when measured on the large indices of accessibility on a high scale.

Coming to the higher end of the connectivity scale, the districts of Lyallpur, Sahiwal, Sheikhupura, Mianwali and Muzaffargarh are important to discuss in respect of the characteristics which separate them from the districts of low connectivity. Lyallpur bounded by the River Ravi on the east with no obstacle in the district is one of the developed districts and represents a highly developed irrigation system. Its agriculture is most developed where the area grew in importance as a grain belt in the Panjab and the towns and villages prospered in the wake of agricultural prosperity. This remarkable agricultural productivity led to the industrial development which increased from 11 (1947)

to 411 units (1971) covering about 15 per cent of the total Panjab's industrial units mainly of textile, grain, agricultural equipment and fertilizer. It is one of the most urbanized districts of the region. According to the Census of 1971, 24.81 per cent of the population was classified as urban, whereas the corresponding ratio for the Panjab as a whole was 24.47 per cent. It shares a proportion of 11.46 per cent to the total urban population of the Panjab and ranks second in this respect. In spite of this it is interesting to note that the district does not have a long standing urban history as in 1881 there was only the one urban centre of Kamalia with a population of 7,594. All the remaining eight centres which acted as nuclei in the development of the transport system, were small villages and became railway stations with the introduction of railways in the region (except for Samundari which is not on the rail network). Both rail and road networks play an equal role in the accessibility of the district. With the exception of Samundari, all the centres are located on the parallel north-south running 'U' shape railway lines. Their internal connections through Samundari (which is located in the centre of the two lines) by a mesh of roads, make the overall degree of connectivity very high and topologically classify it as a 'delta configuration', because of the high proportion of possible routes linking places directly and the high proportion of possible complete circuits.

As space does not permit comment on the district in more detail, a general picture of the characteristics of the district can be assessed by examining its position on the indices of demographic, economic, transportation and urban development, in which it stands among the top three ranks. The indices include total population (1971), growth rate of urban population (1931-1971), increase of total population, density of population (1970), average population per urban centre, connectivity, nodal accessibility, percentage of railway length, width of roads and efficiency of network.

Here it is interesting to compare the opposite roles played by rivers and railway (in changing connectivity of the region) in the two neighbouring districts of Jhang and Lyallpur. Both of these have 'Y' shaped networks of rivers and railways respectively. The lowest connectivity scores of Jhang and highest in Lyallpur suggest that on one hand rivers play an important role in reducing the connectivity

of Jhang while on the other hand (in the same environments) the railways have pushed Lyallpur district to the high peak of connectivity in the region. This analysis suggests that with time and development of transport the core of accessibility shifts towards the geometric centre according to the environment. In this case the shift of the most accessibile part seems to be from the districts, cut by the rivers to the districts bounded by the rivers with a suitable rail network. It also suggests that shape, size and location are important factors in the connectivity of a region.

Sahiwal, another Colony district, resembles Lyallpur in many characteristics particularly in agriculture in which it is one of the richest districts in the region. It has also been selected for agriculture development under the Model Farming Scheme, in which some scientific methods have been used to increase the agricultural productivity. It holds a lower proportion of industrial units and urban population. Its settlement pattern is not very much different from Lyallpur as their scores on spacing index rank nine and 11 respectively. All the urban centres enjoy the nodality of both rail and road, with the exception of Depalpur and Hujra which are pure creations of road development after the final development of the railways, and are located between two parallel railway lines. All these urban centres which are now enjoying the centrality of both rail and road networks, were initially not more than railway stations distributed on the two railway lines. Later on these centres prospered with the revolution in agriculture and became market centres for the local agricultural surplus. As the district is bounded by two rivers, the Ravi and the Sutlej, and there is no obstacle like rivers or mountains in the district, a maximum number of road routes were constructed to connect these towns through the centre of the district, where a number of nodes (junctions) appeared with their commercial importance. It is concluded that the construction of roads and railways has influenced land use in the district in many ways. Having improved the accessibility from and to the centres of consumption in and outside the district, it encouraged the export of surplus and better-grown produce. In exchange for these commodities other articles demanded in the district were imported and commerce gained in importance. The abnormal increase in the population of such railway station towns as Okara, Sahiwal and Arifwala is a clear reflection of their improved

condition owing to the railway connections. In this way it is believed that road development has a big contribution towards the high scores of the district on all the connectivity indices. It is also expected that the towns of this district will show high scores on the accessibility index, measured on large scale indices, due to their accessible position within the district.

The position of two western districts, Mianwali and Muzaffargarh (see Figure 1.1) is different in characteristics. They are similar in area and are sparsely populated with a density of 203 and 279 persons per square mile respectively. These are the districts where irrigation development took place only recently and population densities have remained very low. Away from the River Indus, the whole Lieah Tehsil of Muzaffargarh district was desert until the construction of Thal Canal which brought similar changes in Mianwali district as well. Being the newly developed districts their scores on economic indices cannot be compared with the already discussed Canal Colony districts; however, their position can be assessed by the changes in the recent decade of 1961-1971.

Mianwali district has a relatively long standing urban history with some old towns on the Indus, such as Isa Khel, Kalabagh and Bhakkar that have been acting as trade centres since and before the railway development in the region; therefore it is comparatively more urbanized with 21.5 per cent urban population while Muzaffargarh has only 7.7 per cent. Similarly the change between 1961-71 in urban population of Mianwali (65.9 per cent) and Muzaffargarh (64.0 per cent) districts is higher than their change in total population (47 per cent and 57 per cent respectively). This indicates a rapid urban growth in these districts which can be simply explained by the recent development of the T.D.A. (Thal Development Authority), and their big share in rail and road networks by which the towns of these districts are well connected. The construction of a road between Mianwali and Multan running parallel to the railway line at a short distance, provides a short cut connection to the towns (located on railway line) and ranks the districts high on connectivity indices.

Sheikhupura, irrigated by the Upper Chenab and the Lower Chenab canals is included in the agricultural and rapidly growing districts

of the region. Because of its location in the industrial belt a recent and rapid growth of industries particularly along the Lahore-Sheikhupura road has developed the district as an industrial centre. This is due to the fact that Lahore has already reached its peak point in industrial concern and is also near the border. The towns of the district are well connected by rail and road within the districts and to the main centres of the region. Apart from that the recent development of roads in the district has ranked it highest on the indices like connectivity, area per mile of route, width of roads and traffic flow, which has been one of the important factors responsible for the rise of Sheikhupura as an industrial centre.

Among the rest of the intermediately ranked districts, Lahore and Gujranwala, which are characterized as the most urbanized and industrially developed, deserve special comments. Both are small in size and are hinterlands for their respective cities of Lahore and Gujranwala, which are connected to the smaller towns of their district and the towns of the region. As vertices of these districts they are well connected with each other, though accessibility to the rest of the district is poor. In this way the role of these districts as inter-regional transport nodes is superimposed on their local networks.

8.10 Relationship

Finally in the light of district level indices of transport network, we can proceed to discuss its relationship with some geo-economic aspects. For this purpose 13 parameters (for the same 19 districts) have been selected to establish their relationship with connectivity (X). The variables* include:

Y1 = Total population 1971

Y2 = Per cent variation in total population

Y3 = Density of population 1971

Y4 = Urban population 1971

Y5 = Percentage of urban population 1971

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*The values for these parameters have been transformed into spatial index relatives, taking those for Jhang district as 100, reasoned by 1.00 β values which has also been multiplied by 100. (See Appendix K).

Y6 = Percentage variation in urban population 1961-1971
Y7 = Number of urban centres 1971
Y8 = Total receipts of Municipal Committees 1971
Y9 = Medical services (number of hospitals) 1971
Y10 = Number of registered factories 1971
Y11 = Arrival of wheat in the markets 1971
Y12 = Number of inter/degree colleges 1971
Y13 = Shape index

The computed relationship between Beta Index (X) and geo-economic parameters (Y1 - Y13) can be given in the following fashion along with correlation co-efficients (Y) and co-efficient of determination (r^2)

Y			r	r^2 (%)
Y1	=	-149.5 + 2.31 X	.840	70.6
Y2	=	81.55 + 0.19 X	.251	6.31
Y3	=	-128.45 + 2.2 X	.564	31.86
Y4	=	-221.37 + 3.2 X	.410	16.81
Y5	=	66.76 + 0.45 X	.151	2.30
Y6	=	88.28 + 0.12 X	.162	2.60
Y7	=	40.38 + 0.93 X	.406	16.50
Y8	=	-580.21 + 7.18 X	.536	28.76
Y9	=	-119.21 + 2.25 X	.698	48.66
Y10	=	-2099.17 + 24.73 X	.494	24.46
Y11	=	-285.75 + 3.33 X	.757	57.33
Y12	=	-50.10 + 1.40 X	.517	26.75
Y13	=	107.19 + 0.57 X	.290	8.40

The analysis presented above shows the highest (+.84) correlation between the connectivity and population distribution, which seems to have come out as expected. Similarly a positive relationship exists between each development characteristic and the network structure, with 'medical services' and 'grain market activities' being the most important variables. The less than moderate relationship with the industrialization (.494) exhibits a facet of an under developed economy.

Chapter 9
CONCLUSION

This study has attempted to analyse a functional relationship between transport and urban development. This relationship was analysed for the period since 1881. The study was divided into two parts. The first analysed the spatial and economic consequences of the historical development of transport facilities in the region, while the second part outlined the effect of accessibility (by different modes of transport) on urban growth and economic activities.

On the basis of available data, the indices discussed provided insight into the general levels of urbanization and transportation over time and space in the Panjab. The periods of varied connectivity were identified in chapter 3. By relating the indices of transportation to the indices of urban development the validity of the relationship was put to the test. Using the Panjab as a case study at division and district levels, the exercise was taken up (in chapters 4 to 6) after providing a background overview of the study and region in chapter 1.

The historical origins of spatial organization in the Panjab have been examined with emphasis on the urban system and the orientation of trading links. The early towns on the rivers were shown to be a product of the expansion of the trading empires*. These towns served as trade centres mainly linked with towns outside the area rather than with the interior of the region. British rule led to a very different pattern of spatial organization. Along with the construction of the railway and roads a number of facilities were established to facilitate the export of agricultural produce, which encouraged internal trade.

Urbanization in the region may be traced long back in history. However, modern urban development was initiated by the activities of

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* Either British or pre-British

immigrants (in the centre of the Panjab) and the expansion of the colonial economy, which gave rise to the different patterns of development. The analysis suggests that the interior centres could not have become an integrated spatial urban system but for the transport networks, which were created for the efficient functioning of the colonial space economy. It may be concluded that the present day urban system in the region is largely the product of the colonial developments. The history of internal transport can be traced even further back, as it reflected pre-British historical processes. However, this was subject to major changes as a result of the political and economic changes in the region after 1881.

The study concluded that the towns which already existed in 1881 provided a basic urban framework for the initial development of transport in general and the railway network in particular. The growth of transport took the form of river clearing, railway construction and road building. Initially the railway proved to be the most effective means of transporting agricultural goods. This was followed by road development to link market centres. This development stimulated urban growth and expansion, which was accompanied by political and administrative centralization and economic integration. Many towns grew due to changes in the environmental potentialities for both agriculture and industry with the concentration of services in these centres (which were linked by rail and roads). An urban system began to take shape in the centre of the region, while the north and south were relatively inaccessible and experienced slow development. The location of fast growing towns had been shifted from the north-east to the centre.

The analysis demonstrated that urbanization was mainly related to the three factors of agriculture, transport accessibility and internal migrations, which are so completely interrelated and mutually dependent that it is difficult to distinguish the influence of the individual factor at this stage. However, the results suggest that transportation connectivity was probably the most important factor throughout the period. In many stages of urbanization agriculture and migration are not sufficient to bring towns into existence or to make them grow. It is very difficult to imagine any urban centre at any time growing or surviving for that matter without minimal transportation accessibility.

Apart from that it is understood that the growth of the Panjab towns might have different factors underlying it, but there is one element common to all of them. The towns were no longer confined to their isolated surroundings and were brought closer to one another by the greatly improved network of communications. Similarly the distribution of these towns suggested that the devlopment of the transport network had injected life into patterns of urban growth. Particularly since the partition of 1947, the pace and nature of urban development has both quickened and changed, and the urban landscape features of cantonment and market towns have been re-shaped by the interplay of accessibility.

Chapter 3 provided information on the historical growth of the railway along with its spatial and economic consequences. The sequence of development corresponds to the general colonial model.* The temporal analysis of the rail network for the region provides ordered information on regional trends which cannot be extracted from simple density. Until 1900 transport investment was concentrated around the mining (Miani) and administrative nodes (Lahore, Rawalpindi and Multan). These earliest core regions developed very rapidly due to their locational and political advantages. In the second period of development (1901-31), the trend emphasized investment in the centre, where with the development of irrigation the existence of 'mandi towns' took place for the collection of agricultural produce. The railways on which these towns were located carried the agricultural produce to Karachi for shipment. While this was happening certain routes became dominant as 'corridors' and at the end of this stage (1931) another cycle of transport development with an alternative mode (roads) was imposed on the first. The importance of the railway network in relation to the evolution of the urban system cannot be over emphasized. The railway had not only linked all the major centres in a spatial structure, and reoriented their external relationships but also enlarged the economic base of the individual centres. Along the railway many towns grew in size and importance.

The analysis suggests that the development of both rail and road

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* Taaffe, Morrill and Gould (1963)

networks was as important as the emergence of urban centres themselves in the process of the evolution of the regional urban system. The growth of transport acted as an artery, bringing life into the entire system and regulated its structural and spatial growth. The temporal linkage of railway networks reflected the existence of specific complementarities between places, and inland penetration * was related to the achievement of either political or economic objectives. However, networks may also be seen as cause as well as effect.

On the basis of the analysis presented in the first four chapters it can be concluded that the introduction of railways and the improvements of the roads added a new dimension to the spatial arrangement of the distribution of towns. The gradual increase in connectivity encouraged the cultivation of cash crops and the rise of market centres. The period between 1931-71 witnessed the string development of towns enumerated earlier along the railways. This period led to the enlargement of existing towns, the growth of new ones and the creation of an urban complex along the arteries of transport. The period has great importance for both the changes in population and road development. The analysis shows that during the period (1931-71) the change in total population was followed by the change of urban population, indicating that at the early stage railway development played a vital role in the change of total population rather than the change in urban population, but later on road development had a significant effect on urban growth. In the light of this relationship it appears to suggest that at early stages the rail development had followed the urban growth in the old settled areas of major towns (Lahore, Rawalpindi, Multan and Bahawalpur) to connect them, whereas in the decades of railway development the growth and development of new urban centres was following rail development in central areas of new settlements. The analysis also suggests that with the exception of the areas like Bahawalpur division, where the urbanization is a recent phenomenon, all the sub-regions show a strong temporal relationship between transport and urban population, whereas the temporal relationship between total population and transport is high in the centre and south and low in the north east (Lahore and Rawalpindi divisions). The division

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* as defined by Taaffe, Morrill and Gould (1963)

level relationship also indicates that in Multan and Bahawalpur the growth of the network and of urban population was not equal before 1931, but later on this gap was closed with the abrupt growth of urban population.

