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COMMUNICATION, TRANSPORTATION AND THE DECENTRALIZATION OF SELECTED PUBLIC SERVICES IN NEW SOUTH WALES (AUSTRALIA)

A DISSERTATION SUBMITTED TO THE GRADUATE DIVISION OF THE UNIVERSITY OF HAWAII IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

IN GEOGRAPHY

AUGUST 1973

By

John V. Langdale

Dissertation Committee:

Forrest R. Pitts, Chairman
Robert J. Earickson
Roland J. Fuchs
Rudolph J. Rummel
Paul J. Schwind
The topic of decentralization of population and economic activity in Australia is one that is receiving increasing attention in recent years. This study hopefully contributes to an understanding of a part of the general question—namely, transportation and communication factors as they impinge on the location of selected public services.

I am very grateful for the assistance of numerous people and organizations in carrying out this research. Macquarie University Research Fund supported the computing expenses. The Telecommunications Branch of the Post Master General's Department supplied me with much useful information. I also wish to thank David Ellis of the School of Earth Sciences at Macquarie University for his cartographic assistance.
COMMUNICATION, TRANSPORTATION, AND THE DECENTRALIZATION OF SELECTED PUBLIC SERVICES IN NEW SOUTH WALES (AUSTRALIA)

by John V. Langdale

A dissertation submitted to the Graduate Division of the University of Hawaii in partial fulfillment of the requirements for the degree of Doctor of Philosophy

ABSTRACT

New South Wales, in common with most other Australian states, has an urban hierarchy dominated by the state capital city. The proposal to decentralize population and economic activity away from the capital city has received an increasing amount of support in recent years. In this research the decentralization of selected public services is examined with respect to the structure and flows within transportation and communication networks.

Factor analysis was used to identify regions for the structure and flows of several transportation and communication networks. In addition, the question of the optimal location of branch facilities in a tertiary service organization was discussed using several computer programs which solved variants of the location-allocation problem. The location of these branch facilities and the
boundaries of their service areas were compared with, firstly, the results obtained in the factor analysis of structure and flows in the transportation and communication networks and, secondly, empirical studies of the location, type and service areas of central places within the state.

The question of decentralizing public services was linked to the general problem of urban and regional development within the state. The development of growth centers was discussed as a possible planning strategy. A conclusion that emerges from the analysis of the structure and flows in transportation and communication networks was that the location and nature of growth centers must take into account the dominance of state capital cities. In addition, future innovations in transportation and communication technology may further increase the dominance of the existing metropolitan areas.
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CHAPTER I

Introduction

The focus of this dissertation is on the decentralization of population and economic activity to regional centers or growth points in country areas of New South Wales (N.S.W.). The major aim of the research is to examine the structure of the transportation and communication networks within the state and to relate this structure to the optimal locations and service regions for decentralized facilities. A secondary aim is to examine the relevance of the regional planning areas recently delimited by the state government in the light of the analysis of networks and location of tertiary organizations. Included in this secondary aim is the testing of various analytical solutions for the location of regional administrative centers and the comparison of these solutions with the actual regional planning areas. While the analysis is focused on the location of government administrative centers, it is assumed that the location of these centers will have an important influence on the location of the tertiary industries in the private sector.

Decentralization is considered from both urban and regional growth aspects. Urban growth is considered in the sense that decentralization of population and economic activity occurs from large to smaller cities. However, regional
growth is closely tied to variations in the rate of urban growth. Adopting a systems approach to the spatial organization of society, it is obvious that regions are closely interrelated with cities and that changes in one part of the system will have repercussions to a varying degree throughout the rest of the system.

Theoretical Background
The theoretical background of the research is discussed in three parts. The first part considers initially some of the goals of urban and regional development which are relevant in New South Wales (N.S.W.). Having, tentatively at least, established these goals, the problems of overurbanization are discussed so as to illustrate the "push" factors behind the demand for decentralization. In other words, the negative aspects of large cities have led to a demand for alternative locations for population and industry. In addition, the development of growth centers as a possible strategy in overcoming these problems is investigated. The linkages between growth centers and central place theories are examined, especially with respect to the flows of information between nodes in the settlement hierarchy. Thus the understanding of the pattern of communication and transportation linkages is important in accounting for past urban growth and in attempting to plan a regional development policy.
The problems of over-urbanization discussed in this section are not followed up in the research. This section is designed to provide background material for the major thrust of the research—namely, the location of branches of tertiary organization in non-metropolitan areas of N.S.W.

The second part of the review of literature considers the geographical literature on tertiary industry location and the regionalization of network structure and flows. This section is concerned with demonstrating the interrelationships in the spatial structure of an economy between the location of tertiary industry and the structure and flows in networks. An understanding of the regional structure of these networks is important in the location of tertiary industry.

Two alternative though complementary strands are discussed in the review of tertiary industry location: namely, the descriptive central place studies and the optimal location solutions for single organizations. A further aim is to provide a partial integration between these two areas of research. A major limitation of the study is that it is focused mainly on one level of the settlement hierarchy—regional service centers. However, some attention is given to the existence of a hierarchy in the regionalization of telephone calls, although the data are too aggregated to
identify lower order nodal centers.

The third part of the review focuses on the question of decentralization. The optimal degree of decentralization in market-oriented organizations is defined as the determination of the number of branches (or central facilities), their geographic spacing and their spatial hierarchical structures. The basic location decision is viewed as a trade-off between the fixed and operating costs for an organization against the elasticity of demand of consumers. The purpose of chapter four is thus to lay the basis for the discussion of the location-allocation problem for type I organizations in chapter nine and the location of type II organizations in chapter ten. In addition, this chapter considers in more detail the basic features in the location of tertiary industry organizations presented in chapter three.

**Empirical Background**

In the fifth chapter the major features of the regional economic structure of N.S.W. are discussed. This chapter

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1 Type I organizations are characterized by an individual trip for service between a customer's home location and the central facility. Type II organizations service a number of requests from consumers on a single trip.
provides a background for chapter six, which considers the question of regional planning and decentralization within the state. The nature of the regional divisions suggested for planning purposes is discussed. These regional divisions have been put forward, firstly, to encourage decentralization of secondary and tertiary industries and, secondly, to increase the degree of regional consciousness within rural areas. The two aims have not been clearly separated in government reports, and one aim of this research is to clarify the implication of each in terms of urban and regional development.

The nature of communication systems within the state is examined in some detail in chapter seven. The first aim of this analysis is to provide information for the efficient planning of the location of switching centers in the telex and telephone networks. In addition, the question of the location of regional mail exchanges for the delivery and collection of mail in rural areas is considered. A second aim is based on the assumption that the structure as well as the pattern of flows within communication networks reflect the overall linkages between different parts of the state. Thus the nature of the regions existing within the state, the possibility of developing regional and growth centers and the realism of the planning regions are discussed with reference to the communication and, to
a lesser extent, transportation systems.

Analytical Section
The analytical section of the research is divided into two parts. The first considers the structure of transportation and communication networks, while the second investigates the location of branches of tertiary organization. In the first section questions concerning the nature of the cost surfaces and regionalization of different modes of transportation and communication networks are raised. How similar are the regions delimited for different modes of transport and communication? What are the implications for regional planning of the regions obtained from, firstly, the transportation and communication network structure and, secondly, the telephone message flows?

It is often assumed that regions exist in an area. The presence or at least the strength of such regions can be questioned in N.S.W., given the vast difference in population between the rural regional centers and the Central Coastal Region. If nodal regions based on regional centers are non-existent or only weakly developed, then attempts at regional planning must take this into account. For example, the location of high order tertiary services in some towns may be of little value, since Sydney may be close enough for consumers to bypass the regional center. Thus in
providing services in rural regions the effect of metropolitan competition must be taken into account.

The second part of the analytical section is covered in chapters nine and ten. These chapters consider the problem of the optimum location of central facilities for type I and II organizations. Several computer programs solving variants of the location-allocation problem are used to optimally locate central facilities for a type I organization. Central facilities for a single level of an organizational hierarchy are optimally located, although the number of facilities to be located is not solved. The location-allocation problem provides an optimal solution for the existing population distribution. However, underlying the provision of many public services is the assumption that no member of a community should be deprived of these services because he lives in an isolated community. A further aim in this section, therefore, is to consider whether the optimal solutions give an adequate areal coverage of N.S.W. in the provision of different public services.

The location of type II organizations is discussed in chapter ten using the example of mail collection and distribution for regional mail exchanges. Type II organizations must not only locate central facilities but must
also plan the delivery and collection routes to customers. These two features are mutually interdependent, and a type II organization may have a centralized system of facilities with long collection and delivery trips or a decentralized system with short trips. The particular system selected by an organization depends on the fixed, operating and transportation costs as well as the demands of consumers and the presence of competition.

Conclusions
In chapter eleven an integration of the analyses in the empirical and analytical sections of the thesis is provided. The results of the factor analyses of network structure and telephone calls as well as the conclusions from the location-allocation model are compared with empirical evidence concerning the provision of services in the central place hierarchy.

In defining the optimal locations and boundaries of service areas of decentralized activities, it is necessary to consider the structure of and flows within networks. One conclusion stemming from the analysis of telephone message flows and network structure is that the attempt to decentralize tertiary services to country towns must take into account the importance of metropolitan dominance within Australia. This conclusion has a direct bearing on the
other major aim of the research—namely, the usefulness of the regional planning areas. It is unlikely that regions within one hundred (and possibly two hundred) miles have a high probability of evolving a high degree of separate regional "consciousness." To some extent, the degree to which these areas evolve as satellites of Sydney or as regions focused on major provincial towns will depend on the innovations in transportation and communication which may be applied in N.S.W.

In chapter twelve the effect of future transportation and communication modes on decentralization is examined. It is hypothesized that the relative economic growth of regions within the state is dependent on their linkages via different transportation and communication modes to the rest of the state. However, the effect of these innovations on decentralization is unclear. Reduced costs of movement or communication may encourage decentralization or may reinforce the extent of metropolitan dominance.

A further conclusion is that the use of the term growth center should be restricted primarily to centers which have a high growth potential. The basis of growth of these centers is likely to be secondary industry, although tertiary industries will contribute to their development. While these growth centers will probably become high order
central places, it is necessary to plan for the growth of a separate tier of cities—regional centers which provide central goods and services for a surrounding region. The development of these centers is necessary to ensure a reasonable degree of comparability in access to services for country as against city residents. Thus central place theory is useful in planning the development of regional centers. However, the location of growth centers is dependent more on industrial location considerations than on the provision of services to a rural hinterland.

A final conclusion relates to the restriction of the focus of the research to N.S.W. as well as to the planning of decentralization solely on a state basis. In considering the distribution of population and economic activity and the location of transportation and communication networks, the Central Coastal Region is by far the most desirable area for firms to locate in. Attempts to decentralize on a state-wide basis run into the problems of inertia characteristic of most location patterns. The rest of the state is peripheral to the core area. However, in considering the national population distribution and major transportation and communication axes between states, decentralization to some of these peripheral areas becomes a more feasible possibility. Thus the growth of cities along a development corridor from Sydney to Melbourne and from
Sydney to Brisbane is an example of a decentralization strategy involving considerations of interstate linkages. Similarly, it may be necessary to plan the growth of cities and their functional regions which extend into two or more states.
CHAPTER II
Policy Goals, Urbanization Problems
and Alternative Strategies

One difficulty in discussing decentralization is caused by the fact that goals for public policy are rarely clearly stated. Given that goals for regions, states and national governments may conflict, it seems necessary to outline some of the issues involved in the Australian setting. This discussion of goals, therefore, is important in the context of defining the problems associated with urbanization and the strategies employed to overcome them.

The problems associated with urbanization and the related question of the optimal size of a city are presented as background material to the discussion of decentralization of tertiary services. One important component of the demand for decentralization has come from a widespread belief in society that cities are too large and have reached a stage of diseconomies of agglomeration. This assumption is examined in this chapter with special reference to N.S.W.

In addition, the growth center concept as a means of overcoming these problems is discussed. The linkages between growth centers, central place theory, information flows and transportation networks are discussed, emphasizing the
spatial structure of the region into which decentralized facilities are to be located. The major emphasis in this research is on this aspect of decentralization rather than on the problems of large cities.

Goals of Urban and Regional Development
Implicit in much of the discussion on the problems of urbanization and in the strategies of decentralization is the question of goals for regional and national development. Richardson (1969, 365) claims that a regional policy should have two broad functions. Firstly, it should help to promote growth in the national economy and, secondly, it should aim to reduce interregional disparities in indices of growth and welfare. It is likely that there will be a conflict in achieving both these goals. Without public programs to reduce interregional differences in welfare, growth in many countries would occur in one or two "core" regions (Friedmann, 1966).

Given perfect competition and flows of labor and capital to eliminate interregional differences in wage and interest rates, efficiency goals would be adequate. In reality, it is necessary to balance efficiency with equity considerations. However, Reiner (1965, 114) and Alonso (1971, 46) discuss some of the difficulties in defining equity in regional development policies. One of the
problems relates to the fact that average incomes within a region contain a spread from high to low values; a development policy could increase the average by increasing the income of the wealthy in the poorer regions. Another problem is that attempts to equalize incomes in one time period may produce new disequilibrating outcomes in the next time period as population and capital shifts occur.

The existence of a federal system of government in Australia leads to some complications in the formulation of regional goals. Unless regional boundaries coincide with state boundaries, the allocation of Commonwealth money to regions involves interstate cooperation in developing shared regions. A possible conflict exists between national and state goals, since maximizing national growth may lead to the economic growth of some states being reduced. While the development of Albury/Wodonga as a growth center would contribute to the growth of N.S.W., it is likely that the city and its functional region would continue to be dominantly linked with Melbourne in the state of Victoria (Figure 1). The N.S.W. government would prefer the development of a growth center whose region was entirely within the boundaries of N.S.W. It is of interest to note that the N.S.W. government has chosen the site of its first growth

1 In chapter eight the presence of interstate linkages in N.S.W. will be discussed.
Figure 1

Major Regions and Physiographic Features in N.S.W.
center at Bathurst/Orange in the center of the state, whereas the Commonwealth government has chosen Albury/Wodonga. ²

The growth center strategy reflects an attempt to combine the efficiency and equity goals. By concentrating investment at selected points, a government can create external economies in these growth centers so that industry locating there is relatively efficient. Also diseconomies in large cities are reduced or at least maintained at present levels, since much of the growth of population and industry is siphoned off. In terms of equity considerations, it is argued that growth centers allow more regions to grow rapidly. However, because only one or two successful growth centers can be envisaged in N.S.W. by the year 2000, it is desirable on equity grounds to plan the development of regional centers. These centers are basically regional service centers providing high order goods, some of which were previously located only in large metropolitan areas.

² The basis for selecting these sites for development as growth centers is unclear. Neither the Federal nor the N.S.W. state governments have published any detailed studies of the advantages of these two sites as against other possible candidates. However, it would appear that the state government would desire to promote the development of a growth center which would maximize economic growth for the state. The federal government, on the other hand, would be more interested in maximizing national growth. These policies may lead to conflicts in the joint financing of growth centers by federal and state governments.
The equity criterion here is that access to these services for many country residents should be reasonably equal to that for metropolitan areas.

In addition, the development of growth and regional centers offers households and firms a wider freedom of choice in the type of urban center in which they wish to locate. While most countries have a wide variety in city sizes, there are few intermediate-sized cities (50,000 to 500,000) in Australia. However, Thompson (1972, 101) casts some doubt on the strength of the demand for this goal in the U.S., where there are alternative city sizes for people to choose to live in.

An additional goal related to the question of decentralization is the establishment of a "balanced" urban hierarchy. However, there is little evidence to suggest that a rank-size distribution of cities is better than a primate distribution (Richardson, 1972, 37). In considering city sizes in a federally governed country, should the distribution of city sizes for the state or nation be considered? Attempts at decentralization in Australia have been conducted on a state wide basis—the goal being to produce a "balanced"

---

3 This question is further examined in chapter eleven in the section Towards a National Urban System.
city-size distribution for the state. In chapter eleven, it is argued that this goal is not likely to succeed given the present size of the urban complexes around state capital cities.

Problems of Urbanization

The world trend towards urbanization has resulted in a relative or, in many cases, an absolute decline in rural population. Unfortunately, cities have in many cases grown too quickly, accentuating a number of problems such as: local and city government; internal transportation congestion, especially journey-to-work travel and parking in the central business district; pollution of the environment (noise, air and water); the provision of water for domestic and industrial use; and problems of overcrowding, such as poorly planned high density housing and lack of recreation areas. In this chapter some of these problems are discussed, as is the strategy of decentralization of population and economic activity to rural areas.

However, the success of the decentralization strategy is closely related to the nature of the problems in the metropolis itself. For example, severe traffic congestion in some of the older industrial areas combined with high prices for industrial land in other parts of the city may force a particular type of firm out of the city. A partial
focus in this chapter, therefore, is on the "push" factors which tend to force firms and individuals out of large cities.

It is extremely difficult to evaluate whether a city is too large, since many of the important factors are difficult to measure. Examples are the strategic significance of centralization of population and economic activity in planning for national defense; social costs of air, noise and water pollution; rising crime rates; and a decline in accessibility of urban amenities for the majority of urban dwellers due to the sheer size of the city and the concentration of these amenities (large libraries, botanical gardens, zoos) near the center of the city.

The only study which considers some of the problems of large cities in Australia is by Neutze (1965). However, Neutze restricts his focus to economic factors, although acknowledging the importance of social and political factors in affecting the actual growth of cities. Neutze discussed the costs of traffic congestion in Sydney compared with other cities in N.S.W. Traffic congestion was studied in detail because of its relative importance both for the movement of individuals and for industrial supplies. Traffic congestion increases travel time for individuals on their journey to work; Becker (1965) has estimated this time to be valued at
approximately 40 percent of a traveller's hourly earning rate. For the businessman, congestion decreases the value of the city as a place for the interchange of ideas with other businessmen and it restricts the movement of supplies and finished products. Thus even though cities allow large number of people to live within a relatively small area, the possibility of contacts is decreased with increased congestion.

Neutze estimated for three cities of widely differing populations the traffic congestion caused by an additional resident in the early 1960's (Table 1).

Table 1
Population and Traffic Congestion for Cities in N.S.W.

<table>
<thead>
<tr>
<th>Population 30th June 1961</th>
<th>Traffic congestion cost in dollars caused by an additional resident</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sydney</td>
<td>2,179,022</td>
</tr>
<tr>
<td>Wollongong</td>
<td>128,360</td>
</tr>
<tr>
<td>Wagga Wagga</td>
<td>22,092</td>
</tr>
</tbody>
</table>

It is probable that the differences in traffic congestion costs between the three cities have become even greater since this time, because the population of Sydney had increased to 2,712,610 in 1969 while road building activity has lagged far behind. (Statistical Divisions and Subdivisions, 1970).

In considering the provision of public services, there has been considerable debate as to whether or not economies of scale exist in large cities. Gabler (1969) found that for the population size range of 25,000 to 250,000 for cities in Texas, Ohio and New Jersey there were no major economies or diseconomies of scale. For cities greater than 250,000 there was evidence of diseconomies of scale in most public services, with the exception of expenditure on highways and general services. However, Gabler and others have not been able to measure the quality of urban services very effectively, and some of the so-called diseconomies of providing urban services may be because large cities provide better quality services than small towns.

However, Alonso (1971a) points out that most analyses of the optimum size of cities have concentrated on the "presumed diseconomies of urban scale, and have sought to establish that population at which costs per capita are least, regarding this as optimal" (Alonso, 1971a, 68). In addition, the focus on the provision of public services
has ignored the variation in producers' costs with city size. Alonso considers that the population size which achieves minimum per capita cost (Pa) is unimportant (Figure 2).

![Urban Cost and Product Curves with City Size](image)

Source: Alonso (1971a, 71).

**Figure 2**

Urban Cost and Product Curves with City Size

The point at which a city makes its maximum contribution to national income occurs at Pc, where marginal cost is equal to marginal product. Alonso considers that from "the point of view of the inhabitants of the city a more sensible objective would be the maximization of the difference between average product ... and average cost (Pf).... This
difference may be regarded as per capita disposable income" (Alonso, 1971a, 71).

The evidence Neutze (1965) presents for Australia concerning costs and products is very scanty and it seems difficult to decide whether cities derive economies of scale or not. However, the cost of living in Sydney is substantially higher than in the rest of N.S.W. No accurate figures are published on the cost of living in different areas; Neutze uses the old 'C series' Cost of Living Index, last published in 1952, which shows Sydney to have the highest cost of any city in N.S.W. apart from the isolated mining center Broken Hill. However, the cost of housing in Sydney has risen very steeply since this time, becoming a major component of personal expenditure. In addition, prices of industrial land have risen steeply as the flat accessible areas in the Cumberland Plain are filled up. However, despite the fact that average and marginal costs are high, it is possible that the average and marginal products will be still higher. Since there has been no analysis of the average product for Australian cities, the accurate determination of optimal sizes of cities on economic grounds is not possible. To a large extent, this problem reflects the difficulty of measuring many of the relevant variables in economic terms.
While there is some disagreement over the economic arguments concerning the growth of large cities, other considerations, such as national defense and the provision of alternative city sizes as alternatives for urban dwellers, point to the need for at least some decentralization within Australia. The importance of these goals is very difficult to assess. However, as the difference in size between the country towns and the state capital cities increases, it seems likely that the demand for cities away from the existing metropolitan areas will grow. This demand will probably reflect a combination of different goals.

**Growth Centers**

Two of the most frequently suggested alternative strategies that have been proposed to ease the congestion in cities are: firstly, new towns or satellite cities and, secondly, the decentralization of population and economic activity to areas outside the metropolitan area. However, decentralization has not been very successful in Australia mainly because it has been envisaged as a policy which builds up the population of every country town. This policy has failed because it deprives the manufacturer of the advantages of agglomeration that a city provides.

In addition, Neutze (1965) makes a distinction between
decentralization and a depressed area policy. Depressed areas are characterized by a decline or stagnation in economic activity and are often present in places which are not adaptable to changes in technology. The two policies may coincide, as in the case of Lithgow, which is a possible site for decentralization projects and depressed area aid. However, the two are quite different in intent, since a decentralization policy attempts to identify growth centers which are in a favorable position for economic growth rather than propping up chronically depressed areas. The two policies could be linked together under the broader question of regional development.

Darwent (1969) has reviewed the literature on growth poles and has distinguished between growth poles and growth centers, the former being developed independently of geographic space. The growth center concept is of greater interest in this research where focal points and their associated functional regions are identified. Richardson (1969) states that the concept of a growth center is related to an optimum size of production and population at which maximum advantage is gained from scale and external economies without incurring serious diseconomies of agglomeration. External economies are found in large cities, and the development of a growth center attempts to recreate these advantages at other points in space.
Growth centers arise either as a result of free market forces or by deliberate government action. The former type is termed a natural center and the latter a planned center. This research is concerned with planned centers, although the distinction between the two is not as clear-cut as it might seem, since planned centers should be located at points which are likely to grow even with limited governmental assistance. 4

Nichols (1969), in reviewing the development of the growth center literature, states that much of the early research by French economists during the 1950's was developed without reference to geographic space. However, Boudeville (1966) emphasized the regional character of economic space and, in particular, discussed polarized space or what amounts to functional regions. The emphasis in this type of approach is on the linkages that exist between points distributed in geographic space and the intensity of interaction associated with those linkages. As such, polarized space is compatible with the central place structure of a hierarchy of cities of ascending size and function. The propulsive

4 This policy is not always followed in practice and a growth center policy is often confused with one for depressed areas. Hansen (1971, 38) discusses an example in the United Kingdom where attempts were made to develop growth centers in areas which were economically depressed and had little chance of achieving any significant economic growth.
industries that create economic growth poles have a geographic location in growth centers which are the larger, more functionally complex centers in the urban hierarchy (Gauthier, 1970, 616).

One of the basic notions behind the growth center concept is that economic activity tends to agglomerate around certain focal points. "The polarisation flows (commodities, factors, services, traffic, communications, etc.) will gravitate within a sub-region towards the control center (or dominant pole), but because of the costs of moving through space their density will be reduced by distance" (Richardson, 1969, 416).

Central place theory, with its nested hierarchy of central places, underlies a part of the growth center literature. Richardson (1969) considers that growth points are almost certain to be high ranking central places, and that one of the major agglomeration economies is the provision of services to the hinterland.

At the conceptual level, however, the two phenomena (growth point and central place) are by no means identical. Central places will be very numerous in a region though arranged in an urban hierarchy, while growth points will be few, in some cases only one within a region. An even more significant difference is that the polarization flows will be more intense and of a wider character around a growth point than around a central place where commuting flows for shopping, leisure and other services will predominate (Richardson, 1969, 420).
Hansen (1971) considers that one of the major problems in applying central place theory to the study of growth centers is in identifying precisely how growth is transmitted through an urban hierarchy. Hansen (1971) and Richardson (1969) consider that few of the studies on the spatial diffusion of innovations down the settlement hierarchy have been based on industrial innovations and new production techniques.

However, these criticisms ignore the work by Pred investigating the relationships between industrial inventions and innovations with urban growth in the U.S. (Pred, 1966). In addition, more recent research by Pred (1971a and 1971b) on the flows of information and diffusion of innovations in the development of the U.S. urban system in the preelectronic communications era identifies the hierarchical and non-hierarchical components in the diffusion of industrial innovations. Pred (1971a) concludes that a gravity model formulation which allows for lateral and smaller-to-larger diffusion dyads often describes diffusion within an electronic era urban system better than any strictly hierarchical model.

Growth Centers, Flows of Information and Transportation Networks

Meier (1962) hypothesized that cities have grown rapidly
because they are places of high information content and provide a means of allowing easy transfer of information between decision-makers. Thus decision-makers located in a city have a better chance of making correct decisions than if they were located in peripheral areas outside the city. Similarly, Tolosa and Reiner (1970) define growth centers as being vertices in a directed network of economic and information flows. Information and economic flows are interdependent (one to a large extent generates the other); thus these sets of flows tend to have similar patterns.

Törnqvist (1970), in analysing Swedish data, argues that a strong force in the process of urbanization is the need for personal contacts in the exchange of information between specialized work functions in society. Instead of concentrating on flows of raw materials and finished products as being the determinants of industrial location, Törnqvist cites a characteristic feature of postwar location trends in Sweden as being concerned with industries which are information processing activities. While the importance of distance is declining for the movement of goods, distance—or more particularly travel time—is still extremely important in the movement of decision-makers.
One of the important external economies of growth centers, therefore, is the increased volume of information available. The presence of government administration, universities, technical and teachers colleges would thus increase the information content as well as improve urban amenities for the region. Nichols (1969) gives two advantages of industries of this type: firstly, they improve the educational standard of the indigenous population, thus improving the labor force; secondly, such improvements make the area more attractive to people who desire an urban standard of amenities.

The relationship between a growth center or regional center with its hinterland is an extremely important variable in the growth of the city. Other things being equal, the better the transportation connections between the market area and the growth center, the greater will be the diffusion of economic development. Since a high order central place is the focal point for a region in the provision of goods and services, it is desirable to take advantage of these existing linkages in stimulating the economic development of the region by selecting the high order central places as growth centers.

Gauthier (1968, 1970) points out that improved transportation connections with the metropolitan area may
increase the agglomerative advantage of the large city over the rest of the region. However, growth centers could be encouraged by improving the accessibility of the city to its hinterland by road, rail and air. Links to other growth centers could also be improved so that the development of a highly interlocked system of cities is encouraged. The central place hierarchy tends to have few linkages between settlements of similar rank in the hierarchy, since most interaction is with lower or higher order centers. However, the success of manufacturing and tertiary industries, normally located in metropolitan areas, requires good connections to markets and sources of raw materials. Hansen (1968) points out a similar possibility with the highway building program started by the Appalachian Regional Development Act of 1965. The act assumed that by providing access to Appalachia, industry would be attracted to the area. However, it is possible that the improved highways will stimulate out-migration or simply improve the competitive position of cities and towns outside the region.

This area of research on transportation impact in regional development is not discussed in any detail in this study, even though it has important implications for decentralization and regional development. The implications of a reduction in communications costs is briefly
outlined in chapter seven, and problems of reorganizing transportation networks are discussed in the context of the location of regional mail exchanges in chapter ten.

Growth and Regional Centers in New South Wales

For the purposes of this research a distinction is made between growth and regional centers: the latter refer to centers which are high order central places performing primarily service functions for their region. Growth centers include tertiary activities but, with the exception of Canberra, should have some industrial activities. They may be located quite independently of a surrounding region, although it is often desirable that the tertiary and secondary sectors should be integrated when planning the location and type of growth center. To some extent the distinction between growth and regional centers is artificial, since it is possible that regional centers will attract some secondary industry. However, this proposition seems unlikely at the present time.

A regional center is linked to lower order settlements within its region and to the next higher order city in the state, which in the case of N.S.W. is Sydney. As a service center for a region, a regional center's eventual size will be determined by the population and the resources of the region it serves. It is apparent that many
functions which could exist in these centers have in the past centralized their operations in Sydney. Thus a certain potential for growth exists in the decentralization of these functions to the regional centers. The identification of these cities as regional foci with clearly defined boundaries is an important step in the development of regional planning in the state.

However, regional centers, in and of themselves, will neither generate sufficient internal growth to attain a high rate of economic growth for their region nor attract industry to them without some form of government aid. Given the scarce resources for this type of development in the state, it is unlikely that sufficient aid for more than one or two cities will be available in the next thirty years. For planning purposes two types of cities must be considered: the first are regional centers whose regions provide a mesh which cover the entire state and ensure an adequate standard of services for the rural community; the second are growth centers which should be located at one or two points possessing the maximum growth potential.

The centralized nature of the settlement pattern and of the transportation and communications networks of N.S.W. is similar in some respects to that of France, where
Paris has dominated the rest of the country. Cities in the major French provinces have been bypassed in favor of the capital by government departments and private firms.

The policy is to concentrate investment in the eight regional metropoles, each of a minimum target size of one million, and develop an appropriate 'armature urbaine', that is, a central place structure, which will maximize the interdependencies of the peripheries of each polarized region with its respective center by gathering flows from the periphery and directing them through the hierarchy, and by bringing the benefits of urban life down to the smaller centers (Darwent, 1969, 14).

