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Public service applications of the central place structure of western Guatemala

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Iowa State University, 1990

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Public service applications of the central place structure of western Guatemala

by

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A Dissertation Submitted to the

Graduate Faculty in Partial Fulfillment of the

Requirements for the Degree of

DOCTOR OF PHILOSOPHY

Major: Economics

Approved:

Signature was redacted for privacy.

In Charge of Major Work

Signature was redacted for privacy.

For the Major Department

Signature was redacted for privacy.

For the Graduate College

Members of the Committee:

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Iowa State University
Ames, Iowa

1990

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I. INTRODUCTION

1.1. Introduction

This is a study of the place of local public service facilities in a system of cities. The term "place" is used literally, because an important question is the physical location of such facilities. However, there is a figurative meaning of the term as well. How does the public sector influence the development of the system of cities itself? How can the supply of public goods be coordinated to provide maximum access and efficiency in their distribution, while not introducing distortions into the spatial distribution of the private economy?

The approach of this study is to examine the actual distribution of local public services in an empirically identified system of central places. Such a project requires a great quantity of specialized data, which are not easily obtained. For that reason, the region to be examined must be selected with an eye to the available information. Fortunately, in 1979 the government of Guatemala, in cooperation with the United States Agency for International Development (AID), conducted a survey of approximately three-quarters of that country, with a specifically central place orientation. This survey featured a census of the public and private facilities of all places above 50 persons in population and a sample of the smaller places. The current survey uses the result of this survey to examine the central place system based on Quetzaltenango, the second largest city of Guatemala.

1.1.1. Locational Analysis

Locational analysis is at the heart of regional economics. The question which sets this field of economics apart from the others is that it persistently asks, "where?" Where do firms locate? Where are goods shipped? Where are resources to be found? The logical extension of these questions is to ask where the optimal location, etc., is. As standard price theory begins with questions of optimal quantity for the consumer or firm, and ends with markets and systems of markets, so does regional economics begin with individual locations and end with market areas and systems of cities. We can apply the tools of price theory, with some adaptation, to ask questions about the optimal quantity of public goods. In a similar way, we can apply the tools of regional economics to ask, "where are the optimal locations from which to supply public goods?"

1.1.1.1. Location theory

A common approach to answering this question draws on the large body of literature dedicated to enterprise location, or the optimal location of a profit-maximizing firm[1]. Public authorities are assumed to have an objective function, which may be specified in various ways. Often, it is a composite function based on the preferences of the residents of the region for a public good and a composite private good. The region is specified as a set of interconnected nodes (which may be called "cities," "places," "settlements," etc.) or a two-dimensional area. The production or cost functions for the goods are specified, as is the method of tax

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[1]One example of this sort of model can be found in Johansson and Leonardi (1986).

collection (to pay for the public good). On the basis of these specifications, the conditions for optimal provision of the public good are derived. It is in the nature of spatial economics that the results of such derivations are often quite complex; many cannot be solved analytically. In these cases, simulation or Monte Carlo techniques are often employed to investigate the variety of possible outcomes and identify the most crucial parameters.

This "locational theoretic" approach to public facility location is very useful. It draws its strength from the main pillar of neoclassical economics, optimal decision making. It can be applied to a wide variety of interesting questions by suitably selecting the initial specifications. However, it also has certain limitations. The parameters of such models, particularly those of the objective functions, often require information which is not obtainable, even in principle. In many cases even the cost and production parameters are unavailable for use in any application to real regions. These optimization models also ignore the fact that public facilities are elements in a larger "ecology" of facilities, and that there are many interdependencies in this ecology. The *ceterus paribus* assumption, that public facilities may be introduced without disturbing the distribution of population or of commercial services, is often invalid. This is particularly true if government services provide a substantial supplement to standards of living, which may be the case in developing countries. Locational models which attempt to account for the dynamics of a region's response to facility location usually become analytically unwieldy and are even more demanding of data.