A high increase in the values of regional connectivity during 1931-71 indicates that the changes in rail connectivity over the period were less variable than those of road. This would tend to suggest that more of the recorded changes in the recent development are likely to be contributed to road transport. This aspect is clearer at the disaggregated level where roads have provided better short cuts between towns (which is evident from increased values of circuit connectivity in chapter 5).

The temporal side of the study discussed in the early chapters did not show what have been termed as systematic factors. The second part of the study concentrated therefore on the role played by nodal accessibility to urban centres in the spatial patterns of urban change at all three levels. This section is based on several alternative measures of accessibility, which were applied to the analysis of spatial patterns of urban change. The study of relationship between nodal accessibility and urban growth discussed in chapters 5 to 7 has brought to light several important features relating to the spatial organization of the region. The analysis showed that despite pronounced contrasts in accessibility within the Panjab, the definition of accessibility adopted had a crucial bearing on the patterns which were found. It was shown that with the change of level of analysis and size of urban centres, the pattern of regional accessibility was changed. At Panjab level the accessibility to the transport network linking the major towns was highest in the centre and declined to the periphery, while the sub-regional accessibility contrasted strongly and in some peripheral sub-regions it was high. Similar variations in the patterns of accessibility were also evident with the change in modes of transport and with alternative measures of accessibility. The patterns of nodal accessibility to the road network are different from those of the rail network. However, a positive correlation between topological and non-topological accessibility suggests similarity in the patterns.

The points which emerged from the correlation analysis between accessibility and variables of change can be summarized as follows:

1. The physiography and level of urbanization directly affect the areal distribution of accessibility.
2. The major towns connected by links of high bus flow had a higher growth rate during 1961-71.
3. Recent developments in transport and accessibility have been more effective in the growth and expansion of new towns than the towns of pre 1931. These new towns have gained a lead (in population) to the old towns accessible by railway due to diversion in the channel of trade by road. Similarly the chances for the growth of new towns are higher by new linkage than on the link with heavy traffic flow.
4. Changes in accessibility disrupt the existing pattern of spatial competition and have an effect on relative rates of urban growth.
5. The importance of direct accessibility varied according to variables and sub-regions but inspite of this low level of explanation some variables of change were found with a consistent and significant correlation. Some of the variables are highly interlinked in practice, as seen by the use of controls in the correlation analysis.
6. In the central districts (of major agricultural, industrial and commercial activities) road transport has played an important role in all economic and social changes. The existing roads have facilitated and strengthened connections between the main growth centres.
7. The current patterns of spatial organization that emerged through the indicators of interaction (flow of people and goods) reveals that the towns along the main transportation corridors have both high growth and accessibility. This is due to the reduced friction of distance and time by roads.

Finally, it is necessary to comment specifically on the place of small urban centres, since they are at the interface between rural and urban systems in the region and are vital spatial decision points for development. The study reveals a high increase of such urban centres during 1931-71 particularly in the newly settled districts of Muzaffargarh and Mianwali with a significant development of transport nodes

during the same period. Almost all such nodes owe their growth and existence to the development of various bus routes, which now cross the greater portion of the sub-regions and expedite commercialization. At this level the roads have proved to be much more useful to the people in the greater portion of the region where railways have not been able to reach the remote rural areas.

Having discussed the relationships between transportation and urban development, a number of further points need to be emphasized. The variables of agriculture and industrialization have not been analysed in detail, but their district level relationship shows that all these variables are highly interlinked in the complex structure of the region. In order to examine this complexity fully, a second stage of analysis, which is beyond the scope of this thesis would be necessary. However, this study has demonstrated that both the transportation and some systematic forces had a measurable bearing on the urban growth of the region before 1931 and on subsequent patterns of development.

APPENDIX A

1. Definitions [1]

1.1 Transportation networks are defined as 'a set of geographic locations interconnected in a system by a number of routes' (Kansky 1963)

1.2 Topology is a form of geometry which is concerned with positions and relationships between points and lines and areas, but not with the distance between points, the straightness of lines or the size of areas.

1.3 Vertices[2] (also known as nodes, junctions, intersections and terminals) are points usually located at the junctions of two or more edges.

1.4 Edges[3] (also known as links, sides, arcs, segments, branches and routes) are lines which link the vertices.

1.5 Paths are sets of consecutive edges linking together a number of vertices.

1.6 A Circuit or a closed path is a path which begins and ends at the same vertex.

1.7 A fundamental circuit is a circuit which does not contain any other circuit.

1.8 Region or faces are areas completely enclosed by fundamental circuits.

1.9 Topological graphs (networks) are of many different types. They may be distinguished from one another by the different ways in which vertices are linked together by edges.
A 'null graph' contains only vertices with no edge to link them together. In a 'connected graph' every vertex is linked to the network by means of an edge, but not necessarily with a direct link to every other vertex. A graph which has a direct link from each vertex to every other vertex is called a 'complete graph'. A connected graph which has no circuit is known as a tree. A tree graph which links all the vertices is called a

spanning tree. Each of the separate graphs within the same network is known as a sub graph. Networks in which the edges meet only at the vertices are known as planar graphs. The network in which two edges cross without forming a vertex (ie. air routes) is called a non-planar graph. (Non-planar graphs are not analysed in this study).

1.10 Binary Matrices or matrix (singular) are tables containing rows and columns in which the characteristics of topological graphs (networks) are set out and where each of the rows and each of the columns is labelled with the name of the vertex of the networks. These are used to measure nodal accessibility.

1.11 Connectivity expresses the degree to which a network permits direct movement between its various nodes and is therefore a single aggregate measure relating to the structure as a whole.

1.12 Accessibility is specific to individual nodes, which are differentiated in terms of their location relative to one another.

2. Measures

Kansky (1963) introduced a large number of graph theoretic measures in the geography literature. Many of these are index numbers whose utility appears to be marginal. The topological and metricated indices used in this study are given below. (In the indices 'E' and 'V' are edges and vertices respectively). These indices provide a precise way of describing connectivity and accessibility numerically.

Connectivity

2.1 Cyclomatic number

Known as the first Betti number is one of the fundamental indices of graph theory. This is not a ratio measure and is the simplest way of measuring connectivity. It is written as:

$$\mu = E - V + P$$

where 'P' is number of sub graphs.

This index cannot distinguish between networks of very low connectivity, as the simple networks have the value of '0'.

2.2 Beta Index

This index measures the ratio between the number of lines (E) and number of points (V). Beta is defined as:

$$\beta = \frac{E}{V}$$

giving a range of numbers between 0.5 and 3.0. This index is designed so that any network with a beta index less than 1.00 indicates the presence of one complete circuit. A ratio of over 1.00 indicates the presence of more than one complete circuit. This is less useful for complex networks.

2.3 Alpha Index

This index is the most useful and perhaps the best measure of the connectivity of a fairly complex network. It is a further refinement of the cyclomatic number (μ) and can be defined as:

$$\alpha = \frac{E - V + P}{2V - 5} \quad \text{or} \quad \frac{\mu}{2V - 5} \quad \text{(in a connected graph)}$$

This may then be multiplied by 100 to change it into a percentage. The index indicates the number of fundamental circuits possessed by the network expressed as a fraction of the maximum possible number. The values for the index range from '0' to 1.0 (ie. 0 to 100 %), and the higher the index the higher the level of connectivity of the network. A value of 1.0 (100%) indicates a network in which every possible link exists between the vertices.

2.4 Gamma index

This is the ratio between the actual and the maximum possible number of edges in a graph (network). It is defined as:

$$\gamma = \frac{E}{3(V-2)}$$

and can also be multiplied by 100 for percentage values, which range between '0' and 100 %. Unlike the alpha index, this enables one to differentiate between 'paths' and 'trees', because it is based on edges rather than circuits. This index is very useful for relative linkage connectivity of the network.

2.5 Diameter

The description of a network by diameter involves the counting of the number of edges in the shortest possible path between

the two vertices located at the maximum distance in the network. As the size of the network increases, so in general does the diameter (δ). In many ways the diameter of a network is not a reliable measure, because a simple change in connectivity can alter it.

2.6 Pi Index

Also known as degree of development is a ratio between the total length of the network (C) and the actual distance along the diameter (d). It can be defined as:

$$\pi = \frac{C}{d}$$

This is a useful index in the complex networks of good shapes, while it gives low values even in the well developed networks of Chile and Sweden.

2.7 Eta Index[4]

This is a ratio measure and indicates the length of an average edge. It is written as:

$$\eta = \frac{M}{E}$$

where 'M' is the total mileage of the network

2.8 Theta Index[4]

This is a ratio of the network as a whole to its vertices. It may be written as

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

where 'T' is total traffic flow or the total volume of freight carried. It is suggested that it can be used as an accessory to 'η' by describing as:

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

It is important as it offers information on the length, structure and degree of connectivity of the network simultaneously (Kansky 1963).

2.9 Iota Index

It measures the ratio between the network as a whole and weighted vertices. It measures the aspects including structure,

length and functions. It may be written as

$$\alpha = \frac{M}{W}$$

where 'M' is total mileage of the network and 'W' is observed number of vertices weighted by their functions. It can be refined as $\frac{M}{T}$, where 'T' stands for 'traffic flow'.

Accessibility of the individual vertices is measured by the shortest-path matrix which is constructed by inserting the number of shortest-path edges (between all possible pairs of vertices) in the cells of the matrix. In the case of a metricated matrix the weighted edges are inserted. When the matrix has been compiled, several measures of accessibility can easily be derived from it.

2.10 Associated Number (AN)

The AN of any vertex is the number of edges needed to connect it with the (topologically) most distant vertex from it. The lowest AN represents the most accessible node. The ANs are arranged in the form of a histogram which gives a clear impression of the amount of variation in the accessibilities of the vertices of the network. Similarly, mean AN indicates the general level of accessibility provided by the network.

2.11 The Shimbel Index

This measure indicates the number of edges needed to connect any vertex with all the other vertices in the network by the shortest path. The mean Shimbel index (Ai) shows the average nodal accessibility of the network. The values of this index are used to construct an isopleth map of the pattern of accessibility. The low values on this index suggest a high level of accessibility.

2.12 Index of topological circuity (Itc)

This index is used to standardise the accessibility of the vertices to derive comparability between the regions (see text). It is expressed as:

$$Itc = \frac{Ai}{Ai\ min} \times 100$$

Ai = Mean Accessibility Ai min = n-1

FOOT NOTES

1. In this section only a brief introduction is given. For further study of transportation networks the reader is referred to the advanced works of Haggett (1965), Haggett (1969), Kansky (1963) and Taaffe (1973).

2. In other words the vertices can be defined as the points upon which movements are focused. In the strict sense a vertex is formed by any junction of edges on the network, (Haggett 1969). Taaffe (1973) advise the use of urban centres as vertices in the topological analysis of the region, because these are the foci of the transport system and can be grouped hierarchically according to size and function. In the analysis of the Panjab the definition of town as vertex is used for nodal accessibility, whereas for connectivity all the definitions are used at different levels (see text).

3. In the study of networks by other writers the definition of the edges has varied. For example Garrison and Marble (1961) used national highways and railways as edges and Kansky (1963) used national railway networks for the analysis. In this case (of the Panjab) both the networks have been considered separately at different scales. Because of the varied classifications of the roads, only the roads under the Panjab Works Department (PWD) are considered.

4. Both 'eta' and 'theta' indices are mostly based on route length. The width of the roads (route) varies in the region, the values of these indices have been computed for both Actual length and Equivalent length (based on 10feet as standardised width).

Appendix B

Simple Correlations

1.Panjab Level

	η	Y_J	Y_T	α_J	α_T	β_J	β_T	μ	R.L	θ
1.1881-1931										
1.Total Population	.947	.507	.956	.863	.935	.864	.936	.973	.952	.804
2.Urban Population	.823	.462	.865	.693	.807	.692	.801	.892	.830	.749
3.% Of U.Pop.	.611	.392	.686	.440	.593	.427	.577	.723	.617	.523
4.U.Pop.in > 20,000	.772	.404	.819	.644	.758	.641	.750	.851	.783	.698
5.U.Pop.in < 20,000	.953	.652	.977	.251	.934	.828	.857	.986	.939	.923
6.U.Pop.in class A	.746	.403	.793	.589	.738	.588	.717	.833	.756	.659
7.U.Pop.in class B	-.174	-.219	-.257	.094	-.182	.103	-.116	-.318	-.173	-.088
8.U.Pop.in class C	.496	.333	.580	.308	.480	.294	.459	.620	.500	.403
9.U.Pop.in class D	.950	.585	.918	.916	.947	.919	.940	.929	.305	.956
10.U.Pop.in class E	.956	.621	.980	.868	.933	.854	.943	.984	.949	.922
11.U.Pop.in class F	.397	.460	.493	.179	.374	.142	.359	.505	.371	.341
12.Urban Centres	.751	.543	.816	.591	.727	.569	.723	.833	.742	.689
13.U.Cen.in < 20,000	.793	.627	.861	.645	.761	.614	.768	.866	.776	.747
14.U.Cen.in > 20,000	.593	.291	.650	.415	.590	.416	.562	.696	.605	.492
15.Route Density(T.P)*	.940	.437	.887	.956	.958	.977	.959	.892	.958	.945
16.Route Density(U.P)	.771	.340	.673	.854	.782	.876	.796	.663	.775	.808
2.1931-1971										
1.Total Ponulation	.661	.347	.581	.483	.437	.506	.599	.659	.673	.618
2.Urban Population	.581	.292	.494	.396	.342	.420	.514	.588	.594	.539
3.% of U.Pop.	.647	.369	.606	.465	.456	.478	.589	.682	.442	.590
4.U.Pop.in > 20,000	.562	.273	.469	.375	.317	.401	.493	.565	.574	.532
5.U.Pop.in< 20,000	.677	.392	.623	.051	.479	.518	.604	.698	.684	.628
6.U.Pop.in Class A	.563	.273	.468	.372	.315	.399	.492	.566	.576	.522
7.U.Pop.in class B	.441	.176	.345	.342	.021	.507	.392	.418	.453	.423
8.U.Pop.in class C	.584	.307	.511	.387	.354	.408	.516	.603	.596	.535
9.U.Pop.in class D	.570	.285	.478	.378	.326	.413	.501	.572	.584	.532
10.U.Pop.in class E	.724	.517	.784	.320	.552	.632	.718	.785	.726	.670
11.U.Pop.in class F	.474	.485	.594	.368	.531	.330	.473	.569	.460	.416
12.Urban Centres	.690	.416	.617	.513	.508	.522	.636	.725	.699	.635
13.U.Cen.in < 20,000	.726	.525	.718	.564	.579	.564	.680	.772	.731	.668
14.U.Cen.in > 20,000	.580	.288	.498	.387	.345	.411	.512	.592	.589	.533
15.Route Density(T.P)*	.230	.138	.104	.413	.422	.415	.299	.158	.221	.286
16.Route Density(U.P)	-.174	-.117	-.193	.039	.001	.043	-.107	-.268	-.185	-.092