While a focus on developing cities away from the central metropolis is important in any regional development policy, it is necessary to consider the nature of metropolitan dominance in analysing growth and regional centers. For example, what is the areal extent of Sydney's functional region? Is it possible to establish a central place structure in all parts of the state, considering that large areas are dominated by the functional region of at least one state capital city (namely, Sydney, Melbourne and Brisbane)? While a potential growth center such as Albury/Wodonga is well situated in terms of its accessibility to both Sydney and Melbourne for some types of industries, its position as a regional center is questionable since many consumers in the Riverina may obtain high order central goods from Melbourne.
Due to the lack of empirical research, it is difficult to predict whether businessmen in particular industries are prepared to establish plants in country areas. Even if costs within the Sydney Metropolitan Area were so high that relocation was necessary, it would be important in an analysis of the location decision to consider cities in other states as potential sites. In fact, the N.S.W. state government would like industry to locate outside the Central Coastal Region. However, it does not want to lose industry to other states and is not prepared, therefore, to put tight controls on the growth of Sydney.

An important component of a government decentralization policy is its attitude to future growth in the cities and regions which are growing rapidly. While this subject is not considered in this research, it is obviously an important problem in any practical implementation of a policy of decentralization. Rodwin (1970) discusses the difficulties the French have had in implementing controls on the growth of Paris and its region. Many difficult decisions must be made as to which industries will be allowed to grow and which ones must be forced to locate elsewhere. Perhaps a more important argument against the placement of controls on the growth of Sydney and other large cities is that there is no conclusive evidence that they have reached the stage of diseconomies of scale.
The research reviewed in this chapter has shown conflicting views concerning the presence of diseconomies of agglomeration in large cities. Perhaps, as Richardson (1972, 43) suggests, some of the problems of large cities could be solved by more efficient planning within the city. Unfortunately, the spatial form of a city with approximately three million people has a strong inertial force on the direction of future growth. Given the projected rapid increase in population in Sydney by the year 2,000, it is unlikely that existing and future development can be rationally planned.
CHAPTER III
Spatial Analysis of Tertiary Industry Location, Network Structure and Flows

In this chapter the linkages between tertiary industry location and transportation and communication networks are explored. This chapter lays the basis for the later analyses of the empirical interrelationships between networks and the decentralization of tertiary industry location. It is hypothesized that linkages between nodes reflect the regional structure of the state as well as influence this structure.

In considering the location of tertiary industries, the relationships between descriptive and normative approaches is discussed. This theoretical discussion is followed up in chapter eleven by a discussion of some of the empirical correspondences between descriptive central place studies and normative approaches to the location of tertiary industries in N.S.W. In addition, a typology of tertiary organizations is presented in this chapter, which is discussed in the context of finding the optimal locations for central facilities. This typology is used in chapter nine in discussing the location of type I organizations, in chapter ten for type II organizations and in chapter eleven for relating the location problem to the results of the
regionalization of transportation and communication networks.

**Review of Geographic Literature**

The literature on tertiary industry location in geography is quite extensive and is mainly concerned with central place theory (Berry and Pred, 1965). However, in this study the problem of decentralization of tertiary industry and the location of regional centers is approached by regionalizing network structure and flow patterns, as well as by the use of an optimizing location-allocation model. The descriptive analysis of different modes of transportation and communication provides an underpinning for the location of central facilities (branch locations) of a tertiary organization. In this section the linkages between descriptive and normative approaches to central place studies are discussed. The concepts of range of a good and threshold developed by Berry and Garrison (1958) in descriptive central place theory are also useful in normative approaches to the location of branches of tertiary organizations.

An analysis of the transportation and communication networks is important in understanding the settlement hierarchy in a particular region. Haggett's outline of a systems approach to human geography stressing movements, networks, nodes, hierarchies and surfaces is based on the concept of a nodal or functional region as an open system (Haggett, 1965).
Movements of goods, people and information take place between the major centers or nodes of economic activity and are constrained by the existing transportation network structure. The systems approach has stimulated research on integrating studies of movement to tertiary facilities with those concerned with the spatial structure or pattern of these facilities. Thus the spatial structure of an economy may be viewed as a set of nodes of economic activity joined together by transportation and communication networks.

Berry and Garrison (1958) have emphasized the concepts of population threshold and the range of a good as the two basic concepts which determine the spatial organization of tertiary activities. The range of a good delineates the market area of a central place and represents the maximum distance a customer is willing to travel to buy that good. In addition, the decisions made by entrepreneurs must be taken into account in determining the central place hierarchy. The minimum purchasing power or the sales volume at which firms enter or go out of business is termed the threshold sales level of a firm.

Research in central place theory discussing the range of a good has regionalized space on the basis of a nested set of functional regions: smaller centers and low order functions have trade areas which nest within those of large centers and
high order goods. Thus central place theory leads to an interpretation of the spatial organization of an economy which stresses interconnections between areas based on the travel behavior of consumers. These functional regions, in the modern formulations of central place theory, are not defined exactly by the theory but are empirical generalizations which may be observed for particular regions. However, apart from the early formulations of Christaller and Lösch, little research has been conducted on the optimal service areas of settlements.

However, some research in human geography concerned with regionalization of tertiary activities has attempted to derive a set of optimal regions for a particular organization. These studies, stemming out of operations research, have used the transportation model to derive the optimal regions (Gould and Leinbach, 1966; Goodchild and Massam, 1969). A limitation of the studies is that the facilities being located are at an equal rank in the organizational hierarchy. There has been very little discussion on the optimal hierarchical location of facilities apart from one study by Scott (1971a). The concept of range is not applicable unless a constraint is built into the model limiting consumer travel to distances less than a certain value. However, the transportation model is a fairly rigid optimizing model and other techniques such as simulation or dynamic programming offer more scope for
building in realistic features of an organization's operating environment.

A further limitation of these studies is that the solutions refer to a particular organization, such as a school or hospital system in a region, and only indirectly to the settlement hierarchy. An aim of this research is to demonstrate some partial links between the location of branches of an organization and regional centers in a settlement hierarchy. There is an obvious need for this linkage to be made in location theory with the increased importance of the location decisions of large organizations in both the public and private sectors of the economy. The range of a good is to some extent dependent on the organizational structure of firms and the extent to which they enjoy internal economies of scale. Where the sale of a particular set of goods is dominated by one or two sellers, the location of their branch facilities will determine the distance consumers will have to travel. Similarly, if large economies of scale are present in selling a particular good, then consumers will be forced to travel further for the good.

Berry and Garrison (1958) defined threshold as the minimum amount of purchasing power necessary to support the supply of a good from a central place. Geographers have largely
neglected the concept of threshold, although Davies (1968) has criticized the work by Berry and Garrison for equating the threshold of central functions with the population of the central places rather than with that of their market areas. The term threshold is essentially an economic concept describing the cost-revenue structure of the firm. However, data limitations have made it virtually impossible to measure thresholds in this form, and in most empirical studies the population of a town or the town and its market area has been used.

A location problem similar to that faced by central place theory has been discussed in the operations research literature for central facilities, such as warehouses, although the method of approach has been to derive the optimum location and size of the facilities. The shape of the fixed and variable cost functions for an organization has been used in the determination of the number, size and location of these central facilities rather than the more empirically convenient threshold population sizes used in central place theory. This problem will be discussed in more detail in the next chapter, but there seems to be a point of contact here between the central place literature and the optimal location of central facilities.
Optimal Locations of Tertiary Organizations

The nearness problem, according to Bunge (1966), takes the form of finding the spatial arrangement of interacting objects, often of different dimensions (point-lines, points-areas, lines-areas, lines-volumes), and placing these objects as near as possible to each other on the earth's surface. Nearness is not necessarily expressed in straight line distance, since the shortest path between two points may be dependent on the cost of movement as well as on social, cultural and psychological factors.

The problem of locating a point to serve an area was considered by Hotelling, who dealt with the relationship of a seller at a point serving a linear market. He then introduced a number of sellers and identified the best competitive location of each seller. The solution to the problem of finding the best location for a single seller serving an area is relatively easily found and is given by the point of minimum aggregate travel, which is also the most accessible point to the market population. The simultaneous location of more than one seller is much more complicated, since the location of one seller affects the location of the others and vice versa. The aim of the seller is still to locate as close as possible to the market population with the constraint that the
location of the other sellers must be taken into account in the location decision. In addition, the competitive and the socially optimal solutions may be quite different.

Bunge also considered the problem of locating lines to serve points. One example is the travelling salesman problem, which is concerned with finding the shortest path through a sequence of nodes and returning to the origin without using any node more than once. A more practical version of the travelling salesman problem is the vehicle scheduling problem, which introduces capacity constraints for the carrier and demand variations at individual nodes (Figure 3).

![Vehicle Scheduling Problem](image)

The vehicle scheduling problem is applicable to both collection and delivery problems and provides a measure
of the nearness of a central point to a region given certain constraints on operation. Thus the problem of locating lines to serve points can either entail the building of new links between nodes or the selection of paths within the set of links already available.

Types of Tertiary Organizations
Organizations with branch locations or central facilities are considered where the location of these central facilities is characterized by: (1) distribution and/or collection of goods and services from a market population of many buyers and/or sellers dispersed in space; (2) the location's not being tied down to specific areas due to natural resource variations, such as port facilities or mineral deposits; (3) a strong desire to minimize the movement of consumers to the central facility for either competitive or social welfare reasons. Apart from the dichotomy between private and public organizations, three basic types can be recognized in terms of locational considerations. Type I organizations are characterized by point facility locations and single trips between facilities and consumer locations. For type I organizations two basic divisions can be recognized: firstly, type Ia organizations in which individual consumers travel to the facility located in their district; secondly, type Ib organizations in which the facility sends a service unit in response to an individual consumer's request (Table 2).
Table 2

Types of Tertiary Organizations

<table>
<thead>
<tr>
<th>Type of Organization</th>
<th>Examples of Organizations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TYPE I</strong></td>
<td></td>
</tr>
<tr>
<td>(a) Individuals travel to the facility in their district</td>
<td>department store in a shopping center, out-patient clinic, over-the-counter services provided by government departments (post office, employment offices)</td>
</tr>
<tr>
<td>(b) Facility sends a unit to service an individual request</td>
<td>fire, police, ambulance, taxi-cab, television repair, plumbing and electrical services provided for consumers at home</td>
</tr>
<tr>
<td><strong>TYPE II</strong></td>
<td></td>
</tr>
<tr>
<td>Facility sends a unit to service a number of requests from consumers on the one trip</td>
<td>school bus, delivery of mail, servicing of petrol (gas) stations by tankers and newspaper delivery</td>
</tr>
<tr>
<td><strong>TYPE III</strong></td>
<td></td>
</tr>
<tr>
<td>Facilities characterized by continuous connections in space (networks)</td>
<td>water, sewer, electric power, and telephone companies</td>
</tr>
</tbody>
</table>
Type Ia organizations are widespread. The most common example is the retail store which serves a region within which individuals make trips to buy goods or services. Service regions can be defined around each central facility for types Ia and Ib, and it is possible to optimally assign customers to facilities using the location-allocation models. Type Ib organizations service individual requests so that transportation costs are high in proportion to the number of consumers serviced. However, examples of these organizations are emergency (police, fire and ambulance) and commercial (taxi-cab, individual delivery courier service) services where time rather than cost of the service is more important for consumers.

In a series of studies by the New York City Rand Institute, a number of type Ib organizations have been examined in which mobile units are stationed at selected locations within a city and then despatched to requests for service from points within each facility's service region (Larson and Stevenson, 1971; Carter et al., 1971). The minimization of average travel time or response time is used as one measure of the organization's performance, although in actual operating environments there are usually several, often conflicting, effectiveness measures that need to be considered.
Type II organizations must not only locate central facilities, but also deliver to and/or collect from a number of consumers on any one trip. Thus in deciding on the number, size and location of schools in a particular district, not only must the potential school population and the distances of students from the proposed school sites be taken into account, but the costs and maximum travel time limitations in picking up and collecting the students must also be taken into consideration. Some alternative solutions to this problem range from a centralized operation with long distribution trips to final consumers (Figure 4a) to a highly decentralized set of central facilities with only short trips to the final consumers (Figure 4b).

(a) Centralized  
(b) Decentralized

- Central facility  
- Customer location

Figure 4

Type II organizations

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This assumes that the education authorities are responsible for the movement of students to and from schools.
For type II organizations Bunge's problems of, firstly, locating points to serve an area and, secondly, finding a network (a set of distribution or collection paths) to serve a set of points are interrelated and must be considered together in deciding on the location and capacity of central facilities. Type Ia organizations only indirectly consider the travel costs of consumers to central facilities, since it becomes an important consideration in competitive systems if a competitor could find a location closer to the consumers. In type Ib and II organizations, however, the organization must directly bear the costs of distribution to the final consumer, so that delivery routes and frequency of delivery could become important components of the location decision.

Type III organizations are only briefly treated in this research, although the location of telephone switching centers and nodal points for other types of networks have some interesting implications in discussing the spatial structure of a region.²

² Changes in communications technology have resulted in changes in the number and type of switching centers in N.S.W. One result of these changes is that some towns have lost workers due to the improved automatic handling of telephone calls. Conversely, changes in the distribution of population within a region will possibly require changes in the capacity of links between nodes.
One problem in analysing organizations in terms of these abstract spatial properties is that an organization may fit into several categories, since for some types of service consumers come to the facility, whereas for other types of services it may be cheaper for the organization to arrange a collection and delivery service. An example of such an organization would be a post office, which delivers mail and as well provides over-the-counter services for customers wishing to send parcels, buy stamps, etc.

The optimal locations and boundaries of service areas for type I and II organizations may, in fact, coincide if there are points in the transport network that are much more accessible to the market than most nodes in the network. However, using an example of locating a single facility in an urban area, a single type Ia facility should most probably be located at a central point to take advantage of the radial pattern of highways and public transport routes serving the central point. A type Ib organization may select a location away from the congestion of the center to reduce the response time in answering a call for service. Thus the accessibility of a location may vary for different organizations. A further consideration is that type Ib organizations provide their own transport, whereas for type Ia organizations consumers may use a car or public transport.
Regionalization of Transportation and Communication Networks

Both the location-allocation and the vehicle delivery problems involve a partitioning of space to minimize some measure of distance travelled. Scott (1971b, 155) considers that the regionalization and political districting problems are directly derivative from the location-allocation model.

The regionalization problem is basically to partition a set of n data points distributed in Euclidean N-space into m groups so as to optimize some objective function. Usually the criterion of optimization chosen for a particular problem will be one which in some sense makes each of the m groups of points maximally homogeneous.... The problem may, in addition, be associated with side-conditions which permit aggregation only of contiguous sub-regions. This would prevent the major regions in the final solution from being fractionated and dispersed over space (Scott 1970, 114-5).

The object of regionalizing transportation networks in terms of their flows or structure is to group nodes or towns together on the basis of the similarity in their incoming or outgoing flows or the presence of similar types of connections (in terms of travel cost) with other nodes. This approach to regionalization has affinities with the location-allocation problem, which attempts to locate a number of central facilities by optimally partitioning space to serve consumers.

From data on telephone message flows one can define a set
of functional regions using factor analysis. Similarly, factor analysis of travel cost data between nodes delineates a set of regions which group nodes with similar patterns of connections to other nodes in the region. It would be expected that the regions produced by both sets of factor analyses will provide somewhat different emphases in the regionalization of the state, which may be compared with those produced by the location-allocation model.

Regionalization of Network Structure
Garrison and Marble (1964), Gauthier (1967), and Gould (1967) regionalized transport networks using factor analysis. The aim was to break down the complex network structure into simpler independent components which can be assigned some geographical meaning. Gauthier factor analysed the accessibility surfaces of the São Paulo highway network over three time periods. He found that a small number of independent factors resulted from the collapse of highly intercorrelated connections between nodes of the network. These factors formed clusters of nodes which displayed similar patterns of connectivity. The analysis then classified nodes on the basis of the similarity in their accessibility to the highway network.

One problem with this approach is that towns may be
connected by several transportation and communication modes, and the clusters produced for one mode of transportation may be quite different from those in another. This problem has not been tackled in the geographical literature, although this is partly because a complete listing of the volume of goods, people and messages between nodes in a region would be impossible, and even partial surveys of flows are extremely difficult to collect. Thus it is difficult to evaluate the relative importance of each mode of transportation and communication when regionalizing the structure of different networks. Most geographical studies have concentrated on road networks, but it is likely that regionalizing railway, air and telephone cost matrices will lead to different clusters of nodes being formed. It is hypothesized that the clusters formed by regionalizing different modes of transportation and communication will provide a number of alternative views of the spatial structure of N.S.W. Each mode is considered of equal importance, since information is not available on the relative volume of traffic carried by the different modes.

Regionalization of Telephone Message Flows

Flows of information provide a measure of regional
economic structure of a particular area. While flows between settlements may be of many kinds (e.g. newspaper distribution, travel for work, retail and educational purposes), Nystuen and Dacey (1961) claim that the number of telephone calls between nodes provides a single index of this multidimensional association among settlements. Theories of nodal regions and central place hierarchies provide the bases for the identification of linkages between settlements. The direction and magnitude of flows between nodes are indicators of spatial order in the regional structure of urban society.

Berry's methodology in studying commodity flows in India (Berry, 1966) is adopted in this study. Berry factor analysed origin-destination matrices of commodity flows to identify functional regions for each commodity. The data matrices were arranged so that rows represented origins and columns, destinations. The factor analytic approach explores the similarities in flow patterns, groups origins and destinations into functional regions on the basis of these similarities, and reveals the structure of the flows.

Factor analysis of any one of the matrices can proceed in two ways:
(a) R-mode. Each column is correlated with every other column, and the resulting matrix of correlations showing similarities in the way destinations assemble their needs is factored. Rotated factor loadings yield groups of columns, or consuming regions, and factor scores indicate the most prominent sources of shipments to each group.

(b) Q-mode. Each row is correlated with every other, yielding a correlation matrix showing the similarities in the way origins ship their products to destinations. Factoring yields . . . producing regions, and indicates the most prominent destinations of shipments from each group (Berry 1966, 148).

Illeris and Pedersen (1968) use factor analysis to regionalize a matrix of inter-district telephone calls in Denmark. The resulting factor loadings show the regional foci and factor scores their influence zones. The factor analytic results were compared to other methods of measuring the centralities of central places, such as employment in wholesale trade and occurrence of high order central functions. The differences were not very large except for several towns situated in densely populated regions near major metropolitan areas which had moderately high centrality values. In contrast, the factor analytic technique delimited foci of a more independent character remote from other major urban areas which tend to be spaced far apart, each dominating its own hinterland but located outside the influence fields of other centers. The authors consider that these regional foci defined by factor analysis will often be the most appropriate ones for
the location of regional activities such as local government.

The regional nodes identified in the factor analysis of flows and structure provide an alternative view on the location of central facilities to that given by the location models discussed earlier. In addition, it is of interest to compare the results from both approaches with the actual central place structure of a region. Thus the research attempts to tie together aspects of the descriptive central place literature with, firstly, transportation and communication networks and, secondly, the location of different organizations.
CHAPTER IV
The Optimal Degree of Decentralization

In this chapter after discussing the general problems of decentralization, the question of the optimal degree of decentralization is considered. Methods of solving this latter question are then considered. For type I organization, the location-allocation problem and the related question of sequential allocation is discussed. For type II organizations, the vehicle delivery and a dynamic combinatorial problem are reviewed. The techniques discussed are relevant to chapters nine (type I organizations) and ten (type II organizations), although an optimizing solution is not used in the latter chapter.

This chapter builds on the general discussion of tertiary industry location introduced in chapter three. It provides a basis for the analytical section of the thesis, which is concerned with the location of branches of organizations. In addition, the scope of the research concerned with the problem of decentralization is more clearly defined.

Decentralization: The General Problem

With increasing centralization in modern society the question of the optimal degree of decentralization has
become important in many political, social and economic problems. Limited aspects of this area of research have been considered in political science (Kochen and Deutsch, 1969) and public administration (Maass, 1959; Fesler, 1968). For example, political scientists use the term to describe a condition or trend in an areal hierarchy of power. Governments or administrative agencies can be viewed as exercising power over formal regions (e.g., states, districts, local communities), as well as in a set of functional regions where the powers of governments are arranged in a pyramidal structure with those at higher levels having control of larger geographic areas.

Decentralization is also important in organizational structure from the economic standpoint, since the profits earned by an organization are influenced by the number and roles performed by branch office locations. Levy and Truman (1971) stress that this economic aspect of decentralization is quite different from its use in political science due to a number of factors. Among the most important are: firstly, the possibility of the presence of conflict between the government organization and its clients on the form or substance of what is produced; secondly, performance is difficult to judge in governmental organizations since there are no "prices" or measures of an organization's performance. This research
is concerned with the economic aspects of decentralization in both the public and private sectors. While the non-economic aspects mentioned by Levy and Truman (1971) should be recognized, to function effectively many governmental agencies must be located as near as possible to their customers.

Teitz (1968) has discussed some of the problems in developing a theory of public facility location. He points out that many public facility organizations must consider the location of the entire system of facilities covering their area of jurisdiction. Private organizations may or may not cover the entire area, depending on competition in other areas, the relative profits to be made and the growth prospects of certain regions. One basic division in public organizations is between emergency services and others. As Teitz points out:

When a man's house is on fire he rarely pauses to consider whether or not to call the fire brigade. Nor, in our present system, is he usually presented with a bill for fire protection service that varies with the size of fire he enjoyed during the previous year. Thus, once some communal decisions about form and quantity of expenditure on fire service have been made, the form of system will depend on the expected scale and pattern of fires, the technology of surveillance and response, and the measures of effectiveness employed (Teitz 1968, 43).
A second category of public organizations is those that provide a service which has a complete coverage of the area of jurisdiction, such as schools and post office delivery of mail. However, the speed of service is not as critical in this category as in the former.

A third category includes such organizations as hospitals, government departments (employment, social services) and libraries. For these services travel cost, including time and inconvenience, represents a major cost to the consumer. Thus the demand for these services decreases with distance. Klaassen (1968) reviewed an extensive body of literature on the distance elasticity in various types of educational and medical facilities. He found that high school students, in the case where education is not compulsory, have a steeper distance decay function than university students. However, where education is compulsory (i.e., for students up to the age of sixteen) the distance elasticity is zero.

Optimal Degree of Decentralization in Organizations

In chapter three a typology of tertiary organizations was

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1 Exceptions to the negative distance decay function arise for many organizations. For example, in considering patient travel to hospitals, racial discrimination or religious preferences frequently lead to patients' travelling longer or shorter distances than would be expected if distance only were considered (Earickson 1970).
outlined. In this section the previous general discussion on decentralization is focused on the optimal degree of decentralization for type I and II organizations. The last section in this chapter considers the methods which have been used to optimally locate the different types of organizations.

In discussing the location of health care facilities, Schultz (1970, 383) states that the degree of decentralization is socially significant because it affects:

1. the cost of producing services and thus the user charges which must be made;
2. the cost of travel to consumers, visitors and medical personnel;
3. the frequency with which people in a region use health care facilities;
4. the external costs to society caused by increased travel and by reduced utilization of facilities.

The general question of decentralization of an organization in a locational context is to determine the optimal number of central facilities, their geographic spacing in a particular region and the particular hierarchial structure. The number of central facilities is largely dependent on cost criteria, the utility of time and
economics of centralization. The spacing of the facilities depends on the spatial structure of the region. Factors such as the structure of the transport network, the population or market distribution and the location of existing centers influence the location of central facilities. The areal hierarchial structure adopted by an organization leads to different types of decisions being associated with different orders of regions or administrative areas. The particular hierarchial structure adopted will depend on the number and spacing of central facilities, but it in turn will influence these factors.

Trade-off Problem
The basic location decision for private and some types of public organizations can be represented as a trade-off between the cost of building and operating facilities to meet the demand for a product or service and the cost of transportation for consumers. The larger the number of central facilities, the lower will be the cost of distribution to consumers. However, as travel costs decrease, the investment in facilities must rise. At some number of facilities total costs will be at a minimum. Beyond this point, the cost of adding a facility exceeds the savings in transport costs. Thus
with free entry of firms the number of central facilities is maximised so that aggregate transport costs are at a minimum, a solution which obviously benefits consumers. However, when this solution is used, production takes place at relatively high unit costs and consequently high prices are charged.

Basically, the higher the costs of building and operating facilities, the greater the trend towards centralization. The higher the relative cost of transportation for consumers, the greater the dispersal of central facilities. Obviously there will be differences between organizations in the cost of building and operating the central facilities, so that some will be decentralized and others centralized. Similarly, the frequency of travel to organizations will vary considerably. For services with a high frequency of use a decentralized pattern of facilities may result.

Service Cost
The differences between organizations may be examined using an example of health care facilities discussed by Schultz (1970). Three levels of health care facilities are recognized: (1) neighborhood health center; (2) general hospital; (3) specialized medical center. Each order of services has a different long-run average cost function, which is
the sum of capital and operating costs for various levels of output. Since facilities are non-profit, prices are set equal to the expected long-run average costs:

\[ p_k (y_k) = c_{1k} (y_k) + c_{2k} (y_k) + c_{3k} (y_k) \]

where \( k \) is the order of services considered

- \( p_k \) the average cost/unit of the service
- \( y_k \) the number of service units provided/day
- \( c_{1k} \) the average capital cost/unit of service for neighborhood health centers
- \( c_{2k} \) the average operating cost/unit of service for hospitals
- \( c_{3k} \) the average operating cost/unit of service for specialized medical centers

The expected shapes of average service costs functions for the three orders of services are shown in Figure 5.

\[ y_k \] number of service units provided/day

Figure 5

Average Service Cost Functions for Health Care Facilities
The average cost/unit of service for a particular level of supply is much higher for the specialized medical centers. One would expect, therefore, that the level of output which minimizes average service cost will be greater for those specialized services. In this example Schultz applies central place hierarchical concepts: so that the specialized medical center might service an entire city; a general hospital, a large subsection of the city; and a neighborhood health center, as the lowest order, a local neighborhood.

Thus the three levels in the medical care hierarchy illustrate the range from centralization to a high degree of decentralization of facilities based on the fixed and variable costs of providing a service. Some organizations can establish branch facilities at a very low cost simply by renting office space and hiring locally some office staff. In contrast, organizations with high fixed and/or operating costs are characterized by a centralized pattern of facilities.

**Location - Allocation Problem for Type I Organizations**

A more specific formulation of the general decentralization question which applies to type I organizations is the location-allocation problem. Cooper has formulated
the problem:

There frequently arises in practical affairs problems that are concerned with how to serve or supply, in an optimum fashion, a set of destinations that have fixed and known locations. What must be determined, in these problems, is the number, location and size of the sources that will most economically supply the given set of destinations with some commodity, material or service (Cooper, 1963, 331).

We are given:

(1) The location of each destination;
(2) The demand or requirements at each destination;
(3) Transportation costs for shipping a unit of commodity a given distance;
(4) Fixed capital costs and variable operating costs for origins of any size.

It is necessary to determine the number, location and capacity of origins.

Revelle et al., (1970, 697) state the general mathematical formulation of the location-allocation problem

Minimize \[ z = \sum_{j=1}^{n} \sum_{i=1}^{m} d_{ij} (x_{ij}) + \sum_{i=1}^{m} F_1 (y_i) \]

subject to \[ \sum_{j=1}^{n} x_{ij} = y_i \quad i = 1, 2, \ldots, m \]

\[ \sum_{i=1}^{m} x_{ij} = D_j \quad j = 1, 2, \ldots, n \]
\[ x_{ij} \geq 0 \quad i = 1, 2 \ldots m \]
\[ j = 1, 2 \ldots n \]
\[ y_i \geq 0 \quad i = 1, 2 \ldots m \]

where

- \( z \) = total costs;
- \( x_{ij} \) = amount shipped from origin \( i \) to demand area \( j \);
- \( y_i \) = total amount shipped from origin \( i \);
- \( d_{ij}(x_{ij}) \) = cost of shipping the quantity \( x_{ij} \) from \( i \) to \( j \) (in dollars);
- \( F_i(y_i) \) = the cost of establishing and operating an origin at site \( i \), where \( y_i \) is being shipped from \( i \) (in dollars);
- \( D_j \) = the demand at area \( j \);
- \( n \) = the number of demand areas;
- \( m \) = the number of proposed origin sites.

With reference to the warehousing problem Revelle states that

the function \( F_i(y_i) \) is frequently nonlinear, and generally exhibits a large fixed investment for land, foundations, utilities, etc., before any amount may be stored or manufactured. Once the facility is begun, the marginal cost of storage or manufacture may decrease (economies of scale). The function then is usually concave and not amenable to linear programming (Revelle et al., 1970, 697).

The location-allocation problem is a generalization of Weber's classic formulation of the location problem for a
single central facility. It is difficult to solve: since all the central facilities must be located simultaneously, each central facility to be located will affect the location of the other central facilities. Scott (1970) suggests that much of the difficulty in solving location-allocation problems arises from the strongly developed indivisibilities which appear in most of these problems and require the use of cumbersome combinatorial methods. However, these problems have the fortunate property of having many near-maximal solutions. Thus it is possible to design a heuristic method which will find one of these near-optimal solutions and give a result within 2 or 3 percent of the fully optimal solution.

Kuenne and Soland (1971) have provided two algorithms which solve the multisource Weber problem. The first algorithm, Crosscut, is an approximate method which has proved to be easily solved for problems of quite large dimensions. "It is capable of yielding good approximate solutions which may suffice in some practical applications or which can be used in the branch-and-bound algorithm (Multiweb)... as initial feasible solutions for reducing computational time in obtaining the global minimum" (Kuenne and Soland, 1971, 4).

It is usually assumed that the spacing of the central
facilities is an important variable and that deviations from optimal locations will cause a significant increase in the cost of travel of consumers. Larson and Stevenson (1971) suggest that in an urban area with a demand surface that is homogeneous, the mean travel time resulting from a totally random distribution of facilities in the region served is reduced by only 25 percent when the facilities are optimally distributed. They suggest that the computational expense involved in finding the optimal solutions may be unnecessary, since heuristic algorithms give near optimal solutions. However, most regions have marked variations in population density due to urbanization forces, and a random allocation of facilities would most probably result in a larger than 25 percent increase in consumer costs for the region as a whole.

This research is concerned with those organizations in which the minimization of consumer travel is an important component of the locational decision. Even in cases where this factor is important, other considerations, such as agglomeration economies or short-run planning horizons, may be more important in affecting the final location of the central facilities. However, it is possible to build some constraints into the model to make it conform with more realistic factors. One
possibility suggested by Gould and Leinbach (1966) is that the set of potential sites must be drawn from towns above a certain size. This constraint enormously reduces the number of possible combinations of sites to be considered. Kuehn and Hamburger (1963) also develop a heuristic program based on the fact that most geographical locations are not potential sites, since in practice most potential sites will be located at or near concentrations of demand—i.e., cities or large towns rather than isolated areas.