1.1.1.2.Central place theory

Regional economics has always had a second type of model which explicitly recognizes the ecological aspects of facility location, both public and private. This is the central place model. Central place theory will be discussed in more detail in the next chapter, but for now, a few crucial elements should be mentioned. The key building block of the theory is, naturally enough, the "central place," which is a supply point for goods and services to a region or part of a region. In all but the simplest of central places, a specific set of such services will be offered. The primary concern of the theory is the composition of the sets of services in different central places and the locational patterns of those places.

While central place theory assumes optimizing behavior (such as profit and utility maximization), it does not generally employ formal models of optimization. The analysis is more heuristic and implicit. Thus, central place theory lacks some of the analytical power of the location theoretic models. On the other hand, its conclusions and predictions can be stated simply and in an empirically verifiable form. There is a large body of literature dedicated to empirical investigation of central place systems. It is readily adaptable to extension into questions of public goods provision, since these can be treated as additional central goods. The question then becomes the appropriate group of existing central goods with which to "package" the public goods. Since much of central place theory is concerned with the relative attractiveness of central places, based on their locations and goods offered, the ecological ramifications of introducing a new type of good can be examined in a simple and straightforward fashion.

1.1.2.Government Provision of Goods and Services

1.1.2.1.Private goods

Most goods and services are *private* goods, in the terminology of public finance. This does not refer to the owners of the goods, but rather to the characteristics which allow the goods to be produced efficiently by means of private firms. The chief characteristics of such goods are that access to them can be controlled rather easily and that the number of persons who can benefit from any individual unit of a good consumed is small (about the size of a single household, and often only one person). Since a potential consumer cannot obtain access to the good without payment, he will be willing to pay for a good rather than go without it. Since few people can enjoy the good simultaneously, he will not permit others to use the good he has purchased, because it would reduce (and often eliminate) the benefits he himself receives. This means that private goods can be produced by private firms which can compel payment by withholding the good. Also, each person has an incentive to reveal how much the good is worth to him, by bidding on it. Someone who fails to do so will go without it, since the purchasers of the good both can prevent him and want to prevent him from consuming it. The market price will thus reflect the value that people put on having the good.

Any typical consumer good will stand as an example of a private good. An apple is a private good. Nonpayers can be excluded from using the apple if the supermarket's employees keep a watchful eye out for shoplifters. However, only one person can consume the apple. If the apple is cut into pieces and shared, the benefit received by each consumer is diminished.

1.1.2.2.Pure public goods

Pure public goods are defined as those commodities which are neither excludable nor rival in consumption (Musgrave and Musgrave, 1984, 50-51). This means that it is expensive or impossible to prevent persons who refuse to pay for the good from consuming it (i.e., it is impossible to *exclude* nonpayers) and that the consumption of the entire quantity supplied by one person does not reduce the quantity available to anyone else (i.e., consumers are not each others' *rivals* for the consumption of each unit of the good). These goods cannot be provided efficiently by private markets, because potential consumers will have an incentive to wait for someone else to pay for the good. Since the good is nonexcudable, those who do not pay will be able to consume the good anyway. (Such persons are referred to as "free riders.") It is also difficult to assess the value of a unit of such a good, since each such unit confers benefits on everyone, not just on the purchaser. The purchaser (assuming one can be found who is willing to pay at all), will only be willing to pay as much as the good is worth to himself. The market price will only reflect the value of the good *to the purchaser*, and not to all the people who consume it. The result of these two characteristics will be that the good is underproduced: because potential consumers will avoid paying for it, and because the price will undervalue the good (thereby discouraging firms from producing it).

The standard example of the "purest" of public goods is national defense. If a citizen refuses to pay for national defense, it is impractical to deny him the protection of the armed forces. Each citizen is protected by the nation's entire armed might, without diminishing the amount of protection received by any other citizen. This good is not provided by private firms. They would have difficulty convincing enough persons to subscribe to the service, when it would be available even to those who refused to pay. Instead, the government provides the service for free. The government can obtain the resources to do this through compulsion, by requiring citizens to pay taxes. This is not a price, since there is no direct connection between the amount a citizen pays and the amount of the good he consumes.