2.Division Level

		β		η		R.Length		Average	
		r	R	r	R	r	R	r	R
1.1881-1931									
1.Rawalpindi	1.1 Total Pop.	.683	46.64	.853	72.76	.783	61.31	.733	53.73
	1.2 Urban Pop.	.620	38.44	.853	72.76	.694	48.16	.752	56.55
	1.3 % of U.Pop.	.548	30.03	.808	65.29	.601	36.12	.652	42.51
	1.4 Urban Centres	-.060	0.36	.307	9.42	.029	0.09	.092	0.81
2.Sargodha	2.1 Total Pop.	.926	85.74	.943	88.92	.994	98.80	.954	91.01
	2.2 Urban Pop.	.967	93.51	.994	98.80	.907	82.26	.956	91.39
	2.3 % of U.Pop.	.543	29.48	.559	31.25	.416	17.30	.506	25.60
	2.4 Urban Centres	.994	98.80	.975	95.06	.919	84.46	.963	92.67
3.Lahore	3.1 Total Pop.	.817	66.74	.875	76.56	.909	82.63	.867	75.17
	3.2 Urban Pop.	.772	59.60	.928	86.12	.888	78.85	.863	74.48
	3.3 % of U.Pop.	.786	61.78	.936	87.60	.885	78.32	.869	75.51
	3.4 Urban Centres	.586	34.34	.742	52.41	.657	43.16	.662	43.78
4.Multan	4.1 Total Pop.	.897	80.46	.885	78.32	.894	79.92	.892	79.75
	4.2 Urban Pop.	.792	62.73	.796	63.36	.794	63.04	.794	63.04
	4.3 % of U.Pop.	-.600	36.00	-.508	25.80	-.571	32.60	-.560	31.32
	4.4 Urban Centres	.754	56.85	.702	49.28	.730	53.29	.729	53.09
5.Bahawalnur	5.1 Total Pop.	.901	81.18	.948	89.87	.915	83.72	.921	84.82
	5.2 Urban Pop.	.438	19.18	.464	21.53	.520	27.04	.474	22.46
	5.3 % of U.Pop	-.706	49.84	-.707	49.84	-.647	41.86	-.687	47.15
	5.4 Urban Centres	.525	27.56	.537	28.84	.556	30.91	.539	29.09
2.1881-1971									
1.Rawalpindi	1.1 Total Pop.	.389	15.13	.516	26.62	.474	22.47	.460	21.16
	1.2 Urban Pop.	.340	11.56	.516	26.62	.417	17.39	.424	17.98
	1.3 % of U.Pop.	.401	16.08	.607	36.84	.487	23.72	.498	24.83
	1.4 Urban Centres	.306	9.36	.533	28.41	.398	15.84	.412	17.00
2.Sargodha	2.1 Total Pop.	.723	52.27	.764	58.37	.709	50.27	.753	56.70
	2.2 Urban Pop.	.591	34.93	.627	39.31	.548	30.03	.587	34.46
	2.3 % of U.Pop.	.671	45.02	.710	50.41	.607	36.86	.663	43.96
	2.4 Urban Centres	.867	75.17	.885	78.32	.816	66.58	.856	73.27
3.Lahore	3.1 Total Pop.	.568	32.26	.691	47.75	.649	42.12	.636	40.45
	3.2 Urban Pop.	.544	29.59	.680	46.24	.628	39.44	.617	38.07
	3.3 % of U.Pop.	.690	47.61	.840	70.56	.784	61.46	.771	59.50
	3.4 Urban Centres	.571	32.60	.720	51.84	.658	43.30	.650	42.20
4.Multan	4.1 Total Pop.	.597	35.64	.561	31.47	.768	58.98	.642	41.22
	4.2 Urban Pop.	.488	23.81	.449	20.16	.685	46.92	.541	29.26
	4.3 % of U.Pop.	.364	13.24	.348	12.11	.540	29.16	.416	17.32
	4.4 Urban Centres	.654	42.77	.624	38.93	.749	56.10	.676	45.65
5.Bahawalnur	5.1 Total Pop.	.595	35.40	.704	49.56	.599	35.88	.633	40.06
	5.2 Urban Pop.	.483	23.33	.592	35.04	.487	23.72	.521	27.14
	5.3 % of U.Pop.	.483	23.33	.622	38.69	.492	24.21	.532	28.33
	5.4 Urban Centres	.639	40.83	.780	60.84	.644	41.47	.688	47.28

Appendix C

1.Topological Accessibility Matrix of Major Towns(50,000+) 1971.

1.Rawalpindi	+																						
2.Wah Cantt.	1	+																					
3.Jhelum	1	2	+																				
4.Gujrat	2	2	1	+																			
5.Sargodha	1	1	1	1	+																		
6.Jhang	1	1	2	2	1	+																	
7.Chiniot	2	2	2	2	1	1	+																
8.Lyallpur	2	2	3	2	2	1	1	+															
9.Kamalia	2	2	3	3	2	1	2	1	+														
10.Lahore	3	3	3	2	3	2	2	1	2	+													
11.Kasur	3	3	4	3	3	2	2	1	2	1	+												
12.Sialkot	3	3	2	1	2	3	3	2	3	1	2	+											
13.Gujranwala	3	3	2	1	2	3	2	2	3	2	3	1	+										
14.Kamoke	4	4	3	2	3	3	3	2	3	1	2	2	1	+									
15.Hafizabad	3	3	2	1	2	2	1	1	2	2	2	2	1	2	+								
16.Sheikhupura	3	3	3	2	3	2	2	1	2	1	2	2	1	1	1	+							
17.Multan	1	1	2	2	1	1	2	2	2	3	2	3	3	4	3	3	+						
18.Khanewal	2	2	3	3	2	1	2	2	1	3	2	4	4	4	3	3	1	+					
19.Burewala	3	3	4	4	3	2	3	2	2	2	1	3	3	3	3	3	1	1	+				
20.Sahiwal	3	3	4	3	3	2	2	1	1	2	2	3	3	3	2	2	2	1	1	+			
21.Okara	3	3	4	3	3	2	2	1	2	1	1	2	2	2	2	2	2	2	1	1	+		
22.Dera Ghazikhan	1	1	2	2	1	1	2	2	2	3	3	3	3	4	3	3	1	2	2	3	3	+	
23.Bahawalpur	2	2	3	3	2	2	3	3	2	3	2	4	4	4	4	4	1	1	1	2	2	2	+
24.Rahimyarkhan	2	2	3	3	2	2	3	3	3	4	3	4	4	5	4	4	1	2	2	3	3	1	1 +
Totals.	51	52	59	50	45	40	47	40	48	50	51	58	56	65	51	53	44	51	53	52	49	50	57 64

2.Accessibility Scores of Major Towns on different Indices (1971).

Ranks	Rail Acc.	Road Acc.	Distance	Flow Capacity	Ranks
1.	Sargodha	Lyallpur	Sheikhupura	Kamoke	1
2.	Khanewal	Jhang	Lyallpur	Gujranwala	2
3.	Multan	Multan	Chiniot	Lahore	3
4.	Chiniot	Sargodha	Lahore	Sheikhupura	4
5.	Lyallpur	Chiniot	Jhang	Gujrat	5
6.	Sheikhupura	Kamalia	Kamoke	Lyallpur	6
7.	Hafizabad	Okara	Gujranwala	Okara	7
8.	Burewala	Lahore	Okara	Sahiwal	8
9.	Gujrat	D.G.Khan	Sahiwal	Jhelum	9
10.	Jhang	Gujrat	Kasur	Kamalia	10
11.	Bahawalpur	Rawalpindi	Sargodha	Rawalpindi	11
12.	Kamalia	Hafizabad	Kamalia	Kasur	12
13.	Rawalpindi	Khanewal	Hafizabad	Wah Cantt.	13
14.	Lahore	Kasur	Burewala	Chiniot	14
15.	Sialkot	Sahiwal	Sialkot	Sialkot	15
16.	Wah Cantt.	Wah Cantt.	Gujrat	Khanewal	16
17.	D.G.Khan	Sheikhupura	Khanewal	Multan	17
18.	Kasur	Burewala	Jhelum	Hafizabad	18
19.	Jhelum	Gujranwala	Multan	Jhang	19
20.	Sahiwal	Bahawalpu	Bahawalpur	Sargodha	20
21.	Gujranwala	Sialkot	Rawalpindi	Burewala	21
22.	Okara	Jhelum	D.G.Khan	Bahawalpur	22
23.	Kamoke	Rahim Yarkhan	Wah Cantt.	D.G.Khan	23
24.	RahimYarkhan	Kamoke	Rahim Yarkhan	Rahim Yarkhan	24

Appendix D

Panjab level metricated accessibility matrix of major towns 1971.

	1	2	3	4	5	6	7	8	9	10	11	12
1.Rawalpindi	x											
2.Wah Cantt.	39.1	x										
3.Jhelum	8.6	6.8	x									
4.Gujrat	6.2	5.2	27.9	x								
5.Sargodha	0.7	0.6	0.9	0.8	x							
6.Jhang	0.5	0.5	0.6	0.5	2.4	x						
7.Chiniot	0.6	0.5	0.7	0.6	16.4	2.4	x					
8.Lyallpur	2.0	1.8	2.7	2.4	9.3	11.1	23.8	x				
9.Kamalia	1.5	1.4	1.9	1.7	4.2	3.8	5.8	9.0	x			
10.Lahore	3.8	3.4	8.6	14.3	1.6	3.9	2.3	10.0	2.9	x		
11.Kasur	2.5	2.3	4.0	5.3	1.3	3.1	1.7	7.3	2.4	17.5	x	
12.Sialkot	1.6	1.4	3.6	7.0	0.8	2.6	1.0	3.1	2.1	5.5	4.0	x
13.Gujranwala	4.9	4.3	14.6	35.3	1.0	3.5	1.4	4.3	2.6	28.4	7.4	13.6
14.Kamoke	4.5	4.0	12.0	24.6	0.9	3.4	1.2	5.3	2.9	40.4	8.9	9.5
15.Hafizabad	1.4	1.2	2.7	4.2	1.2	1.2	1.8	1.7	0.9	3.4	2.3	4.3
16.Sheikhupura	2.5	2.2	4.6	7.0	2.1	4.7	3.1	13.6	4.7	45.5	10.0	7.0
17.Multan	1.1	1.0	1.3	1.5	1.0	2.1	1.2	2.9	4.2	2.1	0.9	1.4
18.Khanewal	1.1	1.1	1.5	1.7	1.2	2.6	1.3	3.6	5.9	2.3	1.0	1.6
19.Burewala	0.8	0.8	1.1	1.2	1.7	3.1	2.1	2.5	6.2	1.9	1.4	1.2
20.Sahiwal	2.2	2.0	3.1	3.7	3.1	2.2	3.9	4.7	13.1	6.3	1.8	2.3
21.Okara	2.7	2.4	3.9	4.8	3.2	2.4	4.7	5.0	8.3	9.7	2.3	2.6
22.Dera Ghazikhan	0.3	0.3	0.4	0.4	0.7	1.3	0.8	0.8	1.1	0.5	0.7	0.4
23.Bahawalnur	0.9	0.9	1.1	1.3	0.8	1.3	0.9	2.0	2.6	1.6	0.7	1.3
24.Rahim Yarkhan	0.4	0.3	0.4	0.5	0.6	0.9	0.6	0.7	0.9	0.5	0.5	0.5
Total	89.9	83.5	113.0	158.1	56.5	60.1	73.8	129.6	90.1	216.4	39.3	78.3

	13	14	15	16	17	18	19	20	21	22	23	24
14.	100.2	x										
15.	9.4	6.2	x									
16.	13.0	20.6	7.6	x								
17.	1.7	1.8	1.6	1.8	x							
18.	1.9	2.0	1.9	2.4	16.3	x						
19.	1.5	1.6	1.3	1.7	3.5	5.1	x					
20.	4.4	4.8	2.6	5.1	4.1	5.7	6.7	x				
21.	5.9	6.6	3.0	7.1	3.3	4.4	4.3	28.0	x			
22.	0.4	0.5	0.4	0.5	2.2	1.5	1.0	0.8	0.7	x		
23.	1.4	1.4	1.3	1.6	8.3	5.6	2.0	3.0	2.3	1.1	x	
24.	0.5	0.5	0.5	0.5	1.4	0.9	0.9	0.8	0.7	0.8	1.7	x
Total	261.6	263.8	62.4	168.9	66.7	72.6	53.6	114.4	118.3	17.6	45.1	15.9