Schneider and Symons (1971) have developed a heuristic approach to solving the location-allocation problem which is based on the idea "that man's intuition can be of significant use in guiding a computer-assisted search of the combinational space that contains all possible solutions" (Schneider and Symons, 1971, 1-2). The technique involves a man-computer interactive approach in which a participant attempts to reduce the cost of travel to a set of central facilities by a trial and error process. In addition, a constraint is added that the maximum distance for any trip should not exceed a certain travel time.

The location-allocation problem simply provides the optimal size, number and distribution of facilities
given the present market distribution and nearness of the nodes. Given that the present distribution of population in a region is over-centralized, then optimally locating facilities according to the location-allocation model may simply reinforce the present undesirable situation. Related to this problem is the fact that the location-allocation solution may not provide a good areal coverage in the provisions of public services. An additional constraint could be included, therefore, to ensure that no community is further than a specified distance from a central facility (Holmes et al., 1972).

Sequential Allocation

Many systems of central facilities are planned on what amounts to an ad hoc basis. A region is partitioned into smaller administrative areas as the organization expands its services or changes occur in the population and transport structure of the region. Often the new central facility will be established to relieve pressure on an office which is overburdened with work. The planning horizon of the organization is in general fairly short, and only a small number of future branch office locations are considered at any one time. Scott states that:

Most location-allocation systems, however simple their structure would in practice not
be unchanging over time. Temporal instability in such systems could result from changes in the spatial structure of the set of points to be served or from the progressive obsolescence of existing central facilities or from the installation of successive generations of central facilities or from any admixture of these possibilities (Scott, 1970, 101).

The sequential allocation of central facilities produces non-optimal results for the organization in terms of the final pattern of central facilities and their trade area boundaries. It is different from the location-allocation problem in which all branch offices are located with reference to each other as well as to the market population. Thus, from the standpoint of minimizing consumer travel, the sequential allocation approach gives a non-optimal distribution of central facilities.

However, Scott (1971b) discusses several dynamic location-allocation models. One of these models uses dynamic programming, which allows future events to be taken into account. Scott considers that this technique is potentially very useful in solving dynamic location-allocation problems and could be used to optimize joint construction and operating costs over some specified planning horizon. However, many problems remain, as for example:

(a) imposing a limited life-span on any facility;
(b) permitting facilities to relocate and defining appropriate relocation costs;
(c) structuring short-run systems;
(d) identifying strategies for purely competitive systems; and so on (Scott, 1971b, 154).

For many organizations the cost of minimizing customer travel is not as important as the constraint of a limited budget, uncertainty of population size over time in market areas and changes in transportation networks or technology. Government departments frequently add or lose functions, and to plan for a long-term period for an individual department could be hazardous. Similarly, a commercial company must plan its location policy with respect to the strategy of its competitors. However, the resulting competitive solution may be very inefficient from the consumer standpoint.

If the location-allocation solution can be characterized as the optimal long-term solution, then sequential allocation solutions would result from short to medium-term planning. A planning horizon of five to ten years may be a much more realistic time period for many organizations in planning future expansion. Thus a small number of future central facilities would be located over a short time period, such as five years, taking into account expected population changes, transportation improvements, changes in the organizational structure and
budgetary constraints. For organizations faced with a rapidly fluctuating operating environment, the advantages of flexibility gained from short-term planning far outweigh any advantages that a location-allocation solution would give.

Methods of Solving Collection and Distribution Problems for Type II Organizations

The geographical literature has not emphasized research on the location of type II organizations, even though they represent an important component of the tertiary sector. Given the computational difficulty of solving the location-allocation problem, it is not surprising to find that there have been few efforts to find the number, size and location of central facilities as well as the delivery and/or collection routes for a type II organization.

The literature in operations research is, however, quite well developed in terms of providing optimal solutions for finding the best set of delivery and collection routes from known locations (Scott, 1969). The problem of

\[2\]A type II organization is defined as one in which a central facility sends a unit to service a number of requests from consumers on the one trip.
optimally collecting and distributing commodities and services is an important component of modern economic life. The applications vary widely and include collecting school children by bus, milk delivery, garbage collection, distribution of goods from warehouses to retail stores and distribution of goods from warehouses to retail stores and distribution of petrol to service stations. In addition to the basic question of minimizing the cost of collecting and distributing commodities and services, there are a large number of complicating elements which vary according to the particular problem considered.

The problem is known by a variety of names, such as delivery, vehicle scheduling and truck-dispatching. It is a generalization of the classic travelling salesman problem, which attempts to find the shortest path between a set of nodes given the constraints that the tour must start and finish at the same node and that every node can be visited only once. The vehicle scheduling problem allows for multiple trips from the origin of the nodes to be serviced and requires that the delivery points be partitioned into sectors small enough to be serviced by one trip from the central point.
Pierce (1969) discusses some of the complications to the basic vehicle scheduling problem which are commonly encountered in practical applications. The first is that the goal sought in a solution may be to: (1) minimize total time trucks are on the road; (2) use fewest carriers; (3) maximize contribution to profit. The second problem is to determine whether the carrier must stop at all delivery points, partially service them, or miss them completely in any run. An example of a mandatory pick-up situation would be the collection of school children. However, in many commercial applications a delivery point may be bypassed completely or have its demand only partially satisfied. A third problem is that demand at the delivery points may vary widely over time and may have to be expressed as a probability function. Other complications include multiple origins, deadlines on the time of delivery, and variations in carrier capacity and speed.

Kuenne (1968, 1972) has pointed out that the travelling salesman problem is a limiting case for a more general dynamic combinational problem in which a number of vehicles are to be allocated to a set of destinations from a set of origins so as to minimize the sum of distances travelled by the vehicles. This problem is more difficult to solve than the travelling salesman
problem, since whether or not "a given vehicle at a
given station should move on Leg p to Station q depends
upon what that vehicle and all other vehicles have done
on the previous p-1 legs and upon what that vehicle and
all other vehicles will do on Legs p+1 through n" (Kuenne,
1968, 167). The dynamic combinatorial problem is
similar in some respects to the vehicle scheduling
problem. However, the latter is often solved using
fairly rough heuristic procedures because of the
practical complications mentioned above.

Conclusion
The methods used to solve the optimal location problems
for type I and II organizations have serious weaknesses
in terms of either planning new central facilities or in
reorganizing the location and boundaries of existing
facilities. The vehicle scheduling problem provides
optimal solutions only for type II organizations with
known locations. However, the objections to the
location-allocation model as applied to the location
of type I organizations are more fundamental. The first
is that it is basically a static model and therefore
changes in population distribution, transportation costs,
building and operating costs of facilities are not
easily taken into account. The second problem, especially
apparent in attempts to link the location of central
facilities with settlement location, is the lack of a hierarchy in the central facilities located. The third problem is that it may be difficult to incorporate some factors which affect the location of specific organizations. An example would be the incorporation of physician referral and religious affinities in the location of hospitals.

These problems will be discussed in the application of the location-allocation model to the location of integrated government office centers (type I organization) in chapter nine. The location of regional mail exchanges, as an example of a type II organization, will not be approached using an optimizing location model. Instead in chapter ten a number of possible sites are identified from a consideration of the transportation and communications networks, changes in the population distribution within the state and demand for interregional mail services.
CHAPTER V
Regional Structure of New South Wales

The major features of the regional economic structure of N.S.W. are discussed in this chapter in order to provide a framework for subsequent analysis. The present distribution of population, economic activity and transportation networks is highly centralized, and given the inertia in the location of these elements of the settlement pattern, it would seem to be extremely difficult to reverse this centralization trend.

In chapter six several proposals for regional planning and decentralization are discussed. The boundaries of the planning regions and the sites selected as growth and regional centers reflect the regional economic structure of the state. Similarly, changes in the structure discussed in this chapter are of importance in planning future development. Some implications of the growth in the workforce engaged in tertiary industry are discussed in chapter six. The problems of change are further pursued in chapter twelve in looking at the effect of future transportation and communication technologies on decentralization and regional development. Chapters five and six, therefore, provide much of the empirical background for the analytical section of the research.
Location of Economic Activity

The major focus of economic activity in N.S.W. is in the Central Coastal Region based on the Sydney Metropolitan Area and extending north to Newcastle and south to Wollongong. This region in 1969 had 77 percent of the state's population, 78 percent of the factory establishments and 91 percent of the factory employment in the state (Table 3).

Apart from the Central Coastal Region the rest of the state is primarily agricultural with some mining activity in the western section. The largest concentrations of population outside of the Central Coastal Region occur in the North Coast, Central-Western Tablelands and Slopes, and the Riverina (Figure 1). All three regions have a high level of agricultural production and support relatively large agricultural and service communities. The western margin of the study region has less rainfall; consequently the intensity of farming activity is less and the spacing of service centers tends to be further apart. The Great Dividing Range, which roughly parallels the coast, is another area where population density is quite low. The mountains present a fairly strong barrier to east-west communication within the state with the major crossings being the Hunter Valley, Blue Mountains and between Mittagong and Goulburn (Figure 1).
## Table 3

Economic Activity in the Central Coastal Region

<table>
<thead>
<tr>
<th>Area</th>
<th>Total Area</th>
<th>Population</th>
<th>Factory Establishments</th>
<th>Factory Employment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TOTAL</td>
<td>SQUARE MILES</td>
<td>% OF STATE TOTAL</td>
<td>No. (1969)</td>
</tr>
<tr>
<td></td>
<td>AREA</td>
<td>% OF STATE TOTAL</td>
<td></td>
<td>% OF STATE TOTAL</td>
</tr>
<tr>
<td>Sydney</td>
<td>1,573</td>
<td>0.5</td>
<td>2,712,610</td>
<td>60.6</td>
</tr>
<tr>
<td>Outer Sydney</td>
<td>3,213</td>
<td>1.0</td>
<td>113,150</td>
<td>2.6</td>
</tr>
<tr>
<td>Hunter</td>
<td>11,903</td>
<td>3.9</td>
<td>397,760</td>
<td>8.9</td>
</tr>
<tr>
<td>Illawarra</td>
<td>3,276</td>
<td>1.0</td>
<td>241,740</td>
<td>5.4</td>
</tr>
<tr>
<td>TOTAL</td>
<td>19,965</td>
<td>6.4</td>
<td>3,465,260</td>
<td>77.5</td>
</tr>
</tbody>
</table>

Study Area

The area of study includes all N.S.W. with the exception of the Western Division, which is excluded because of its low population density compared with the rest of the state. The Western Division had a population of only 60,681 in 1966, of which approximately 50 percent lived in Broken Hill, a city located in a semi-desert area and dependent on mining activity. Canberra and the rest of the Australian Capital Territory is included, as the city is rapidly becoming a regional focus for much of the Southern Tablelands and South Coast of N.S.W. The southern and northern boundaries of the study area are artificial in the sense that they reflect only the state administrative boundaries. The use of these boundaries is unfortunate since towns such as Albury/Wodonga straddle the border and thus have a trade area in N.S.W. and Victoria. Albury has a high potential for development as a growth center since it is centrally located in relation to three state capitals, and firms located here have the advantage of being able to avoid the state road tax.¹

¹ The N.S.W. state government charges a fairly heavy road tax for truck hauls over twenty-five miles. However, this tax cannot be levied on interstate movement. Thus a firm located in Albury could ship goods from the Victorian side to Sydney and from the N.S.W. side to Melbourne to avoid the tax.
A similar argument is applicable to towns such as Murwillumbah and Lismore in the far north of the state. While the Riverina and North Coast are in part oriented towards Melbourne and Brisbane respectively, much of the transportation network development directly counters this trend. The development of different railway gauges in the three adjoining states has discouraged movement across state borders. To some extent the standard gauge lines linking the state capital cities have diminished this border effect, but the states still tend to function as separate functional regions oriented towards their respective capital cities.

Settlement Hierarchy in N.S.W.
The N.S.W. settlement hierarchy shows large divergences from the rank-size distribution found in some urban systems (Figure 6). The state exhibits a strongly primate distribution of settlements with the largest deviations from the rank-size distribution occurring from the second to fifteenth rank. This distribution is characteristic of most Australian states, which exhibit a high concentration of population in the state capitals with only a few medium-sized towns. Most state capitals contain 55 to 65 percent of the population in the state and each functions as "the gateway to its state for goods and people; it is the pre-eminent governmental, financial, cultural and
Figure 6
N.S.W City-Size Distribution

Source: Commonwealth Bureau of Census and Statistics,
POPULATION AND DWELLINGS IN LOCAL GOVERNMENT AREAS, 1966
transport center, and is the funnel through which the great bulk of the rural exports must pass on the way to overseas markets" (Rose, 1966, 20).

Apart from Sydney, the medium-sized cities of Newcastle, Wollongong and Canberra make up the only cities with a population greater than 100,000. While a large gap exists between Sydney and these cities, there is an even larger break in the settlement distribution between the middle-level cities and provincial cities such as Wagga Wagga, Albury and Orange. This gap has become greater in the postwar period, since the growth rate of the provincial cities has, on the average, been quite low. Rose (1966) considers that this gap shows that small country towns maintain a connection solely with the state capital rather than maintaining some links with the next highest level in the settlement hierarchy as postulated by central place theory.

Little empirical evidence exists in terms of the relative numbers and variety of functions in different urban settlements through the state. Studies by Rose (1966), Saunders (1968), Killion (1967) and Pullinger (1971) have shown that the intermediate levels in the central place
hierarchy are not very strongly developed. Smails (1969), on the other hand, found that in South Australia a rather incomplete nested hierarchy did exist. However, little research has been undertaken in N.S.W. to resolve this problem.

The major clusters of settlement occur in the coastal fringe and on the central-western slopes and plains (Figure 7). On the coastal fringe the north coast has a larger number of towns than the south coast since it has a larger area of flat land suitable for agriculture. In the central-west of the state there exists a broad band of fairly intensive settlement which is basically supported by wheat and sheep production. The pattern of settlement has a fairly strong radial orientation emanating from the Central Coastal Region. Radials along the north and south coast are clearly defined, and a western radial from Sydney to Lithgow, Bathurst, Orange, Parkes and Condobolin can be distinguished. A northwestern radial from Newcastle branches just south of Tamworth into two forks: one through Gunnedah, Narrabri and Moree; the

2 However, Pullinger (1971) found that Tamworth after 1960 has been emerging quite strongly as a regional center for the New England Region. These studies will be reviewed in more detail in chapter eleven, where a comparison is made between the analytical results of regionalization of N.S.W. and the empirical evidence.
Figure 7

Population Growth in N.S.W., 1954 to 1966
second through the New England Tableland including Tamworth, Armidale, and Glen Innes. While other lines of settlement can be recognized in the central-west and south-west, the pattern is much more evenly spaced.

Changes in Population Distribution and in the Location of Economic Activity

In examining the changes in population within N.S.W. from 1954 to 1961, Logan (1965) found that the population of many towns had declined in both relative and absolute terms. While decline was most marked in the smaller town group (i.e., of 1,000 to 3,000) and least pronounced in the large towns, absolute downward shifts have occurred in towns of widely varying sizes. A relative decline occurred even in such large towns as Bathurst, Orange, Parkes, Grafton, Lismore, Goulburn, Coff's Harbour and Inverell. Logan concluded that population change in N.S.W. towns has been more a function of economic activity, both in the town and its rural hinterland, than a function of town size. Thus even large provincial cities such as Wagga Wagga, Bathurst, Orange and Tamworth did not have large enough population bases to generate a significant internal population increase. From 1961 to 1966 a similar pattern emerges. Large towns such as Bathurst, Cessnock, Goulburn and Grafton have shown only small population increases. However, towns such as Wagga Wagga, Tamworth,
Dubbo, Albury/Wodonga, Armidale and Orange have shown a growth rate of greater than 9 percent over the 1961 population figure.

Johnston (1967) tested several hypotheses about growth of small Australian towns in the post-war period. One hypothesis was that population change will be associated with urban function and that service towns are more likely to decline than towns with other functions. Using Smith's functional classification of towns (Smith, 1965), Johnston found only 30 percent of small service centers increased at or greater than the national growth rate and more than 10 percent experienced an absolute decline. Johnston also found that towns which were predominantly administrative in N.S.W. had a rapid growth rate (e.g., Armidale, Bathurst, Dubbo, Nowra and Taree).

The importance of transportation in the growth of large metropolitan centers in Australia has been emphasized by Robinson (1962) and Geissman and Woolmington (1971). Robinson has argued that conditions for the establishment of small town nuclei were much less favourable at the time of maximum population expansion during the nineteenth century than they had been at a comparable stage of development in the older lands of Europe. Road transport had improved and movement became much more rapid as the railways spread, so that small, closely-knit communities—the forerunners of towns—did not
develop (Robinson, 1962, 34).

Geissman and Woolmington (1971) state that the flow of internal trade centered on Sydney, which became the collection point for primary produce and the distribution point for manufacturing goods. Similarly the Vernon report states:

In the early development of Australia, the rural nature of the economy and its dependence on exports and imports, together with its geography, accentuated the importance of a limited number of city-ports. Subsequent development of the inland transport system also became centered on those few major cities. The extensive nature of farming was generally not conducive to the development of large non-metropolitan centers, but rather to a large number of smaller centers with limited opportunities for manufacturing, or tertiary, employment. The decline in the relative size of the rural sector combined with increasing farm mechanisation had a similar effect (Report of the Committee of Enquiry, 1965, Vol. 1, 215).

The concentration in the Sydney Metropolitan Area of the market, labor supply and provision of services in N.S.W. was one of the prime determinants of the location of manufacturing. The presence of good coking coal supplies as well as port facilities in Newcastle and Wollongong has led to an extension of the industrialized area to include the Central Coastal Region. Industry, once located in this region, attracted more population which in turn attracted more industry. It is extremely difficult for a manufacturer located outside this Central Coastal Region to compete with those inside it, since if his major sales
are within N.S.W. he must add an extra transport cost to the price of his product. Even to ship a product from one country town to another he may have to send his goods via Sydney because of the tree structure of the rail network. In addition, the excellent port facilities of Sydney have enhanced its growth potential. Industries which rely on imported materials (oil refining, steel fabrication and pharmaceuticals) have clustered in Sydney to save costs of trans-shipment to road or railway transportation. However, the introduction of containerization would reduce trans-shipment costs considerably, thus reducing the locational advantage of Sydney.

Changes in the postwar period have emphasized the strong centralization of economic activity in N.S.W. The share of the total N.S.W. population has either remained stationary or fallen in every statistical division outside the Central Coastal Region. However, the total population in the rural regions has remained fairly constant apart from the Central Coastal Region and the South-Eastern Region (Table 4). The rapid growth of the latter region reflects the growth of Canberra.

This stagnation of population in the non-metropolitan area of N.S.W. has been due to the lack of growth in the manufacturing sector and the declining labor force needed
Table 4
Population of N.S.W. Statistical Divisions

<table>
<thead>
<tr>
<th>Statistical Division</th>
<th>Principal City</th>
<th>1966 Census</th>
<th>1970 Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sydney</td>
<td>Sydney</td>
<td>2,541,307</td>
<td>2,780,310</td>
</tr>
<tr>
<td>Outer Sydney</td>
<td>Sydney</td>
<td>101,870</td>
<td>117,730</td>
</tr>
<tr>
<td>Hunter</td>
<td>Newcastle</td>
<td>378,620</td>
<td>401,890</td>
</tr>
<tr>
<td>Illawarra</td>
<td>Wollongong</td>
<td>219,656</td>
<td>249,600</td>
</tr>
<tr>
<td>North Coast</td>
<td>Lismore</td>
<td>211,842</td>
<td>216,270</td>
</tr>
<tr>
<td>Northern</td>
<td>Tamworth</td>
<td>155,158</td>
<td>162,320</td>
</tr>
<tr>
<td>North-Western</td>
<td>Dubbo</td>
<td>97,784</td>
<td>99,220</td>
</tr>
<tr>
<td>Central-West</td>
<td>Bathurst/Orange</td>
<td>152,583</td>
<td>152,720</td>
</tr>
<tr>
<td>South-Eastern</td>
<td>Canberra</td>
<td>211,433</td>
<td>247,150</td>
</tr>
<tr>
<td>Murrumbidgee</td>
<td>Wagga Wagga</td>
<td>129,344</td>
<td>134,470</td>
</tr>
<tr>
<td>Murray</td>
<td>Albury/Wodonga</td>
<td>85,377</td>
<td>87,070</td>
</tr>
</tbody>
</table>

Source: Statistical Divisions and Subdivisions of N.S.W.
in the rural sector. For Australia employment in the rural sector is expected to decline from 10.2 percent to 6.5 percent of the total employment in industry (Table 5).

Table 5

Distribution of Australian Employment by Industry 1962-63 and 1974-75 (projected)

<table>
<thead>
<tr>
<th>INDUSTRY</th>
<th>1962-63</th>
<th>1974-75</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>'000</td>
<td>%</td>
</tr>
<tr>
<td>Rural</td>
<td>428</td>
<td>10.2</td>
</tr>
<tr>
<td>Mining</td>
<td>51</td>
<td>1.2</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>1180</td>
<td>28.2</td>
</tr>
<tr>
<td>Tertiary</td>
<td>2529</td>
<td>60.4</td>
</tr>
<tr>
<td>TOTAL</td>
<td>4188</td>
<td>100.0</td>
</tr>
</tbody>
</table>


Linge (1968) states that the industries having the greater part of their work forces outside the capital cities are those associated with primary production (fish preserving, milk processing and sawmilling), and some of the metal working industries (steel smelting and the refining of non-ferrous metals). Since these industries amount to a very
small fraction of the total state industrial employment and output, their distribution within the state will not be discussed.

However, it is likely that major industrial developments will take place in Riverina in the near future. Geissman and Woolmington (1971) and Smailes (1971) consider that manufacturers with interstate markets located at Albury/Wodonga and Wagga Wagga would be in a much better position to supply Sydney and Melbourne than they would be if they were located in Sydney or Melbourne. When Adelaide is also taken into account, the intermediate manufacturer has a possible location advantage, since he is more centrally located than any rival located in any of the other cities. A location in this area is a definite possibility for manufacturers sensitive to transportation costs and independent of external scale economies who wish to reach a market in at least three states. With the development of a national market for products, it is likely that manufacturers will locate in this area to take advantage of its position. Thus a large industrial area located in southeastern N.S.W. serving a national market is a distinct possibility within the next thirty years. A similar situation could exist on the north coast for a manufacturer wishing to locate in between Sydney and Brisbane.
Transport Networks

Expansion of the Central Coastal Region has been aided by the centralized transport systems, which are focused largely on Sydney.

In the inland, the numerous intrastate restraints on road transport in the non-metropolitan area restrict country manufacturers in their distribution arrangements. They also ensure the pre-eminence of rail transport, and rail-freight structures appear to have been generally devised to help the producer of bulk materials, particularly of primary products, as freights are mostly tapered according to distance travelled and often levied according to the value of the product. It may thus be more economic in many cases to move raw materials than finished products, with the result that a market-based location of industry is favoured (Report of the Committee of Enquiry, 1965, vol. 1, 215).

Hirst (1963, 98) considers that the structure of rail-freight charges is sometimes justified by the costs of moving the two types of goods. More frequently, however, it reflects the demand characteristics for the products, since the demand for finished products is more inelastic than that for raw materials. This policy has the effect of maximizing flows of traffic, but it makes a non-metropolitan location difficult for a manufacturer to survive in.

Because the railway gauge in N.S.W. differs from those of neighboring states, all regions within the state tend to
be tied to Sydney rather than to make the trans-shipment to another state's railway network. Smith (1963) has discussed the competition in southern N.S.W. between Melbourne and the more distant state capital city, Sydney. While trans-shipment costs restrict the south-bound flows of goods by rail, Smith found that towns south of the Murrumbidgee river received a smaller total of goods from Sydney than would be expected considering their population. This was due to the presence of road truckers taking advantage of the constitutional restriction on taxation of interstate movements. It is likely that a similar situation exists in northern N.S.W. with road transport carrying goods to and from Brisbane. Thus the presence of road competition in the northern and southern border areas indicates that Sydney does not completely control flows of goods within the state. Despite the tax on road movement many firms still prefer to pay it rather than to ship their products by rail, since road transport provides advantages such as speed of delivery, cheaper terminal and packing costs.

3 In all states of Australia intrastate road transport has been subjected to restrictions since the early 1930's. In N.S.W. this tax is known as the Transport Coordination tax and was designed to ensure that road shipments functioned as feeder services. Adequacy of service is the criterion generally adopted to determine the size of the tax on road transport. In extreme cases, where the costs by rail are significantly in excess of road costs, as in the case with perishables, this traffic is exempt from the tax (Hirst, 1962, 100).
The different railway gauges between the states reflect the desire of state governments to ensure that the area within the state borders is focused towards the state capital and not to any out-of-state nodes. These breaks in the railway gauge have reinforced the dominance of state capital cities, since in most states the rail network is largely focused on the state capital city. However, in recent years standard gauge lines have been built to connect Sydney with Melbourne, Brisbane and Adelaide, although trans-shipment is still necessary on interstate shipments off these main routes.

The greatest mileage of railway track in N.S.W. is in the central and south-west part of the state, which serve the wheat and sheep belt (Figure 8). Most of the branch lines in the Griffith, Wagga Wagga and Albury area are used mainly during the wheat harvest season. Few of these railway lines carry many passengers, and the heaviest flows of commodities and passengers are on those lines leading towards the Central Coast. The network exhibits a tree-like structure in the north with no links connecting the North Coast with inland areas. Similarly, all traffic from the Northern Tableland to the western part of the state has to travel south to Werris Creek before moving west.

It would appear, therefore, from an inspection of the
Figure 8
Frequency of Rail Passenger Service
network structure of rail links that a connection between the three northern regions of the state (North Coast, Northern Tablelands and North-West Slopes) would be justified. However, the construction costs of such a line would be extremely high due to the rugged topography between the coast and the tablelands. Unless a port at the end of the link were considered, then the volume of traffic using the line would be extremely small. The economics of a port at Iluka (near Grafton) and the associated railway line to the Northern Tablelands has been considered. However, the project is uneconomic at the present time (Report on Northern Tablelands Rail Link and Clarence Port, 1970).

A proposal to connect Dubbo with Newcastle by a direct rail link through to Muswellbrook in Hunter Valley was abandoned during the 1930's soon after the project was commenced. Unless a substantial increase in population and economic activity takes place in Dubbo's region, it is unlikely that the link, if completed, would ever be economic. A similar conclusion holds true for most of the other possible connections between country towns: without a massive decentralization of industry to the region, the volume of traffic generated would not make the construction and operation of the line an economic proposition.
The importance of the Great Dividing Range as a barrier to the building of railway lines can be seen by the presence of only three links crossing the mountains. In the south a number of points such as Cootamundra, Wagga Wagga and Goulburn act as foci for a number of feeder lines. To the west Dubbo, Orange and Lithgow perform this function, so that all traffic from the west passes over the one track through the Blue Mountains to Sydney. Werris Creek and Maitland function as the focal points of the northern areas.

The highway connections and road travel time reflect a similar pattern. The largest mileage of paved roads exists in the central-west and south-west of the state, and travel times across the Great Dividing Range are much slower per mile than in the flatter inland areas. Thus the North Coast Region is cut off by mountains from the interior, and travel times by road are relatively faster along the narrow coastal plain than they are to the Northern Tablelands. A similar situation exists in the south coast, except that the coastal plain is smaller and more discontinuous. Population density is lower and the service towns such as Eden, Bega and Nowra are smaller than their counterparts on the North Coast.
Flows on Main Roads and Frequency of Rail and Air Services

Foldvary (1966) has pointed out that the primate settlement hierarchy combined with the central position of Sydney in N.S.W. has led to a radial pattern of highways emanating from Sydney. This decreases the importance of circumferential routes linking major provincial cities. Average daily traffic volumes on roads in the state reflect this radial pattern, with the largest volumes occurring on roads near Sydney. In addition, traffic volumes are much higher on radials leading to Melbourne and Brisbane compared with those radials serving rural areas within N.S.W.

The frequency of passenger service on railway lines is the only indication of the volume of movement between towns in N.S.W. The major orientation of the passenger services out of Sydney is radial (Figure 8). The frequency of service is very high as far as Newcastle, Lithgow and Wollongong, but drops off markedly beyond these points. The railway dominates this short-haul traffic area of up to one hundred miles from Sydney and provides good service for the large population living in this region. The radials extending north, north-west, west, south-east and south are the next most important routes. They have very few connections between different branches and function effectively as separate entities,
each oriented towards Sydney.

The radials providing links to Brisbane and Melbourne show very little decline in frequency of service away from Sydney (north coast, northern and south-eastern routes). As would be expected, the radials serving the north-west, west and south decline rapidly in importance beyond the major provincial cities. From the frequency of rail services in the state there does not seem to be evidence of any increase in the frequency of passenger trains serving regional foci. The number of services depends largely on the distance from Sydney, the presence of a line through to a major capital city and, to some extent, on the population of the provincial city.

The state's air network shows a very strong tree structure (Figure 9). In order to fly from one country town to

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4 It is likely that many of the country services carry very few passengers, since a large part of the losses incurred by the Railways Department is attributed to uneconomic rural passenger services.

5 A city such as Canberra with a population of approximately 120,000 in 1970, which is extremely well connected by air services to Sydney, has only twenty-four rail services per week compared with ninety-six services for Wollongong, a city which is less than double the former's population.
Figure 9

Number of Air Services per Week From Sydney, 1970
another, it is necessary to fly first to Sydney and then to the destination unless the two towns lie along a direct route to Sydney. Apart from towns on the Northern Tablelands, the only centers with connections to more than two other towns are Coolangatta, Dubbo and Wagga Wagga.

Origin-destination movements are not available for the state, but the air passenger movements for the major towns are available for 1970 (Figure 10). The major airports after Sydney were Canberra (577,918), Coolangatta (152,356), Dubbo (54,035), Wagga Wagga (51,263), Tamworth (50,781), Albury (44,889), Cooma (36,401) and Armidale (35,403). The presence of the national capital in Canberra explains the extremely large volume of flights to that city. Coolangatta and Cooma are located near resort areas; the former receives direct flights from other states, since the number of flights per week from Sydney is not exceptionally large.

Provincial cities in the Central-Western and North Coast Regions have fewer air passenger movements than would be expected considering the size of their population. The

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6 The figures were supplied by the Department of Civil Aviation in Sydney and refer to the total number of passengers arriving at a town during 1970.
Figure 10

Air Passenger Movements

Total Number in 1970
former region is close enough to Sydney for the railway to be competitive with air services. The North Coast Region, at least around Lismore, may be partly served by the tourist center Coolangatta.