1.1.2.3.Local public goods

The term *local public good* is used rather loosely to describe goods which have some, but not all, of the characteristics of pure public goods, or which have notable limitations on the *extent* to which they meet the qualifications for such goods. A good may be nonexcludable but rival. These are more often called "common property resources," examples being ocean fish and air quality. A good may be excludable but nonrival. These are called local public goods but also "club goods," since a private firm or club could extract payment for the use of these goods. A third possibility is that a good may be nonexcludable and nonrival for some group of people which is considerably larger than an individual household but smaller than the entire population. Often the size of this group is limited by geographical considerations: persons too far from the source of supply are excluded, and all the population which is not "too far" can be supplied with the benefits of the good. Within this limited population, the characteristics of the public good apply. It is possible to overextend the jurisdiction and reduce the quality of service, or to reduce the jurisdiction and exclude certain persons.

Many familiar services which come under the everyday term of "local public services" have these characteristics: police and fire protection, parks, sanitation, road repair, etc. Because many of them have specific sources of supply (e.g., the police station), the location of these facilities has an important effect on the level of service enjoyed by the residents. In the United States, where there is a strong tradition of federalism, local governments have their own powers to raise taxes and disperse the proceeds as they choose. In many other countries, the local governments merely serve as the agents for implementing decisions and spending funds under the control of the national authorities.

Governments, including local governments, sometimes supply services which, it is said, do not satisfy the conditions for being public goods. An often-cited example is education. It is very easy to exclude nonpayers from a school building–at least as easy as excluding them from a shop or any other place of business. Beyond fairly small class sizes, increasing the number of students benefitting from the same resources devoted to schooling will reduce the quality of education. Of course, it is well known that there are private schools, some of which are run for profit, although most are nonprofit institutions. Thus, one could argue that education is in fact a private good, or at least a club good. Critics of this point of view often point out that the benefits of having an educated populace extend beyond the personal benefits of the educated. Societies in which literacy and arithmetic skills can be taken for granted can function more smoothly than those in which these things cannot be assumed. Thus, everyone benefits, to some extent from the education of all citizens, and it is to this extent a nonrival good. Sometimes the concept of the "merit good" is also invoked. This is a good which is so important that its provision must be supervised and ensured by collective action, usually focused through the institutions of government.

It seems reasonable to argue that a "merit good" is a local public good whose nonexcludability stems from a utility rather than a resource point of view. The usual definition of excludability focuses on the resources needed to prevent access by nonpayers. If the amount of resources is prohibitively great, the good is said to be nonrival. However, the sacrifice of resources is only undesirable because it requires the sacrifice of the alternative uses for those resources, which could have made someone better off. In other words, cost is ultimately a matter of the sacrifice in utility which an action (such as excluding nonpayers) requires. Under most circumstances, this distinction is true but irrelevant, since resource costs both are easier to account for and often account for all the disutility. However, one can argue that excluding people from the consumption of certain kinds of goods entails a direct utility cost for the rest of the citizenry. As even Adam Smith recognized in his *Theory of Moral Sentiments*, people care about each other. They do not like to see children grow up ignorant or sick persons deprived of care. The utility cost of excluding those who cannot pay from at least some minimal access to these goods may be quite high. In this sense, then, one could say that "merit goods" are goods which are nonexcludable because such exclusion imposes a prohibitive loss of utility on the rest of the population. This is certainly an argument which could be overdone, but it seems a reasonable extension of the principles of public finance to account for services which are so often supplied by local governments.

1.2.The Study Region

1.2.1.Guatemala

Figure 1.1. Map of Central America, Showing Guatemala

1.2.1.1.Geography

The Republic of Guatemala is located in the Central American isthmus. To the north, it borders on Mexico. To the southeast are El Salvador and Honduras.

Its land area of 108,889 km^2 (roughly the size of Ohio) spans the isthmus from east to southwest, giving the country coasts on both the Pacific Ocean and the Caribbean Sea. Its eastern neighbor, Belize, is claimed by Guatemala in a dispute with the British dating back to Spanish colonial times. Maps published in Guatemala show Belize as a province of Guatemala. The terrain of the country varies from the dense rain forests of the Petén in the north, to the lush lowland plantations of the Pacific and Caribbean coasts. In between, much of the country is a tangle of mountain valleys, in highlands dotted by volcanos.