Appendix E

Railway acccssibility matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1.RAWAL PINDI	+																												
2.WAH CANTT.	1	+																											
3.GUJAR KHAN	1	2	+																										
4.CAMPBELL PUR	1	1	2	+																									
5.JHELUM	2	3	1	3	+																								
6.CHAKWAL	1	2	1	2	2	+																							
7.GUJRAT	5	6	4	6	3	5	+																						
8.JALALPUR	-	-	-	-	-	-	-	+																					
9.KHARIAN	3	4	2	4	1	3	2	-	+																				
10.LALAMUSA	4	5	3	5	2	4	1	-	1	+																			
11.M.BAHA UD DIN	5	6	4	6	3	5	2	-	2	1	+																		
12.SARGODHA	6	7	5	6	4	6	3	-	3	2	1	+																	
13.BHERA	6	7	5	6	4	6	3	-	3	2	1	1	+																
14.KHUSHAB	5	6	5	5	4	6	3	-	3	2	1	1	1	+															
15.MITHA TIWANA	4	5	6	4	5	5	4	-	4	3	2	2	2	1	+														
16.MIAN WALI	2	3	3	2	4	3	6	-	5	5	4	4	4	3	2	+													
17.DAUD KHEL	1	2	2	1	3	2	6	-	4	5	5	5	5	4	3	1	+												
18.KUNDIAN	3	4	4	3	5	4	5	-	5	4	3	3	3	2	1	1	2	+											
19.BHAKKAR	4	5	5	4	6	5	6	-	6	5	4	4	4	3	2	2	3	1	+										
20.JHANG	7	8	6	7	5	7	4	-	4	3	2	1	2	2	3	5	6	4	5	+									
21.CHINIOT	7	8	6	7	5	7	3	-	4	3	2	1	2	2	3	5	6	4	5	2	+								
22.SHOR KOT	8	9	7	8	6	8	5	-	5	4	3	2	3	3	4	6	7	5	6	1	3	+							
23.LYALL PUR	8	9	7	8	6	8	3	-	5	4	3	2	3	3	4	6	7	5	6	3	1	3	+						
24.JARAN WALA	10	11	9	10	8	10	5	-	7	6	5	4	5	5	6	8	9	7	8	3	3	2	3	+					
25.T.TEK SINGH	9	10	8	9	7	9	5	-	6	5	4	3	4	4	5	7	8	6	7	2	3	1	2	3	+				
26.KAMALIA	9	10	8	9	7	9	6	-	6	5	4	3	4	4	5	7	8	6	7	2	4	1	4	1	2	+			
27.GOJRA	9	10	8	9	7	9	4	-	6	5	4	3	4	4	5	7	8	6	7	3	2	2	1	4	1	3	+		
28.LAHORE	9	10	8	9	7	9	4	-	6	5	6	3	4	4	5	7	8	6	7	4	2	5	2	3	4	4	3	+	
29.KASUR	10	11	9	10	8	10	5	-	7	6	7	4	5	5	6	8	9	7	8	5	3	6	3	4	5	5	4	1	+
30.BHAI PHERU	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
31.SIAL KOT	7	8	6	8	5	7	2	-	4	3	4	4	5	5	6	8	9	7	8	5	3	6	3	5	5	6	4	2	3
32.NAROWAL	8	9	7	9	6	8	3	-	5	4	5	4	5	5	6	8	9	7	8	5	3	6	3	4	5	5	4	1	2
33.SHAKAR GARH	9	10	8	10	7	9	4	-	6	5	6	5	6	6	7	9	10	8	9	6	4	7	4	5	6	6	5	2	3
34.DASKA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
35.GUJRAN WALA	7	8	6	8	5	7	2	-	4	3	4	4	5	5	6	8	9	7	8	5	3	6	3	5	5	6	4	2	3
36.KAMOKE	8	9	7	9	6	8	3	-	5	4	5	4	5	5	6	8	9	7	8	5	3	6	3	4	5	5	4	1	2
37.WAZIR ABAD	6	7	5	7	4	6	1	-	3	2	3	3	4	4	5	7	8	6	7	4	2	5	2	4	4	5	3	3	4
38.HAFIZ ABAD	7	8	6	8	5	7	2	-	4	3	3	2	3	3	4	6	7	5	6	3	1	4	1	3	3	4	2	2	3
39.SHEIKHUPURA	8	9	7	8	6	8	3	-	5	4	3	2	3	3	4	6	7	5	6	3	1	4	1	2	3	3	2	1	2
40.NANKANA	9	10	8	9	7	9	4	-	6	5	4	3	4	4	5	7	8	6	7	4	2	3	2	1	4	2	3	2	3
41.MULTAN	8	9	9	8	8	9	7	-	7	6	5	4	5	5	6	6	7	5	4	3	5	2	5	4	3	3	4	6	6
42.SHUJA ABAD	8	9	9	8	9	9	8	-	8	7	6	5	6	6	6	6	7	5	4	4	6	3	6	5	4	4	5	7	7
43.KHANEWAL	9	10	10	9	7	9	6	-	6	5	4	3	4	4	5	7	8	6	5	2	4	1	4	3	2	2	3	5	5
44.MIAN CHANNUN	10	11	11	10	8	10	7	-	7	6	5	4	5	5	6	8	9	7	6	3	5	2	5	4	3	3	4	4	4
45.VEHARI	12	13	13	12	11	13	9	-	11	9	8	7	8	8	9	10	11	9	8	6	7	5	7	7	6	6	7	5	4
46.BUREWALA	13	14	12	13	10	12	8	-	10	9	9	7	8	8	9	11	12	10	9	7	6	6	6	7	7	7	7	4	3
47.MAILSI	11	12	12	11	10	12	9	-	9	8	7	6	7	7	8	9	10	8	7	5	7	4	7	6	5	5	6	6	5
48.KEHROR PACCA	10	11	11	10	9	11	8	-	8	7	6	5	6	6	7	8	9	7	6	4	6	3	6	5	4	4	5	7	6
49.SAHIWAL	11	12	10	11	9	11	6	-	8	7	7	5	6	6	7	9	10	8	8	5	4	4	4	5	5	5	5	2	2
50.CHICHAWATNI	11	12	11	11	9	11	7	-	8	7	6	5	6	6	7	9	10	8	7	4	5	3	5	6	4	4	5	3	3
51.OKARA	10	11	9	10	8	10	5	-	7	6	7	4	5	5	6	8	9	7	8	5	3	5	3	4	5	5	4	1	1
52.PAKPATTAN	11	12	10	11	9	11	6	-	8	7	8	5	6	6	7	9	10	8	10	9	4	7	4	5	6	6	5	2	1
53.ARIF WALA	12	13	11	12	10	12	7	-	9	8	9	6	7	7	8	10	11	9	10	8	5	7	5	6	7	7	6	3	2
54.MUZAFFAR GARH	7	8	8	7	9	8	8	-	8	7	6	5	6	6	5	5	6	4	3	4	6	3	6	5	4	4	5	7	7
55.LEIAH	5	6	6	5	7	6	7	-	7	6	5	5	5	4	3	3	4	2	1	6	6	5	7	7	6	6	7	8	9

Appendix E (Continued)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
56.KOT ADDU	6	7	7	6	8	7	8	-	8	7	6	6	7	5	4	4	5	3	2	5	7	4	7	6	5	5	6	8	8
57.D.GHAZI KHAN	7	8	8	7	9	8	9	-	9	8	7	7	8	6	5	5	6	4	3	6	8	5	8	7	6	6	7	9	9
58.BAHAWAL PUR	9	10	10	9	8	10	7	-	7	6	5	4	5	5	6	7	8	6	5	3	5	2	5	4	3	3	4	6	6
59.AHMAD PUR EAST	10	11	11	10	9	11	8	-	8	7	6	5	6	6	7	8	9	7	6	4	6	3	6	5	4	4	5	7	7
60.BAHAWAL NAGAR	11	12	12	11	10	12	9	-	9	8	7	6	7	7	8	9	10	8	7	5	7	4	7	6	5	5	6	8	8
61.CHISHTIAN	10	11	11	10	9	11	8	-	8	7	6	5	6	6	7	8	9	7	6	4	6	3	6	5	4	4	5	7	7
62.HAROON ABAD	12	13	13	12	11	13	10	-	10	9	8	7	8	8	9	10	11	9	8	8	8	5	8	7	6	6	7	9	9
63.RAHIM YAR KHAN	12	13	13	12	11	13	10	-	10	9	8	7	8	8	9	10	11	9	8	6	8	5	8	7	6	6	7	9	9
64.KHAN PUR	11	12	12	11	10	12	9	-	9	8	7	6	7	7	8	9	10	8	7	5	7	4	7	6	5	5	6	8	8
65.SADIQ ABAD	13	14	14	13	12	14	11	-	11	10	9	8	9	9	10	11	12	10	9	7	9	6	9	8	7	7	8	10	10
	457	527	454	471	403	482	335		363	317	299	256	298	287	322	386	408	341	359	272	275	271	292	332	298	307	308	312	342

	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65
32	1	+																																	
33	2	1	+																																
34	-	-	-	+																															
35	2	3	4	-	+																														
36	3	2	3	-	1	+																													
37	1	3	3	-	1	2	+																												
38	2	3	4	-	2	3	1	+																											
39	3	2	3	-	3	2	2	1	+																										
40	4	3	4	-	4	3	3	2	1	+																									
41	8	7	8	-	8	7	7	6	6	5	+																								
42	9	8	9	-	9	8	8	7	7	6	1	+																							
43	7	6	7	-	7	6	5	5	5	4	1	2	+																						
44	6	5	6	-	6	5	7	6	5	5	2	3	1	+																					
45	7	6	7	-	7	6	8	9	6	7	5	4	4	5	+																				
46	6	5	6	-	6	5	7	8	5	6	6	5	5	6	1	+																			
47	8	7	8	-	8	7	9	8	7	7	4	3	3	4	1	2	+																		
48	9	8	9	-	9	8	8	7	7	6	3	2	2	3	2	3	1	+																	
49	4	3	4	-	4	3	5	4	3	4	4	5	3	2	6	5	6	5	+																
50	5	4	5	-	5	4	6	5	4	5	3	4	2	1	6	6	5	4	1	+															
51	3	2	3	-	3	2	4	3	2	3	5	6	4	3	5	4	6	6	1	2	+														
52	4	3	4	-	4	3	5	4	3	4	7	7	6	5	3	2	4	5	3	4	2	+													
53	5	4	5	-	5	4	6	5	4	5	7	6	6	6	2	1	3	4	4	5	3	1	+												
54	9	8	9	-	9	8	8	7	7	6	1	1	2	3	5	6	4	3	5	4	6	8	7	+											
55	9	10	11	-	9	10	8	7	7	8	3	3	4	5	7	8	6	5	7	6	8	10	9	2	+										
56	10	9	10	-	10	9	9	8	8	7	2	2	3	4	6	7	5	4	6	5	7	9	8	1	1	+									
57	11	10	11	-	11	10	10	9	9	8	3	3	4	5	7	8	6	5	7	6	8	10	9	2	2	1	+								
58	8	7	8	-	8	7	7	6	6	5	2	1	1	2	3	4	2	1	4	3	5	6	5	2	4	3	4	+							
59	9	8	9	-	9	8	8	7	7	6	3	2	2	3	4	5	3	2	5	4	6	7	6	3	5	4	5	1	+						
60	10	9	10	-	10	9	9	8	8	7	4	3	3	4	5	6	4	3	6	5	7	8	7	4	6	5	6	2	1	+					
61	9	8	9	-	9	8	8	7	7	6	3	2	2	3	4	5	3	2	5	4	6	7	6	3	5	4	5	1	2	1	+				
62	11	10	11	-	11	10	10	9	9	8	5	4	4	5	6	7	5	4	7	6	8	9	8	5	7	6	7	3	4	1	2	+			
63	11	10	11	-	11	10	10	9	9	8	5	4	4	5	6	7	5	4	7	6	8	9	8	5	7	6	7	3	2	5	4	6	+		
64	10	9	10	-	10	9	9	8	8	7	4	3	3	4	5	6	4	3	6	5	7	8	7	4	6	5	6	2	1	4	3	5	1	+	
65	12	11	12	-	12	11	11	10	10	9	6	5	5	6	7	8	6	5	8	7	9	10	9	6	8	7	8	4	3	6	5	7	1	2	+
	366	353	408		361	350	334	305	295	317	312	329	277	312	413	421	383	347	344	340	327	387	407	330	369	358	418	298	351	410	354	472	461	408	526

Appendix F

Road accessibility matrix 1971.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1.RAWAL PINDI																													
2.WAH CANTT.	1	+																											
3.GUJAR KHAN	1	2	+																										
4.CAMPBELL PUR	2	1	3	+																									
5.JHELUM	2	3	1	4	+																								
6.CHAKWAL	1	2	1	1	1	+																							
7.GUJRAT	4	5	3	4	2	3	+																						
8.JALALPUR	5	6	4	5	3	4	1	+																					
9.KHARIAN	3	4	2	3	1	2	2	3	+																				
10.LALAMUSA	4	5	3	4	2	3	1	2	1	+																			
11.M.BAHA UD DIN	3	4	2	3	1	2	1	2	1	2	+																		
12.SARGODHA	2	2	3	2	2	2	2	3	2	3	1	+																	
13.BHERA	3	3	4	3	3	3	3	4	3	4	2	1	+																
14.KHUSHAB	1	1	2	1	2	1	3	4	3	4	2	1	2	+															
15.MITHA TIWANA	2	2	3	2	3	2	4	5	4	5	3	2	3	1	+														
16.MIAN WALI	1	1	2	1	2	1	4	5	3	4	3	2	3	1	1	+													
17.DAUD KHEL	2	2	3	2	3	2	5	6	4	5	4	3	4	2	2	1	+												
18.KUNDIAN	2	2	3	2	3	2	5	6	4	5	3	2	3	1	1	1	2	+											
19.BHAKKAR	3	3	4	3	4	3	4	5	4	5	3	2	3	2	1	2	3	1	+										
20.JHANG	2	2	3	2	3	2	3	4	3	4	2	1	2	1	1	2	3	2	1	+									
21.CHINIOT	3	3	4	3	3	3	3	4	3	4	2	1	2	2	2	3	4	3	2	1	+								
22.SHOR KOT	3	3	4	3	4	3	4	5	4	5	3	2	3	2	2	3	4	3	2	1	2	+							
23.LYALL PUR	3	3	4	3	4	3	4	5	4	5	3	2	3	2	2	3	4	3	2	1	1	2	+						
24.JARAN WALA	4	4	5	4	5	4	5	6	5	6	4	3	4	3	3	4	5	4	3	2	1	3	2	+					
25.T.TEK SINGH	3	3	4	3	4	3	4	5	4	5	3	2	3	2	2	3	4	3	2	1	2	2	2	2	+				
26.KAMALIA	4	4	5	4	5	4	5	6	5	6	4	3	4	3	3	4	5	4	3	2	3	3	3	3	1	+			
27.GOJRA	3	3	4	3	4	3	4	5	4	5	3	2	3	2	2	3	4	3	2	1	2	2	2	2	2	3	+		
28.LAHORE	5	5	6	5	5	5	4	5	4	5	4	3	4	4	4	5	6	5	4	3	2	4	2	2	4	5	3	+	
29.KASUR	6	5	7	6	6	6	5	6	6	6	5	4	5	5	5	6	7	6	5	4	3	5	3	2	5	5	4	1	+
30.BHAI PHERU	5	6	6	5	5	5	5	6	5	6	4	4	5	4	4	5	6	5	4	3	2	4	2	1	4	4	3	1	1
31.SIAL KOT	6	6	5	6	4	6	2	3	4	3	3	4	5	5	5	6	7	6	6	5	6	4	4	6	7	5	2	3	
32.NAROWAL	7	7	6	7	5	7	3	4	5	4	4	5	6	6	7	7	8	7	5	4	3	5	3	3	5	6	4	1	2
33.SHAKAR GARH	7	7	6	7	5	7	3	4	5	4	4	5	6	6	7	7	8	7	6	5	4	6	4	4	6	7	5	2	3
34.DASKA	6	6	5	6	4	6	2	3	4	3	3	4	5	5	5	6	7	6	5	4	3	5	3	3	5	6	4	3	4
35.GUJRAN WALA	5	5	5	5	4	5	2	3	4	3	3	3	4	4	4	5	6	5	4	3	2	4	2	2	4	5	3	2	3
36.KAMOKE	5	5	6	5	5	5	3	4	5	4	4	3	4	4	4	5	6	5	4	3	2	4	2	2	4	5	3	1	2
37.WAZIR ABAD	5	5	4	5	3	5	1	2	3	2	2	4	5	5	5	6	7	6	5	4	3	5	3	3	5	6	4	4	5
38.HAFIZ ABAD	4	4	5	4	4	4	2	3	4	3	3	2	3	3	3	4	5	4	3	2	1	3	2	2	3	4	3	3	4
39.SHEIKHUPURA	4	4	5	4	5	4	3	4	4	4	4	2	3	3	3	4	5	4	3	2	1	3	1	1	3	4	2	1	2
40.NANKANA	5	5	6	5	5	5	4	5	5	5	5	3	4	4	4	5	6	5	4	3	2	4	2	1	4	5	3	1	2
41.MULTAN	4	4	5	4	5	4	5	6	5	6	4	3	4	3	3	4	6	4	3	2	3	1	3	4	3	4	3	5	5
42.SHUJA ABAD	5	5	6	5	6	5	6	7	6	7	5	4	5	4	4	5	6	5	4	3	4	2	4	5	4	5	4	6	6
43.KHANEWAL	4	5	5	4	5	4	5	6	5	6	4	3	4	3	3	4	5	4	3	2	3	1	3	4	3	3	3	5	5
44.MIAN CHANNUN	4	4	5	4	5	4	5	6	5	6	4	3	4	3	3	4	5	4	3	2	3	1	3	4	3	2	3	5	4
45.VEHARI	5	5	6	5	6	5	5	6	6	6	5	4	5	4	4	5	6	5	4	3	4	2	4	5	3	3	4	5	5
46.BUREWALA	5	5	6	5	6	5	5	6	6	6	5	4	5	4	4	5	6	5	4	3	4	2	4	5	2	2	4	4	3
47.MAILSI	5	5	6	5	6	5	6	7	6	7	5	4	5	4	4	5	6	5	4	3	4	2	4	5	3	4	4	6	5
48.KEHROR PACCA	5	5	6	5	6	5	6	7	6	7	5	4	5	4	4	5	6	5	4	3	4	2	4	5	4	5	4	6	5
49.SAHIWAL	5	5	6	5	6	5	5	6	5	6	4	3	4	3	3	4	5	4	3	3	3	3	2	2	3	2	2	3	2
50.CHICHAWATNI	5	5	6	5	6	5	5	6	5	6	4	3	4	3	3	4	5	4	3	3	3	2	1	3	2	1	3	4	3
51.OKARA	4	4	5	4	5	4	5	6	5	6	4	3	4	3	3	4	5	4	3	2	2	3	1	1	3	3	1	2	2
52.PAKPATTAN	5	5	6	5	6	5	6	7	6	7	5	4	5	4	4	5	6	5	4	3	3	4	2	2	4	3	2	2	1
53.ARIF WALA	6	6	7	6	7	6	6	6	6	7	5	4	5	4	4	5	6	5	4	4	4	3	2	3	3	2	3	3	2
54.MUZAFFAR GARH	3	3	4	3	4	3	4	5	4	5	3	2	3	2	2	3	4	3	2	1	2	2	2	3	2	3	2	4	5
55.LEIAH	3	3	4	3	4	3	4	5	4	5	3	2	3	2	2	3	4	3	1	1	2	2	2	3	2	3	2	4	5