**Conclusion**

Sydney is well placed to dominate economic activity within the state. The history of the growth of settlement in N.S.W. has reinforced the initial concentration of European population around Sydney. In addition to having excellent port facilities, Sydney is the focus of the road, rail and air networks for most of the state. The radial orientation of these networks makes any regional development policy difficult to implement, since even though nodes may be accessible to their surrounding region, most interregional flows must pass through Sydney. Conversely, it is likely that any road or rail link which is built will not carry enough traffic to make it an economic proposition. Two projects for railway link additions, which have been considered the best possible choices, have been discussed—namely, the port at Iluka and the associated railway line to the Northern Tablelands as well as the rail link from Dubbo to Newcastle. On economic grounds neither of these projects can be successfully implemented. As far as railway traffic in rural areas of N.S.W. is concerned, it is likely that
many passenger and some freight services should be discontinued and that some branch lines be abandoned. However, the data necessary for such an analysis (commodity flows, railway passenger origins and destinations) are unavailable.  

The general decline in population in rural areas has important implications in terms of regional planning. Some of these are discussed in chapter six. In addition, changes in the location of population and economic activity have an important influence on the structure and flows in transportation and communication networks, which are discussed in chapters seven and eight.

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7 The N.S.W. Department of Railways does not tabulate any of these flows. It is likely that origin-destination flows would show that some branch lines should be abandoned in country areas. Because of the potential political repercussions of branch line closures in these areas, it is unlikely that such figures will be made available.
In this chapter several proposals for promoting regional development are discussed and related to the problem of decentralization within N.S.W. Regional planning to date has exerted negligible influence in determining the economic development of non-metropolitan regions in N.S.W. However, in the late 1960's several proposals which are evaluated in this chapter were put forward for promoting regional growth. In addition, some of the implications in the regional provision of high-order tertiary services are examined.

The distinction between growth and regional centers discussed in chapter two is elaborated for N.S.W. The major focus of this chapter is on the nature of regional centers, even though the development of growth centers is likely to be more spectacular in terms of population and industrial growth rates. A detailed analysis of the future development of growth centers would have to be largely based on an analysis of the locational requirements of secondary industry—a subject outside the focus of this research.
Decentralization: Growth Centers in N.S.W.

Woolmington (1971) presents three alternative possibilities for encouraging decentralization:

(1) stimulation of economic growth in a large number of towns;

(2) selective decentralization to half a dozen growth centers;

(3) selection of not more than one or two growth centers possessing the very best opportunities for growth.

A recent report\(^1\) has argued strongly for a decentralization policy based on a small number of growth points rather than spreading government assistance to a large number of small towns. Selective decentralization refers to the concentrated application of public assistance to a limited number of towns at any given time. On the other hand, dispersed decentralization results in a large number of towns receiving government aid despite the fact that many are not in suitable locations for growth and none reach a size where economies of agglomeration begin to operate.

Woolmington (1971) considers the third alternative to be

the most viable, since the larger the number of growth centers, the bigger the investment gamble and the greater the possibility that none will get off the ground. One city which fits most clearly into the growth center category is Albury/Wodonga, which has numerous advantages, such as accessibility to a national market, a border location to take advantage of the loophole in taxation of trucking movements, the availability of water for urban purposes, and a population of approximately 40,000 in 1970. The city is already attracting substantial industrial activity and promises to have a high growth rate with or without government support in the future. The Albury/Wodonga example is more typical of a growth center than of a regional center, although it functions as the nodal point of a prosperous farming region.

Canberra represents, in effect, the successful application of a growth center concept, although this was not considered when its location was planned. As the national capital it represents a special case in obtaining government aid, although there is no reason why substantial Commonwealth Government support should not be available for other growth centers.

Regional Planning: Regional Centers in N.S.W.
Frequently associated with the proposal to decentralize
population and economic activity out of Sydney is the desire to improve standards of services in rural areas. Thus the establishment of regional service centers which will provide a wide range of services for the residents of the surrounding region has been advocated. In contrast to the growth points, regional centers should be scattered throughout the state to ensure adequate provision of services for all residents of the state. It is possible that in the long run these regional centers could emerge as growth centers by attracting industry. However, at present many of the regions which have been defined for development purposes have a relatively small population (Table 4) and few have much industrial potential.

The need for regional centers in N.S.W. has been demonstrated by the conclusions of several reports commissioned by the Department of Decentralization and Development (Daly, 1968 and Doddridge and Holland, 1970). Both reports found that one of the major causes of dissatisfaction with country living was the inadequate provision of higher order services even in major country towns.²

² The towns in Daly's survey were Albury, Armidale, Bathurst, Dubbo, Goulburn, Grafton, Lismore, Lithgow, Orange, Tamworth, Taree and Wagga Wagga. The towns in Doddridge and Holland's survey were Bathurst, Wagga Wagga and Nowra.
Daly found that although most people were satisfied with country high schools, many respondents felt that the provision of tertiary education facilities was an extremely important factor in the future growth of their towns. Similarly, country residents felt themselves poorly served in terms of specialist medical centers, and at least one person in three had to travel to Sydney to obtain satisfactory attention.

Aside from the requirement of improving service standards in rural areas, several other reasons for promoting regional as well as growth centers are:

(1) the desire of many rural people to continue living within the region and the need to provide varied means of employment;

(2) the desire of some workers and employers at present living in Sydney to move outside of a large metropolitan area;

(3) the need to avoid pollution as well as to minimize the cost of providing urban services;

(4) the argument that can be made on strategic grounds for dispersing economic activity away from one region.

As a preliminary step a new set of statistical divisions have been delimited by the Census Bureau. These new
divisions are intended to represent regions which are characterised by social and/or economic interactions between the inhabitants and economic units within them, under the unifying influence of one or more major cities or towns. Thus the boundaries of the divisions have been delineated on the criterion that the degree of economic and/or social contact and interaction within each division should be maximised. Data used in delineating the boundaries included available information about transportation patterns, the patterns of retail shopping and marketing of fresh foods, the intensity of trunk telephone calls to and from major cities and towns, circulation areas of some provincial newspapers and coverage of provincial radio stations.

The Census Bureau has adopted a functional regional approach in delimiting the statistical divisions, and each division is focused on at least one city. The boundaries of the new statistical divisions cannot be regarded as sharp lines of demarcation: they may, of necessity, be positioned within peripheral zones in which the influence of two or more focal cities or towns overlap in varying degrees.

The statistical divisions have been proposed as possible administrative areas for Commonwealth and State government
departments. This would greatly rationalize the present complexity of administrative areas in non-metropolitan areas of N.S.W. Such a move would help to engender a feeling of regional consciousness among rural residents rather than forcing them to travel to different towns for various government services. In discussing the South Australian urban system, Smailes (1971) found that there was a very complex set of administrative areas covering the state and advocated a rationalization to a common set of regional boundaries.

While the location of Commonwealth and State government departments in selected towns would be valuable in terms of a rationalization of administrative areas, there is a danger that the use of these towns and the associated areas as planning regions would imply that all smaller settlements within a particular regional center's hinterland should be focused on it for services of a regional order. In terms of classical central place

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Skinner (1965, 374) points out this danger of confusing administrative and marketing hierarchies in China. Whereas administrative units are discrete throughout the system, each lower-level unit belonging to only one unit at each ascending level, marketing systems are indiscrete at all levels, except that of the lowest level. Communist planners during 1959-61 attempted to redirect natural flows of goods to a single administrative focus with disastrous results in terms of logistical and storage problems.
theory, Christaller's marketing and transport principles (Christaller, 1966) would lead one to expect that towns immediately below the regional center would be shared by three and two regional centers respectively. The operation of the administrative principle would allow an exclusive domination of smaller centers. However, at present in N.S.W. only Bathurst/Orange has been designated as a regional administrative center, so that it is unlikely that this principle has been very important in the formation of trade area boundaries. Given that planners recognize that a considerable degree of overlapping occurs between trade area boundaries of regional centers, then it is unlikely that any major problems would occur. However, the potential conflict between maximizing regional "consciousness" by orientating all the regional trade to one center and the operation of central place forces should be recognized.

The move to establish these regions is virtually the only step that has been taken towards integrated regional planning in N.S.W. While the regions have been delimited, only Bathurst/Orange has been identified as a regional focus of one of the new regions. However, government

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4 The hesitation to select other regional foci is partly based on the potential political repercussions of selecting some towns in preference to others.
departments are in the process of changing their administrative areas over to the new regions and most should be using these new regions within a few years. Unfortunately, it is possible that different towns will be chosen by different departments as the locations of their regional offices unless regional capitals are identified.

The Southern Tablelands Statistical Division is focused on Canberra, which has achieved a very rapid population growth rate and had a population of 105,000 in 1966 compared to 20,871 for Goulburn, the next largest city in the South-Eastern Region. This growth has been derived mainly from the location of the Federal government and administrative offices in the city, although more recently substantial commercial activity has been attracted.

The North Coast Statistical Division lies along a fairly narrow coastal strip backed by the Great Dividing Range. Because of the length of the region it is difficult for any one city to dominate the entire region, although the two northern subdivisions are densely settled, having an estimated combined population of 150,000 in 1969. Lismore and Casino are located close to one another and the former city seems the most suitable site for a regional capital of the North Coast.
The major cities in the Northern Division are Tamworth and Armidale, with smaller towns such as Inverell, Moree, Narrabri and Glen Innes located to the north and west. The population of this division is relatively large and the boundaries quite distinct. Tamworth seems the obvious choice as a regional center, although it may be possible in the future to encourage industry to locate in between Armidale and Tamworth. This would mean that either city could be only forty-five minutes from the industrial area and both could be assured of continued growth.

Orange, Bathurst and Lithgow dominate the Central-Western Division and the choice of a regional focus is a difficult one to make. Bathurst could be favoured as it is not only central to the other two cities (forty-five minutes to Orange and sixty minutes to Lithgow), but is also the focus of transport routes which cross the Blue Mountains. Rail and road networks converge at Bathurst from the western areas before crossing the Blue Mountains to Sydney. However, Orange has shown a much more buoyant rate of growth in population in the postwar period and has attracted some industry. As with Armidale and Tamworth it is probably desirable to integrate the development of
the two cities since they are quite close together.  

The two South-Western Divisions, Murrumbidgee and Murray, are focused on Wagga Wagga and Albury respectively. The shape of these divisions reflects, firstly, the competition between the two cities and, secondly, the Victorian border. Albury's trade area is larger than that shown on the map for the Murray division, since it extends into Victoria. Both towns had a fairly rapid rate of growth in the 1960's and both are likely to become growth centers.

Tertiary Industry Location and Decentralization

In considering the rank-size distribution of settlements in N.S.W. for 1966, there is a marked absence of medium-sized provincial cities (Figure 6). There are few towns serving as regional capitals which could divert some of the rural-to-urban migration from the already crowded metropolitan areas. Given the present urban growth rates in N.S.W., it appears likely that this gap in the rank-size distribution will be much larger by the year 2,000. While few studies have been undertaken to examine the number and variety of service functions provided by central places in N.S.W., it seems that one of the basic

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5 The N.S.W. state government has announced (October, 1972) that the development of Bathurst and Orange would be planned as a single center.
reasons for dissatisfaction with country living is the lack of higher order services in rural areas (Doddridge and Holland, 1970). This gap in the central place hierarchy between the metropolitan city and the provincial city with a population between 20,000 and 30,000 has led to proposals aimed at encouraging the decentralization of additional higher order functions to the provincial cities.

While arguments still remain over the possibility of the large-scale movement of industry to country cities away from the Central Coastal Region, there is a good case for promoting the growth of regional and, to some extent, growth centers on the basis of the tertiary sector and providing room for industry to move in at a later date. Archer discusses the role of Canberra as an example of a decentralization project. One of the important features of Canberra's growth has been the concentration on tertiary sector employment, "particularly the activities of national government and administration, higher education and research, national defence .... Whereas decentralization theory and policy is usually focussed on the relocation of manufacturing industry activity, Canberra's experience emphasized the important contribution of service industry" (Archer, unpublished manuscript, 2). While it is unlikely that government funds available for
Canberra would be made available on the same scale for any other decentralization project, the Australian tertiary sector employment is projected to rise from 60.4 percent of total employment in 1962-63 to a projected 64.4 percent in 1974-75 (Table 5). The greatest increase in employment will occur in the tertiary employment sector rather than in manufacturing industries.

The Report of the Committee of Enquiry (1965) discussed the geographical distribution of the tertiary work force in Australia. For N.S.W. 55.7 percent of the population, 59.5 percent of the total work force and 62.7 percent of the tertiary work force were in the Sydney Metropolitan Area in 1961. The relatively higher centralization in the tertiary work force reflects a number of factors, among which are the clustering of banking and insurance offices near administrative centers, as well as the force of inertia in maintaining the past patterns of location in tertiary facilities.

Three general types of tertiary activities could be located in regional and growth centers: firstly, government administration; secondly, social, cultural and educational institutions; thirdly, regional service
activities. The following discussion will investigate these three types of activities.

**Government Administration**

Even apart from local services such as roads, water, sewerage, electricity, school, libraries, and post offices, governments in one form or another play a large role in economic life. Some of the activities most characteristic of regional centers are performed by governments—agricultural extension, regional offices and depots for central government departments such as main roads, taxation, education, broadcasting, civil aviation, employment services, police, courts, health, housing, lands and public works. Wherever these regional offices are located will tend to become a regional center so that the government inevitably affects the pattern of location. If it is planning the development of a regional center it can use its own activities as powerful tools to assist it (Neutze, 1965, 127).

The government regional offices could come from, firstly, a regrouping of some offices dispersed in a large number of small towns to a regional focus and, secondly, a decentralization of offices located at present in Sydney. While it is likely that many government offices, such as agricultural extension and child care centers, will always be located in smaller towns, there exists a potential for regrouping the others. However, the greatest growth potential would come from the decentralization of additional functions out of the head offices located at present in Sydney. For example, the highly centralized Education Department could increase the responsibility of its area offices. It is also possible for the state
government to follow the American practice of moving the State Parliament outside of the metropolitan area.

Pullinger (1971) found in Tamworth that out of thirteen government establishments providing information ten had been established since 1955 and eight of these since 1960. Since 1965 the employment in this sector increased by 52.2 percent from 383 in 1965 to 582 in 1970. In addition, most of these jobs had come from a decentralization of offices from Sydney rather than a regrouping of existing facilities within the region.

Of particular interest in this research is the distribution of central facilities for communication systems within the state. The concept of area management has recently been introduced in the telecommunication activities within the Australian Post Office. Area management involves the grouping of the functions performed by the telecommunication section (customer sales and services, engineering maintenance, finance and administration) into common regions administered by a single regional office.

In N.S.W. regional offices for the telecommunications section are planned for Newcastle, Wollongong, Canberra, Wagga Wagga, Grafton, Bathurst and Tamworth. It is of
interest to note that these cities are central points for the statistical divisions, with the exception that the two divisions with the smallest populations (North-Western and Murray) are amalgamated with other divisions (Table 4). This suggests that a threshold population of at least 100,000 must be exceeded before the establishment of an integrated telecommunication office becomes worthwhile. One advantage of this scheme is that the quality of service to customers will be improved, since customers will be able to deal directly with a single regional office rather than with offices located in different towns or in Sydney. A similar proposal has been put forward for regional mail sorting exchanges and this will be discussed in chapter ten.

Social, Cultural and Educational Institutions

With an increased population, the number and variety of social, cultural, and entertainment facilities of a city increases rapidly. Similarly, larger number of television and radio stations, picture theaters and sporting facilities are characteristic of larger regional centers. There is a wide range of government and private enterprise institutions (such as specialist hospitals, educational institutions, cultural and entertainment facilities) which could be grouped in these towns. As far as educational institutions are concerned, universities as well as
technical, teachers and agricultural colleges could be located in these centers. The establishment of a university, for example, could provide a significant number of new jobs as well as increase the range of educational opportunities available, which might help to decrease the flow of school leavers migrating to the city for tertiary education. professional or simiprofessional training. Doddridge and Holland (1970) found that the major reason for the shift from the country to the city in N.S.W., among young people (61 percent of all school leavers) was the desire for further education and career training.

This type of decentralization has been quite common in North America and research organizations are being increasingly attracted to these university centers. In N.S.W. Armidale, the only example of a university town, increased in population between 1961 and 1966 by 2,100 to a population of 12,875. The Report on Selective Decentralization found that during this period if the public authority sector in Armidale had grown at the same rate as it had in other towns of a comparable size, it would have increased by about 2000 persons, whereas in fact it increased by 1,000.
The Report of the Hospital Services Committee (1965) considered that the present system of isolated rural hospitals should be replaced by an integrated, decentralized hospital system. The report recommended the setting up of a number of regional authorities which could make recommendations to the Hospitals Commission on the provision of facilities in individual hospitals, co-ordination of the hospital's services in the region and maintaining liaison with public health and local ambulance authorities. The main function of the regional offices is one of co-ordinating regional hospital services rather than any decentralization of specialized hospital facilities. The boundaries of the regional offices coincide with the new statistical divisions.

The problem of providing library services in country areas also requires that services be located in a central position with respect to the transportation network and population of a region. Apted (1963) considers that an adequate library service for a region requires a threshold population of 100,000 as the minimum size to provide sufficient money from rates and subsidies. In a typical region a central library will be established with a number
of branch libraries in smaller towns. For the rest of the region a number of bookmobiles are used which carry a small travelling library of 3,000 books on a fixed itinerary of small settlements. Thus, in locating libraries within a region, the location problem is to decide on the number, size and hierarchical arrangement of the facilities, taking into account the population distribution and transportation facilities. The smaller branch libraries cater for all general reading needs, lending and reference, whereas the central regional library caters for more advanced needs. In this way small libraries have access to advanced material which they need not carry themselves.

Regional Service Activities
The central place literature has extensively documented the positive relationship between a town's size and the variety of central place functions performed. With increased size, regional centers would attain the necessary threshold populations to attract large department...

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6 Library facilities represent both type I and type II organizations, since some people travel to the service while others in remote locations have the service bought to them. Bookmobiles function as hybrid type I and II organizations, since not only do they follow a travelling salesman type circuit, but they also attract people from the surrounding local area at every stop made in their circuits.
stores and specialized services (specialist doctors, lawyers, etc.) that have up to now only located in Sydney, Newcastle and Wollongong. Archer points out that Canberra, with a population exceeding 100,000, is rapidly replacing Sydney as the commercial service center for south-eastern N.S.W. In looking at the growth of regional services in Tamworth, Pullinger (1971) found that between 1965 and 1971 the growth in employment in the surveyed service establishments was 35.7 percent over the five year period (1,321 in 1965 and 1,793 in 1970). The greatest increases occurred in the transport, finance, commerce, professional and medical sectors.

The possibility exists of commercial organizations introducing another level in their statewide distribution networks. Instead of handling all orders from the Sydney head-office, they could handle all orders for a particular region at the regional center. Pullinger (1971) cites that insurance offices and wholesalers have recently established regional offices in Tamworth.

Conclusion

In this chapter two types of centers have been discussed as the most important components in a decentralization
and regional development program. To a large extent the policy of promoting the growth of regional centers is simply a holding operation aimed at stabilizing the present population drift to the cities by improving the quality of services that people in rural areas enjoy. However, it is unlikely that any regional center would achieve a population greater than 60,000 by the year 2,000. Despite this limited growth potential, these cities are an important component of any decentralization scheme. While this stabilizing influence is extremely important, it seems necessary that a decentralization policy should, in addition, promote the development of growth centers. It is likely that only through the development of industry and tertiary activity in one or two growth centers that significant changes in the location of population and economic activity within the state will occur.

However, the selection of regional and growth center sites and the delimitation of their functional regions is likely to be a difficult practical problem. Leaving aside local political considerations, there are problems involving state borders and metropolitan dominance which will influence the selection and future success of these cities. Some of these factors will be
discussed in chapters eight and ten in considering the pattern of telephone message flows. In addition, it is important to consider the development of growth and regional centers in the context of growth within a state and national urban system. In chapter eleven this aspect will be discussed and related to the linkages between cities that would be expected given a successful decentralization policy.
CHAPTER VII
Structural Analysis of Communication and Transportation Networks in New South Wales

In this chapter as well as in the following one, the focus of the research is on the transportation and communication networks in N.S.W. This chapter is concerned with the structure of various types of networks between the major towns and cities in N.S.W. There are three major purposes of this analysis. The first is to identify the cost surfaces for the different modes and to consider the importance of possible changes in these cost surfaces on urban growth. The second aim is to discuss the implications of network organization for several communication networks in terms of regional development and decentralization. To some extent this section provides background information for the analysis of telephone calls in chapter eight, but also these networks are of interest as examples of type III organizations. The third part of the chapter is concerned with a regionalization of various distance and cost surfaces. The aims of this section are, firstly, to compare regions in the state for the different modes of transportation and communication and, secondly, to relate the various regional groupings to decentralization proposals.
Communication Costs

One of the most significant disadvantages of non-metropolitan locations for many industries is the cost of communications.\(^1\) The Report on Selective Decentralization (1969) found that in a survey of metropolitan companies 91 percent considered that the additional costs of communication would be a major disadvantage of a country location. The costs of communication are more likely to be critical in the type of industries locating in growth centers than in those locating in regional centers. In the latter case the industries are predominately tertiary, and even though such central facilities as warehouses would have heavy communications costs with the central depot (probably located in Sydney), a large percentage of their interaction would be with retail outlets within their region. However, in the case of industries locating in growth centers, it is likely that their markets and raw materials would be located in other parts of the country. It is necessary in these cases for industries to have regular contacts

\(^1\) It is assumed for the purposes of this study that the actual cost of communication is a valid estimate of the perceived costs of communication that a businessman would feel if he located in a non-metropolitan location. In reality, the actual costs may be substantially less than what the businessman perceives them to be, since he may have only a vague feeling which assigns any country location as being highly remote from the centre of economic and cultural life.
with suppliers and distributors, so that communications costs would be quite substantial for an industry located in a non-metropolitan area.

Several methods are used to assess the locational advantage or disadvantage of the nodes in terms of the telephone call cost surface. The simplest approach is to aggregate the cost of making a three minute call to the other thirty-nine nodes in the network, regardless of the actual number of calls and their duration (Figure 11). As would be expected, towns in the Central-Western Region are the most centrally located in the state. However, towns to the north in the Hunter Valley (Muswellbrook and Singleton) as well as Tamworth and Gunnedah have relatively smaller telephone call charges than Young, Cootamundra and Goulburn, located an equivalent distance south of the most central location.

If the size of settlements are taken into account, it is obvious that Sydney is the best location within the state. While the Central-Western Region is centrally located in terms of network structure, the telephone call cost of $0.48 between Sydney and Bathurst would outweigh the advantage of physical centrality of the latter region. However, many industries are concerned with serving a national market, rather than considering a single state
Isolines are in dollar units

Source: Telecommunications Section of the Post Master General's Dept., Sydney, 1971

Figure 11

Telephone Call Cost Surface
as the entire market. Geissman and Woolmington (1971) show that the point of minimum transportation and communication cost for a national market is in the Riverina area.

Several possibilities exist in terms of promoting decentralization by altering communication costs. One is to extend the local telephone charge for the Sydney Metropolitan Area ($0.05) to cover the Central-Western Region. An industry locating here would have as small a telephone call cost as it would have if it were located in metropolitan Sydney, and the firm would have the additional advantage of being centrally located to the inland rural areas. This proposal is inequitable since industry is subsidized in one location in preference to all other regions. An alternative proposal would be to halve or eliminate the charges for trunk line calls. The latter proposal would eliminate areal variations in the telephone call cost surface and would enable firms in country areas to radically reduce communication costs. It would also reduce one of the agglomerative advantages of metropolitan area and, if combined with a reduction or elimination of charges for telex messages, could possibly encourage the movement of

\[2\] Abler (1971, 3) discusses the flat rate fee for business subscribers in the U.S., which gives them unlimited access to the national network.
some industries out of the metropolitan area. 3

**Network Organization**

In this section the focus is on the organization of the telephone trunk call and telex networks. Structure reflects the pattern of flows within the network, and changes in population distribution and in the location of economic activity within the state have important implications for the planning of future network changes. Similarly, the weakening of the importance of intrastate linkages as compared with interstate linkages would have to be taken into account in future planning. Thus the decentralization of population to growth and regional centers will have an important influence on the demand for communication.

**Telex Communication**

The telex method of communication is predominantly used by businesses or government departments that wish to rapidly

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3 The telegraph network in N.S.W. can be divided into three types of service. The public telegraph service consists of facilities for handling telegrams. The private wire services are services leased and operated by subscribers, which vary in magnitude and complexity from point-to-point services to larger networks, such as the meteorological network, stock exchange and airline systems. The telex service is a direct switching teleprinter exchange network provided as a network for interconnecting teleprinter subscribers (Turnbull, 1963).
transmit a large amount of information to a terminal in another location. The volume of telex message flows between regions within the state is not available. However, the distribution of telex subscribers and the structure of the routing of messages reveals some important characteristics of the telex message flows. The distribution of telex subscribers within the state (Figure 12) shows that the largest numbers are in the major centers of population and economic activity—Sydney 69.7 percent, Newcastle 3.6 percent, Wollongong 2.0 percent and Canberra 7.1 percent. The rest of the state accounts for only 17.8 percent of the telex subscribers compared with its 26.6 percent of the 1969 population.

The routing of telex messages is made via Sydney for all parts of the state except for those areas lying within Canberra's and Newcastle's exchange regions (Figure 12). Thus a telex message from Dubbo to Orange (a straight line distance of seventy-five miles) travels from Dubbo to Sydney and then back to Orange (a total distance of approximately three hundred miles). However, the volume of telex messages between country areas is so small as to make the installation of switching centers in country locations unnecessary. Until there is increased business and government activity in rural areas which
Figure 12

Number of Telex Subscribers, June 1971

Source: Post Master General's Department, Engineering Division
requires interregional linkages, then the provision of
teleex exchanges is unwarranted. 4

The number of telex subscribers in Wollongong and
Newcastle is quite small considering their populations,
which possibly reflects the proximity to Sydney of both
cities. On the other hand, Canberra has nearly double
the number of subscribers in Newcastle even though its
population is smaller. The number of subscribers in the
country centers are, in order of importance: Albury,
Wagga Wagga, Orange, Tamworth, Broken Hill and Griffith.
Many of the telex subscribers in the country areas are
motel owners, thus accounting for the large number of
subscribers in the vacation areas of the North Coast and
Snowy Mountains (Cooma). The large number of subscribers
in Canberra reflects its status as the national capital
and center of many information gathering and processing
agencies.

Telephone Trunk Call Network Organization
The location of the telephone network is an example of a

4 The lack of interregional connections in the air and rail
networks was discussed in chapter five. The only
analysis of flows (telephone messages) will be discussed
in an interregional context in chapter ten.
type III organization location problem in which both the routes and the location of exchanges must be decided. The focus in this research is on telephone calls outside of the local area for which a charge greater than $0.05 is made. Freeman (1968) considers that traffic decreases rapidly with distance, since in 1960 approximately 95 percent of all calls in N.S.W. (trunk and local) terminated within thirty miles. To some extent, this figure simply reflects the concentration of the state's population in the Sydney Metropolitan Area. Given a greater dispersal of population and economic activity, the average distance of telephone calls would increase, leading to significant changes in network organization.

Freeman (1968), in considering the problem of determining the best network organization in N.S.W., initially decided which locations justified the establishment of a switching center to serve as a minor exchange for a surrounding area of radius twenty to fifty miles. The second stage was to design a network linking these minor exchanges. The network between minor exchanges is arranged in a nested hierarchy, because of, firstly, the small traffic flows between individual minor exchanges and, secondly, the cost

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5 The following discussion is based largely on Freeman (1968).
of providing direct links between minor exchanges. Rather than providing a mesh network (Figure 13a), a star network (Figure 13b) or combination of both is frequently used (Figure 13c).

(a) Mesh Network       (b) Star Network       (c) Combined Star and Mesh Network

--- Connection

• Telephone subscriber

Figure 13

Basic Alternative Telephone Network Organizations

Direct routes between centers are justified only if the volume of traffic is large enough. Thus a combined star and mesh network would be justified only if locations 1 and 2 had heavy linkages between them (Figure 13c). For a small network, the minor exchanges could be linked using one central exchange. However, for larger networks further levels in the hierarchy of exchanges are necessary to prevent overloading of the central exchange.
This division of the optimal network design problem into, firstly, the location of a fine mesh of minor (local) exchanges and, secondly, the location of exchanges at higher levels in the hierarchy is somewhat arbitrary because of the interlocking nature of the location problems among all levels of the hierarchy. For example, the fineness of the mesh of the minor exchange regions will influence the number and location of exchanges higher up in the hierarchy.

The location of minor exchanges was determined on the basis of the size of the country town (2,500 population and larger) and the presence of a large proportion of internal traffic within the boundaries of the minor area. The location of high order exchanges was then considered. One alternative was to choose the highest traffic route from each minor area. Applying this to N.S.W. resulted in nearly every minor exchange having the route to Sydney as its highest traffic route. Out of one hundred and thirty minors in the state, over one hundred were dominantly oriented towards Sydney. If all the minor exchanges were directly connected to Sydney, the result would be a highly vulnerable network in which a breakdown in the Sydney exchange would fragment the N.S.W. telephone system into a large number of isolated areas. To overcome this problem, a number of higher level exchanges have been built in
country areas, although this results in a more expensive network.

The hierarchy of exchanges used by the post office were primary, secondary, minor and local exchanges. The first three levels of the hierarchy are mapped and the approximate boundaries between the regions delimited (Figure 14). The interior of the state is partitioned into three large regions centered on Wagga Wagga, Orange and Tamworth with a smaller region in the Central Tablelands centered on Lithgow. Nearer the coast, the south-eastern part of the state is focused on Canberra, although a large part of the south coast is in the Sydney primary area. Newcastle's primary region extends as far north as Kempsey, and Lismore is the focal point for the Far and Middle North Coast. The forty-seven secondary switching centers are grouped into eight primary areas in N.S.W., although Albury and Deniliquin are focused towards the Victorian exchange areas.  