1.2.1.2.Population

This study is concerned with conditions in Guatemala in 1979. The last census previous to that date was conducted in 1973, reporting a population of 5.7 million (Guatemala 1978, 7). The next census, in 1981, gave the population as 6.0 million (Guatemala 1984, 21). However, there is considerable dispute about these figures. For example, the World Bank (1978) estimated the Guatemalan population as 6.3 million by mid-1976. (This is the first of many data anomalies which will be encountered in this study.) An unusual feature of Guatemala when compared with its Central American neighbors is its large indigenous population. The 1981 census classifies 2.5 million persons, or 41.7 percent of the population, as indigenous. In Guatemalan terms, this is as much a cultural as a racial or ethnic designation. Those who maintain traditional Mayan languages, dress, and culture are called "indianos" and are classified as indigenous peoples. People who speak Spanish and wear modern western clothes are called "ladinos." Individuals may change their classification by changing their lifestyles. While there are certainly, poor, rural, and illiterate ladinos, there are proportionately more indianos in each of these classifications. The government and commerce are dominated by ladinos.

1.2.1.3.Economy

The World Bank reports that Guatemala's Gross Domestic Product (GDP) in 1977 was $4.36 billion (U.S.–the Guatemalan unit of currency, the quetzal, was fixed at 1Q per $1 U.S. in this period). Average per family income was $302 in 1970. The distribution of income gave 66.5 percent of national income to the top quartile of the population, and only 6.5 percent to the bottom quartile. However, most of the difference incomes occurs between the first (highest) and second quartiles, With fairly even distribution among the lower three. In the words of the World Bank, "a middle class has yet to emerge, and ... the standard of living of three-fourths of the population is very low, slightly below one half of the national average" (World Bank 1978, 12).

Two factors contributing to the income inequality in Guatemala are the differences in productivity between urban and rural sectors of the economy and the unequal distribution of land. Even among the poorest half of the population, urban families have incomes which average 4.5 times that of rural families. At the higher income levels, the difference is even greater (World Bank 1978, 13). Much of the best agricultural land is concentrated the large plantations which grow export crops. The top 10 percent of the landowners own 81.4 percent of the arable land. 90.1 percent of the families in Guatemala own less than the 7 hectares of land (which is the benchmark the World Bank uses as the minimum amount necessary to support a family). About a quarter of the families are essentially landless. Consequently, there is a pattern of the peasants migrating to the plantations for part of the year, in order to earn enough cash to supplement their agricultural production[2].

Guatemala's chief exports are agricultural products. Of the $1,241 million of exports in 1979, $826 million, or 66.56 percent, were such products. The leading export crop is coffee, which accounts for slightly more than a third of total export dollars. The next largest crop, cotton, accounts for about half as much as coffee. Other exports include sugar, fresh meat, cardamom, bananas, cut flowers, and other fruits and vegetables. Guatemala also exports small amounts of rubber products, lead, and zinc. The country began exporting small amounts of low-grade crude oil in 1980. Guatemala's lush landscape and pre-Columbian archeological sites have traditionally provided the basis for a strong tourist industry, but by 1979 this was considerably reduced by several years of rural insurgency. Tourism began to revive in the 1980s. Guatemala is a member of the Central American Common Market (CACM). In the 1960s, CACM stimulated manufacturing industries in region, but the political events of the next decade (particularly the El Salvador-Honduras war and the revolution in Nicaragua) considerably reduced its effectiveness (Nyrop 1983, 83-126 and 224).

1.2.1.4.History

In the pre-Columbian period, the region which now contains Guatemala was the site of the Mayan civilization. Mayan culture extended north into what is now southeast Mexico (Chiapas and Yucatán), and far as Honduras to the south and east. The legacy of this culture can be seen in the temples of the highlands and

[2]See Schmid (1968) for a discussion of this pattern.

Petén and heard in the languages of the indianos. However, the Mayan civilization declined centuries before the Spanish arrived in 1522. By then, Central America was divided into many small political entities which were sporadically at war with one another. The Spanish were able to take advantage of these divisions, applying the principle of "divide and rule."