Appendix F (Continued)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
56.KOT ADDU	3	3	4	3	4	3	4	5	4	5	3	2	3	2	2	3	4	3	2	1	2	2	2	3	2	3	2	4	5
57.D.GHAZI KHAN	4	4	5	4	5	4	5	6	5	6	4	3	4	3	3	4	5	4	3	2	3	3	3	4	3	4	3	5	6
58.BAHAWAL PUR	4	4	5	4	5	4	6	7	6	7	5	4	5	4	4	5	6	5	4	3	4	2	4	5	4	4	4	5	4
59.AHMAD PUR EAST	5	5	6	5	6	5	6	7	6	7	5	4	5	4	4	5	6	5	4	3	4	2	4	5	4	4	4	6	5
60.BAHAWAL NAGAR	6	6	7	6	7	6	7	8	7	8	6	5	6	5	5	6	7	6	5	4	4	4	3	3	6	4	3	3	2
61.CHISHTIAN	5	5	6	5	6	5	7	8	7	8	6	5	6	5	5	6	7	6	4	4	5	3	4	4	5	5	4	4	3
62.HAROON ABAD	6	6	7	6	7	6	8	9	8	9	7	6	7	6	7	7	8	7	5	5	5	4	4	4	6	5	4	4	3
63.RAHIM YAR KHAN	5	5	6	5	6	5	5	6	5	6	4	3	4	3	3	4	5	4	3	2	3	3	3	4	3	5	3	5	6
64.KHAN PUR	5	5	6	6	6	6	5	6	5	6	4	3	4	3	3	4	5	4	3	2	3	3	3	4	3	5	3	5	6
65.SADIQ ABAD	5	5	6	6	6	6	5	6	5	6	4	3	4	3	3	4	5	4	3	2	3	3	3	4	3	5	3	5	6
	253	260	292	259	276	249	263	300	277	315	227	187	250	204	212	247	310	257	215	163	183	196	181	219	225	257	199	245	274

	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65
31	3	+																																		
32	2	1	+																																	
33	3	1	1	+																																
34	4	1	2	2	+																															
35	3	2	1	2	1	+																														
36	2	3	2	3	2	1	+																													
37	5	1	2	2	1	1	2	+																												
38	4	3	2	3	2	1	2	2	+																											
39	2	3	2	3	2	1	1	2	2	+																										
40	1	4	2	3	3	2	2	3	3	1	+																									
41	5	7	6	7	6	5	5	6	4	4	5	+																								
42	6	8	7	8	7	6	6	7	5	5	6	1	+																							
43	5	7	6	7	6	5	5	6	4	4	5	1	2	+																						
44	4	7	6	7	6	5	5	6	4	4	5	2	3	1	+																					
45	5	8	7	8	7	6	6	7	5	5	6	1	2	2	1	+																				
46	4	8	6	7	7	6	6	7	5	5	6	2	3	2	1	1	+																			
47	6	8	7	8	7	6	6	7	5	5	6	1	2	2	2	1	2	+																		
48	6	8	7	8	7	6	6	7	5	5	6	1	1	2	3	2	3	1	+																	
49	2	5	4	5	5	4	4	5	4	3	3	3	5	3	2	3	2	4	5	+																
50	3	6	5	6	6	5	5	6	5	4	4	3	4	2	1	2	1	3	4	1	+															
51	1	4	3	4	4	3	3	4	3	3	2	4	5	4	3	4	3	5	6	1	2	+														
52	2	5	4	5	5	4	3	5	4	4	3	4	4	4	3	3	2	4	5	1	2	1	+													
53	3	6	5	6	6	5	4	6	5	5	4	3	4	3	2	2	1	3	4	1	1	2	1	+												
54	4	6	5	6	5	4	4	5	3	3	4	1	2	2	3	3	4	2	2	3	3	3	4	5	+											
55	4	6	5	6	5	4	4	5	3	3	4	2	3	2	2	3	3	4	4	3	3	3	4	5	2	+										
56	4	6	5	6	5	4	4	5	3	3	4	2	3	3	3	4	4	3	3	3	3	3	4	5	1	1	+									
57	5	7	6	7	6	5	5	6	4	4	5	2	3	3	4	4	5	3	3	4	4	4	5	6	1	2	1	+								
58	5	7	6	7	7	6	6	7	5	5	6	1	1	2	3	3	4	2	1	4	4	4	3	4	2	4	3	3	+							
59	6	8	7	8	7	6	6	7	5	5	6	1	1	2	3	4	5	3	2	5	4	5	4	5	2	4	3	3	1	+						
60	3	5	4	5	6	5	4	6	5	5	4	3	3	4	5	4	3	4	3	2	3	2	1	2	4	6	5	5	2	3	+					
61	4	6	5	6	7	6	5	7	6	6	5	2	2	3	4	4	4	3	2	3	4	3	2	3	3	5	4	4	1	2	1	+				
62	4	6	5	6	7	6	5	7	6	6	5	3	3	4	5	5	4	4	3	3	4	3	2	3	4	6	5	5	2	3	1	1	+			
63	5	7	6	7	6	5	5	6	4	4	5	2	2	3	4	4	5	3	3	4	4	4	5	6	1	3	2	2	3	1	5	4	5	+		
64	5	7	6	7	6	5	5	6	4	4	5	2	2	3	4	4	5	3	3	4	4	4	5	6	1	3	2	2	2	2	4	3	4	1	+	
65	5	7	6	7	6	5	5	6	4	4	5	2	2	3	4	4	5	3	3	4	4	4	5	6	1	3	2	2	4	3	5	4	5	1	2	+
	255	323	302	344	303	251	256	295	228	221	260	224	277	231	238	275	271	278	280	229	237	217	248	272	195	226	209	257	263	283	287	287	326	261	260	267

Appendix G

Division level topological accessibility matrices of towns(20,000+)1971.

1.Rawalpindi

1	Rawalpindi																									
2	1	Wah Cantt.																								
3	1	2	Murree																							
4	1	2	2	Gujar Khan																						
5	2	2	3	3	Campbellpur																					
6	2	1	3	3	1	Hassan Abdal																				
7	3	3	4	4	1	2	Hazro																			
8	4	4	5	5	2	3	1	Gurghashti																		
9	1	2	2	2	1	2	2	3	Fateh Jang																	
10	2	3	3	3	1	2	2	3	1	Pindi Gheb																
11	2	3	3	2	2	3	3	4	2	1	Tala Gang															
12	3	4	4	2	5	5	6	7	4	4	3	Jhelum														
13	2	3	3	1	4	4	5	6	3	3	2	1	Dina													
14	1	2	2	1	3	3	4	5	2	2	1	2	1	Chakwal												
15	4	5	5	4	6	6	7	8	5	5	4	5	4	3	Pind Dadan Khan											
16	2	3	3	2	4	4	5	6	3	3	2	3	2	1	2	Khewra										
17	5	6	6	5	7	7	8	9	6	6	5	6	5	4	1	3	Lilla Town									
18	6	7	7	5	8	8	9	10	7	7	6	3	4	5	5	5	6	Gujrat								
19	7	8	8	6	9	9	10	11	8	8	7	4	5	6	6	6	7	1	Jalalpur							
20	7	8	8	6	9	9	10	11	8	8	7	4	5	6	6	6	7	1	2	Kunjah						
21	4	5	5	3	6	6	7	8	5	5	4	1	2	3	5	4	6	2	3	3	Kharian					
22	5	6	6	4	7	7	8	9	6	6	5	2	3	4	4	4	5	1	2	2	1	Lala Musa				
23	5	6	6	4	7	7	8	9	6	6	5	3	4	4	3	3	4	2	3	3	2	1	Dinggah			
24	5	6	6	3	5	5	6	7	4	4	3	4	3	2	1	1	2	4	5	5	4	3	2	Malakwal		
25	4	5	5	4	6	6	7	8	5	5	4	4	4	3	2	2	3	3	4	4	3	2	1	1	M.B.Din	
	79	97	102	77	104	108	125	148	90	93	83	89	79	70	106	79	129	122	145	145	97	103	104	91	95	Total
	328	404	425	321	433	450	521	617	375	387	346	371	329	292	442	329	537	508	604	604	404	426	433	379	396	I.tc.

Appendix G (Continued)

2. Sargodha

1	Sargodha																																					
2	1	Sillanwali																																				
3	1	2	Bhalwal																																			
4	2	3	1	Bhera																																		
5	2	3	1	2	Phularwan																																	
6	1	2	2	3	3	Kot Momin																																
7	2	3	1	2	2	1	Lilliani																															
8	1	1	2	3	3	2	3	Sahiwal																														
9	1	2	2	1	3	2	3	2	Jhaurian																													
10	1	2	2	2	3	2	3	1	1	Khushab																												
11	3	4	4	4	5	4	5	3	3	2	Hadali																											
12	4	5	5	5	6	5	6	4	4	3	1	Mitha Tiwana																										
13	2	3	3	3	4	3	4	2	2	1	1	2	Jauharabad																									
14	4	5	5	5	6	5	6	4	4	3	1	1	2	Mianwali																								
15	5	6	6	6	7	6	7	5	5	4	2	2	3	1	Daudkhel																							
16	5	6	6	6	7	6	7	5	5	4	2	2	3	1	1	Moch																						
17	5	6	6	6	7	6	7	5	5	4	2	2	3	1	2	2	Musakhel																					
18	4	5	5	5	6	5	6	4	4	3	1	1	2	1	2	2	2	Kundian																				
19	3	4	4	4	5	4	5	4	3	2	2	1	1	2	3	3	3	1	Piplan																			
20	7	8	8	8	9	8	9	7	7	6	4	4	5	3	2	3	3	4	5	Isakhel																		
21	6	7	7	7	8	7	8	6	6	5	3	3	4	2	1	2	2	3	4	1	Kalabagh																	
22	3	3	4	5	5	4	5	2	4	3	3	2	2	3	4	4	4	3	2	6	5	Bhakkar																
23	3	4	4	4	5	4	5	4	3	2	2	1	1	2	3	3	3	2	1	5	4	1	Daryakhan															
24	2	2	3	4	4	3	4	1	3	2	3	2	1	3	4	4	4	3	2	6	5	1	2	Jhang														
25	3	3	4	5	5	4	5	2	4	3	3	4	2	4	5	5	5	4	3	7	[illegible]	2	3	1	Chiniot													
26	2	2	3	4	4	3	4	3	3	3	4	5	3	5	6	6	6	5	4	8	7	3	4	2	1	Rabwah												
27	1	1	2	3	3	2	3	2	2	2	4	5	3	4	5	5	5	5	4	7	6	4	[illegible]	3	2	1	Lallian											
28	3	3	4	5	5	4	5	2	4	3	3	4	2	4	5	5	5	4	3	7	6	2	3	1	2	3	4	Shorkot										
29	3	3	4	5	5	4	5	2	4	3	3	4	2	4	5	5	5	4	3	7	6	2	3	1	2	3	4	1	Ahmadpur									
30	3	3	4	5	5	4	5	2	5	3	3	4	2	4	5	5	5	5	3	7	6	2	3	1	1	2	3	2	2	Lyallpur								
31	4	4	5	6	6	5	6	3	5	4	4	5	3	5	6	6	6	5	4	8	7	3	4	2	1	2	3	3	3	1	Chakjhumra							
32	4	4	5	6	6	5	6	3	5	4	4	5	3	5	6	6	6	5	4	8	7	3	4	2	2	3	4	3	3	1	1	Jaranwala						
33	4	4	5	6	6	5	6	3	5	4	4	5	3	5	6	6	6	5	4	8	7	3	4	2	2	3	4	3	3	1	2	2	Samundari					
34	4	4	5	6	6	5	6	3	5	4	4	5	3	5	6	6	6	5	4	8	7	3	4	2	2	3	4	3	3	1	2	1	1	Tandlianwala				
35	3	3	4	5	5	4	5	2	4	3	3	4	2	4	5	5	5	4	3	7	6	2	3	1	2	3	4	1	2	2	3	3	1	2	Toba T. Sing:			
36	4	4	5	6	6	5	6	3	5	4	4	5	3	5	6	6	6	5	4	8	7	3	4	2	3	4	5	2	3	2	3	2	1	1	1	Kamalia		
37	3	3	4	5	5	4	5	2	4	3	3	4	2	4	5	5	5	4	3	7	6	2	3	1	2	3	4	2	3	1	2	2	1	2	1	2	Gojra	
38	4	4	5	6	6	5	6	3	5	4	4	5	3	5	6	6	6	5	4	8	7	3	4	2	3	4	5	1	2	2	3	3	1	2	1	2	2	Pirma'
Tr	113	132	143	164	179	147	177	108	134	108	113	135	93	133	164	166	167	138	118	233	197	115	118	91	117	134	132	122	126	115	145	147	141	143	118	146	119	146
T.	305	357	386	443	484	397	478	292	362	292	305	365	251	359	443	449	451	373	319	630	532	311	319	246	316	362	357	330	341	311	392	397	381	386	319	395	322	395

Appedix G (Continued)