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6 The pattern of exchanges is quite different in 1972. The primary switching centers have essentially been eliminated within the state (N.S.W. functions as a primary switching area in the Australian network) and the number of switching centers has been reduced to twelve. The 1964 data were used for the analysis of telephone message flows in chapter eight. Differences in the location of major exchanges for the two time periods along with the results of the factor analysis of flows are discussed in chapter eleven.
Figure 14
The Organization of Primary, Secondary and Local Exchanges in 1964
Regionalization of Network Structure

While the structural analysis of networks eliminates a large amount of information about the costs of communication and transportation between smaller settlements, most movement in advanced industrial societies is highly focused in character, and the nodes selected in this analysis generally represent transportation and communication foci for their surrounding regions. The connections between the major urban centers in N.S.W. were tabulated with the forty largest towns and cities at the 1966 census as the nodes of the transport network.\(^7\)

Data were collected on road travel time, straight line distance, telephone call costs and railway fares between the forty towns.\(^8\) Apart from the south coast these urban centers are moderately clustered in two broad groups—a northern and a south-western group. Quite large gaps in the distribution exist between the central-western group

\(^7\) All towns above 5,000 population at the 1966 census were included except towns in the Sydney and Newcastle Metropolitan Areas, which were excluded since the study is primarily concerned with the non-metropolitan part of N.S.W.

\(^8\) Road travel times were tabulated from a 1969 map published by the Department of Main Roads. Telephone call charges between nodes were supplied by the Post Master General's Department and railway fares data from the N.S.W. Department of Railways.
of towns (Dubbo, Wellington) and the New England Tableland (Gunnedah, Tamworth), as well as between the latter area and the north coast.

The regionalization of different transportation and communication networks delimits clusters of nodes which have similar patterns of connections to the rest of the network. This analysis is useful in that it provides a perspective on the spatial structure of N.S.W. One hypothesis raised is: What degree of similarity is there in the regions identified for different modes of transportation and communication? In addition, the relevance of regions delimited in the principal components analysis of network structure to the decentralization of economic activity will be examined.

The straight line distance, road travel time, telephone call cost and railway charge matrices were separately scaled so that the values ranged between zero and plus one.\(^9\) In each matrix all elements were divided by a value slightly greater than the largest element in the

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\(^9\) Air fares between the forty nodes were not factor analysed, because of the extreme dominance of Sydney in the air network (Figure 9).
matrix and then subtracted from one. A high value of 0.95 thus represents a very small distance or cost of movement between the two nodes. The closer together or more similar two nodes are, the higher will be the value in the scaled distance matrix.\(^{10}\) A value of one was inserted in the main diagonal of each matrix to represent the correlation of a node with itself.\(^{11}\)

The scaled distance matrix was then analysed using principal components analysis directly as though it were a correlation matrix.\(^{12}\) The matrix differs from a correlation matrix in that it has only positive and zero elements. However, it is symmetric about the main diagonal: nodes which are similarly located in space have a high "correlation" value. The components analysis program grouped the nodes (columns) in the cost matrix on the basis of their similarity in connection with all other

\(^{10}\) This procedure was followed by Phillip (1968) in a study comparing the value of factor analysis to hierarchical clustering methods in grouping cities by their distance apart.

\(^{11}\) For telephone costs a value of 0.975 was inserted in the main diagonal because of the charge of 5¢ as the cost of making a local call.

\(^{12}\) The components analysis program used was from the Biomedical program package, BMD03M which uses the varimax orthogonal rotation criterion.
nodes. Thus nodes which have high loadings in the same factor tend to be located fairly close to each other on this particular transport cost surface (Table 6). The nodes with high loadings on each factor were then mapped using isolines joining nodes with loadings of 0.7, 0.8 and 0.9.

The actual location of the towns selected will obviously affect the results of the components analysis. The more towns within a region, the greater the chance this region has of being selected as being important in the transport cost surface of the state. However, the selection of the forty largest cities and towns in the state means that the largest concentration of population and economic activity in N.S.W. lives in these settlements. Thus a large percentage of the movement along transportation and communications networks takes place between these nodes.

As mentioned earlier, the two major groups of towns are in the north (Northern Tablelands and North Coast) and in the central and south-west (Central Tablelands and Slopes and Riverina).

The components analysis of straight line distances extracted four factors which have eigen values greater than one, and these were orthogonally rotated (Figure 15). Instead of attempting to group towns which are close
Table 6
Principal Components Analysis of Network Structure

<table>
<thead>
<tr>
<th>Railway Fares</th>
<th>% of total variance</th>
<th>Telephone Call Charges</th>
<th>% of total variance</th>
</tr>
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<tr>
<td>I Central-West</td>
<td>51.8</td>
<td>I Central-West</td>
<td>47.9</td>
</tr>
<tr>
<td>II North Coast</td>
<td>14.5</td>
<td>II North Coast</td>
<td>18.3</td>
</tr>
<tr>
<td>III Northern</td>
<td>8.3</td>
<td>III Western Riverina</td>
<td>6.9</td>
</tr>
<tr>
<td>Tablelands</td>
<td></td>
<td>IV North-Western Slopes</td>
<td>4.5</td>
</tr>
<tr>
<td>IV South Coast and</td>
<td>4.9</td>
<td>V South Coast and Table-</td>
<td>3.0</td>
</tr>
<tr>
<td>Tablelands</td>
<td></td>
<td>lands</td>
<td></td>
</tr>
<tr>
<td>V Griffith-Leeton</td>
<td>3.4</td>
<td>VI Newcastle (less than</td>
<td>2.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>one eigenvalue)</td>
<td></td>
</tr>
<tr>
<td>VI Peripheral</td>
<td>2.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Places</td>
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<td>85.7</td>
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<td></td>
<td></td>
<td></td>
<td>TOTAL</td>
</tr>
</tbody>
</table>

<table>
<thead>
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<th>Straight Line Distance</th>
<th>% of total variance</th>
<th>Road Travel Time</th>
<th>% of total variance</th>
</tr>
</thead>
<tbody>
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<td>I Southern-Western</td>
<td>69.7</td>
<td>I Southern-Western</td>
<td>65.4</td>
</tr>
<tr>
<td>II Northern</td>
<td>14.8</td>
<td>II Northern</td>
<td>16.7</td>
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<td>III Central Coast</td>
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<td>III Central Coast</td>
<td>5.0</td>
</tr>
<tr>
<td>IV Wellington-Muswellbrook</td>
<td>3.0</td>
<td>IV Central and Northwest</td>
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<td></td>
<td></td>
<td>TOTAL</td>
<td>90.0</td>
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</table>
Figure 15
Principal Components Analysis of Straight Line Distance
together in distance terms (such as Orange, Bathurst and Lithgow), the components analysis delimited a south-western factor which extracted almost 70 percent of the variance (Table 6). A second factor delimited a northern region which accounted for approximately 15 percent of the variance. These two broad regions account for most of the settlements in this study, leaving only twelve nodes which have loadings of less than 0.7 on either factor. Two weaker factors group some of the settlements in the central coast and central-west and account for 3.6 percent and 3.0 percent of the total variance respectively.

The components analysis of road travel time data also delimited four factors with eigenvalues greater than one. The factors were very similar to those identified in the analysis of straight line distances. Comparing the loadings for both analyses (Figures 15 and 16) for factor I in the southern part of N.S.W., the 0.8 loading contour is further north for road travel time than for straight line distance, reflecting the ease of driving in this direction. The second factor centered on the north coast shows a slight decline in the loadings towards the north-west. However, the decline is less than expected, considering the difficult driving conditions between the coast and the tablelands. The decline in importance
Figure 16
Principal Components Analysis of Road Travel Time
Figure 17
Principal Components Analysis of Telephone Call Charges
of factor II for road travel time is reflected in the expansion of factor IV to include Gunnedah (Figure 16) on the margin of the Northern Tableland.

The components analysis of the telephone call costs revealed factors which were quite different from the travel time results (Figure 17). The regions delimited tended to be much smaller: five factors had eigenvalues greater than one and a sixth factor with an eigenvalue of 0.966 was also included. The factors grouped clusters of towns which were in straight line distance terms close together as well as maximizing the distance apart of the center of each cluster. The difference in regionalization from the travel time analysis reflects the different weighting of distance in this analysis. The regions delimited tend to be maximally separated, as for example factor IV (Moree and Narrabri), which is as distant as possible from factor II (Lismore and Casino), factor VI (Newcastle) and factor I (Parkes and Forbes).

Components analysis of the railway fare matrix for thirty-eight\(^{13}\) nodes revealed a similar set of regions as the

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\(^{13}\) Deniliquin and Echuca are not connected to the N.S.W. rail network. The railway fare data were for second class one-way fares in 1970.
telephone charge data: Central-West (Orange, Wellington), North Coast (Lismore, Grafton), Northern Tablelands and Slopes (Gunnedah, Narrabri) and Southern Coast and Tablelands (Canberra, Nowra) in order of importance (Figure 18). These regions differ from the set of telephone call cost regions in that the Western Riverina in the latter is quite important, whereas with Echuca and Deniliquin dropped out of the analysis, the Riverina enters as only a minor factor explaining 3.4 percent of the total variance.

The break between the Northern Tablelands and the North Coast Regions is more strongly emphasized in the analysis of railway fares than in the results for the other types of connections, due to the absence of a direct connecting link between the two regions. It is also interesting to note that Sydney and Newcastle, both important focal points for different subgraphs, are not included in any of the regions with the exception of Newcastle in factor VI in the telephone call charge analysis. The factor analytic technique seems to maximize the separateness of the regional clusters of nodes so that focal points being accessible to a number of regions do not fall into any one regional cluster.

The Central-Western Region centered on Orange explains
Figure 18

Principal Components Analysis of Railway Fares
approximately 52 percent and 48 percent of the total variance for railway fares and telephone charges respectively (Table 6). The importance of this region with these modes of transportation and communication reflects its centrality to the inland areas of N.S.W. This aspect of the region's location will be discussed in more detail in chapter eleven. The North Coast Region centered on Lismore and Casino is the second most important factor for both analyses, reflecting the region's isolated location near the Queensland border.

Conclusion
While businessmen in the survey conducted by the Department of Decentralization (Report on Selective Decentralization, 1969) felt that communication costs were a very important factor in decentralization, there is no guarantee that reducing or even eliminating these costs would ever lead to the decentralization of economic activity. A similar conclusion would hold for a reduction in freight rates for rail, air and road transportation. In fact, it is possible that the dominance of Sydney may be reinforced by a lowering of these costs. Firms located in Sydney may find that the agglomerative advantages of the city remain as high as before and that decreased transportation and communication costs allow the distribution of finished products to the
entire state. Thus the advantage in serving the local market that distance provided for the small country town could be eliminated by reducing costs of overcoming distance. Thus the elimination of communication costs may promote the centralization of many of the remaining economic functions found in non-metropolitan areas.

In considering network organization, Freeman (1968) points out that the regional level telephone exchanges are underutilized at present due to the lack of interregional linkages. A comparison is made in chapter eleven between the actual set of regional exchanges in 1964 and 1972 and the major foci in the telephone call data identified in the factor analysis of telephone calls for 1964. It is likely that decentralization to these foci would lead to a more efficient utilization of regional exchanges. The development of these centers as regional foci, however, is not likely to significantly increase interregional linkages. It would be expected that only the development of growth centers would lead to heavy linkages with other growth centers as well as with existing intrastate and interstate metropolitan areas. This topic will be further discussed in chapter eleven.

The most interesting result from the regionalization of
the four transportation and communications networks was the emergence of a central-western region as the most important factor for telephone call costs and railway fares, as against location of the two major factors in the north and south-west for travel time and straight line distance. Because of the clustering of nodes in the south-west and, to some extent in the north, the result for straight line distance was not unexpected. In addition, the regions delimited in the components analysis of travel time are not greatly different from those for straight line distance.

The presence of Bathurst/Orange (Central-Western Region) as the cheapest area on the telephone call cost surface was discussed earlier in the chapter (Figure 11). Given the railway network (Figure 8) and the fact that population distribution is not taken into account, the emergence of this region as the most important component for telephone calls and railway fares is not unexpected. It would appear that Bathurst/Orange has a locational advantage for industries which have as their market a large part of inland N.S.W. Since this area has been selected as a growth center by the state government, it seems desirable to encourage in this area the location of industries which need to be accessible to inland N.S.W.
CHAPTER VIII
Regionalization of Telephone Message Flows in New South Wales

The extent of the hinterlands of nodal centers may be delimited using telephone message flows, although the number of nodes in the flow matrix will determine the degree of accuracy in delimiting the extent of these nodal regions. An origin-destination matrix showing the volume of telephone messages between forty-seven secondary switching centers in N.S.W. was compiled.\(^1\)

With so few nodes in the analysis, only the major regional foci can be isolated, although some of the smaller foci are identified as well.

Rose (1967) states that a well-developed nested hierarchy of settlements does not exist in N.S.W. If this is true, then it would not be expected that the factor analytic

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\(^1\) The data used in the study were obtained from the Post Master General's Department and were based on a sample time period in 1964. The flow of telephone calls was measured in Erlangs: a measure based on the number of circuits which are in use between two towns at any one point in time. The telephone message data gives fairly comparable results with the latest available census figures completed in 1966. It is unlikely that any major changes have taken place since this time in most country areas.
technique would delimit strong functional regions around nodal points in country areas. Since the telephone call matrix is non-symmetrical, the total outflow of calls from a center may not necessarily equal the total inflow. It is hypothesized that an important metropolitan area or provincial city will have an excess of inward calls. In other words, towns within a dominant center's trade area will tend to contact it more than it will contact them.

Principal Components Analysis

Principal components analysis was used in preference to common factor analysis because of the nature of the data matrix. Apart from Sydney, most towns in N.S.W. have a maximum of a dozen connections to other towns in the state. Thus the origin-destination matrix has a large number of zeros. The components analysis results can only be viewed as descriptive of a set of regions, since the assumption of normality of variables cannot be tested with so few observations on each variable. It was felt that the use of a communality estimate, necessary for common factor analysis, would represent an unwarranted sophistication in the analysis, considering the nature of the data.

The original telephone call matrix showing the number of
calls generated in the rows and the number received in the columns was correlated prior to input into a principal components program. Thus, the \( ij \) th element in the correlation matrix shows the similarity in destination nodes \( i \) and \( j \) over the complete range of incoming calls that each receives.

In principal components analysis two destinations \( j \) and \( k \) will load together only on one factor if the pattern of correlations with all other destinations is similar for the two nodes. Thus, not only must two nodes have a similar pattern of incoming calls, but they must also have a similar pattern of connections with all other nodes before they can group together.

Principal components analysis of the correlation matrix extracted thirteen factors with eigenvalues greater than 1.0, which explained approximately 80 percent of the variance. The factors were then orthogonally rotated using the varimax criterion. High factor loadings in the R-mode analysis show areas which have similar patterns of incoming calls, since the components analysis groups columns of the correlation matrix. Thus nodes which have a similar pattern of elements in the correlation matrix will group together as destination regions.
High factor scores for the R-mode analysis indicate the most prominent generators of the destination's incoming calls. The factor scores are exact, since components analysis was used, and are derived by multiplying:

\[ S = B L (L' L) \]

- \( S \) - \( n \times p \) factor score matrix
- \( B \) - \( n \times m \) data matrix
- \( L \) - \( m \times p \) loading matrix

where \( p \) = the number of factors extracted

\( m \) = number of variables
\( n \) = number of observations and \( m > p \)
\( m = n \)

Q-mode analysis extracts dimensions from the transposed origin-destination matrix. Principal components analysis on this transposed matrix yields a loading matrix which groups origins on the basis of outgoing calls to similar destinations. High factor scores indicate the prominent destinations on each dimension extracted and are derived by multiplying:

\[ S = B L (L' L) \]

- \( S \) - \( m \times p \) factor matrix
- \( B \) - \( m \times n \) data matrix
- \( L \) - \( n \times p \) loading matrix

The lower case letters are the same as in the above formula.
The components analysis program calculates standardized scores:
\[ z_{ij} = \frac{x_{ij} - \bar{x}_j}{\sigma_j} \]

- \( z_{ij} \) - standardized score for observation \( i \) on component \( j \)
- \( x_{ij} \) - unstandardized score for observation \( i \) on component \( j \)
- \( \bar{x}_j \) - mean for variable \( j \)
- \( \sigma_j \) - standard deviation of scores for component \( j \)

**R - Mode Analysis**

A series of functional regions in the state is thus identified: some regions are clearly delimited (Dubbo); others Lismore and Grafton, Wagga Wagga and Narrandera) overlap to some extent (Table 7).

For R-mode analysis factor I represents a functional region centered on Sydney and explains approximately a quarter of the total variance. The loadings show two distinct patterns: firstly, a distance decay effect away from Sydney and, secondly, moderately high loadings for larger towns and very low loadings for the smaller towns, which is probably due to the dependence on surrounding regional foci (Figure 19). An example of the latter pattern is shown on the Northern Tablelands, where smaller towns such as Quirindi, Gunnedah, Narrabri, Inverell and Glen Innes have very low loadings, whereas Tamworth and
Table 7

Percentage of Variance Explained and Eigenvalues for R-and Q-mode Analyses

<table>
<thead>
<tr>
<th></th>
<th>R-MODE</th>
<th>Q-MODE</th>
<th>difference in variance explained between R-and Q-mode analyses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>rotated loadings group destinations on the basis of the similarity of incoming calls</td>
<td>rotated loadings group origins on the similarity in outgoing calls</td>
<td></td>
</tr>
<tr>
<td></td>
<td>% of variance</td>
<td>Eigenvalues</td>
<td>% of variance</td>
</tr>
<tr>
<td>SYDNEY</td>
<td>I</td>
<td>26.3</td>
<td>12.4</td>
</tr>
<tr>
<td>TAMWORTH</td>
<td>II</td>
<td>8.8</td>
<td>4.1</td>
</tr>
<tr>
<td>LISMORE</td>
<td>III</td>
<td>7.6</td>
<td>3.6</td>
</tr>
<tr>
<td>NEWCASTLE</td>
<td>IV</td>
<td>6.4</td>
<td>3.0</td>
</tr>
<tr>
<td>WAGGA WAGGA</td>
<td>V</td>
<td>6.2</td>
<td>2.9</td>
</tr>
<tr>
<td>DUBBO</td>
<td>VI</td>
<td>4.8</td>
<td>2.3</td>
</tr>
<tr>
<td>NARRANDERA</td>
<td>VII</td>
<td>4.2</td>
<td>2.0</td>
</tr>
<tr>
<td>CANBERRA</td>
<td>VIII</td>
<td>3.6</td>
<td>1.7</td>
</tr>
<tr>
<td>GRAFTON</td>
<td>IX</td>
<td>3.1</td>
<td>1.5</td>
</tr>
<tr>
<td>ARMIDALE</td>
<td>X</td>
<td>2.9</td>
<td>1.4</td>
</tr>
<tr>
<td>TOTAL</td>
<td>73.9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 19
R-mode Principal Components Analysis of Telephone Calls for Factor I
Armidale have moderately high ones. Towns near the northern and southern borders of the state have low loadings, which reflects the competition from Brisbane and Melbourne.

Succeeding factors isolate functional regions centered on regional foci. Tamworth is the focus of the second factor and its functional region includes Inverell, Narrabri, Gunnedah and Quirindi. Armidale, the other large town on the Northern Tablelands, isolates its own much smaller region which includes Glen Innes and Moree (factor X in Figure 20). However, Inverell, while lying within Tamworth's region, forms a slightly weaker secondary focus for Armidale's region.

In the Northern Coastal Region Lismore is the dominant center and is the third most important region to be delimited. Its functional region includes the Far North Coast and extends south to Grafton. As with the Northern Tablelands, a second regional foci exists in this region. Grafton's functional region stretches as far south as Coff's Harbour and is limited by Lismore's region in the north and mountains to the west.

The next most important regional foci delimited is Newcastle with tributary towns of Muswellbrook, Singleton and Taree. Newcastle's region is surprisingly small considering
Figure 20

R-mode Principal Components Analysis of Telephone Calls for the Rest of the State
its second ranking in the settlement hierarchy of the state. The extent of the region probably reflects the presence of Sydney and Newcastle's main function as an industrial center rather than as a regional focus for northern N.S.W.\(^2\) Wollongong, the third ranking city, reflects this trend even more strongly since it lies almost completely within Sydney's functional region and has few connections to other towns. It functions basically as an industrial outlier of the Sydney Metropolitan Area.

The next region in importance is centered on Wagga Wagga and includes a large part of the Riverina. However, the Riverina is divided into a western section centered on Narrandera and an eastern section on Wagga Wagga. It is of interest to note the lack of importance of Albury as a regional focus of telephone traffic for the sampled towns. This reflects the lack of smaller towns in its immediate hinterland and the presence of only N.S.W. towns in the sample analysed.

Dubbo was isolated as a regional focus for the North-

\(^2\) The lack of interest by Newcastle residents in the new state movement espoused by the Northern Tablelands and North Coast regions is reflected in the high rejection rate by Newcastle in the 1967 referendum concerning a new state in Northern N.S.W., Woolmington (1968).
Western Slopes with Nyngan, Wellington and Coonamble lying within its region. The shape of the functional region reflects the presence of larger towns to the south and south-east.

Canberra appears as the focus for the Southern Tablelands and South Coast with Moruya and Cooma lying within its functional region. Its influence, however, is fairly weak with these towns having loadings of approximately 0.5. Also Nowra and Bega do not load highly on this factor, which indicates that the regionalization on the South Coast is quite weak.

Q-mode Analysis
Q-mode analysis was performed to give a different emphasis to the regionalization of telephone calls. The results give a similar set of regions to R-mode analysis but with several interesting differences (Figures 21 and 22). Nine factors had eigenvalues greater than one, and together explained 84.2 percent of the total variance. The major redistribution of explained variance is that Sydney nearly doubles its variance (from 26.3 percent to 46.9 percent),

3 The weakness of Canberra's functional region probably reflects its status as an administrative rather than a commercial center. The planning of its site was not done with the idea that it should be as accessible as possible to a surrounding region.
Figure 21

Q-mode Principal Components Analysis of Telephone Calls for Factor I
Figure 22

Q-mode Principal Components Analysis of Telephone Calls for the Rest of the State
and only nine factors rather than thirteen are needed to explain a similar amount of total variance. Sydney appears as a more clearly defined receiving center than it does as a sending focus. The number of towns within a two hundred mile radius with high loadings is larger for the Q-mode than for the R-mode analysis (Figures 21 and 19). This is reflected in the origin-destination matrix in which Sydney received 281.48 erlangs and yet generated only 186.17. The direction of dominance is clearly shown—the smaller towns contact the large metropolis more than it contacts them. An important exception is the higher loading for Canberra in the R-mode analysis, which perhaps reflects the status of Canberra as a national capital. Even though Canberra lies within Sydney's functional region, it loads more strongly for the outgoing calls from Sydney than for inward calls to Sydney.

In addition, the importance of the regional foci is less in terms of percentage of total variance explained for the Q-mode analysis. Most functional regions around regional foci decrease in importance by about one or two percent of the total variance, and Armidale's region disappears completely. The two regions which decline by the smallest amount are Lismore and Grafton, both on the North Coast and quite distant from Sydney's influence.
Significance of Results in the Identification of Regional Foci

The study is greatly limited by the small number of towns in the research, which meant that regional boundaries could only be generally delimited for many areas. In addition, only several levels in the settlement hierarchy could be delimited.

The regions delimited in both R- and Q-mode analyses showed double foci in the Riverina, Northern Tablelands and Slopes and the Northern Coastal regions. In all three cases the dominant centers were much more important than the secondary foci. In the Riverina, the economic rivalry between Wagga Wagga and Albury was not apparent in the telephone call data because only N.S.W. and not Victorian calls were analysed. In the Northern Tablelands and Slopes, Tamworth emerges as the most important regional focus, whereas Inverell and Armidale form a weak northern focus only in the R-mode analysis. A similar pattern appears for the North Coast, although Grafton emerges as a fairly strong secondary regional focus, and it seems that in considering the topography of this region it would be difficult for any one center to dominate the complete region. The factor analysis results indicate that Grafton's functional region extends south to cover Coff's Harbour and to a lesser extent Kempsey.
Perhaps one of the most interesting features of the analysis is the confirmation of Illeris and Pederson's (1968) results which found that the technique did not isolate regions around towns close to a large city. Surrounding Sydney it might be expected that a region in the Central Tablelands centered on Bathurst or Orange would be delimited, as well as one in the Illawarra area centered on Wollongong. One implication of the absence of regions in the area adjoining the Sydney Metropolitan Area is that it may be difficult to establish a regional center in the Central Tablelands because of the relative proximity of Sydney. It is likely that consumers in this region will bypass Bathurst and travel to Sydney for many high-order functions that a regional center might provide.

Canberra only weakly emerges as a regional focus for the Southern Tablelands and South Coast. Goulburn has moderately large flows to both Canberra and Sydney and seems to suffer the same problem as Bathurst and Lithgow of being too close to Sydney. Perhaps with more recent data Canberra would show an increased importance as a regional focus, since it has grown rapidly since 1964.

The pattern of loadings on Sydney's dimension indicates a distance decay effect away from Sydney superimposed on a pattern of high loadings to large provincial cities. This
pattern would be expected from a gravity model interpretation of the interaction between towns, since interaction varies directly with the population size of towns and inversely with the distance between them. Thus smaller towns located at a distance of over one hundred and fifty miles from Sydney tend to have a stronger interaction with the regional foci, an interpretation entirely consistent with the findings of central place theory.

Analysis of the difference between the total number of calls generated and received by a town reveals some interesting results (Table 8). The nodes in order of the magnitude of the difference between calls received and calls generated are: Sydney, Canberra, Newcastle, Tamworth, Wagga Wagga, Lismore and Albury. It would seem that these nodes act as foci for telephone calls from smaller tributary towns, which receive fewer calls than the number they generate.

In general the larger towns receive more calls than they generate (Table 8). The two major exceptions are Wollongong and Gosford, which lie close to the Sydney Metropolitan Area. Gosford, despite its sixteenth rank in population size, ranks fourth and sixth in the number of calls generated and received respectively. This possibly reflects its status as a dormitory suburb of Sydney. However, other large towns such as Orange, Goulburn, Lithgow, Taree and Nowra
Table 8
Telephone Calls Generated and Received for Secondary Switching Centers

<table>
<thead>
<tr>
<th>Switching Center</th>
<th>Telephone Calls Generated</th>
<th>Telephone Calls Received</th>
<th>Difference Between Calls Generated and Received</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Volume</td>
<td>Rank</td>
<td>Volume</td>
</tr>
<tr>
<td>Sydney</td>
<td>186.1</td>
<td>1</td>
<td>281.5</td>
</tr>
<tr>
<td>Newcastle</td>
<td>68.1</td>
<td>2</td>
<td>74.1</td>
</tr>
<tr>
<td>Wollongong</td>
<td>50.0</td>
<td>3</td>
<td>40.0</td>
</tr>
<tr>
<td>Albury</td>
<td>10.0</td>
<td>21</td>
<td>10.3</td>
</tr>
<tr>
<td>Wagga Wagga</td>
<td>26.4</td>
<td>5</td>
<td>28.1</td>
</tr>
<tr>
<td>Orange</td>
<td>20.5</td>
<td>7</td>
<td>16.7</td>
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<tr>
<td>Tamworth</td>
<td>18.2</td>
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<td>20.2</td>
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<td>Goulburn</td>
<td>16.6</td>
<td>10</td>
<td>13.4</td>
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<td>9.6</td>
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<td>11.7</td>
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<td>26</td>
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<td>Dubbo</td>
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<td>41.5</td>
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<td>Nowra</td>
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<td>Parkes</td>
<td>15.2</td>
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<td>Moree</td>
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<tr>
<th>Switching Center</th>
<th>Telephone Calls Generated</th>
<th>Telephone Calls Received</th>
<th>Difference Between Calls Generated and Received</th>
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<td></td>
<td>Volume</td>
<td>Rank</td>
<td>Volume</td>
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<td>Coff's Harbour</td>
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<tr>
<td>Murwillumbah</td>
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<tr>
<td>Cowra</td>
<td>10.5</td>
<td>19</td>
<td>8.5</td>
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<td>Muswellbrook</td>
<td>8.7</td>
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</tr>
<tr>
<td>Deniliquin</td>
<td>3.3</td>
<td>45</td>
<td>1.9</td>
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<tr>
<td>Singleton</td>
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<td>Narrabri</td>
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</tr>
<tr>
<td>Narrandera</td>
<td>13.5</td>
<td>14</td>
<td>11.6</td>
</tr>
<tr>
<td>Nyngan</td>
<td>8.2</td>
<td>29</td>
<td>6.5</td>
</tr>
<tr>
<td>Quirindi</td>
<td>4.9</td>
<td>40</td>
<td>2.5</td>
</tr>
<tr>
<td>Rylstone</td>
<td>2.8</td>
<td>46</td>
<td>1.0</td>
</tr>
<tr>
<td>Temora</td>
<td>6.0</td>
<td>37</td>
<td>4.7</td>
</tr>
<tr>
<td>West Wyalong</td>
<td>4.4</td>
<td>42</td>
<td>3.1</td>
</tr>
</tbody>
</table>

Volume of telephone calls are in Erlangs

Source: Traffic Engineering Section, Post Master General's Department, Sydney.
also generate many more calls than they receive. These towns are within a two-hundred mile radius of Sydney and do not act as regional foci as strongly as towns further away.

Conclusion

The telephone call data suggest that at least a three-level hierarchy exists in N.S.W. The highest level is Sydney; second ranking towns in the hierarchy are Canberra, Newcastle, Tamworth, Wagga Wagga and Lismore; and the remaining towns form the third level. The significance of the regional foci identified will be discussed in relation to central place theory in chapter eleven. However, the amount of variance explained by the factors identifying regional foci in N.S.W. is comparable to Illeris and Pederson's results for Denmark (Table 9).

---

4 Albury, with only a slight excess of calls received over those generated, is not included in the second level of the hierarchy, as it does not separate out as a significant component in the principal components analysis.
Table 9
Percentage of Variance Explained by Regional Foci and Metropolitan Areas in N.S.W. and Denmark

<table>
<thead>
<tr>
<th></th>
<th>N.S.W.</th>
<th>Denmark *</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R-mode</td>
<td>Q-mode</td>
</tr>
<tr>
<td>Number of significant regional components +</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>% of variance explained by regional factors</td>
<td>47.6</td>
<td>37.3</td>
</tr>
<tr>
<td>% of variance explained by the major metropolitan area</td>
<td>26.3</td>
<td>46.9</td>
</tr>
<tr>
<td>% of total variance explained</td>
<td>73.9</td>
<td>84.2</td>
</tr>
</tbody>
</table>

* Illeris and Pederson (1968) do not comment on whether they used R- or Q-mode factor analysis nor do they state why they extracted a total of ten factors.