The conquest of Guatemala began in 1523, when the Spaniard Pedro de Alvarado set out from Mexico, under the authority of the Governor of Mexico, Hernán Cortéz. Through a combination of diplomacy and firepower, the region was fully conquered by 1527. In that year, King Charles V appointed Alvarado governor and captain general of Guatemala. Later, in 1544, Guatemala was incorporated in an *audiencia* which also included southeastern Mexico and the rest of Central America (Belize, El Salvador, Honduras, Nicaragua, and Costa Rica). After 1549, this area was ruled from the city that is now known as Antigua Guatemala. It was in this period that the pattern of land tenure began to develop. The first Spanish soldiers were allotted *encomedias*, which were large tracts of land, plus the labor of the indianos who lived on them. Although embodied in different legal formulas, the Spanish-speaking rulers of Guatemala retained the right to compel indiano labor through the late twentieth century, until after World War II.

Guatemala declared its independence from Spain as a result of the upheavals precipitated by the Napoleonic occupation of the ruling nation twelve years before. The political vacuum caused by the subsequent war in Spain allowed the colonies to develop local autonomy. When Mexico broke with Spain in April, 1821, the northern provinces of Guatemala (Chiapas and Yucatán) joined in. This induced Central America (then commonly referred to as "Guatemala") to issue its own declaration on September 15, 1821. At that time, the Federation of Central America was a still a single political unit, with five provinces. However, by 1840 the provinces had broken off one by one, forming the nations of today (plus Belize).

From the middle of the nineteenth century until early in the twentieth, political power in Guatemala swung between the Liberals and Conservatives. The precise meanings of these terms in the Guatemalan context are complex, but two major issues were the mobilization of resources and the status of the Roman Catholic Church. The Conservatives were the party which favored the Church and preferred to maintain the large landed estates. The Liberals were anticlerical and "developmentalist," which meant they wanted to reallocate land and labor in Guatemala to spur economic growth.

Neither party was very helpful to the poor, particularly the indiano poor. The preservation of the landed estates, traditional agriculture, and authority of the Church hierarchy all bore most heavily on the lowest levels of society, which had long since been displaced from the lands best suited for growing food crops. On the other hand, the Liberals' desire to mobilize the manpower of the nation was quickly translated into institutions for squeezing more labor out of the indianos. The peasants were trapped by debt peonage, whereby debtors and their heirs could be forced to work in lieu of paying off their debts. Later, indianos were required to carry books which documented whether they worked for pay the required 150 days per year. Meanwhile, the Liberals instituted the cultivation of coffee as the major export crop. Coffee grows best on mountain slopes, which was the only land left in the hands of the indianos. More laws were passed to force the indianos off of this now valuable real estate.

The development of coffee as an export crop also brought in major foreign investors, chiefly from Germany and the United States. Foreign ownership of Guatemalan resources reached its peak in the 1920s and 1930s. Most banana and coffee plantations were in foreign hands, as was the railway, the electrical power grid, and the port facilities at Puerto Barrios. The president of Guatemala at the end this period, Jorgé Ubico, ran a regime which emphasized financial probity combined with political repression. Although he personally sympathized with the Germans in World War II, as the likelihood of an Allied victory increased, he permitted more and more American use of Guatemala. Nevertheless, he was overthrown in a popular uprising in 1944.

The fall of Ubico initiated a decade of reform. The first president of this era, Juan José Arévalo, began a program of cautious democratization. The new constitution of 1945 extended suffrage to all males and literate females. Arévalo established a social security system and abolished forced labor. He began the process of land reform by redistributing the plantations seized from the Germans during the war. He was one of only two presidents in Guatemalan history to be elected, serve his term, and yield to an elected successor.

Arévalo's successor was Jacobo Arbenz Guzmán. He was elected in 1950 with 65 percent of the popular vote. Arbenz pursued a more active policy of reducing foreign control of the Guatemalan economy. He built new hydropower facilities to compete with the electric company, new highways to compete with the railway, and new port facilities to compete with Puerto Barrios. He also expanded the land reform to include expropriation of idle estates. At that time, the largest holder of such estates was the American-owned United Fruit Company, which held 85 percent of its land as reserves against banana diseases and declining fertility.