3. Lahore

No.	Values	Place
1		Lahore
2	1	KahnaNau
3	2 3	Kasur
4	1 2 1	Lulliani
5	1 2 2 2	Kot Radhakishan
6	1 2 1 2 1	Rajajang
7	2 2 1 2 2 2	Chunian
8	2 2 2 2 1 2 1	Pattoki
9	1 1 2 2 2 2 1 1	Bhai Pheru
10	4 5 6 5 5 5 6 6 5	Sialkot
11	3 4 5 4 4 4 5 5 4 1	Pasrur
12	4 5 6 5 5 5 6 6 5 1 1	Chawindah
13	3 4 5 4 4 4 5 5 4 2 1 2	Narowal
14	2 3 4 3 3 3 4 4 3 3 2 3 1	Badomalhi
15	4 5 6 5 5 5 6 6 5 3 2 3 1 2	Shakargarh
16	3 4 5 4 4 4 5 5 4 2 1 2 2 3 3	Daska
17	4 5 6 5 5 5 6 6 5 1 2 2 3 4 4 1	Sambrial
18	4 5 6 5 5 5 6 6 5 1 2 2 3 4 4 1 2	Jamke
19	2 3 4 3 3 3 4 4 3 2 1 2 2 3 3 1 2 2	Gujranwaln
20	2 3 4 3 3 3 4 4 3 4 3 4 4 3 5 3 4 4 2	Kamoke
21	3 4 5 4 4 4 5 5 4 3 2 3 3 4 4 2 3 3 1 3	Qilla Didar Singh
22	3 4 5 4 4 4 5 5 4 3 2 3 3 4 4 2 3 3 1 1 2	Eminabad
23	4 5 6 5 5 5 6 6 5 2 2 3 3 4 4 1 1 2 2 4 3 3	Wazirabad
24	3 4 5 4 4 4 5 5 4 3 2 3 3 4 4 2 2 3 1 3 2 2 1	Gakhar
25	5 6 7 6 6 6 7 7 6 3 3 4 4 5 5 2 2 4 3 5 2 4 1 2	Akalgarh
26	4 5 6 5 5 5 6 6 5 4 3 4 4 5 5 3 3 4 2 4 1 3 2 3 1	Hafizabad
27	3 4 5 4 4 4 5 5 4 5 4 5 5 5 6 4 4 5 3 3 2 4 3 4 2 1	Pindi Bhattian
28	1 2 3 2 2 2 3 3 2 3 2 3 3 3 4 2 3 3 1 1 2 2 3 2 4 3 2	Sheikhupura
29	2 3 4 3 3 3 4 4 3 4 3 4 4 4 5 3 4 4 2 2 3 3 4 3 3 2 1 1	Chuharkana
30	3 4 5 4 4 4 5 5 4 5 4 5 5 5 6 4 4 5 3 3 2 4 3 4 2 1 2 2 1	Sangla Hill
31	3 4 5 4 4 4 5 5 4 5 4 5 5 5 6 4 5 5 3 3 3 4 5 4 3 2 2 2 2 1	Shahkot
32	2 3 4 3 3 3 4 4 3 4 3 4 4 4 5 3 4 4 2 2 3 3 4 3 3 2 1 1 1 2 1	Mananwala
33	1 2 3 2 2 2 3 3 2 5 3 4 3 2 4 4 4 5 3 1 3 2 5 4 5 4 3 1 2 3 3 2	Muridkey
34	1 2 3 2 2 2 3 3 2 4 3 4 2 1 3 4 4 5 4 2 4 3 5 5 6 5 4 2 3 4 4 3 1	Narang
35	1 2 3 2 2 2 2 2 1 5 4 5 4 3 5 4 5 5 3 3 4 4 5 4 5 4 4 2 3 3 2 3 2 2	Sharqpur
36	2 2 3 2 2 2 2 2 1 5 4 5 5 4 6 4 5 5 3 3 4 4 5 4 4 3 3 2 3 2 1 2 3 3 1	Nankana
37	2 3 4 3 3 3 3 3 2 4 3 4 4 4 5 3 4 4 2 2 3 3 4 3 5 4 3 1 2 3 2 2 2 3 2 1	Warburton
Total	89 120 147 119 118 118 143 143 114 134 105 137 123 123 158 108 132 141 88 110 112 117 131 118 148 129 128 80 105 123 129 104 103 113 113 112 108	
I,tc.	247 333 408 331 328 328 397 397 317 372 292 381 342 342 439 300 367 392 244 306 311 325 364 328 411 358 356 222 292 342 358 289 286 314 314 311 300	

Appendix G (Continued)

4. Multan

1	Multan																															
2	1	Shuja Abad																														
3	2	1	Jalalpur(pirwala)																													
4	1	2	3	Kabirwala																												
5	2	3	4	1	Abdul Hakeem																											
6	1	2	3	1	1	Khanewal																										
7	2	3	4	2	2	1	Mian Channun																									
8	1	2	3	2	2	1	2	Jahanian																								
9	3	4	5	2	1	2	1	3	Tulamba																							
10	2	3	4	2	2	1	1	2	2	Vehari																						
11	3	4	5	3	3	2	1	3	2	1	Burewala																					
12	2	3	3	3	3	2	2	1	3	1	2	Mailsi																				
13	2	2	1	3	4	3	3	2	5	2	3	1	Kehror Pacca																			
14	1	1	1	2	3	2	3	1	4	3	4	2	1	Dunyapur																		
15	4	5	6	4	4	3	2	4	3	3	2	4	5	5	Sahiwal																	
16	3	4	5	3	3	2	1	3	2	2	1	3	4	4	1	Chichawatni																
17	5	6	7	5	5	4	3	5	3	4	3	5	6	6	1	2	Okara															
18	6	7	8	6	6	5	4	6	4	5	4	6	7	7	2	3	1	Renala Khurd														
19	6	7	8	6	6	5	4	6	4	5	4	6	7	7	2	3	1	2	Depalpur													
20	7	8	7	6	7	6	4	6	5	4	3	5	6	7	2	3	2	3	1	Havaili												
21	8	9	8	7	8	7	5	7	6	5	4	6	7	8	3	4	3	2	2	1	Basirpur											
22	7	8	9	7	7	6	5	7	6	6	5	7	8	9	3	4	2	1	1	2	1	Hujra										
23	5	6	6	5	5	4	3	5	4	3	2	4	5	6	1	2	2	3	2	1	2	3	Pakpattan									
24	4	5	5	4	5	3	2	4	4	2	1	3	4	5	1	2	2	3	3	2	3	4	1	Arifwala								
25	1	1	2	2	3	2	3	2	4	3	4	3	3	2	5	4	6	7	7	8	9	8	6	5	Muzaffargarh							
26	2	2	3	3	4	3	4	3	5	4	5	4	4	3	6	5	7	8	8	9	10	9	7	6	1	Leiah						
27	2	2	3	3	4	3	4	3	5	4	5	4	4	3	6	5	7	8	8	9	10	9	7	6	1	1	Kot Addu					
28	2	2	3	3	4	3	4	3	5	4	5	4	4	3	6	5	7	8	8	9	10	9	7	6	1	2	1	D.G.Khan				
29	3	3	4	4	5	4	5	4	6	5	6	5	5	4	7	6	8	9	9	10	11	10	8	7	2	2	1	1	Taunsa			
30	4	4	5	5	6	5	6	5	7	6	7	6	6	5	8	7	9	10	10	11	12	11	9	8	3	3	2	2	1	Vehowa		
31	3	3	4	4	5	4	5	4	6	5	6	5	5	4	7	6	8	9	9	10	11	10	8	7	2	3	2	1	2	3	Jampur	
32	4	4	5	5	6	5	6	5	7	6	7	6	6	5	8	7	9	10	10	11	12	11	9	8	3	4	3	2	3	4	1	Rajanpur
Total	99	127	137	109	124	96	97	107	123	102	110	114	128	122	123	109	144	170	167	175	201	195	141	125	113	140	135	134	160	190	162	192
I.tc.	319	410	442	362	400	310	313	345	397	329	355	368	413	394	397	352	464	548	539	565	648	629	455	403	365	452	435	432	516	613	523	619

5. Bahawalpur

1	Bahawalpur												
2	2	Hasilpur											
3	1	1	Khairpur										
4	1	3	2	Ahmadpur									
5	4	2	3	5	Bahawalnagar								
6	5	3	4	6	1	Dongabonga							
7	3	1	2	4	1	2	Chishtian						
8	5	3	4	6	3	2	2	Fortabbas					
9	4	2	3	5	2	1	1	1	Harunabad				
10	4	6	5	3	8	9	7	9	8	Rahimyarkhan			
11	3	5	4	2	7	8	6	8	7	1	Trinda Swai		
12	2	4	3	1	6	7	5	7	6	2	1	Khanpur	
13	5	7	6	4	9	10	8	10	9	1	2	3	Sadiqabad
Total	39	39	38	42	51	58	32	60	49	63	54	47	74
I.tc.	325	325	317	350	425	483	267	500	408	525	450	392	617

Appendix H

District level topological accessibility matrices 1971.

Rawalpindi

1						Wah Cantt.
1	2					Murree
1	2	2				Kahuta
1	2	2	1			Gujarkhan
4	7	7	6	6	Total	

Area 2022*

Campbellpur

1								Hasan Abdal
1	1							Hazro
2	1	2						Wah Cement
2	2	1	3					Gurghashti
1	2	2	3	3				Fatehjang
1	2	2	3	3	2			Pindigheb
2	3	3	4	4	1	1		Khaur
2	3	3	4	4	2	1	1	Talagang
12	15	15	22	22	16	15	19	20 Total

Area 4148*

Jhelum

1								Dina
2	1							Khakha
2	1	1						Mangla Cantt.
3	2	1	2					Chakwal
3	3	2	3	1				Bhaun
1	2	3	3	2	2			Pind Dadankhan
2	3	2	3	1	1	1		Khewra
2	3	3	4	2	1	1	2	Lilla Town
16	16	15	19	14	16	15	15	18 Total

Area 2772*

Gujrat

1									Jalalpur
1	2								Kunjah
2	3	1							Mangowal
2	3	3	2						Kharian
1	2	2	2	1					Lalamusa
2	3	2	1	1	1				Dingah
3	4	4	3	1	2	2			Sarai Alamgir
3	4	2	1	2	2	1	2		Phalia
4	5	4	3	3	3	2	2	2	Malakwal
3	4	3	2	2	2	1	1	1	M.B.Din
22	31	24	20	20	18	16	24	20	29 20 Total

Area 2264*

Sargodha

1																			Sillanwali
1	2																		Bhalwal
2	3	1																	Bhera
3	4	2	1																Miani
2	3	1	2	3															Phularwan
1	2	2	3	4	3														Kotmomin
2	3	1	2	3	2	1													Lilliani
1	2	1	2	3	2	2	2												Shahpur Sadar
1	2	2	3	4	3	2	3	1											Sahiwal
2	3	1	1	2	2	3	2	1	2										Jhawrian
2	3	2	3	4	3	3	3	1	2	2									Shahpur City
2	1	3	4	5	4	3	4	2	1	3	3								Faruka
1	2	1	2	3	2	3	2	1	2	1	2	3							Kalra
3	4	3	4	5	4	4	4	2	3	3	1	4	3						Khushab
5	6	5	6	7	6	5	5	4	5	5	3	6	5	2					Hadali
6	7	6	7	8	7	7	7	5	6	6	4	7	6	3	1				Nitha Tiwana
4	5	4	5	6	5	5	5	3	4	4	2	5	4	1	1	2			Jauharabad
5	5	5	6	7	6	6	6	4	5	5	3	6	5	2	2	1	1		Nurpur
6	7	6	7	8	7	7	7	5	6	6	4	7	6	3	1	1	2	1	Quaidabad
4	5	4	5	6	5	5	5	3	4	4	2	5	4	1	3	4	2	3	4 Sakesar
4	5	4	5	6	5	5	5	3	4	4	2	5	4	1	3	4	2	3	4 1 Naushehra
58	77	57	74	94	77	77	75	50	65	62	54	83	62	60	87	103	72	87	102 79 79 Total

Area 4775*

Appendix H (Continued)

Mianwali

1 Daudkhel
1 1 Moch
1 2 2 Musakhel
1 2 2 2 Kundian
1 2 2 2 2 Liaqatpur
1 2 2 2 1 1 Piplan
3 2 3 3 4 4 4 Isakhel
2 1 2 2 3 3 3 1 Kalabagh
1 2 2 2 2 2 2 4 3 Bhakkar
1 2 2 2 2 2 2 4 3 1 Daryakhan
1 2 2 2 2 1 1 4 3 2 1 Kalurkot
14 19 21 22 23 22 21 36 25 23 22 21 Total

Area 5403*

Jhang

1 Chiniot
2 1 Rabwah
3 2 1 Lalian
1 2 3 4 Shorkot
2 3 4 5 2 Ahmadpur
1 2 3 4 1 1 Garhmaharaja
10 11 14 19 13 17 12 Total

Area 3401*

Lyallpur

1 Chak Jhumra
1 1 Jaranwala
1 2 2 Samundri
1 2 1 1 Tandlianwala
2 3 3 1 2 T.T.Singh
2 3 2 1 1 1 Kamalia
1 2 2 1 2 1 2 Gojra
2 3 3 1 2 1 2 2 Pirmahal
11 17 15 10 12 14 13 13 15 Total

Area 3516*

Lahore

1 Raiwind
1 1 Kahnanau
1 2 2 Padhana
1 2 2 2 Dogrikalan
2 2 3 3 3 Kasur
1 3 2 2 2 1 Lulliani
3 3 4 4 4 1 2 Khudian
2 1 2 3 3 3 4 3 Kot Radhakishan
2 1 2 3 3 1 2 2 2 Rajajang
3 3 3 4 4 2 3 1 2 3 Chunian
2 2 2 3 3 3 3 2 1 3 1 Pattoki
1 2 1 2 2 4 2 3 2 3 2 1 Bhai Pheru
4 4 5 5 5 2 3 1 4 3 1 3 4 Kanganpur
3 3 3 4 4 4 4 3 2 4 2 1 2 4 Wan Radharam
27 30 33 40 40 34 34 36 34 34 34 30 31 48 43 Total

Area 2216*

Appendix H (Continued)

Sialkot

1 Pasrur
1 1 Chawinda
2 1 2 Kalaswala
2 2 2 3 Narowal
3 2 3 3 1 Badomalhi
2 1 2 2 1 1 Qila Sobhasingh
1 2 1 3 1 2 2 Zafarwal
3 3 3 4 1 2 2 2 Shakargarh
2 1 2 2 3 3 2 3 4 Daska
1 2 2 3 3 4 3 2 4 2 Sambrial
2 2 3 3 4 4 3 3 5 1 1 Begowal
2 2 3 3 4 4 3 3 5 1 1 2 Bhopalwala
1 2 3 3 3 4 3 2 4 1 2 2 2 Jamke

23 22 28 34 30 36 27 27 42 27 30 35 35 32 Total

Area 2067*

Gujranwala

2 Kamoke
1 3 Qilla Didarsingh
1 1 2 Eminabad
2 4 3 3 Wazirabad
1 3 2 2 1 Gakhar
1 3 2 2 1 2 Akalgarh
2 4 3 3 2 3 1 Ramnagar
2 4 1 3 2 3 1 2 Hafizabad
3 5 2 4 3 4 2 3 1 Pindi Bhatian

15 29 19 21 21 21 15 23 19 27 Total

Area 2312*

Sheikhupura

1 Chuharkana
2 1 Khangah Dogran
3 2 2 Sangla Hill
2 1 1 1 Dhabansingh
2 2 2 1 1 Shahkot
1 1 2 2 1 1 Mananwala
1 2 3 4 3 3 2 Muridke
1 2 3 4 3 3 2 1 Narang
1 2 3 4 3 3 2 1 1 Sharaqpur
2 2 3 3 2 2 1 3 2 1 Nankana
1 2 3 3 2 2 1 2 2 2 1 Warburton