+ Components with eigenvalues greater than one were interpreted in this study.
CHAPTER IX

Locational Analysis—Type I Organizations

Type I organizations are characterized by the presence of single trips between consumers and central facilities. In this chapter several variants of the location-allocation model are applied to determine the optimal location of central facilities for type I organizations. In addition, some of the social costs attached to the optimal solutions are considered.

Some of the limitations of the location-allocation model were discussed in chapter four and these problems should be considered in the practical application of the model. One of the most important objections to its use as a guide to the location of public facilities is that the optimal solution may reinforce an existing undesirable situation in the location of economic activity. Since the Central Coastal Region contained 77.4 percent of the population of the state in 1969, it might be expected that the optimal solution would favor this region in terms of the number and capacity of facilities. It is possible that people living in areas with low population density might be required in the optimal solution to travel long distances for services.
Some of the other objections mentioned earlier are avoided, since the locations derived in the analysis are not necessarily optimal for individual organizations. For a particular organization there may be specific features of its operating environment which lead to "non-optimal" locations being selected. The application of the model in this chapter concerns the location of regional centers at which government office blocks are to be established. The solutions to the location-allocation model thus may be viewed as providing some guidelines for the optimal location of these centers. While individual government departments may have conflicting locational criteria for placing their central facilities, the advantages in terms of savings in fixed costs of buildings and for consumers in travelling to the one center are likely to exceed those of locating the facilities in separate towns.

The static nature of the location-allocation model would seem to conflict with the changes in the population distribution within the state, especially since the fixed costs of establishing some types of public services are quite high. While many rural shires have lost population, the regional population totals have either remained constant or shown slight overall gains in the past twenty-five years (Table 4). The trend has been for the population in most regions within the state to become
increasingly urban and it is likely that the number of people leaving rural industries will stabilize before too long. With this long-run stability in regional population totals, the static nature of the location-allocation model is less critical than in other situations in which there is a high degree of uncertainty in the operating environment.

The bases of the optimal location solutions for a private tertiary firm in locating central facilities are very much different from those of a public organization. For example, the private firm may only wish to locate in settlements which are at present large and have good growth prospects, leaving regions with limited present and future demand without the service. However, it is likely that the selection of a small number of regional centers for the location of public central facilities would have a strong multiplier effect and that additional private firms would be attracted by the increased population and the favorable climate for economic growth.¹

¹ It is emphasized that these regional centers would not necessarily attract much industry, although some light industry may move (for example, textiles). Thus the growth will be constrained to some extent by the population base of the service region.
Location-Allocation Model—Computer Algorithms

Two algorithms are used in this chapter to provide solutions to the location-allocation problem. Neither algorithm provides an exact solution, but when used together they provide some insights into the problem of optimally locating central facilities within the state. In addition, the solutions show some interesting correspondences which are useful in confirming the centrality of some locations to surrounding regions.

Crosscut

The Crosscut algorithm was developed by Kuenne and Soland (1971) to provide a fast and fairly good approximate solution to the multi-origin Weber problem. This problem is a variant of the location-allocation problem. We are given:

1. $n$ destinations;
2. the destination weights $w_j$ which must move to or from one or more origins in the solution;
3. shipping costs proportional to weight and Euclidean distance.

The problem is to find the location of the origins such that the sum of the weighted distances between origins and destinations is a minimum.

In order to use the algorithm it is necessary to select a
set of origin locations. Kuenne and Soland (1971) consider that the best solutions are obtained by selecting locations that permit all portions of the space to be represented. Step one of the algorithm involves the assigning of destinations to a particular origin, using the criterion of minimum distance. The cost of the weighted distances between origins and destinations is then calculated. Step two involves taking the same clusters of destinations which were assigned to a particular origin in step one and locating a new origin, using the single-origin Weber problem. This is repeated for each of the origins so that a new set of origin locations is defined. The costs are then determined for this allocation. This procedure is continued until a convergence criterion for the coordinates is met.

While the program gives only an approximately optimal solution, Kuenne and Soland suggest that the objective functions of multi-origin Weber problems are relatively flat-bottomed. Thus even approximate solutions are frequently close to the global solution, and they consider that Crosscut gives close approximations to global minima. Given the computational difficulty of providing fully optimal solutions for even relatively small problems, it seems necessary that heuristic algorithms such as Crosscut be used.
Data Analysis

The program utilizes the population as a measure of demand, and distance between nodes is calculated using latitude and longitude. The forty major towns and cities of the 1966 census were used as a measure of demand. ²

The algorithm was run with five origins or facilities to be located. The initial origins were specified so as to achieve a fairly wide coverage of all regions and were Glen Innes, Muswellbrook, Sydney, Forbes and Deniliquin. The minimum cost solution formed regions around Sydney, Wollongong, Newcastle, Wagga Wagga and Albury (Figure 23). Newcastle and Sydney shared the northern half of the state, whereas Wagga Wagga dominated the southern half with Wollongong and Albury forming small regional clusters.

For the three other trials (locating eight, ten and twelve facilities) Newcastle, Sydney and Wollongong's regions were greatly restricted in extent (Figures 24, 25 and 26). Thus the large populations found in these cities did not allow them to dominate extensive regions. In the eight facility solution the major region is centered on Tamworth. This

² The source of population data was the 1966 population census published by the Commonwealth Bureau of Census and Statistics.
Figure 23

Crosscut Solution for Five Facilities
Figure 24

Crosscut Solution for Eight Facilities
Figure 25

Crosscut Solution for Ten Facilities
Figure 26
Crosscut Solution for Twelve Facilities
region is divided into two in the ten facility solution (Northern Tablelands and North Coast). A third region, the Far North Coast, separates out for the twelve facility solution. The inclusion of Glen Innes in the coastal region for the twelve and ten facility solutions illustrates the fact that the cost of travel was not included in the distance between points, since Glen Innes is fairly remote from the coast in terms of travel time.

For the eight facility solution a region centered on Orange is delimited, which is partitioned into two for the ten facility solution—an eastern (Bathurst and Lithgow) and a western cluster. This western cluster is further partitioned for the twelve facility solution into a northern group (Dubbo and Wellington) and a cluster centered on Orange. In the southern part of the state, a number of clusters emerge in the eight facility solution (namely, those centered on Wagga Wagga, Albury and Goulburn) which remain unchanged for the ten and twelve facility solution. Unlike the northern part of the state, these three regional clusters are fairly tightly defined and have relatively large distances between them. In contrast, the towns on the North Coast are strung out in a linear fashion and do not, therefore, form stable regional clusters.

The objective function value is not measured in units to
which a cost can be attached. However, the plot of the value of the objective function against the number of facilities reveals that the value of the solution declines with increasing numbers of facilities (Figure 27). The greatest relative decline occurs from five to eight facilities. This indicates that the greatest relative decrease in distance travelled to a central facility occurs somewhere between five and eight facilities. This conclusion is valid only for the range of five to twelve facilities. The shape of the graph indicates, however, that the slope would increase slightly for fewer facilities and decrease marginally for more than twelve facilities.

![Graph of the Value of the Objective Function Against the Number of Facilities for Crosscut Trials](image)

**Figure 27**

Graph of the Value of the Objective Function Against the Number of Facilities for Crosscut Trials
Miniware

A computer program called Miniware\(^3\) was used to solve a variant of the location-allocation problem. The program, to arrive at an optimal central facility solution for a set of cities, utilizes demand at a number of points, linkages in the form of straight line distances or travel time between points,\(^4\) the fixed costs of building warehouses or facilities and transportation unit costs.

The algorithm initially calculates the shortest path between any two points in the network and, by using each node in turn as the origin of a tree, determines a set of minimum tree paths based on the linkage information supplied. These minimum tree paths are then weighted by multiplying each linkage by the demand of the receiving city.

\(^3\) The program was developed for use on the UNIVAC 1108 and was supplied by a Sydney based company, Compunet.

\(^4\) Computational experience suggests that the program cannot handle many problems using travel time between nodes. It appears that the complexities of alternative routes in the travel time matrix are too great for the program to handle. It is unlikely that any difficulty would be encountered if an average speed of travel for the entire state were assumed. However, the difference between the results with this measure of distance and straight line distance would be trivial. For further discussion of the computational experience in using travel time see footnote 15 in this chapter.
The option exists in the program for initially specifying trial facility locations, although these may or may not be kept in the final solution. If the initial facility candidates have not been fully specified, then a complementary number are selected from the remaining set of permissible sites, using the greatest demand as the criterion. Subsets of nodes around chosen facilities are formed by assigning a node to a particular grouping because it is nearer in terms of weighted paths to this facility than to any other. The true center of gravity in each set is checked by comparing the minimum path trees generated when each member of a set serves as the supplier for its particular group. If the true center of gravity for any set is not the candidate initially chosen, then the node which is the calculated center of gravity replaces the initial one; the program then goes back and forms subsets of nodes around the origin nodes until an optimum solution for a given number of facilities is reached.

The objective is to minimize the overall transportation costs.

---

5 The option also exists of not allowing some nodes to enter as possible facility sites.
Minimize \( C_n = S \sum_{i=1}^{n} T_{wi} \cdot D_i \)

where \( C_n \) = overall transportation cost for \( n \) facilities;
\( S \) = transportation cost per unit distance;
\( T_{wi} \) = shortest distance from facility \( w \) to node \( i \);
\( D_i \) = demand at node \( i \).

The minimum path trees are then calculated, using each of \( n \) facilities in the solution as an origin in a set of nodes containing the \( n \) facilities as receiving locations. The algorithm thus checks at this step the cost of distributing goods from each facility; this step forms the basis of the deletion of a facility in the next step.\(^6\) The algorithm then decreases the number of facilities in solution by deleting from the current optimal solution that facility which has a maximum set of weights when used as the origin in the set of facilities. As each facility is deleted the program goes back and forms subsets of nodes around the remaining facilities, checks the center of gravity and so on.

---

\(^6\) The computer program is set up for a warehouse distribution problem in which the problem is to select the set of warehouses which minimize costs of distribution. The solution is exactly the same for facilities which are the destinations for consumers.
The algorithm has a provision for building in an average cost per facility. However, this cost figure does not take into account the variable costs associated with different capacities of facilities and was not used. Thus the location-allocation problem is not solved by the algorithm: it merely indicates the particular set of nodes for a given number of facilities which will minimize transportation costs for a network of cities.

Data Analysis

Twenty-two statistical divisions and sub-divisions delimited by the Census were used as the origin areas for input into Miniware (Figure 28). The use of these divisions is advantageous in that the boundaries of the central facility's regions conform to regional boundaries of the statistical subdivisions. Thus if reorganization of statistical division boundaries is required, it can be achieved simply by amalgamating statistical subdivisions. However, the boundaries of the statistical subdivisions are not necessarily desirable in terms of the integrated government offices which are under consideration in this chapter. However, at the macro-level view of regional

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7 In addition, the Australian Capital Territory (including Canberra) was included in the population figures for the Southern Tablelands Subdivision.
Figure 2.8
Origin Areas and Nodes for Miniware Input
amalgamation considered in this research, the statistical subdivisions are adequate building blocks for locating hinterland boundaries of central facilities.\(^8\)

Most of the origin areas have a clearly defined city or town as a focus and these nodes were used in computing the straight-line distances between origin areas (Figure 28). The 1970 population estimate for each statistical subdivision was used as a measure of demand for each of the twenty-two nodes. It was assumed that the population of the subdivision was concentrated at a central point within each subdivision. It was also assumed that the cost of travel was ten cents a mile for all consumers. This assumption has no empirical evidence apart from the fact that many car rental firms charge this figure in renting cars. However, such a linear cost of travel has little theoretical or practical justification, so that the units on the vertical axis have little substantive meaning (Figure 29). The main purpose of the analysis is to interpret the significance of any breaks in the negative slope of the graph.

\(^8\) The boundaries of the subdivisions are based on available information on the functional regions of the major country towns within the state. However, the subdivisions are quite large in size and some consumers may have to travel appreciably longer distances than they would if a finer mesh of regions were used as origin areas.
The least cost solution for the four trials.

Total cost of consumer travel to facilities in millions of dollars

(Assuming straight line distance is used)

Figure 29
Graphs of Consumer Travel Costs Against the Number of Facilities for Miniware Trials
The program was used with no fixed costs introduced and the minimum cost combination from one to twelve facilities was calculated. The graph of these solutions shows, as would be expected, a negative slope with a flattening out occurring from ten to twelve facilities. This break in the downward slope indicates that the addition of a single facility beyond eight does not significantly reduce the travel costs for consumers.

The program was run a number of times with twelve, ten, eight and five facilities set as the maximum number of facilities to be located, and the results of these solutions for each combination were graphed (Figure 29). The graphs for the trials with twelve and ten facilities were identical. However, both these trials gave more costly solutions for the corresponding points on the graphs for the trials with eight and five facilities. It seems that the algorithm gives a non-optimal solution in deleting facilities when it starts initially with a large number.

Unlike the graph for Crosscut (Figure 27), which produces only one optimal solution for each trial, Miniware calculates for each trial involving n facilities the cost for n-1, n-2, . . . ., 1 facilities. Both graphs (Figures 27 and 29) show a slight break in the downward slope at around
eight facilities, which suggests that this number of facilities is the optimum.

For five locations facilities were located at Sydney, Newcastle, Wollongong, Canberra and Lismore (Figure 30). Canberra's tributary region is extensive and reaches as far north-west as Nyngan, as well as to the Riverina, Southern Tablelands and a section of the South Coast. Newcastle's region is also quite large, including part of the Northern Tablelands and Slopes as well as a part of the North Coast. Perhaps the most surprising aspect of this trial is the non-existence of an extensive region around Sydney; instead, the Central Tablelands Subdivision forms a part of Wollongong's region.

To some extent Sydney's constricted region reflects the presence of large cities to the north (Newcastle) and south (Wollongong) as well as relatively large populations centered on Bathurst and Forbes. In contrast, centers such as Wagga Wagga, Canberra and Tamworth have much larger areas which can be dominated without much competition from other cities. This feature of the results illustrates a general weakness of the location-allocation model as applied to the settlement hierarchy. Unless the "nesting" present in the hierarchy can be built into the model, the "true" extent of a large city's dominance cannot be
Cities selected as a location for a facility shown in heavy print

Figure 30

Miniware Solution For Five Facilities
Lismore has a region which includes the Northern Tablelands and two subdivisions of the North Coast Division. The three regions in the Central Coast remain the same for the four trials, with the exceptions that Wollongong loses the Central Tableland and that Newcastle's region is restricted to the Hunter Division on all subsequent trials.

The major change for the eight facility trial is that Canberra's region is greatly reduced in area to occupy only the South-Eastern Division with Dubbo and Wagga Wagga sharing the remainder (Figure 31). The boundaries for the Riverina (Wagga Wagga) and the South-Eastern Division (Canberra) remain constant for the two subsequent trials with all changes occurring in the central-west, north-west and northern parts of the state. In addition, for this trial Newcastle's region is greatly diminished, with Dubbo and Tamworth partitioning the Northwestern Slopes and Plains. Tamworth reduces Lismore's region by dominating the Northern Tablelands Region (Armidale).

With ten facilities to be located, the Dubbo Region was partitioned into three parts centered on Dubbo, Forbes and Bathurst (Figure 32). The next trial, with twelve facilities to be located, partitioned the regions
Figure 31

Miniware Solution for Eight Facilities
Figure 32

Miniware Solution for Ten Facilities

Cities selected as a location for a facility shown in heavy print
centered on Tamworth and Lismore into four; the first of
the two additional regions was centered on Armidale
(including the lower North Coast) and the second, on
Grafton (Figure 33).

A comparison can be made with the ten census-defined
regions and those produced by the computer program. Com­
parisons between the two are very rough, because Miniware
grouped only the statistical subdivisions. However, for
the ten facility trial the computer program gave comparable
regions for Canberra, Wollongong, Sydney, Newcastle and
Dubbo. The first deviation was that a Murray Region did
not separate out for any of the four trials. Despite the
elimination of northern Victoria in the study, this result
is somewhat surprising since the combined population in the
Murray Division is approximately 80,000. However, Wagga
Wagga is well positioned to capture Deniliquin and Albury's
population. This result suggests that the planning of
regional and growth centers may need to proceed on
different lines. It is likely that Albury/Wodonga will be
developed as a growth center. However, for the N.S.W.
population Albury, as a border city, is not as central as
Wagga Wagga to the Riverina. This competition between the
two cities could be reflected in the location of state
government offices in Wagga Wagga, whereas Commonwealth
government offices could prefer to locate at Albury, a site
Figure 33

Miniware Solution for Twelve Facilities

Cities selected as a location for a facility shown in heavy print
which considers interstate population distributions.

The second difference between the Miniware results and the census-defined regions is that the Central-Western Division is broken up into two separate regions. This possibly reflects the approximate equality of their populations as well as their proximity to major population centers.

The Northern Division focused on Tamworth includes a section of the North Coast—namely, the Hastings Subdivision focused on Port Macquarie. This reflects the use of straight line distance as well as the attenuated nature of the North Coast Division with the concomitant difficulty of any one center's dominating the region. The straight line distance does not take into account the difficulty of contact across the Great Dividing Range. It is possible that the Hastings Subdivision (Port Macquarie) should be part of the Newcastle Region.

Minware and Crosscut Results and the Location of Central Facilities
The consumer travel cost graphs for an increasing number of facilities (Figures 27 and 29) indicate some difficulties in the implementation of the division of the state into a fixed number of regions. The number of divisions selected
by the Government seems to be correctly chosen as a maximum, since for more than eight divisions the savings in consumer costs levels out very markedly as the state becomes increasingly better served by facilities.

However, there may be several reasons, based on the costs of building and operating facilities for a particular set of organizations, which suggest that fewer than eight would be a much cheaper solution for the system as a whole. In addition, fewer facilities would keep the real price of the service down to a reasonable level. Unfortunately, the graph of the consumer travel costs is roughly linear from one to eight facilities (Figure 29) and does not provide any indication on travel cost minimization grounds for selecting any one combination of facilities. If an organization decided to locate five or eight facilities, then the results of the computer program merely indicate which towns should be selected as well as the extent of their tributary areas.

9 Locating central facilities next to consumers would reduce consumer travel costs to a very small figure. However, the price which should be charged, based on costs, would be extremely high.
There is a fairly close similarity in the results of the two algorithms when the locations of the central facilities and their associated regions are compared. One of the most prominent similarities is that the three major cities (Sydney, Newcastle and Wollongong) form fairly stable regions in the different trials for both algorithms. This feature is quite important, since it is difficult for any one center to dominate the North Coast Region. It also means that cities on the Northern Tablelands (Tamworth and Armidale) are not able to extend their influence down to the coast, as is the case in some Miniware solutions. Given the difficulty of contact between the North Coast and the Northern Tablelands Regions as well as the attenuated nature of the coastal region, the extension of Newcastle's region up to Port Macquarie seems a desirable feature in any optimal regionalization.

Unlike the Miniware trials, Albury forms a very stable region for the Crosscut trials. To a large extent this seems to be a function of the different input data for the two algorithms. The use of forty destinations in Crosscut (as against twenty-two in Miniware) allows the formation of a regional cluster around Albury.

The major provincial cities (Wagga Wagga, Bathurst, Tamworth and Lismore) have regions formed in the trials with both
algorithms. However, the northern part of the state has much less stability in regional groupings than the central-west or southern parts. This stability is shown quite markedly in the Crosscut trials and reflects the relatively discrete clusters of settlements in the south and south-west. It would appear that the introduction of travel time constraints or physical barriers would force a clearer regional grouping of settlements in the Northern Tablelands and North Coast Regions. However, unless Newcastle's region is extended north to Port Macquarie or Kempsey, it does not seem possible for any one center to dominate this region.

In general, the correspondences between the location and boundaries of the central facilities for the two algorithms is quite surprising, since the number of initial data points in Crosscut was almost double that used for Miniware. However, considering that both programs were solving the location-allocation problem, the degree of similarity in the solutions is, perhaps, not so surprising after all.

10 Miniware was initially used with forty origin areas but did not function properly and worked only with twenty-two origin areas.
The most important limitation of Miniware and Crosscut in solving the location-allocation problem is their inability to incorporate fixed and variable costs of building and operating facilities. However, it is possible to use an additional criterion of the size of market population in each tributary region around a facility. \(^{11}\) Before a facility is built, a population threshold of 50,000 or 100,000 may have to be exceeded; otherwise the facility would not generate sufficient business to justify the fixed costs entailed. In practical applications for both public and private organizations, this threshold population measure is often used to determine whether or not a facility should be built in a region. The population served for the Miniware trials shows that three regions have tributary populations with less than 100,000 for ten facility solutions, although with eight facilities the minimum population for a region (Table 10) has risen from 61,280 (Grafton) to 156,730 (Lismore). The minimum number of people in a region which can support a facility will depend on the cost structure of an organization. Thus the

\(^{11}\) The assumption is made that the total population of a region is a measure of the demand for the services of an organization. In many cases this assumption is quite inaccurate: as, for example, the demand for an employment service is stronger in depressed areas or areas with seasonal unemployment (fruit growing).
Table 10
Population in Each Facility's Region for Each Miniware Trial

<table>
<thead>
<tr>
<th></th>
<th>Number of facilities in a trial</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>12</td>
<td>10</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>Sydney</td>
<td>2,898,040</td>
<td>2,898,040</td>
<td>2,898,040</td>
<td>2,898,040</td>
</tr>
<tr>
<td>Newcastle</td>
<td>401,890</td>
<td>401,890</td>
<td>401,890</td>
<td>568,580</td>
</tr>
<tr>
<td>Wollongong</td>
<td>249,600</td>
<td>249,600</td>
<td>249,600</td>
<td>333,940</td>
</tr>
<tr>
<td>Canberra</td>
<td>247,750</td>
<td>247,750</td>
<td>247,750</td>
<td>550,230</td>
</tr>
<tr>
<td>Lismore</td>
<td>95,450</td>
<td>156,730</td>
<td>156,730</td>
<td>216,520</td>
</tr>
<tr>
<td>Wagga Wagga</td>
<td>212,160</td>
<td>212,160</td>
<td>212,160</td>
<td>-</td>
</tr>
<tr>
<td>Forbes</td>
<td>68,530</td>
<td>68,530</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Dubbo</td>
<td>85,950</td>
<td>85,950</td>
<td>238,670</td>
<td>-</td>
</tr>
<tr>
<td>Tamworth</td>
<td>102,530</td>
<td>221,860</td>
<td>221,860</td>
<td>-</td>
</tr>
<tr>
<td>Armidale</td>
<td>119,330</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Grafton</td>
<td>61,280</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Bathurst</td>
<td>84,190</td>
<td>84,190</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
particular trial which achieves this minimum could be adopted by an organization (e.g., the nine or ten facility solution for an organization with a minimum service capacity of 100,000).

Given that many tertiary organizations will locate fewer than ten facilities, then cities which are regularly in these optimal solutions will grow more rapidly than cities in solutions from five to ten facilities. Thus while Newcastle, Wollongong, Tamworth, Canberra and Dubbo may have an equal rank as regional foci for some organizations and in official planning, there will be, in effect, an increasingly marked division in the growth of regional capitals unless governmental policy attempts to reverse this trend. 12 A problem also arises in planning the regional boundaries for public organizations with fewer facilities than the government defined regions. A conflict in goals appears likely between the desire to keep common regional boundaries for different government organizations and the desire to minimize costs for a particular organization.

12 This assumes that there is stability in the towns selected for different numbers of facilities. With a few exceptions this is the case in the use of Miniware, in which Sydney, Newcastle, Wollongong, Canberra and Lismore form the five commonly selected foci in the trials. With Crosscut Sydney, Wollongong, Newcastle, Wagga Wagga and Albury form the five commonly selected foci.
Significant economies in building costs may be gained by government departments locating in the one building. However, for government departments, such as agricultural extension, forestry and irrigation, it is obvious that the location of offices and regional administrative boundaries is influenced more by the distribution of natural resources than by the market distribution. Thus the application of the planning regions to all government agencies may be undesirable in terms of the efficiency of operation of some departments.

The Miniware solutions for the 1970 population are largely unchanged from those of 1960, indicating that the location of facilities is fairly stable over time.\(^{13}\) This would be expected, since the population of rural areas has been relatively static in the postwar period; most of the major increases in population have occurred in the large cities. Similarly, the transportation network has remained relatively stable in this period. The major change in transportation has been the increasing importance of truck shipments compared with those of the railway. However, this trend

\(^{13}\) The 1960 population estimate for each region was used as input data for Miniware in a nine-facility trial. While a trial with nine facilities was not run with the 1970 population, the differences between the 1960 population with nine facilities and the 1970 population with eight and ten facilities were very slight.
has occurred in spite of the poor conditions of many roads in the state. Thus the location-allocation model seems to be quite suitable for locating facilities within the state.\(^{14}\)

There are a number of different measures of distance which have been used in practical applications of the location-allocation model.\(^{15}\) Some of the measures used are straight line distance (Holmes et al., 1972), shortest distance through the network (Scott, 1971a), distance weighted by the quality of the road (Gould and Leinbach, 1966), and the approximate road travel time (Godlund, 1961). In many situations, especially in urban areas, consumers travelling to central facilities use a variety of modes of transport.

\(^{14}\) If the population distribution were changing rapidly, then it would be possible to plan only a short-term basis. Several facilities in each time period could be allocated using a heuristic sequential allocation approach.

\(^{15}\) Miniware was also used with the square of the travel time between the same twenty-two nodes. For the twelve facility solution the changes were that Port Macquarie came out as a separate region, and Tamworth became the focus for Armidale's region in addition to the region it had for straight line distance. The program did not function properly for the trials with smaller numbers of facilities assigned. This possibly reflects a difficulty in constructing extensive minimal path trees around destinations when travel time is being used.
Thus it may be necessary to take car travel time as well as public transport cost and frequency of service into account in locating facilities. This was not done in the study, since the proportion of people travelling by train, bus or air to regional foci is quite small as compared with that travelling by car.\footnote{Student reports in a course at Macquarie University, Sydney, on Location Theory (August 1971) found that a large majority of people used their cars in travelling to tertiary facilities in Dubbo from its hinterland.}

While the regionalization produced by programs such as Miniware and Crosscut are applicable to many commercial and public organizations, there are some facilities in which it is important to maximize the areal coverage of service areas in the state rather than to plan for optimal locations. Thus hospitals, ambulance, police and fire stations may be best planned on the basis of maximizing the area of the state within, for example, one hundred miles of a facility. The Miniware solution for twelve facilities shows a considerable degree of overlap in the one hundred mile boundaries around each of the central facilities (Figure 34).\footnote{Straight line distance was used.}

The regions most poorly served are North Central Plain
Figure 34
One Hundred Mile Radii Around Locations Selected in
Twelve Facility Mineware Solution
(Moree and Narrabri), Hastings (Port Macquarie), Lower Murrumbidgee (Griffith), Central Murray (Deniliquin) and Lower South Coast (Bega). Miniware does not locate facilities to maximize the spatial coverage of the central facilities' service regions. A considerable degree of overlap exists: for example, Tamworth and Armidale are only fifty-five miles apart, and Lismore and Grafton tributary areas also overlap considerably. Similarly Dubbo, Forbes and Bathurst have a moderate amount of overlap in radii around each center.

While it is important that essential services such as hospitals, police and ambulance stations be distributed so that all areas are within a specified distance of a central facility, most of these services operate for very limited regions around small towns scattered throughout the state. The location of central facilities on a macroscale, as has been considered in this chapter, would be relevant only in the planning of large hospitals serving a regional population. There has been some interest in the establishment of such regional services; however, the criteria on which such planning is being undertaken have not been publicly announced.

**Conclusion**

The solutions given by Miniware and Crosscut locate
facilities initially in the larger cities and subsequently in the major provincial cities. This type of solution is reasonable for most type I organizations, and the development of integrated government office blocks in Newcastle, Wollongong, Canberra, Lismore, Wagga Wagga, Dubbo and Tamworth would provide a much improved access to public services for most rural residents. Apart from an additional center's being located in the Central-Western Region, the remaining locations have little weight in being considered as possible sites. Forbes, Armidale and Grafton are relatively close to one of the cities mentioned previously and do not seem to greatly reduce the cost of travel for consumers.
CHAPTER X
Locational Analysis—Type II Organizations

Interregional Telephone Message Flows
The pattern of interregional telephone message flows is examined in this section using the same data as were used in chapter eight. In chapter two, studies by Törngqvist (1970), Tolosa and Reiner (1970) and Richardson (1969) which emphasized the importance of flows of information between nodes in the development of growth centers were reviewed. In contrast, towns functioning as central places have little interaction between each other, except in the hierarchical distribution of goods to lower order centers for eventual sale to consumers.

The analysis in chapter eight showed that Sydney dominates the telephone message flows within the state, apart from the northern and southern border areas, where Brisbane and Melbourne respectively dominate the pattern of flows. It would not be expected, therefore, that interregional flows between non-metropolitan areas would be very significant in volume. The hypothesis of metropolitan dominance of intrastate linkages is further substantiated in chapter five by the discussion on the regional structure of the state.
Using the regional boundaries delimited by the Census, the flows between the statistical divisions are examined. The percentage of flows out of the nine statistical divisions ranges from a minimum of 43.7 percent (Northern) to a maximum of 97.0 percent (Murray) (Table 11). For most divisions the volume of message flows to Sydney comprises at least half of the total interregional flow. The highest percentage flows to Sydney are from Wollongong (78.8 percent) and Newcastle (71.8 percent), which reflects the importance of communication between large urban-industrial centers. There seems to be a distance decay effect: regions adjoining Sydney (Central-West and South-Eastern) have a higher percentage of their total flows directed towards Sydney than those more distant (Figure 35). One exception is the North-Western Region centered on Dubbo, which is over two hundred miles from Sydney but has a high percentage flow to Sydney (37.9 percent).