The Arbenz law specified that landowners were to be recompensed on the basis of the assessed value of the land for tax purposes, which was often much lower than the land's market value. Arbenz also legalized the Communist Party and encouraged the growth of labor unions. In the era of Senator McCarthy and the Korean war, it was not difficult for Arbenz' opponents to paint him as a communist. He was overthrown in 1954 when a CIA-backed army invaded the country and the Guatemalan Army refused to defend the government.

The new president, Castillo Armas, moved swiftly to reverse many of the reforms of the Arévalo-Arbenz era. Land reform was annulled, and the United Fruit Company received its land back. Left-wing parties were outlawed, but the new constitution did still permit labor unions to organize. Throughout the 1960s, the government was dominated by the right, and most especially, the army. Industrial production rose in this era, fueled by the development of the Central American Common Market. A guerilla movement began in 1960, alternating between rural insurgency and urban terrorism. It was met by increasing repression by the army and by the growth of right-wing death squads, the most notable being the Organized National Anticommunist Movement (this was the "MANO Blanca," or White Hand, from the initials of its name in Spanish, *Movimiento Anitcommunista Nacional Organizado)* which was sponsored by the chief party of the right, the National Liberation Movement (*Movimiento de Liberacion Nacional* –the MLN). Foreign investment decreased in the late 1960s and early 1970s. The government bought up the railway, electrical, and port facilities. Most banana and coffee lands were sold to Guatemalans, as the international corporations decided that marketing produce was less risky than growing it.

Although the guerilla war intensified, the early part of the 1970s saw some cautious moderation on the part of the government. Labor unions were less persecuted, and the formation of rural cooperatives was encouraged. Colonization of the Petén was begun as an alternative to real land reform. This softening of repression was interrupted by the earthquake that shook the country in 1976, badly damaging Puerto Barrios, killing 30,000, injuring 77,000, and leaving 1 million people homeless. A vast reconstruction effort and $25 million in emergency aid from the United States helped to soften the blow, but the devastation of the earthquake brought many of the country's internal tensions to the boiling point. Insurgency flared in the highlands at the same time that the government's human rights record brought an end to U.S. military and economic aid. Thus, by 1979, Guatemala was a country in turmoil, with dwindling tourist revenues, little outside aid, and unrest in the countryside. The president, Brigadier General Fernando Romeo Lucas García, who had been installed by the army after a fraudulent election the previous year, was to be overthrown by disaffected officers of that same army in 1982. His successor, General José Efraín Ríos Montt, would last for little more than a year before falling to a coup in August of 1983.

1.2.1.5.Political organization

The present capital, Guatemala City, became the seat of government when Antigua Guatemala ("Old Guatemala [City]") was badly damaged in an earthquake in 1773. With a population of approximately 683,000 in 1973 (Guatemala 1979, 10), Guatemala City is ten times as large as any other place in Guatemala. It is the site of the major university (San Carlos), most important government offices, the major secondary schools, and, of course, the seat of the central government.

The largest sub-national governmental units of Guatemala are the 22 departamentos. These are generally named after their capitals, which are usually the most important urban places. These have generally functioned as administrative districts of the central government, although a few of the predominantly independent departamentos of the highlands functioned as separate states for a brief period after independence. Belize is sometimes treated as a 23rd departamento in Guatemalan publications.

Below the level of departamentos are the municipios, of which there are 324 (plus 6 more in Belize). The word is variously translated into English as "counties" or "townships." Many of these have borders which were set down early in the colonial period, by grants of the Spanish crown. Like the departamentos, the municipios are named after their capitals. The municipio usually defines the horizons of rural dwellers, particularly the indianos. People from a particular municipio can be identified by their distinctive clothing, and often by their own languages. Until very recently, the mayors of the municipios were elected by the people in contested races, and the governments had their own revenues from some minor taxes and fees (World Bank 1978, 160). Although there was always tension between the central government and the municipios, the latter maintained a certain degree of autonomy. This was essentially the state of affairs during the period of this study. In 1982, the new regime of José Efraín Ríos Montt instituted a comprehensive revision of the system of local government, which replaced the elected mayors with government appointees and dismissed the municipio councils (Nyrop 1983, 146). Whether these changes will be maintained by the newly instituted constitutional government remains to be seen.