17 18 25 29 20 22 16 24 24 23 22 21 Total

Area 2312*

Multan

1 Shujaabad
2 1 Jalalpur
1 2 3 Kabirwala
2 3 4 1 Abdul Hakeem
1 2 3 1 1 Khanewal
2 3 4 2 2 1 Mianchannun
1 2 3 2 2 1 2 Jahanian
3 4 5 2 1 2 1 3 Tulamba
2 3 4 2 2 1 1 2 2 Vehari
3 4 5 3 3 2 1 3 2 1 Burewala
2 3 3 3 3 2 2 1 3 1 2 Mailsi
1 1 1 2 3 3 4 2 5 3 4 2 Lodhran
2 2 2 3 4 3 3 2 4 2 3 1 1 Kehror Pacca
1 1 2 2 3 2 3 1 4 3 4 2 1 1 Dunyapur

24 32 42 29 34 25 31 27 41 29 40 30 33 33 30 Total

Area 5630*

Appendix H (Continued)

Sahiwal

1									Chichawatni
1	2								Okara
2	3	1							Renala Khurd
2	3	1	2						Depalpur
2	3	2	3	1					Havaili
3	4	2	2	1	1				Basirpur
3	4	2	1	1	2	1			Hujra
1	2	2	3	2	1	2	3		Pakpattan
1	2	2	3	3	2	3	4	1	Arifwala
16	24	15	20	16	17	19	21	17	21 Total

Area 4224*

Muzaffargarh

1									Khangarh
1	2								Leiah
1	2	1							Karor
1	2	1	2						Kotaddu
1	2	1	1	1					Daira Dinpanah
3	2	4	4	4	4				Alipur
3	2	4	4	4	4	1			Jatoi
2	1	3	3	3	3	1	1		Shahrsultan
13	14	17	18	18	17	23	23	17	Total

Area 5613*

Dera Ghazikhan

1									Kot Chuta
1	2								Taunsa
2	3	1							Vehova
2	1	3	4						Jampur
3	2	4	5	1					Dajal
7	2	4	5	1	2				Rajanpur
4	3	5	6	2	3	1			Kot Mithan
5	4	6	7	3	4	2	1		Rojhan
25	18	26	33	17	24	24	25	32	Total

Area 9359*

Bahawalpur

1									Samasata
1	2								Yazman
2	3	3							Hasilpur
1	2	2	1						Khairpur
2	1	3	4	3					Ahmadpur
3	2	4	5	4	1				Uch
10	11	15	18	13	14	19			Total

Area 9587*

Bahawalnagar

1							Donga Bonga
1	2						Minchinabad
2	3	1					Sadiqgang
1	2	2	3				Chishtian
3	2	4	5	2			Fort Abbas
2	1	3	4	1	1		Harunabad
10	11	13	18	11	17	12	Total

Area 3428*

Rahimyarkhan

2									Kot Samaba
1	1								Trinda Sawai
3	2	3							Liaqatpur
2	2	3	1						Allahabad
2	1	2	1	1					Khanpur
1	2	2	2	1	1				Chachran
1	3	2	3	2	2	1			Sadiqabad
2	4	3	4	3	3	2	1		Ahmadpur
2	4	3	4	3	3	2	1	1	Sanjarpur
16	21	20	23	18	16	14	16	23	23 Total

Area 4493*

*square miles

Appendix I

District level metricated accessibility(time) matrices 1971.

Rawalpindi

2 Wah Cantt.
6 9 Murree
2 5 9 Kahuta
3 5 9 5 Gujarkhan
13 21 33 21 22 Total

R.L. 586 miles

Campbellpur

2 Hasan Abdal
1 2 Hazro
2 1 2 Wah Cement
2 3 1 2 Gurghashti
2 4 3 5 4 Fatehjang
4 6 6 7 6 3 Pindigheb
5 6 6 7 7 2 1 Khaur
7 8 8 9 8 4 2 2 Talagang
25 32 31 35 33 27 35 36 48 Total

R.L. 502 miles

Jhelum

1 Dina
2 1 Khakha
3 2 2 Mangla Cantt.
6 5 4 5 Chakwal
8 7 6 7 1 Bhaun
5 5 7 8 4 3 Pind Dadankhan
5 5 7 8 4 3 1 Khewra
6 7 8 8 4 3 2 2 Lilla Town
36 32 37 43 33 38 35 35 39 Total

R.L. 398 miles

Gujrat

1 Jalalpur
1 2 Kunjah
2 3 1 Mangowal
2 4 4 5 Kharian
1 3 3 4 1 Lalamusa
3 5 3 3 2 2 Dingah
3 5 5 5 1 2 3 Sarai Alamgir
3 5 2 2 4 4 3 4 Phalia
6 8 6 6 5 4 4 6 3 Malakwal
4 6 4 4 4 2 2 3 1 2 M.B.Din
26 42 31 35 32 26 30 37 31 50 32 Total

R.L. 401 miles

Sargodha

3 Sillanwali
2 5 Bhalwal
4 7 2 Bhera
6 10 4 1 Miani
3 6 1 3 4 Phularwan
3 6 1 3 4 2 Kotmomin
3 6 1 3 4 2 1 Lilliani
1 4 3 4 5 3 5 5 Shahpur Sadar
2 2 4 6 1 5 5 5 3 Sahiwal
2 5 2 2 4 3 3 3 3 4 Jhawrian
2 5 4 5 6 4 5 5 1 4 4 Shahpur City
4 1 6 7 8 6 6 7 4 1 5 5 Faruka
2 5 2 2 4 3 3 3 4 4 1 4 5 Kalra
2 5 4 6 8 5 5 5 1 4 3 1 5 4 Khushab
3 6 5 7 9 6 6 6 2 5 4 2 6 5 1 Hadali
4 7 6 8 10 7 7 7 3 6 5 3 7 6 2 1 Mitha Tiwana
3 6 5 7 9 6 6 6 2 5 4 2 6 5 1 1 1 Jauharabad
7 10 10 12 14 11 11 11 7 10 9 7 11 10 5 4 3 4 Nurpur
4 7 6 8 10 7 7 7 3 6 5 3 7 6 2 1 2 1 4 Quaidabad
7 10 10 12 14 11 11 11 7 10 9 7 11 10 5 6 7 6 10 7 Sakesar
5 8 7 9 11 8 8 8 4 7 6 4 8 7 3 4 5 4 8 5 2 Naushehra
72 124 90 118 146 106 108 109 74 99 86 83 126 95 77 90 107 90 178 108 183 131 Total

R.L. 772 miles

Appendix I (Continued)

Mianwa Mianwali

2 Dau 2 Daudkhel
2 1 M 2 1 Moch
2 4 5 2 4 5 Musakhel
1 4 4 1 4 4 4 Kundian
3 6 6 3 6 6 6 1 Liagatpur
3 6 6 3 6 6 6 1 1 Piplan
6 4 5 6 4 5 9 8 10 10 Isakhel
3 2 3 3 2 3 6 5 7 7 3 Kalabagh
7 10 10 7 10 10 10 6 5 5 14 10 Bhakkar
6 9 9 6 9 9 9 5 4 4 13 9 1 Daryakhan
2 5 5 2 5 5 5 2 1 1 9 5 4 2 Kalurkot
37 53 37 53 55 66 41 50 50 91 60 82 73 41 Total

R.L. 606 miles

Jhang

4 Chiniot
5 1 Rabwah
6 1 1 Lalian
3 8 9 9 Shorkot
5 10 11 11 2 Ahmadpur
4 9 10 10 1 1 Garhmaharaja
27 33 37 38 32 40 35 Total

R.L. 481 miles

Lyallpur

1 Chak Jhumra
2 2 Jaranwala
2 4 3 Samundri
4 5 2 1 Tandlianwala
5 6 6 3 4 T.T.Singh
6 7 6 3 3 2 Kamalia
3 5 5 2 2 1 3 Gojra
3 7 7 4 3 1 1 3 Pirmahal
28 37 33 22 24 28 31 24 31 Total

R.L. 520 miles

Lahore

3 Raiwind
2 1 Kahnanau
2 6 5 Padhana
1 5 4 4 Dogrikalan
3 2 3 6 5 Kasur
2 3 4 5 4 4 Lulliani
6 4 4 8 3 6 5 Khudian
3 1 3 6 5 2 4 4 Kot Radhakishan
4 1 2 7 6 1 3 3 2 Rajajang
5 3 3 8 7 3 5 2 2 3 Chunian
4 1 3 7 6 4 5 4 2 3 1 Pattoki
3 3 2 6 5 5 5 6 3 4 3 2 Bhai Pheru
7 6 5 10 9 3 5 2 5 5 2 3 5 Kanganpur
4 2 3 7 6 5 5 5 4 3 2 1 2 4 Wan Radharam
49 41 44 87 75 44 54 60 44 47 49 46 54 71 51 Total

R.L. 353 miles

Appendix I (Continued)

Sialkot

2 Pasrur
2 1 Chawinda
2 1 3 Kalaswala
4 2 4 3 Narowal
6 4 6 5 1 Badomalhi
3 1 1 2 1 2 Qila Sobhasingh
3 3 2 4 2 4 2 Zafarwal
6 4 5 5 4 5 5 4 Shakargarh
1 2 3 4 4 4 3 4 5 Daska
1 4 3 5 6 6 5 4 6 1 Sambrial
2 5 4 5 6 6 5 5 6 1 1 Begowal
2 5 3 5 6 5 4 5 5 1 1 1 Bhopalwala
1 3 3 5 5 5 4 4 5 1 1 1 1 Jamke
35 36 39 49 48 59 38 46 65 34 44 48 44 39 Total

R.L. 484 miles

Gujranwala

1 Kamoke
1 2 Qilla Didarsingh
1 1 2 Eminabad
1 2 2 2 Wazirabad
1 2 2 2 1 Gakhar
2 3 2 3 1 2 Akalgarh
3 4 3 4 2 3 1 Ramnagar
2 3 2 3 2 3 1 2 Hafizabad
5 6 5 6 5 6 5 6 3 Pindi Bhatian
17 24 21 24 18 22 20 28 21 47 Total

R.L. 394 miles

Sheikhupura

1 Chuharkana
2 1 Khangah Dogran
5 3 3 Sangla Hill
3 2 2 1 Dhabansingh
3 2 3 2 3 Shahkot
2 2 3 3 4 1 Mananwala
4 4 4 9 10 6 6 Muridke
5 6 6 11 12 9 9 3 Narang
3 4 5 9 10 7 7 4 5 Sharaqpur
3 4 6 5 8 3 3 6 8 3 Nankana
2 3 5 6 9 4 4 6 9 4 1 Warburton
33 32 40 57 64 43 44 62 81 61 50 53 Total

R.L. 505 miles

Multan

3 Shujaabad
7 3 Jalalpur
2 6 6 Kabirwala
4 3 7 2 Abdul Hakeem
2 5 5 1 2 Khanewal
4 8 7 2 2 1 Mianchannun
2 3 5 2 4 1 3 Jahanian
6 10 8 3 1 2 1 4 Tulamba
5 7 7 7 6 4 4 4 5 Vehari
6 8 8 7 5 5 6 6 4 1 Burewala
4 6 9 6 5 3 2 2 6 1 2 Mailsi
4 2 2 4 5 3 5 1 6 4 4 2 Lodhran
5 4 4 5 5 4 6 3 7 3 4 2 1 Kehror Pacca
3 3 4 4 4 3 5 1 6 4 5 3 1 1 Dunyapur
57 75 82 57 60 41 56 41 69 62 71 53 44 54 47 Total

R.L. 807 miles

Appendix I (Continued)

Sahiwal

2 Chichawatni
1 3 Okara
2 4 1 Renala Khurd
3 5 2 3 Depalpur
4 6 4 5 3 Havaili
5 7 3 4 1 1 Basirpur
5 7 3 2 1 3 2 Hujra
2 4 4 5 2 1 3 4 Pakpattan
2 4 5 6 4 2 4 5 1 Arifwala
26 42 26 32 24 29 30 32 26 33 Total

R.L. 544 miles

Muzaffargarh

1 Khangarh
4 6 Leiah
6 8 1 Karor
2 3 2 3 Kotaddu
3 6 3 3 1 Dajra Dinpanah
5 4 9 10 6 8 Alipur
5 5 10 11 7 8 2 Jatoi
4 3 8 9 5 6 1 1 Shahrsultan
30 35 42 51 29 38 45 49 37 Total

R.L. 521 miles

Dera Ghazikhan

1 Kot Chuta
5 7 Taunsa
8 9 3 Vehova
3 1 9 12 Jampur
5 3 11 14 1 Dajal
7 5 13 16 2 3 Rajanpur
8 7 14 17 3 4 1 Kot Mithan
9 8 15 18 4 6 2 2 Rojhan
46 41 77 97 35 47 49 54 64 Total

R.L. 519 miles

Bahawalpur

1 Samasata
1 3 Yazman
5 7 6 Hasilpur
3 5 4 2 Khairpur
2 1 4 8 5 Ahmadpur
4 3 6 9 8 1 Uch
16 20 24 37 27 21 31 Total

R.L. 463 miles

Bahawalnagar

1 Donga Bonga
2 4 Minchinabad
3 6 1 Sadiqgang
2 3 5 5 Chishtian
4 4 7 7 5 Fort Abbas
2 1 5 5 2 3 Harunabad
14 19 24 27 22 30 18 Total

R.L. 439 miles

Rahimyarkhan

1 Kot Samaba
1 1 Trinda Sawai
5 5 5 Liaqatpur
8 6 6 1 Allahabad
2 1 1 2 4 Khanpur
5 5 5 4 4 2 Chachran
2 3 3 5 7 4 5 Sadiqabad
4 5 5 6 8 5 6 1 Ahmadpur
4 5 5 7 8 5 7 2 2 Sanjarpur
32 32 32 40 52 26 43 32 42 45 Total

R.L. 500 miles

Note. Route Length includes both roads and railway

Appendix J

Eta Index Scores 1971.

a.Non-motorised Traffic.

Bicycles		Animal drawn Vehicles		Traffic Units*	
1.Lyallpur	1462	1.Gujrat	295	1.Lyallpur	577
2.Lahore	991	2.Lyallpur	284	2.Gujrat	442
3.Sialkot	791	3.Gujranwala	277	3.Gujranwala	430
4.Sheikhupura	780	4.Sheikhupura	269	4.Lahore	428
5.Gujranwala	767	5.Sialkot	249	5.Sheikhupura	325
6.Gujrat	737	6.Lahore	229	6.Sialkot	407
7.Bahawalnagar	531	7.Rahim Yarkhan	126	7.Rahim Yarkhan	227
8.Rahim Yarkhan	504	8.Bahawalnagar	109	8.Bahawalnagar	216
9.Bahawalpur	423	9.Sahiwal	109	9.Sahiwal	191
10.Sahiwal	411	10.Multan	92	10.Multan	170
11.Dera Ghazikhan	391	11.Sargodha	80	11.Jhang	146
12.Multan	389	12.Jhang	76	12.Sargodha	137
13.Jhang	352	13.Dera Ghazikhan	59	13.Dera Ghazikhan	137
14.Muzaffargarh	343	14.Jhelum	58	14.Bahawalpur	136
15.Sargodha	290	15.Bahawalpur	52	15.Muzaffargarh	115
16.Jhelum	211	16.Muzaffargarh	47	16.Jhelum	100
17.Rawalpindi	154	17.Mianwali	29	17.Mianwali	58
18.Mianwali	147	18.Campbellpur	28	18.Campbellpur	50
19.Campbellpur	110	19.Rawalpindi	13	19.Rawalpindi	43

*5bicycles=1 A.D.V.

b.Motorised Traffic.