Flows to all other regions excluding Sydney are, with the exception of Albury (97.0 percent), quite small and range from 8.5 percent (Wollongong) to 30.6 percent (Murrumbidgee). Most of these flows are to contiguous regions and in some cases reflect the artificiality of division boundaries (e.g., 16.3 percent of outgoing calls for Young are to other centers in its statistical division compared with
### Table 11

Interregional Telephone Message Flows

<table>
<thead>
<tr>
<th></th>
<th>North Coast</th>
<th>Northern</th>
<th>North-Western</th>
<th>Hunter</th>
<th>Central-West</th>
<th>Wollongong</th>
<th>South-Eastern</th>
<th>Murrumbidgee</th>
<th>Murray</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Volume of calls</strong></td>
<td>72.89</td>
<td>80.72</td>
<td>45.48</td>
<td>85.14</td>
<td>76.96</td>
<td>64.28</td>
<td>84.91</td>
<td>60.17</td>
<td>37.13</td>
</tr>
<tr>
<td><strong>Calls Within region</strong></td>
<td>34.25</td>
<td>45.47</td>
<td>17.23</td>
<td>14.50</td>
<td>25.10</td>
<td>8.18</td>
<td>27.17</td>
<td>25.60</td>
<td>1.13</td>
</tr>
<tr>
<td><strong>Percent</strong></td>
<td>46.9</td>
<td>56.3</td>
<td>37.9</td>
<td>17.0</td>
<td>32.6</td>
<td>12.7</td>
<td>32.0</td>
<td>42.5</td>
<td>3.0</td>
</tr>
<tr>
<td><strong>Calls out of region</strong></td>
<td>38.64</td>
<td>35.25</td>
<td>28.25</td>
<td>70.64</td>
<td>51.86</td>
<td>56.10</td>
<td>57.74</td>
<td>34.57</td>
<td>36.00</td>
</tr>
<tr>
<td><strong>Percent</strong></td>
<td>53.0</td>
<td>43.7</td>
<td>62.1</td>
<td>83.0</td>
<td>67.4</td>
<td>87.3</td>
<td>63.0</td>
<td>57.5</td>
<td>97.0</td>
</tr>
<tr>
<td><strong>Calls to Sydney</strong></td>
<td>17.08</td>
<td>20.22</td>
<td>17.25</td>
<td>61.14</td>
<td>36.52</td>
<td>50.65</td>
<td>34.62</td>
<td>16.17</td>
<td>3.76</td>
</tr>
<tr>
<td><strong>Percent</strong></td>
<td>23.4</td>
<td>25.1</td>
<td>37.9</td>
<td>71.8</td>
<td>47.5</td>
<td>78.8</td>
<td>40.8</td>
<td>26.9</td>
<td>10.1</td>
</tr>
<tr>
<td><strong>Calls to all other regions</strong></td>
<td>21.56</td>
<td>15.03</td>
<td>11.00</td>
<td>9.50</td>
<td>15.34</td>
<td>5.45</td>
<td>23.12</td>
<td>18.40</td>
<td>32.24</td>
</tr>
<tr>
<td><strong>Percent</strong></td>
<td>29.6</td>
<td>18.6</td>
<td>24.2</td>
<td>11.2</td>
<td>19.9</td>
<td>8.5</td>
<td>27.2</td>
<td>30.6</td>
<td>86.8</td>
</tr>
</tbody>
</table>

* All volume of call figures are in Erlangs

# Calls to all other regions besides Sydney

Source: See footnote one chapter eight
Figure 35

Volume of Telephone Calls Between Regional Divisions and Sydney
22.0 percent to Murrumbidgee and 32.9 percent to the Central-Western Division).

The importance of the Great Dividing Range in the northern part of the state is illustrated by the small flows between the Northern and North Coast Divisions (Figure 36) and between the Hunter and, firstly, the Central-West and, secondly, the North-West. However, where there are important transportation routes, such as the Hunter Valley and the North Coast, the flows are relatively high.

The largest flows between rural regions within the state are, firstly, between the Central-West and North-West Regions and, secondly, between the Murray and Murrumbidgee Regions. The flow from the North-West to Central-West Region is only slightly larger than that in the reverse direction, but the flow is a much larger percentage of the total traffic for the former region. To some extent this situation represents the nearness of Bathurst and Orange to the southern boundary of the North-Western Region. From

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1 The proposed Sandy Hollow railway line, which would complete the connection between Newcastle and Dubbo, is unlikely to make any difference to the telephone message flows between the Hunter and North-Western Regions.
Figure 36

Volume of Interregional Telephone Calls
(Excluding Sydney)
field observations\(^2\) it seems that the position of the Dubbo-Orange trade area divide is much closer to Dubbo than defined administratively. The factor analysis results provide no additional assistance, since the Central-West was not delimited as a separate region. The large flows between Murray and Murrumbidgee Divisions reflect the geographical proximity of the major foci (Albury and Wagga Wagga).

Apart from calls to out-of-state points and to Canberra and Sydney, the only flows which cross an intervening region are those between Wollongong and Newcastle. The rest of the state has only intra-regional flows or flows between contiguous regions. Interstate calls are quite significant in some of the border regions: the North Coast and Northern Divisions have high flows to Queensland, and the Murray and Murrumbidgee Regions have high flows to Victoria. The artificiality of the N.S.W. section of the Murray Region is illustrated by the very high percentage of calls outside the region (97.0 percent), of which 64.3 percent are to Victoria. Both the North Coast

\(^2\) Reports on a field trip to Dubbo by students in a Location Theory course at Macquarie University in Sydney in August, 1971.
and Northern Divisions have quite large flows to Queensland (18.8 percent and 7.0 percent respectively). Major cities are located in Queensland close to the N.S.W. border, whereas Sydney and Newcastle are quite distant. Thus, while Sydney dominates most of N.S.W., its functional region becomes much weaker in the northern and southern border areas. This feature raises problems in terms of regional planning by the N.S.W. state government. It would be desirable in the case of Albury and Deniliquin for cooperation in regional planning to take place with the Victorian government in the development of a region centered on Albury/Wodonga and extending into both states. A similar arrangement might also be desirable for the North Coast Division with the Queensland government. However, such interstate agreements are unlikely to be made if this would result in border regions in N.S.W. becoming progressively integrated into the regional structure of neighboring states.

The weak interregional links between rural regions illustrate the fairly simple vertical hierarchical arrangement of settlements within the state (Figure 37). These flows reflect the lack of large urban centers in the rest of the state, although the radial pattern of transportation routes reinforces this centralization trend. The development of regional centers by the decentralization
of private and public tertiary organizations would lead to a strengthening of this vertical integration and a diminution of the direct contacts between lower level centers and the state capital city.

However, if growth centers were established, then superimposed on and possibly overlapping with the regional center hierarchy would be a set of growth centers requiring heavy transportation and communication linkages between themselves and with all state capital cities and major industrial cities (Figure 38). Canberra (South-Eastern Region), as the only growth center within the state, shows
a much broader pattern of telephone message flows to other regions than those for other rural regions.

Interregional Flows: A Case Study of the Location of Regional Mail Sorting Exchanges

The location problem for type II organizations includes not only the siting of facilities, but the collection and distribution of goods and services to the tributary region around each facility. As in the discussion on type I organizations, the focus in this section is on the question of costs of transportation, although the full location
problem includes a balancing of these costs with the fixed and variable costs for building and operating facilities. Since the volume of mail between nodes is not available, the interregional telephone calls are used as a surrogate measure in determining the need for regional mail sorting exchanges.  

Mail Collection and Distribution
The present pattern of mail collection and distribution in non-metropolitan areas of N.S.W. has a number of components. The first level, or local area, represents the primary collection or distribution point. Letters coming from the local area are collected at a central point, and if their addresses are also in the local area, they are sorted; otherwise they are sent to the Sydney Mail Exchange. Thus most letters pass through a central sorting point in Sydney before being consigned to their destinations. However, there is some sorting of mail while it is in transit.

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3 The relationship between flows of mail and telephone messages has not been examined in the geographical literature. Over short distances it is probable that the telephone would be substituted for letters as a form of communication. However, the volume of long distance mail flows within the state may be underpredicted using telephone message flows because of the relatively high cost of making a telephone call. At the state-wide level, where distances are not excessive, it seems that telephone messages are an adequate surrogate of mail flows.
by train to Sydney. The present mail exchange sorting areas are basically centered on Sydney and reflect the pattern of railway lines radiating out from this central point (Figure 39).

Most mail moving by rail leaves Sydney in the evening and arrives at the country towns by the following morning. In the majority of cases mail is delivered that day, although remote areas may not have a delivery until the following day. All small letters are moved by air if the air service is faster than the rail delivery. In cases where towns have frequent air services (Canberra, Wagga Wagga), it is likely that a large percentage of mail arrives by air (Figure 40).

Recently the Post Office Department announced that it is planning area or regional mail sorting offices. In this scheme mail is collected directly by a central point in a region and then distributed to the following: Sydney Mail Exchange, other regional mail exchanges, and smaller centers within the region. This regional exchange principle is planned initially for intra-urban locations in Sydney and Melbourne and at a later date for a number of large provincial cities within each state. The cost of establishing these exchanges is quite high, since modern mail handling equipment will be used, and it is envisaged
Figure 39

Mail Sorting Regions and Railway Network
Source: MAIL NOTICE, Feb 2nd, 1971, Post Master General's Department, Sydney

Figure 40

Number of Air Mail Flights per Week to Sydney
that the exchanges will be established to serve only communities of 100,000 people or more.

Instead of large volumes of mail from all over N.S.W. being sorted in the Sydney Mail Exchange and then distributed throughout the state (Figure 41a), the area office will establish mail sorting regions for various regional exchanges (Figure 41b).

(a) Centralized Mail Sorting    (b) Regional Mail Sorting

- Local post office
- Mail sorting exchange

Figure 41

Alternative Mail Sorting Organizations
In considering mail collection and delivery as a type II organization, it seems that the present centralized system in N.S.W. gains economies of scale by sorting mail at one large exchange which has expensive automatic mail sorting and handling equipment. The Sydney Mail Exchange handled 355,000 items of mail a day when it opened in 1965 and has an ultimate sorting capacity of 732,000 (Fielder-Gill, 1966). There are indications that it may be at a size where further growth is undesirable, if only because of the poor labor and management relations and the number of stoppages to the flow of mail through the exchange. A decentralized system of mail exchanges would possibly improve industrial relations, since more contact between labor and management would be possible in the smaller regional exchanges.

The centralized system results in the Post Office's carrying mail over long distances to and from rural areas. A decentralized system of regional mail exchanges would reduce the distance mail is transported. However, the demand for mail linkages between different areas must be considered in locating these exchanges. In addition, the structure of the rail and air networks must be taken into account, since it may be quite difficult to move mail in some directions because of a lack of air or rail connections.

The main advantage of the area mail sorting scheme is that
it saves much unnecessary carrying of mail to and from Sydney, thus speeding delivery time for rural residents and minimizing the distance that mail has to be carried. However, considering the radial pattern of rail services (Figure 39) and air services (Figure 40), the introduction of area sorting offices could actually increase delays in the delivery of mail. The present pattern of air mail services reflects the pattern of air connections in the state, and most letters, apart from those sorted locally, would be sorted in Sydney. The number of air mail services per week in rank order from Sydney to country cities are: Canberra (36), Tamworth (19), Wagga Wagga (17), Armidale (12), North Coast (11), Dubbo and the Riverina (10). For a businessman requiring rapid communication, the number of air mail flights per day to other towns is an important locational consideration in where he decides to locate his business. Unless a major rerouting of flights occurs, it is unlikely that any other town in the state could have such a high accessibility to the rest of N.S.W. as Sydney.

The radial pattern of the railway network has already been discussed in chapter five. While air networks can be changed to link towns previously not connected by a direct link, it is most unlikely that any major additions will be made to the railway network in the foreseeable future. Although cities such as Lismore, Tamworth, Dubbo and Wagga
Wagga appear as possible regional foci by other criteria, they are not particularly central to a surrounding region in terms of being good collection and distribution points on the railway network. The closer a node is to the central point on a tree network, the greater the chance that the node will be accessible to a large region. Thus Orange, Bathurst, Newcastle and Goulburn are highly accessible to large regions on the rail network, since little branching has taken place before these nodes are reached.

The conclusions from the analysis of telephone message flows indicates that it is unlikely that a large volume of mail would be generated between rural regions. Thus the installation of expensive mail sorting equipment as well as the rerouting of present air and rail services to provide interregional mail links does not appear to be justified. However, it appears that Newcastle and Canberra are large enough to generate a sufficient volume of mail to other destinations besides Sydney and warrant the location of a mail exchange.  

4 Newcastle, which dominates the Hunter Region, has very minor links with the North Coast and Northern Tablelands Region in terms of telephone message flows. However, the city is well situated to serve both these regions as a collection and distribution center on the existing rail network and has a very rapid population growth.
in population for both Newcastle and Canberra, it seems especially important that regional mail exchanges be established to relieve some of the volume of mail currently being channeled through Sydney. Newcastle is in an ideal location to act as a central sorting point for the delivery and collection of letters for the North Coast, Northern Tablelands and North-West slopes. However, Canberra is in a much more isolated location and could only serve by rail the area south to Cooma and Bombala and north to Goulburn.

The use of population as a surrogate measure of the volume of mail received by a town is substantiated by an analysis of a sample of mail flows for towns in 1970 and 1971. The only data available on mail flows in N.S.W. are on the number of letters to a town which pass through the central mail sorting exchange in Sydney. The plot of the population of a town against the number of letters received reveals an expected positive relationship. The number of letters received increases as population size increases (Figure 42). Only major deviations around the general trend are discussed. Linear regression is not used, since the data

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5 The data were supplied by the Sydney Mail Exchange and covered a sample period from December, 1970 to February, 1971.
Figure 42

Population and the Number of Letters Received by a Town
represent a biased sample of flows of mail in the state; therefore, the deviations from the trend line can only be discussed at an intuitive level.

Some towns deviated quite markedly from the general trend, two examples of positive deviations being Gosford and Armidale. In the case of Armidale it was possible to distinguish between letters to the university and those to the town itself. Excluding letters to the university (594), the total for Armidale (3021) places it very close to Dubbo and very near the average for its population. Thus the presence of the University of New England and the associated teachers college significantly increases the number of letters received by Armidale. To some extent this positive deviation might reflect the number of external students taking university courses by mail, although it is more likely that it reflects the wider communications field of the university itself.

Albury, Wagga Wagga and Lismore receive less mail than would be expected, which is probably due to the dispatching of mail to Melbourne for the first two towns and to Brisbane for Lismore. The analysis of telephone calls in chapter eight confirms this interstate communication pattern in the northern and southern border areas of N.S.W. Similarly, small towns near the northern border (Casino and Murwillum-
Lithgow and Goulburn also tend to receive less mail than expected.\(^6\) The reason could be that they are towns that are experiencing a relative decline in economic activity. Lithgow in particular has been declining in population in the post-war period; its percentage decline from 1954 to 1966 was 15.1 percent. The position of Nowra on the graph is more difficult to explain. Two possible reasons for the small number of letters are: firstly, that the town functions as a regional sorting office for the South Coast mail, since the railway comes only as far as Nowra; and secondly, that a fairly large naval establishment which largely handles its own delivery of letters is located there.

Gosford and Gosford forwarded shows a very large flow of letters into the town. This possibly reflects the presence of tourists during the sampled period,\(^7\) although Gosford

\(^6\) It might be hypothesized that both towns are close enough to Sydney for it to be cheap enough for someone in Sydney to telephone rather than to send a letter.

\(^7\) The data were collected during the summer months of December, 1970 and February, 1971 when this area receives large numbers of tourists. The Gosford forwarded mail refers to the letters addressed via Gosford to smaller towns in the local area.
also ranks very high for incoming and outgoing telephone calls (Table 8). Coff's Harbour, another large vacation center, also receives more mail than would be expected.

The flows of inward mail indicate that population is a fairly good indicator of the number of letters a town or region will receive. The fact that border areas receive fewer letters than expected illustrates a further problem in setting up regional mail sorting exchanges. If Wagga Wagga were selected as a regional exchange for the Riverina, then much of the mail which formerly went directly to Melbourne or Sydney would be first sorted in Wagga Wagga. The problem arises that many border towns within the region, such as Albury, are better connected to Melbourne than they are to Sydney or Wagga Wagga. To introduce regional exchanges could cause some expensive alterations to rail and air schedules which might not be justified by the volume of mail generated.

**Conclusion**

The introduction of regional mail exchanges at present for all parts of the state does not seem to be a worthwhile investment, considering the interregional mail flows which are likely to be generated. However, unless linkages between regional exchanges are improved, it is unlikely that industries relying on a state or nation-wide market would
locate outside the Central Coastal Region. It would seem desirable, therefore, to introduce the regional mail exchanges as a part of a complete plan for decentralization involving government assistance in many other sectors besides communication linkages.

It would be expected that the location of central facilities for type II organizations would be strongly influenced by the structure of the transportation network. However, in considering the location of regional mail exchanges within N.S.W., the limiting factors are: firstly, the lack of large population concentrations in most rural areas and, secondly, the lack of heavy interregional linkages between these regions. The selection of Newcastle and Canberra as sites for future regional mail exchanges is thus based on their present size and expected rate of population growth in the next decade. However, Newcastle is also well situated to provide linkages between the North Coast and Northern Tableland Regions.

Little information has been released by the Post Master General's Department on the bases of planning underlying the location of these exchanges. However, it appears that the use of a threshold population of 100,000 as indicated would involve the location of a mail exchange in at least each of the nine statistical divisions within the state.
Assuming that telephone message flows are an adequate surrogate measure for mail flows, then few of these exchanges would supply mail to exchanges besides those in contiguous regions.

The vehicle delivery problem, reviewed in chapters three and four, which optimally locates delivery routes for a type II organization is not applicable at the scale of this analysis. However, at the level of the individual post offices in country towns, the location of mail delivery and collection routes is more important than at the broad macro-regional level considered in this research. With a population decline in many rural areas, it is likely that an elimination of small post offices and the establishment of more efficiently organized collection and delivery routes could significantly reduce costs while maintaining present levels of service.
CHAPTER XI

Locational Analysis of Tertiary Services:
An Integrative Approach

In this chapter some of the common aspects of the different regionalizations of the state which have been presented in previous chapters are discussed and related to the question of planning regional development. The results are also discussed in terms of the limited amount of empirical research identifying the central place hierarchy in N.S.W.

The second section of this chapter is concerned with the development of a national urban system. This section represents a broadening of the focus of interest from a state to a national level. In attempting to put forward a regional development program in the first part of the chapter, one difficulty discussed is the need for interstate cooperation in developing some regions. In the light of the discussion on policy issues in chapter two, it is likely that a decentralization program should be couched in the framework of developing a national urban system involving cooperation between Commonwealth and state governments as well as planners at a regional level.
The final part of the chapter considers the typology of tertiary organizations initially discussed in chapters three and four. While the first section represents an integration of the results of the various methods of regionalization in the light of the settlement hierarchy, this section attempts to evaluate the results of the different analyses in terms of the typology of organizations.

Empirical Verification of Regionalization Results

The results of the factor analyses of network structure and telephone calls in the state were presented in chapters seven and eight, the regionalization produced by the location-allocation model in chapter nine and regional mail exchanges in chapter ten. Each of these approaches to the regionalization of the state focuses on somewhat different aspects of the general problem. In this section some of the common threads in each will be discussed, as well as their relationship to the central place hierarchy. Unfortunately, only a fragmentary picture of the central place hierarchy in N.S.W. exists. The empirical work has been concerned with the trade areas of individual towns or of a small region. However, these studies are useful in checking the boundaries of the hinterlands of regional centers identified in this study.
The regional foci located most frequently by Miniware in chapter nine were cities with the largest populations. Thus Sydney, Newcastle, Wollongong and Canberra were the first four facilities located in each trial. Subsequent facilities were located in the major regions—namely, Lismore (North Coast), Wagga Wagga (Riverina), Dubbo (North-Western Slopes) and Tamworth (Northern Tablelands)—in order of their appearance in a solution. Similarly, Crosscut delimited regions around Sydney, Newcastle and Wollongong, although, surprisingly, Canberra was not identified as a focus for a region.

In contrast, the regionalization produced by the factor analysis of telephone calls delimits regional foci which dominate regions maximally separated from one another rather than being determined by population size. While Sydney forms a very prominent functional region in this analysis, Newcastle and Canberra form fairly weak regions and Wollongong does not separate out at all. Instead Tamworth, Lismore, Wagga Wagga and Dubbo are identified as clear regional foci, each serving a surrounding region. None of the three cities (Newcastle, Wollongong and Canberra) had initially developed as a result of its service function to a surrounding region, the first two being industrial centers and the last a national capital. In contrast, the factor analytic technique delimited
towns whose primary function is in providing services.

These conclusions are reinforced by the empirical evidence available. Rose (1966), reporting on a field survey south of Wollongong to Jervis Bay, found that with increasing distance from Wollongong its importance in providing higher order goods diminished rapidly. In contrast, Sydney's share of the higher order goods purchased increased even though consumers would have had to pass through Wollongong to shop in Sydney. In addition, Nowra, a town with a population of 9,633 in 1966, was quite important as a source of high order goods to its surrounding region. Thus the size of population of a town or city may not necessarily indicate its importance as a regional center. The results of the location-allocation model, therefore, must be viewed with some suspicion if they are to be used as the basis for optimally locating regional services. A similar conclusion emerges for Canberra from the analysis of telephone messages. Despite its size Canberra only weakly emerges as a regional center in 1964. However, it is likely that in recent years it has become the regional center for much of the Southern Region (Archer, mimeo).

Newcastle emerged as the fourth factor in the principal
components analysis of telephone messages. Saunders (1968) examined Newcastle's role as a regional focus for the Hunter Valley Region and found that as a center of trade Newcastle's hinterland included a large part of northern N.S.W. for bulk commodities such as wheat and wool. However, in terms of services for rural residents Newcastle's region is much smaller and is basically confined to the Hunter Valley. The northern coastal boundary of Saunders' region lies approximately twenty miles to the south of the Hunter Statistical Division boundary. The boundary delimited by Saunders also lies south of that predicted by the gravity model, indicating that Newcastle's influence is truncated by that of Taree, the regional center for the Manning Valley.

The pattern of regional centers in the North Coast Region has been examined in a series of studies prepared for the Department of Decentralization and Development. Sharma and Woolmington (1968) used the gravity model to find the 'breaking point' between the hinterlands of Sydney and Brisbane. They advanced a case for Grafton as a growth center on the basis that the town is accessible to Sydney and Brisbane, that it has a plentiful water supply and that its growth would mean that much of the escape spending from the region to Queensland would be retained
Killion (1967) examined the functional linkages of the Tweed Valley, centered on the town of Murwillumbah, which is adjacent to the Queensland border. He found that while Sydney was an important source of wholesale goods in the past, Brisbane was usurping its role as the border between the two states assumed diminished importance. Killion considered that Murwillumbah, a town with a population of 7,311 in 1966, fulfilled many of the functions of a regional service center apart from the higher order functions which were provided by Sydney and Brisbane. This seems to confirm Rose's hypothesis that larger regional centers such as Lismore do not have a particularly important role in providing higher order central goods and services. The only exception mentioned in Killion's study was in the provision of specialized medical services in Lismore to serve the needs of the North Coast. However, the empirical studies did not investigate the relationship between Lismore and Grafton, two centers which emerged from the analysis of telephone messages as being possible regional foci for the North Coast.

Two problems are highlighted by the empirical studies in the development of a single North Coast Region focused on one major center. Firstly, Brisbane is relatively close to the area around Lismore and Grafton and can be expected to
usurp some of the higher order functions of a regional center. Secondly, because of the nature of the settlement pattern along the narrow coastal plain, it is difficult for any one city to dominate the entire region.

Little published work exists on the central place hierarchy in the rest of the state. Pullinger (1971) found that Tamworth has been emerging quite strongly as a regional center for the Northern Tablelands. However, he makes no comment on the relationship of Tamworth to Armidale, the two cities which emerge in the components analysis of telephone message flows. Both cities have shown rapid growth in recent years and it is possible that the two cities will complement one another to some extent in terms of the services provided. The boundaries of Tamworth's hinterland which Pullinger established coincide fairly well with the Northern Statistical Division.

The regionalization of network structure discussed in chapter seven gives only a limited interpretation of the regional structure of the state. The factor analysis of straight line distance and road travel time reflects the two major groupings of nodes—namely, a north-east and a south-west cluster. However, in the regionalization of telephone call costs and railway fares, the Central-
Western Region (Parkes, Forbes and Bathurst) emerged as the most important regional cluster. This region is not delimited in the regionalization of telephone flows, since it is dominated by Sydney, and the factor analytic technique tends to delimit centers that are distinctly separate as functional regions in the analysis of flows.

The Central-Western Region is centrally located to the north-west, west and south-west of the state and presents a favorable location for organizations which, for example, make large numbers of telephone calls to towns in this western region. No evidence is available to show whether this region has attracted activities of this type. In fact, it is likely that Sydney has usurped the role of this region as the central point in the state.¹

Thus it seems desirable to develop a city such as Orange or Bathurst as a distribution and/or collection center

¹ There has been much discussion on the suitability of this region as the site for the state parliament, at present located in Sydney, on the grounds that such a location would make politicians more accessible to and more aware of the needs of country people.
for those regions west of the Great Dividing Range.\(^2\) This center would be superimposed over the pattern of regional centers delimited by the telephone call and location-allocation analysis. The development of such a city would require the coordination of services for different transportation modes, as was discussed for the location of regional mail exchanges in chapter ten. This region could be expected to assume a much greater importance in the spatial organization of the state as the degree of interdependence between regions increases. It is quite important that this pivotal role in the linkages between regions be prevented from being drawn to Sydney.

Towards a National Urban System

In considering city sizes in N.S.W., it is quite clear that a primate distribution exists which has become more pronounced from 1961 to 1972, especially if Newcastle and Wollongong are considered as part of a central coastal urban area. Rose (1967) has suggested that this pattern is characteristic of all Australian states with the

\(^2\) In fact, this region with Orange/Bathurst as the central point has been selected by the state government in October, 1972 as the first growth center for the state.
exception of Tasmania and reflects the dominance of each capital city in its respective state. It has been argued in this research that the primacy of Sydney in N.S.W. is undesirable. The development of growth and regional centers would reduce the degree of primacy and help to create a more even spread of cities throughout the state. It is not argued that a rank-size relationship within N.S.W. would be an optimal distribution of city sizes. In fact, it is likely that a fairly high degree of primacy would remain even if the growth and regional center strategy proved to be successful.

A major limitation of this study has been its focus on decentralization solely within N.S.W. While decentralization is planned on an individual state basis, it is unlikely to make major changes to the distribution of population and economic activity. Decentralization in N.S.W. should be based on a recognition of population distribution and the location of economic activity in all contiguous states. The emergence of a national market as

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3 The rank-size rule is essentially an empirical regularity with few normative implications for urban growth planning (Richardson, 1972, 36-37).
discussed by Geissman and Woolmington (1971) is likely to provide a stimulus to the planning of the growth centers which are accessible to interstate population concentrations. It was considered in chapter six that Albury/Wodonga, as the site of a growth center, would be suitable to attract these industries. The linkages between states are largely between the large connurbised regions around the state capital cities: for example, the Central Coastal Region of N.S.W. and the Melbourne and Geelong areas in Victoria (Figure 43).

The development of growth centers serving interstate markets would tend to create a national urban system with connections between states at several levels of the hierarchy. It would be expected that these growth centers would develop into intermediate-sized cities, which are lacking at present in Australia, leading to a city-size distribution which approaches rank-size in shape. Services found in smaller cities serving regions largely within

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4 The linkages are based primarily on the analysis of telephone message flows discussed in chapters eight and ten. Further evidence is presented in the discussion of the various transportation modes in chapter five. The linkages in Victoria are hypothetical, since no analysis was made of the telephone call traffic within other states. However, information was available on calls from towns and cities in N.S.W. to other states and these data generally supported the inferences on interstate linkages (Table 11).
Direct linkages between small settlements and the state capital cities and industrial cities are not shown. Only several regional centers and small towns are shown in each state settlement hierarchy.

Figure 43

Interstate and Intrastate Linkages Between the Victorian and N.S.W. Urban Systems
state boundaries would be provided by regional centers.

Tolosa and Reiner (1970) state:

The combination of lognormal (rank-size) city-size distributions with the erection of (growth) poles in the periphery, as advocated by Rodwin and Hirschman, suggests that the poles should be chosen to create an even spacing of urban centers of the same order. This criterion recognizes that with economic development, growth poles assume the character of the economic geographer's central places (Tolosa and Reiner, 1970, 454).

While it is desirable to integrate peripheral areas of a state or country into the developing core, this spread of urban centers can be achieved by using central place concepts to locate regional centers. Growth centers, on the other hand, are sites which should have the maximum growth potential and these sites may not necessarily be evenly scattered. In addition, with limited finance available only the best sites should be chosen and investment concentrated in them.

Alonso (1971a, 78) considers it unlikely that there will be a well-defined threshold size from which a growth center could achieve self-sustaining growth. This is because small cities are more likely to be affected by particular events than large cities, where something similar to the law of large numbers might be expected to operate. Thus, to ensure the continued growth of a city such as Albury/Wodonga, it would be desirable for
large amounts of government aid to be concentrated there over a long period of time. On economic efficiency grounds, therefore, it is desirable to concentrate Commonwealth government expenditure in one or at the most two growth centers. On the other hand, regional centers should be located largely on equity grounds so as to achieve a fairly complete areal coverage of the state. These regional centers could be financed from state government funds with some support from the Commonwealth government.5

Recent literature on the interdependence within urban systems has identified hierarchical as well as non-hierarchical linkages between urban centers. Central place networks are characterized by hierarchical linkages. However, Pred (1971a) has shown that the theory is inadequate in terms of providing an understanding of the full range of linkages between urban centers, partly on the grounds that it does not allow lateral linkages between central places of the same order in the hierarchy.

5 In considering the problem of decentralization in N.S.W. from a national viewpoint, a further alternative is possible. This is that the Commonwealth government should encourage movement of population and industry out of N.S.W. and Victoria to other states. Such a movement would be valuable on strategic grounds by reducing the concentration of population and industry in one part of the country.
In addition, the theory does not allow direct linkages between nodes of different order in separate regional hierarchies.

The pattern of linkages that would be expected from central place theory provides a fairly good description of the pattern of telephone message flows within N.S.W., although the number of steps in the hierarchy is fairly small, with intermediate central places having in some cases a relatively minor role. This present pattern of flows reflects the lack of secondary industry outside the Central Coastal Region. The proposal to introduce regional centers would basically strengthen the hierarchical position of intermediate-sized centers.

However, central place theory ignores other types of interurban interaction, such as non-hierarchical linkages which are generated by the flow of inputs and outputs associated with industries other than market-oriented manufacturing (Pred, 1971a). At present these industries are located in the state capital cities and their associated industrial outliers, such as Newcastle, Wollongong, Geelong (Victoria) and Kwinana (Western Australia). However, the development of growth centers would attract some of these industries to other locations. Thus central place theory is not of much use in studying
the location and development potential of growth centers, even though these cities are likely to attract high order services over time by virtue of their size. A good example is provided by Canberra, which is a growth center developed as the federal capital. The city has only begun to emerge as a central place for high order goods for surrounding areas after its population grew rapidly in the 1960's.