1.2.2.Western Highlands

The focal point of this study is Quetzaltenango, Guatemala's second largest city. Quetzaltenango is a departamento capital in the country's western highlands or *altiplano*. The western highlands are an area of small farms which grow subsistence crops of corn or beans. The mountainous area is also suitable for coffee cultivation, although the large plantations are found out of the study area, to the southwest. The *altiplano* has a high proportion of indigenous population, living in small villages among the mountains. Being rural and indiano, it is considerably poorer than the area around Guatemala City.

1.2.2.1.Geography

The area which will (in Chapter III) be found to be tributary to Quetzaltenango stretches from the eastern shores of Lake Atitlán in Departamento Sololá to the Mexican border with San Marcos and Huehuetenango. It includes the most mountainous terrain in Guatemala. Almost all of the region is more than 1500 meters above sea level, and most is over 2100 meters. Two mountain ranges cut through the region, roughly northwest to southeast: the Sierra Madres in San Marcos, Quetzaltenango, and Totonicapán, and, further north, the Sierra Los Chuchumantes in Huehuetenango. Guatemala's two tallest volcanos, Volcán Tajumulco (4220 m) and Volcán Tacaná (4093 m) are in this region, as are many of the smaller ones. A sparse network of paved roads connects the departamento capitals and principal municipio capitals, supplemented by some unpaved roads and tracks.

1.2.2.2.Population

Table 1.1 shows some population measures for the departamentos in the Western Highlands. The region includes about 32.2 percent of the national population and 21.7 percent of the area. This implies that the population density of the highlands is higher than the national average, which is the case. On the average, the highlands are about half again as dense as the country's average. However, this is somewhat misleading, because population density within the region varies widely. The departamentos which make up the northern and eastern edges of the study region, Huehuetenango and El Quiché, are comparable in density to the national average with the latter departamento being on the low side. By contrast, the other four departamentos have population densities which are two to three times greater than the national average. These are, in fact, the most densely settled parts of the country, outside the environs of Guatemala City.

Table 1.1. Population of Departamentos in the Western Highlands (1973)[a]

	Population (thousands)					
Departamento	Total	Urban	Rural	Percent Urban	Area (km^2)	Density
Totonicapán	144	55	89	38.19	1,061	136
Sololá	193	31	162	16.06	1,061	182
Quetzaltenango	352	137	215	38.92	1,951	180
San Marcos	433	55	378	12.70	3,791	114
Huehuetenango	390	64	326	16.41	7,400	53
El Quiché	334	46	289	13.77	8,378	40
Highlands	1,846	388	1,459	21.02	23,642	78
National	5,730	2,047	3,683	35.72	108,889	53

[a]Source: Guatemala 1979, 7-9.

The greater population density of the highlands is not consistently associated with greater urbanization. Two departamentos, Quetzaltenango and Totonicapán, do in fact have populations which are slightly more urbanized than the national average. However, the rest of the departamentos, including the one with the highest population density of all, are only about half as urbanized as the nation. The western highlands are thus the site of a densely settled, primarily *rural* population—and this among the mountain ranges and volcanos.

Table 1.2. Percentage of Western Highland Population Which is Indigenous by Departamento and Urbanization[a]

Departamento	Total	Urban	Rural	Indigenous Urban
Sololá	94.49	87.96	97.74	30.99
Totonicapán	97.11	83.79	99.39	12.62
Quetzaltenango	62.80	48.10	71.33	28.13
San Marcos	63.55	27.69	64.85	5.64
Huehuetenango	69.01	45.53	73.07	9.74
El Quiché	85.88	62.16	88.97	8.35
Highlands	74.49	54.15	78.19	14.08

[a]Source: Guatemala 1973, 10-17.

Although about 40 percent of the national population is indiano, Table 1.2 above shows that this proportion is nearly doubled in the Western Highlands. Indeed, two departamentos have less than 10 percent ladino population, and another has less than 15 percent. Even here, however, the indiano population is overwhelmingly rural. While the urban population appears to have a high proportion of indianos in some cases, this is only because there are few other persons in the departamentos. In all cases, the percent of indianos which is urbanized is lower than the percent of total population in urban areas.