Motor Cycles		Motor Cars		Buses		Trucks		Total Units.*	
1.Lahore	482	1.R.Pindi	813	1.G.Wala	533	1.G.Wala	815	1.R.Pindi	9614
2.Lyallpur	271	2.Jhelum	633	2.S.Pura	521	2.Jhelum	752	2.Lahore	6217
3.G.Wala	237	3.G.Wala	612	3.Lahore	455	3.Lahore	653	3.G.Wala	4775
4.S.Pura	222	4.S.Pura	550	4.Jhelum	408	4.S.Pura	653	4.S.Pura	4185
5.Sialkot	172	5.Lahore	484	5.Lyallpur	398	5.R.Pindi	593	5.Jhelum	4161
6.Gujrat	134	6.C.Pur	330	6.R.Pindi	370	6.R.Y.Khan	581	6.Lyallpur	2785
7.R.Y.Khan	134	7.Lyallpur	270	7.Sahiwal	278	7.Jhang	477	7.R.Y.Khan	2289
8.Multan	112	8.Gujrat	200	8.Multan	260	8.Multan	416	8.Jhang	2268
9.Sahiwal	103	9.Multan	150	9.Jhang	223	9.C.Pur	409	9.Multan	2236
10.B.Nagar	96	10.Sargodha	140	10.Gujrat	211	10.Lyallpur	395	10.C.Pur	2167
11.Jhelum	95	11.Sialkot	131	11.C.Pur	199	11.B.Pur	344	11.Sahiwal	2019
12.B.Pur	87	12.Jhang	129	12.Sialkot	190	12.Gujrat	337	12.Gujrat	1910
13.D.G.Khan	86	13.Sahiwal	128	13.Sargodha	186	13.Sahiwal	335	13.B.Pur	1638
14.Jhang	77	14.R.Y.Khan	96	14.B.Pur	158	14.M.Garh	294	14.Sargodha	1571
15.R.Pindi	71	15.B.Pur	89	15.R.Y.Khan	128	15.Sargodha	281	15.M.Garh	1322
16.Sargodha	62	16.D.G.Khan	71	16.M.Garh	118	16.D.G.Khan	172	16.Sialkot	1281
17.M.Garh	45	17.M.Garh	65	17.B.Nagar	101	17.Sialkot	164	17.D.G.Khan	932
18.Mianwali	33	18.B.Nagar	52	18.D.G.Khan	101	18.Mianwali	119	18.B.Nagar	682
19.C.Pur	27	19.Mianwali	44	19.Mianwali	62	19.B.Nagar	92	19.Mianwali	606

*2 motor cycles=1 car
3 cars=1 bus or truck.

Appendix K

District level socio-economic indices 1971

(based on Jhang=100)

DISTRICTS.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1.Rawalpindi	122	113	125	228	268	236	135	71	377	327	305	204	190	171	1031
2.Campbellpur	129	64	95	52	43	67	108	128	34	78	84	190	205	128	54
3.Jhelum	114	68	91	83	58	85	88	128	45	88	96	187	203	100	86
4.Gujrat	132	122	97	183	97	79	100	157	62	154	161	146	153	128	113
5.Sargodha	141	135	96	96	172	127	112	314	55	225	262	118	137	200	320
6.Mianwali	163	71	104	44	82	115	99	171	48	80	90	166	187	114	48
7.Jhang	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
8.Lyallpur	164	274	130	263	365	133	126	128	285	779	780	169	179	257	620
9.Lahore	149	244	117	371	841	345	98	214	393	1369	1408	147	151	300	2280
10.Sialkot	153	151	105	247	133	88	79	200	67	186	187	132	133	171	201
11.Gujranwala	154	132	133	194	205	155	112	143	143	365	324	155	137	100	220
12.Sheikhupura	142	106	119	156	84	80	122	171	49	135	141	134	140	100	111
13.Multan	139	259	108	155	305	118	79	214	143	559	581	159	166	357	561
14.Sahiwal	169	181	74	146	134	74	91	143	94	291	305	180	188	171	200
15.Muzaffargarh	156	100	130	61	42	41	97	128	32	100	98	178	176	100	66
16.Dera Ghazikhan	131	73	105	27	51	69	75	128	40	78	81	155	172	100	58
17.Bahawalpur	113	69	102	24	78	113	94	100	78	132	129	157	154	86	87
18.Bahawalnagar	138	70	68	68	58	84	96	100	58	144	148	208	212	71	64
19.Rahimyarkhan	123	91	84	68	71	78	131	143	50	164	168	200	205	114	151

DISTRICTS.	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1.Rawalpindi	776	29	155	215	55	310	122	130	432	1090	206	219	120	100	119
2.Campbellpur	82	6	78	191	202	12	93	83	18	69	76	69	153	122	112
3.Jhelum	123	3	144	221	145	41	75	65	34	104	93	80	115	100	92
4.Gujrat	659	42	122	172	134	90	80	85	92	85	121	128	97	127	111
5.Sargodha	341	255	100	223	425	122	145	135	175	312	104	93	225	112	100
6.Mianwali	47	13	55	136	217	56	105	88	65	83	66	55	219	108	93
7.Jhang	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
8.Lyallpur	2418	329	211	165	132	411	79	90	468	535	76	87	240	189	173
9.Lahore	4817	129	311	200	285	949	52	56	461	674	79	86	169	127	104
10.Sialkot	853	81	155	213	219	116	94	87	49	47	154	144	131	128	107
11.Gujranwala	2588	177	78	232	166	212	73	82	92	129	107	120	123	130	116
12.Sheikhupura	770	168	78	119	287	44	90	104	47	110	132	154	171	125	107
13.Multan	1253	226	189	200	174	331	131	140	291	275	79	85	332	153	126
14.Sahiwal	588	297	111	213	162	128	94	102	134	211	76	82	198	140	125
15.Muzaffargarh	41	19	78	104	89	32	104	101	30	58	63	61	127	100	92
16.Dera Ghazikhan	112	13	55	108	159	29	84	72	81	62	30	26	214	100	92
17.Bahawalpur	359	52	55	167	102	73	85	78	60	49	30	28	148	86	86
18.Bahawalnagar	159	181	78	121	85	53	72	60	58	8	71	59	179	100	100
19.Rahimyarkhan	341	26	78	240	94	67	98	106	88	59	74	80	131	110	96

VARIABLES

1.Beta Index (V=Road Junctions).
2.Total Population 1971.
3.% Variation in Tot.Pop. 1961-71.
4.Populatin Density(p.sq.m) 1971.
5.Urban Populatin 1971.
6.Percentage of Urban Population.
7.% Variation in Urb.Pop. 1961-71.
8.Number of Urban Centres 1971.
9.Average Population per U.Centre.
10.Total Receipts of M.Committees.
11.Total Expenditures of M.C.
12.Per Capita Receipts.
13.Per Capita Expenditures.
14.Number of Hospitals.
15.Motor Vehicles.
16.Number of Factories.
17.Arrival of Wheat in the Markets.
18.Number of Colleges (Inter./Degree).
19.Shape Index.
20.Urban Pop. in Towns below 20,000.
21.Urban Pop. in Towns above 20,000.
22.Route Length (actual).
23.Route Length (quivalent).
24.Number of Buses on roads.
25.Number of Trucks on roads.
26.Road Density per 100 sq.m.(actual).
27.Road Density per 100 sq.m.(equivalent).
28.Length of Railroads.
29.Beta Index (V=towns).
30.Gamma Index (V=towns).

Appendix L

List of towns 1971.

NO.	NAME OF TOWNS	CODE*	CLASS**
1.	Abdul Hakeem	140	D
2.	Ahmad Pur East	184	C
3.	Ahmad Pur Lamma	201	E
4.	Ahmad Pur Sial	74	D
5.	Akalgarh	120	D
6.	Alah Abad	197	F
7.	Ali Pur	167	E
8.	Arifwala	160	C
9.	Bado Malhi	105	D
10.	Bahawal Nagar	186	C
11.	Bahawal Pur	179	A
12.	Basir Pur	157	D
13.	Begowal	111	E
14.	Bhai Pheru	97	C
15.	Bhakkar	66	C
16.	Bhalwal	37	D
17.	Bhaun	20	E
18.	Bhera	38	C
19.	Bhonalwala	112	E
20.	Burewala	146	B
21.	Campbellpur	6	C
22.	Chachran	199	E
23.	Chak Jhumra	77	D
24.	Chakwal	19	C
25.	Chawinda	102	D
26.	Chichawatni	152	C
27.	Chiniot	70	B
28.	Chishtian	190	C
29.	Chuharkana	125	D
30.	Chunian	95	D
31.	Daina	16	D
32.	Daira Din Panah	166	F
33.	Dajal	175	E
34.	Darya Khan	67	D
35.	Daska	109	C
36.	Daud Khel	58	C
37.	Depalpur	155	D
38.	Dera Ghazikhan	170	B
39.	Dhaban Singh	128	E
40.	Dingah	30	D
41.	Dogri Kalan	89	E
42.	Donga Bonga	187	D
43.	Dunyapur	150	D
44.	Eminabad	117	D
45.	Faruka	47	E
46.	Fateh Jang	11	D
47.	Fort Abbas	191	D
48.	Gakhar	119	D
49.	Garh Maharaja	75	E
50.	Gojra	83	C
51.	Gujarkhan	5	C
52.	Gujranwala	114	A
53.	Gujrat	24	A
54.	Gurghashti	10	D
55.	Hadali	50	D
56.	Hafizabad	122	B
57.	Harunabad	192	C
58.	Hasanabdal	7	D
59.	Hasilpur	182	D
60.	Havaili	156	D
61.	Hazro	8	D
62.	Hujra	158	D
63.	Isa Khel	64	D
64.	Jahania	143	D
65.	Jalalpur Jattan	25	C
66.	Jalalpur Pir.	138	D
67.	Jamke	113	D
68.	Jampur	174	D
69.	Jaranwala	78	C
70.	Jatoi	168	E
71.	Jauharabad	52	D
72.	Jhang	69	A
73.	Jhaurian	45	D
74.	Jhelum	15	B
75.	Kabirwala	139	D
76.	Kahna Nau	87	D
77.	Kahuta	4	E
78.	Kalabagh	65	D
79.	Kalaswala	103	E
80.	Kalra	48	E
81.	Kalurkot	68	E
82.	Kamalia	82	B
83.	Kamoke	115	B
84.	Kanganpur	98	E
85.	Kasur	90	A
86.	Kehror(Lalisan)	164	E
87.	Kehror(Pakka)	149	C
88.	Khairpur Tamew	183	D
89.	Khanewal	141	B
90.	Khangah Dogran	126	E
91.	Khangarh	162	E
92.	Khanpur	198	C
93.	Kharakha	17	E
94.	Kharian	28	C
95.	Khaur	13	F
96.	Khewra	22	D
97.	Khudian	92	E
98.	Khushab	49	C
99.	Kot Addu	165	C
100.	Kot Chota	171	F
101.	Kot Fithan	177	F
102.	Kot Momin	41	D
103.	Kot Radhakishan	93	D
104.	Kot Samabah	194	F
105.	Kundian	61	C
106.	Kunjah	26	D
107.	Lahore	85	A
108.	Lalamusa	29	C
109.	Lalian	72	D
110.	Liaqat Abad	62	E
111.	Liaqatpur	196	E
112.	Lieah	163	C
113.	Lilla Town	23	D
114.	Lilliani	42	D
115.	Lodhran	148	E
116.	Lulliani	91	D
117.	Lyallpur	76	A
118.	Mailsi	147	C
119.	Malakwal	33	D
120.	Mananwala	130	D
121.	Mandi Bahaodin	34	C
122.	Mandi Sadiqganj	189	E
123.	Mangla Cantt.	18	F
124.	Mangowal	27	E
125.	Mian Channu	142	C
126.	Miani	39	E
127.	Mianwali	57	C
128.	Minchinabad	188	E
129.	Mitha Tiwana	51	C
130.	Moch	59	D
131.	Multan	136	A
132.	Muridke	131	D
133.	Murree	3	D
134.	Musa Khel	60	D
135.	Muzaffargarh	161	C
136.	Nankana Sahib	134	C
137.	Narang	132	D
138.	Narowal	104	C
139.	Naushehra	56	E
140.	Nurpur	53	F
141.	Okara	153	A
142.	Padhana	88	F
143.	Pakpattan	159	C
144.	Pasrur	101	D
145.	Pattoki	96	D
146.	Phalia	32	F
147.	Phularwan	40	D
148.	Pind Dadankhan	21	D
149.	Pindi Bhattian	123	D
150.	Pindi Gheb	12	D
151.	Piplan	83	D
152.	Pirmahal	84	D
153.	Qilla Didarsingh	116	D
154.	Qilla Sobhasingh	106	F
155.	Quaidabad	54	F
156.	Rabwah	71	B
157.	Rahim Yarkhan	193	B
158.	Raiwind	86	F
159.	Rajajang	94	D
160.	Rajanpur	176	D
161.	Ramnagar	121	E
162.	Rawalpindi	1	A
163.	Renala Khurd	154	D
164.	Rojhan	175	F
165.	Sadiq Abad	200	C
166.	Sahiwal	151	A
167.	Sahiwal(sargodha)	44	D
168.	Sakesar	55	F
169.	Samasata	180	E
170.	Sambrial	110	D
171.	Samundari	79	D
172.	Sangla Hill	127	D
173.	Sanjarpur	202	F
174.	Sarai Alamgir	31	F
175.	Sargodha	35	A
176.	Shahar Sultan	169	F
177.	Shahkot	129	D
178.	Shahpur City	46	E
179.	Shahpur Sadar	43	F
180.	Shakargarh	108	C
181.	Sharaqpur	133	D
182.	Sheikhupura	124	B
183.	Shorkot	73	C
184.	Shujaabad	137	C
185.	Sialkot	100	A
186.	Sillanwali	36	D
187.	Talagang	14	D
188.	Tandlianwala	80	D
189.	Taunsa	172	D
190.	Toba Teksingh	81	C
191.	Trinda Sawai	195	D
192.	Tulamba	144	D
193.	Uch Sharif	185	E
194.	Vehowa	173	D
195.	Vehari	145	C
196.	Wah Cantt.	2	A
197.	Wah Cement Works	9	F
198.	Wan Radharam	99	F
199.	Warburton	135	D
200.	Wazirabad	118	C
201.	Yazman	181	F
202.	Zafarwal	107	F

*Code number for towns in location map

**Class of town size
A=100,000+
B=50,000-100,000
C=20,000-50,000
D=10,000-20,000
E=5,000-10,000
F=Below 5,000

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