It would be desirable to select as growth centers sites which were suitable for both secondary and tertiary industry. Given that a conflict existed in the locational requirements of the two types, then requirements for secondary industry (abundant water supplies, good road and rail connections and level land for factory sites) would outweigh the centrality of the site to the surrounding population.

However, central place theory is very useful in justifying the planning of regional centers. Unfortunately, most central place studies are descriptive in approach and offer few guidelings as to: firstly, where these regional centers should be located; secondly, what the strength of the multiplier effect would be with the location of higher order services in the town; thirdly, whether a government should be prepared to subsidize some types of public services with high thresholds, normally located in cities,
on the grounds that these services are essential to bring the standard of living in country areas up to a level which is comparable to that enjoyed in metropolitan areas.

The empirical relationships between the central place hierarchy, location-allocation model and factor analysis of telephone messages for N.S.W. were discussed earlier in this chapter. In chapter three the relationships between central place theory and the optimal regionalization of tertiary organizations were discussed in terms of range and threshold sales level of a central good. The integration of these two approaches has not been conclusively demonstrated in this research, even though there were similarities in the regions and nodal centers identified in the empirical analysis. One reason for this lack of integration is that the location-allocation model as formulated did not consider the location of facilities at different levels of the central place hierarchy. This problem limits the applicability of the location-allocation model, although Scott (1971a) has modified the model to allow for the introduction of a simple hierarchy.

One area of further research is the general question of determining the effects of changes in organizational hierarchies on the development of urban regions. Wärneryd (1968) has developed several models which have a three-
level hierarchy—namely national, regional and local levels. He investigated the spatial effects of changes at various levels in the hierarchy. For example, if a firm expanded its regional level branch, what would be the effect on the regional city and local areas subordinate to this office? A decentralization of a set of functions from the head office to a number of offices at a regional level will produce a multiplier effect at the regional level, which in turn will influence offices further down the hierarchy. This multiplier effect illustrates a weakness of the location-allocation model as a device for optimally locating central facilities when time is introduced as a variable. Should the strength of the multiplier in different regions be taken into account when planning facility location? It would appear that simulation models would allow greater flexibility in handling this problem as well as those raised in the section on sequential allocation discussed in chapter four.

Richardson (1972) has emphasized the need for a balanced national and state urban hierarchy.

The urban hierarchy is an efficient vehicle for transmitting new technology, managerial expertise and general economic functions from the centre of the economy to the periphery. This permits social and economic change to "leap-frog" over distance and avoid the slower gradual diffusion over space from the central city. This transmission function is aided by the fact that many modern forms of business organization (in commerce, finance and industry) are
themselves hierarchical with head offices and centres of decision making in the metropolitan centres and their decision trees spread out spatially down the urban hierarchy. Given the large scale and multiple establishments characteristic of modern business, a hierarchy of cities makes it easier to distribute the hierarchical structure and functions of business organisation over the economy as a whole (Richardson, 1972, 38).

Even though there is doubt of the importance of the "spread" and "trickle-down" effects in the diffusion of innovations and economic growth to low-order centers in an urban hierarchy (Richardson, 1969), it seems likely that intermediate-sized cities would receive innovations soon after large cities. It is unlikely that firms locating in growth centers would be greatly disadvantaged in terms of access to information relevant to their production or sales of their products.

Given that a government stimulus to the development of growth and regional centers achieves some degree of success, then it is likely that firms will choose this hierarchy for the location of their central facilities. Cities which achieve a fairly large size and a healthy growth rate will have their central facilities upgraded in their decision-making capacity, thus contributing further to the growth of the city. Given that the trend towards oligopolistic control of industry continues in Australia, then an understanding of the spatial implica-
tions of hierarchical control within organizations is extremely important in predicting urban growth.

Typology of Tertiary Organizations

The location-allocation model was used to locate a set of central facilities for type I organizations. However, the distinction made between types Ia and Ib organizations has not been substantiated in this research. The differences in the location of central facilities for the two types of organizations require a fairly detailed study of several organizations, which was not attempted in this research. The location of these different types of organizations may, in fact, overlap considerably. An example is provided in the planning of a decentralized system of specialized hospitals to serve country areas. These regional hospitals (type Ia organizations) would have to be centrally located to their hinterlands in terms of the road and public transport network. However, ambulance stations (type Ib) would have to be not only centrally located to their districts, but also must take into account the location of the nearest local and regional hospitals.

The location of regional mail exchanges was discussed as an example of a type II organization. Several nodes are well
situated for the delivery and collection of mail. However, the lack of an adequate demand for interregional linkages was considered to be the limiting factor in locating mail exchanges at these sites. Thus the problem of locating collection and delivery routes for type II organizations was found to be much less significant in this example than was hypothesized. While it is possible that the location of type II central facilities in country areas would improve linkages and thus promote economic development, it is unlikely that many of these facilities would conduct sufficient business to justify their location in country areas. However, given that the government were to initiate a regional development program within the state, then the results of the analysis in chapter six indicate that the Central-Western Region is an ideal location for organizations requiring linkages to rural areas in the form of collection and/or delivery of goods and services or simply in terms of centrality to rural areas.

There is a considerable degree of similarity in the organi-

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6 The railway network is the critical mode of transportation in the collection and delivery routes for the location of regional mail exchanges. This is because of the inflexibility of the railway connections compared to the ease with which air links between towns can be altered.
zation of the telephone network switching centers (type III organization)\(^7\) in 1964 and 1972 with the nodal points identified in the factor analysis of telephone message flows (Table 12).

The reason for the similarity in the location of the switching centers and the results of the factor analysis is that the nodes identified in the factor analysis act as prominent origins or destinations for a region's telephone message flows. Switching centers provide a means of minimizing the cost of routing a message through the telephone network. The hierarchy of switching centers, therefore, acts as an interlocking set of functional regions where at each level in the hierarchy a set of dependent nodes is identified for a particular focal point. It is desirable that these network functional regions be based on actual linkages between the nodes; otherwise, unnecessary costs in the routing of message flows will take place.

The cities which are switching centers for both time

\(^7\) A type III organization again is characterized by continuous connection between points. The location problem may be defined as locating lines to serve a set of points so as to optimize some objective function.
Table 12
Telephone Switching Centers and Nodal Centers in the Message Flow Matrix

<table>
<thead>
<tr>
<th>1964 primary switching centers</th>
<th>factor analysis of 1964 telephone message flows (nodal centers)</th>
<th>1972 secondary switching centers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Sydney</td>
<td>Sydney</td>
<td>Sydney</td>
</tr>
<tr>
<td>2</td>
<td>-</td>
<td>Wollongong</td>
</tr>
<tr>
<td>3 Newcastle</td>
<td>Newcastle</td>
<td>Newcastle</td>
</tr>
<tr>
<td>4 Lismore</td>
<td>Lismore (dominant) Grafton (secondary)</td>
<td>Grafton</td>
</tr>
<tr>
<td>5 Tamworth</td>
<td>Tamworth</td>
<td>Tamworth</td>
</tr>
<tr>
<td>6 Dubbo</td>
<td>Dubbo</td>
<td>Dubbo</td>
</tr>
<tr>
<td>7 Orange</td>
<td>-</td>
<td>Orange</td>
</tr>
<tr>
<td>8 Wagga Wagga</td>
<td>Wagga Wagga</td>
<td>Wagga Wagga</td>
</tr>
<tr>
<td>9</td>
<td>Narrandera</td>
<td>Griffith</td>
</tr>
<tr>
<td>10 Lithgow</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>11 Canberra</td>
<td>Canberra</td>
<td>Canberra</td>
</tr>
<tr>
<td>12</td>
<td>-</td>
<td>Goulburn</td>
</tr>
<tr>
<td>13</td>
<td>-</td>
<td>Armidale</td>
</tr>
</tbody>
</table>

Source: Traffic Engineering Division of the Post Master General's Department.
periods as well as being nodal centers in the factor analysis are Sydney, Newcastle, Tamworth, Dubbo, Wagga Wagga and Canberra. While 1972 telephone message flow data are not available, the change in switching center location from Lismore to Grafton suggests that Grafton may be emerging as the regional focus for the North Coast Region. One important difference between the location of the telephone switching centers and the factor analysis results is the location of switching centers fairly close to the Sydney Metropolitan Area (Orange, Lithgow, Goulburn and Wollongong). It is unlikely that any of these cities has emerged since 1964 as a regional center—if anything, they are likely to be even more dominated by Sydney.

Freeman (1968) concludes that, in planning the telephone trunk network in N.S.W., a major problem is the dominance of Sydney in acting as a focus for the telephone traffic of the rest of the state. Any artificially imposed hierarchy increases costs, although a centralized system is undesirable on the grounds of vulnerability of the total system. Decentralization of economic activity would lead to an increase in the average distance of calls. However, it would tend to reduce costs since exchange centers in rural areas would actually have a more important role. They would not only connect points within their region (as the factor
analysis of message flows showed), but would provide interregional connections which at present are very small between rural areas. At present, the ability of the network to route messages directly between high order exchanges in rural areas is largely wasted.

While the typology of tertiary organizations was developed for both the public and private sectors, most of the analysis in this research has been concerned with public organization. One important difference between the two sectors is that there is no requirement for private organizations to locate so as to be accessible to all regions within the state. In terms of the location-allocation model, therefore, the cities in the optimal solution for a small number of facilities may be preferred, since each dominates a large market population. The effect of competition between private market-oriented organizations is often important in the location of central facilities. However, the location-allocation model has not been used to locate central facilities for competitive organizations in the operations research literature. It is likely that such a solution would be extremely difficult to achieve and might be more profitably analysed using a gaming-simulation approach.
Conclusion
In terms of integrating the results of the different analyses, the factor analysis of telephone message flows indicates nodes which are suitable for the location of type I organizations. These nodes are maximally separated and dominate a relatively large volume of telephone message flows within the state. The use of the location-allocation algorithm to locate type I central facilities identified a similar set of nodes except that the order of importance in the location-allocation model was strongly influenced by population size for the location of the first four facilities. This correspondence is to be expected in light of the similarity between the regionalization and location-allocation problems discussed in chapter three.

The similarity of the location of switching centers (type III organization) with the factor analysis of telephone message flows and the location-allocation model indicates that the desire to locate at focal points to serve regions is common to a variety of organizations. Thus there is a fairly close similarity in the location of central facilities in N.S.W. for the different types of organizations examined in this research. In addition to the desire to locate at focal points, it is likely that organizations gain sufficient economies of agglomeration to outweigh
differences in locational requirements. The reasons discussed in chapter nine for government departments locating at a similar set of locations may be used for different public and private tertiary organizations. If a set of cities has been chosen as regional or growth centers, then this concentration of public investment is likely to maximize multiplier effects (Neutze, 1965). In considering the private sector, it has been assumed in this research that it is necessary for the government to create a favorable growth potential image in a town for private enterprise to be attracted to the decentralized location.

Growth of a highly interdependent national urban system would have extremely important implications for a decentralization policy within N.S.W. However, future linkages between cities will be dependent to some extent on the available modes of transportation and communication. Some of the implications of these changes are discussed in the next chapter.
CHAPTER XII
Effect of Future Transportation and Communication Modes on Decentralization

This research has focused on the nature of transportation and communication systems within the state. In part, the emphasis has been on transportation and communication agencies as tertiary organizations. The relative degree of decentralization is important for these organizations in terms of providing adequate service at low cost to the community. However, transportation and communication links and flows reflect the overall linkages between different parts of the state. Given the increasing importance of communication systems in the space economy, an understanding of the pattern of flows is necessary in order to plan for regional growth in the future.

There is a strong possibility that future forms of communication are likely to dramatically alter existing spatial relationships.

Our present geography and our geographical concepts are mechanical—distance-decay, gravity model, heartland-hinterland. To be sure, existing electronic technologies, if used in conventional ways, can so reduce the frictions of space and the delays of time that the traditional processes moulding today's geography will take on their limiting forms.... The revolutionary aspect of electronic environments is not that they reduce the frictions in moving goods and people, but that they move the experience itself to the human nervous system (Berry, 1970, 49).
Thus new communication linkages will have extremely important effects on the location of people and economic activity. Some substitution can be expected in that people will change from making trips for face-to-face contact to using electronic communication methods for contacting people. Berry (1970) considers that this trend is likely to allow a scattering of some people and industries away from large cities. However, the impact of future communication technology on regional structure depends largely on the extent to which trips for face-to-face contact are replaced by electronic communication.

Törnqvist (1970) stressed the importance of time for businessmen in making trips in Sweden. "A strong motive force in the process of urbanization—and particularly in the concentration of certain activities to the large urban regions—is the need for contacts in the exchange of information between specialized work functions in society" (Törnqvist, 1970, 26). Since much of this exchange of information is of the face-to-face kind, Törnqvist found that executives spent a great deal of time in direct personal contacts with representatives of competing firms, customers, sub-contractors, consultants, service companies and research authorities. Given that the businessman would accept the new forms of communication as being as good as personal contact, then some industries could move away from
the city. However, Wilmoth (1971) points out that face-to-face contact
is not likely to be even nearly eliminated by remote communications. It is a very efficient medium because it involves many senses at the same time, provides instant feedback, and minimizes the effects of noise. Thus face-to-face contact will continue to be best for interaction that involves intimacy, delicate negotiation, secrecy, great risk, joint creativity, and of course such purposes as medical examination (Wilmoth, 1971, 15).

It seems likely that some decentralization will take place away from large cities given these improved methods of communication. A factor which is, perhaps, equally important is the increasing traffic congestion in large cities. It may become quite difficult to maintain face-to-face contact within the city due to the increased traffic congestion and the wide areal spread of the large metropolis. Thus a combination of cheap intercity electronic communication and expensive (in terms of travel time) intracity face-to-face communication may promote decentralization out of large cities in the future.

The development of growth centers should be accompanied by the location of activities which have a high information generating ability. Thus universities, research institutes and legislative bodies could be located in growth centers. While the spread effect of economic growth from growth centers to the peripheral parts of the surrounding region
has been questioned (Richardson, 1969), there is little doubt that the growth center could provide information concerning new production techniques to farmers and businessmen in the region. The important role that information and national government have is illustrated by the growth of Washington, D.C., which, even though it is located in a heavily industrialized part of the country, has few manufacturing industries to support the large population.

Törnqvist, in looking at the growth of large urban centers, has utilized the concept of threshold derived from central place theory.

The principle of threshold values can . . . be applied to the communication apparatus in the broadest sense. Each component of a communication system—e.g., transport routes, ports, post offices, telegraph stations, airports and railway stations—must have a certain minimum supporting clientele. The trend in communications has also been towards larger and fewer units. The coverage and trafficability of the communication networks have changed . . . . The accessibility of the large urban regions, in particular, has increased in relation to others (Törnqvist, 1970, 21).

Growth centers, by concentrating economic activity at selected points, are able to achieve economies of agglomeration for communication and transportation systems. Thus it may be possible to build high cost transportation (high speed ground transportation) and communication (coaxial cables for television signal transmission) systems to the growth centers in rural areas where previously
demand would have been too dispersed for their economic operation. Similarly, the Report on Selective Decentralization (1969) discussed the possible reduction in freight rates for growth centers provided that large enough shipments are required. In addition, a successful growth center could be connected to the large metropolitan areas by fast and frequent freight deliveries.

Improvements in transportation will reduce the friction of distance, allowing long distance movement of people and goods at low cost. These developments will lead to cities' spreading out over large areas, but will also allow areas presently in peripheral regions to become integrated into the national urban system. Thus the lessening of the importance of transportation allows firms greater locational flexibility.

The construction of the railway in N.S.W. had an important influence on the economic growth of the Sydney Metropolitan Area as compared with the rest of the state. It is desirable that new modes of transportation and communication be planned to allow cities away from the Central Coastal Region to be situated in accessible sites and thus avoid the centralizing influence caused by a radial system of connections.
Given that these new modes will require a fairly large threshold population, it will be necessary to integrate the development of growth centers with the transportation and communication systems. In planning these facilities in N.S.W., it is likely that if the threshold population criterion is used, the only cities likely to be connected by these new modes would be Sydney, Newcastle, Wollongong and Canberra. In discussing the proposed regional mail sorting exchanges in chapter ten, it was concluded that most rural areas would not generate sufficient demand in order to provide direct interregional linkages. However, unless the new growth centers have access to the national market, then they are unlikely to ever match the rate of growth of the metropolitan areas. Thus the transportation and communication linkages may have to be heavily subsidized for a fairly long period of time until population is large enough to generate sufficient traffic.
Decentralization of population and economic activity in Australia is an issue which is of considerable importance in the 1970's. Plans by the federal and state governments have been advanced to develop growth centers in N.S.W. and Victoria. Forces behind the demand for decentralization can be broadly divided into "push" and "pull" factors. "Push" factors refer to the fact that cities such as Sydney and Melbourne are too large and that much of the future growth of these cities should be diverted elsewhere. In contrast, "pull" factors refer to the need for urban and regional development outside the existing "core" areas. By encouraging secondary and tertiary industry to locate in these peripheral areas, it is hoped that, firstly, the growth rates of the large cities can be reduced to an acceptable level and, secondly, better amenities and services as well as wider opportunities of employment can be provided for residents in country areas.

To promote decentralization the development of two types of cities has been advocated in this research. The first type is growth centers, the development of which is to be based primarily on secondary industry, although the growth of tertiary employment will substantially contribute to
their development. The second type is regional centers, the term referring to cities which basically supply central goods and services for a surrounding region. Their major function is to provide improved amenities and services for residents in country areas. However, their development will involve decentralization of selected public (and at a later stage, private) industries out of metropolitan areas and contribute, to some extent at least, to a slackening of the growth of these cities. However, it should be emphasized that only a program of massive investment in growth centers would be sufficient to significantly reduce the problems of large cities.

This research has been basically concerned with the location of regional centers and the identification of the boundaries of their functional regions. In addition, the structure of the transportation and communication networks was examined and related to the location and boundaries of the regional centers. The importance of Sydney as a pivot for the transportation and communication networks within the state can be seen with reference to the pattern of routes, the frequency of services and the volume of flows. It seems unlikely that major changes in these networks will occur in the future. Given this locational inertia, the success of decentralization proposals will depend on the identification of locations which are highly accessible.
Regional centers should be centrally placed within their regions. Growth centers, on the other hand, should be located so as to be accessible to interstate and intrastate markets and sources of raw materials.

Since the concern in this research was the location of regional centers, network structure and flows were analysed to identify nodes accessible to large regions. The regionalization of network structure identified the similarities in the regional groupings of nodes using different costs of distance (straight line distance, travel time by road, telephone call cost and railway fares). A conclusion emerging from this analysis was that the central-west of the state is an area which is centrally located to the rest of the state for telephone call costs and railway fares. Thus, in terms of decentralization proposals, this region is a suitable area for a firm to locate in, providing that it wishes to be central to the inland areas of the state. However, this location is not the most accessible point when population distribution of the state is taken into account, because of the size of the Sydney Metropolitan Area.

The regions produced by the factor analysis of telephone message calls provided a different emphasis in the regionalization of the spatial structure of the state. Unlike the
network structure analysis, the regionalization of flows identified Sydney as the center of a major region covering most of the state. Functional regions were identified around smaller cities and towns which nest within Sydney's region. One conclusion emerging from this analysis was that Sydney's functional region was likely to dominate a surrounding area within a radius of one hundred and possibly two hundred miles. Thus planners decentralizing activities within this radius must take into account the possibility of escape spending to the Sydney area. A further conclusion, derived from an inspection of the magnitude of interstate message flows in border areas, is that the Murray Region and the Far North Coast should be joined to areas across the border in Victoria and Queensland respectively to form interstate regions. The centers identified in this analysis as focal points in the telephone message flow traffic were largely the major provincial towns. The extent of their functional regions was corroborated in chapter eleven when empirical central place studies within the state were considered.

The next major section of analysis was concerned with the location of branches of different types of public tertiary organizations. The problem was to identify a set of cities or towns which would be the best locations for type I organizations. This analysis, therefore, attempted to
optimally locate regional centers within the state. The locations selected as sites for the central facilities were similar to those identified in the factor analysis of telephone message flows. However, facilities were initially located in the larger cities, and only when increased numbers of facilities were to be located were the smaller provincial cities included. These solutions tend to over-emphasize the importance of population as an indicator of a city's regional importance compared with the results from the regionalization of telephone message flows. Thus Canberra, Newcastle and Wollongong did not emerge as importantly as regional centers in the telephone call analysis as they did when considered as sites for type I central facilities.

The analysis of the location of a type II organization was approached in a descriptive manner, using as an example the problem of locating regional mail sorting exchanges outside the Sydney Metropolitan Area. The major finding was that the volume of interregional linkages was not sufficient to justify the cost of installing and operating these mail sorting exchanges. The two exceptions were Newcastle and Canberra, which are justified as sites mainly on the basis of their present population and future growth potential. The analysis of the location of mail sorting exchanges emphasizes the hierarchical movement of informa-
tion within the state. The greatest demand for linkages in N.S.W. is with the Sydney Metropolitan Area. While the factor analysis of telephone message flows identified regions around the major provincial centers, the flows between the major regions are in general quite small.

The analysis of this type II organization illustrates a major problem in implementing any decentralization proposals. Because demand for interregional linkages is low, the provision of direct transportation and communication links is, in general, fairly poor. Thus, even if a firm located in a country area desired links to other parts of the state, most linkages would be made via Sydney. To overcome this problem it is necessary to plan an integrated approach to decentralization involving simultaneously improvements in interregional linkages and the decentralization of firms to make use of these linkages.

One theoretical conclusion of this research has been to question the assumption made by several writers that the identification of high order central places is useful in selecting the location of growth centers. Given that, in theory at least, central places evolve to supply central goods and services to a hinterland, there is no necessary connection between growth center and central place theory. However, many high order central places contain manufactur-
ing industries. In planning the selection of growth centers, it seems desirable to investigate those sites which have maximum potential for economic growth. These sites may be high or low order central places, manufacturing towns or sites with no industry at all. Little is gained by forcing the propulsive industries of the growth center into central places which may have few advantages for these particular types of industries. Since the focus of this research has been on regional centers, no conclusion can be reached as to whether they might also be suitable as growth centers. However, given the practical constraints of limited government finance, it seems unlikely that more than one or two growth centers could be successfully developed. Therefore, the sites selected should possess maximum growth potential.

In the locational analysis section of the research, several problems have been raised in applying the location-allocation model to optimally locate central facilities. One problem is the necessity of incorporating a hierarchical structure into the allocation of facilities. It would be desirable, therefore, to be able to locate central facilities in regional centers which "nest" within the functional region of a larger city.

A second problem is the potential conflict between the
efficiency solution given by the location-allocation model and equity considerations. The most efficient solution may force some consumers to travel excessive distances in visiting the facility. This problem may be tackled by incorporating a maximum travel time constraint on the optimum solution so that a solution is optimal only if all trips are less than a certain value. However, the actual balance that is arrived at between efficiency and equity considerations depends on the magnitude of the fixed and operating costs for the central facilities compared with the importance of travel time and convenience for consumers in reaching the facility. How these questions are to be resolved has received little attention in the literature.

A third problem relates to the need to incorporate a dynamic component into the location-allocation model. While changes in the N.S.W. population distribution between 1960 and 1970 did not alter the optimal solution, there are still some important difficulties raised in a dynamic context in using the location-allocation model. One consideration raised is that not all organizations will want to locate the same number of central facilities. Assuming that the largest cities are the first to have facilities assigned to them, then these cities will be selected as sites by more organizations and thus have a much faster growth potential. A further question concerns the multiplier effects on a
regional economy caused by the construction of a public central facility. It may be more desirable to select a particular location because the multiplier effect is greater, even though other sites may be accessible to a larger population. A final problem arises as to how to incorporate into a model, giving the optimal locations of regional centers, the location of one or two growth centers planned on entirely different grounds. It would appear that a two stage model is necessary. In the first stage growth centers should be located and in the second, regional centers should be located so as to serve remaining areas which are remote from urban centers.

The analytical techniques used in this research have provided a number of alternative regionalizations of the state. The factor analyses of network structure and flows provide a descriptive regionalization of the spatial structure of the state. However, the regionalization given by the location-allocation models provides an optimal set of central facilities and boundaries of administrative areas. Unfortunately, because of the limitations of the location-allocation model in its application to the

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1 An example might be that the multiplier effect of locating a facility in a town within one hundred miles of Sydney would not be as great as one located further away.
settlement hierarchy, only limited interpretations in terms of planning can be made of the results of the model.

**Urban and Regional Development in N.S.W.**

The policy implications of this research refer basically to the location and boundaries of regional centers within N.S.W. These centers are unlikely to cause a major alteration in the future location of population and economic activity. Instead, their major purpose is to provide an adequate range of public and private tertiary services so as to improve the standard of amenities and range of employment opportunities in country areas. The development of these centers would be primarily the responsibility of the state government, although it would be desirable for federal government departments to locate in these centers and adopt the same boundaries of administrative areas.

The towns which appear to be the most suitable for development as regional centers are Tamworth, Lismore, Wagga Wagga and Dubbo. In addition, Bathurst and Orange are suitable as centers for the general area west of the Great Dividing Range rather than being foci solely for the Central Western Region. This region lacks a clearly defined focus, since the major towns within the region are quite close to Sydney. In addition, with the rapid expansion of the Sydney Metropolitan Area, it seems likely that the eastern part of the
Central Western Region (Lithgow and possibly Bathurst) will become progressively integrated into the Central Coastal Region. Similarly, in a north-south direction the urbanized part of the Central Coastal Region is likely to extend from Port Stephens (thirty miles north of Newcastle) to Jervis Bay (fifty miles south of Wollongong), since both areas are potential sites for harbor and industrial development.

In examining the usefulness of the statistical divisions to be used as planning regions by the state government, it seems that the Hunter, Central-West and Illawarra Divisions will become a part of the connurbated Central Coastal Region. The pace of the extension of Sydney's influence westward is likely to be increased with the introduction of high speed rail transportation in the future. Instead of treating these regions as separate statistical divisions, it seems desirable to consider them as part of a larger urbanized region focused on the Sydney Metropolitan Area.

One other major problem with the use of statistical divisions as planning regions is that state borders demarcate several regional boundaries. In the case of Canberra, which lies in the Australian Capital Territory and is federally controlled, it is obvious that its influence extends into a large part of the South-Eastern Division. The Murray Division, focused on Albury, faces a similar problem in
that Albury's region extends into Victoria. There is a need for cooperation between the states in planning the development of such regions.

One of the major limitations of this study has been the relative neglect of the effect of the size and growth of the Sydney Metropolitan Area on the decentralization proposals. The city is expected to grow to five million by the year 2,000 (N.S.W. State Planning Authority, 1968). It is likely that this will mean steep rises in the price of land in the Cumberland Plain as well as increased traffic congestion and pollution of the environment. How these changes affect firms and residents will partially determine the magnitude of the demand for alternative sites for industry, tertiary services and population. Aside from the expected unplanned infilling of flat areas along the coast, it is possible to plan the development of satellite centers within a one-hundred mile radius of the city and/or to develop growth centers in country areas.

The development of growth centers such as Albury/Wodonga will have an important bearing on the growth of regional centers delimited in this study. In order to present a comprehensive study of regional development within the state, an analysis of the possible development of growth
centers needs to be undertaken.² Such a study would consider factors in the location of industry and population such as the cost of land, availability of water for industry, provision of amenities, transportation and communication costs and economies of agglomeration for different industries.

This research has focused only on a very limited aspect of regional development. Many questions which should be incorporated into any program of regional development have remained untouched. One important problem not dealt with in this research is the question of the future development of towns not selected as regional or growth centers. Those towns which are within daily commuting range could be gradually incorporated into the urban field of the regional or growth center. However, towns further away are likely to suffer a relative and possibly an absolute decline in size and importance. It may be necessary, therefore, to provide

² The Snowy River Scheme (Figure 1), designed to supply hydro-electricity and water for irrigation, could take on a new function to support the future development of the Albury/Wodonga growth center. Electricity could be supplied to the growth center, thus saving long distance transmission costs to Sydney and Melbourne. In addition, water which was to be used for irrigating crops could be used for industrial purposes. An alternative use for the water is necessary, since it is unlikely that world demand for some of the region's irrigated crops (dried fruits, pears and peaches) would be sufficient to sustain many of these producers after 1975.
financial assistance for people wishing to sell houses and businesses in these towns. The nature of this assistance and the future of small towns is a very difficult problem. It is unlikely that these towns will accept their fate without exerting as much political pressure as possible to avoid it. However, to some extent, many small towns will still be required as service centers for the surrounding local community.

In chapter two a distinction was drawn between decentralization to growth centers and a depressed area policy. This research has neglected the latter problem, although it is one which has important political implications in regional development. The future of the Riverina, for example, is in some doubt due to the entry of Britain into the European Common Market. ³ It is likely that there may be a long-term depression in Leeton and Griffith, the major employment centers in the region.

An example of an area which has been through a depressed phase is the Cessnock district near Newcastle (Figure 1).

³ The Riverina is an important fruit growing area and a large percentage of the products are exported to Britain. However, with the entry of Britain into the European Common Market, the tariff barriers are likely to make many types of Australian fruit too costly in comparison with those of European competitors.
Holmes (1971) has discussed the pattern of external commuting around Newcastle, especially with reference to the Cessnock district. He found that employment "in the mines of the Cessnock field declined from 6,700 in 1954 to 1,400 in 1964 with employment being maintained at this lower level in subsequent years" (Holmes, 1971, 781). The amount of economic dislocation and population decline has been mitigated, however, by the growth of commuting to Newcastle.

Little information exists on the patterns of migration within N.S.W. Doddridge and Holland (1970) conducted a pilot survey to establish the reasons why people in rural areas of N.S.W. migrated to urban areas. They concluded that more studies were necessary to establish the reasons for migration from rural to urban areas as well as from small towns to metropolitan areas before a decentralization program could be initiated. In addition, the size of inducements which might be required for urban dwellers to migrate out of existing metropolitan areas should be investigated. A further recommendation was that attention be directed at the possible social and economic problems in country towns caused by the selective outmigration of the younger, better educated, higher income groups. Doddridge and Holland considered that by increasing the number and type of tertiary services in certain country towns, it might
be possible to stem the outmigration to large metropolitan centers.
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