1.2.2.3.Income

It is very difficult to obtain accurate and up-to-date income data for Guatemala, especially for political units below the national level. However, the data published by the World Bank implies that in 1969 family income in the Western Highlands was around 989 quetzales, about 60 percent of the national average, 1653 Q (World Bank 1978, 13, Table 2.2). Average family income in urban areas of the region is about 6.7 times higher than in rural areas. This differential is somewhat lower than the country's average of 7.0. Thus, the Western Highlands is considerably poorer than most of the country, but income is slightly more evenly distributed.

1.2.3.Survey Data

The primary data source for this study was a survey conducted in 1979 by the Instituto de Fomento Municipal, the Institute for Municipal Public Works. This was part of the Integrated Study of Rural Areas which was being conducted in conjunction with USAID. This particular survey was entitled "Inventario de Infraestructura y Servicios" (Inventory of Infrastructure and Services). The survey document itself is 66 pages long and contains 199 main questions. Many of the main questions have subquestions–some have as many as two dozen. The questions concern population, municipal services, commercial establishments, government offices and facilities of all kinds, agriculture, cultural and recreational facilities, and much besides. Many of the questions are locationally oriented. They ask where the residents of the village go for various goods and services, or from where nonresidents come to take advantage of the facilities of the village. Often space for three different destinations are specified, with distances.

As befits an inventory, this survey was administered to the mayors of all places with populations over 50 persons, and a sample was made of smaller places as well. The region surveyed covered about three fourths of the country, including all of the central highlands. The areas excluded were Petén, the area around the national capital, and the Pacific coast.

Some of the North American personnel involved in the project were faculty members in the Departments of Economics and Community and Regional Planning at Iowa State University. They received copies of the survey data, stored on magnetic tapes. Unfortunately, much of the documentation concerning survey methods (and, indeed, much of the data) has since been lost. Thus, many interesting details about how things were done are unknown. The survey also suffered from overambition, in that the detailed questions often required knowledge which a mayor did not have. He might know whether there was a school, or taxi service, or telephones, but not the numbers of students, teachers, taxis, or phone lines. One must approach the results reported for such questions with caution and skepticism.

Each place in the survey dataset is has an identification number of the form, "DDMMPPP," where "DD" is the departamento number, "MM" is the municipio number, and "PPP" is the place number. Municipio and departamento capitals always have the place number "001." Departamento capitals always have municipio number "01." Thus, San Marcos city, which is a departamento (and hence, also a municipio) capital, has ID number 1201001. "12" is the departamento number of San Marcos. San Pedro Sacatepéquez, a municipio capital in Departamento San Marcos, has the ID number 1202001, showing that it is the capital of San Marcos' municipio number 02. Piedra Grande, a village in the same municipio, has ID number 1202039. These ID numbers will be referred to from time to time in this study. The departamento numbers for the region which makes up the Quetzaltenango central place system (as identified in Chapter III) are shown in Table 1.3.

Table 1.3. Departamento Numbers for the Study Region

Departamento	Number
Sololá	7
Totonicapán	8
Quetzaltenango	9
San Marcos	12
Huehuetenango	13
El Quiché	14

1.3.Objectives of the Study

The first step in any central place study must be to determine the extent and structure of the system of central places. This study begins by assuming Quetzaltenango as the top level of the central place system. It proceeds outward from that city, tracing links to other places until these are exhausted. The set of places thus identified are the members of the Quetzaltenango system. The bundles of goods making up the levels of the central place hierarchy (and the number of such levels) are determined empirically. Each place is assigned a central place level on the basis of the goods it offers.

Once the central place system has been identified, it is studied further. The different levels of markets are examined to determine their geographical extent and the size of the populations served. Differences among different parts of the study region are identified and explained. Central places with unusual characteristics are investigated to try to determine the reasons for their special features.

Finally, the geographical distribution of the educational and health facilities are examined and evaluated in a central place context. An attempt is made to assign each type of facility to a central place level. The places tributary to such facilities are recorded and compared with the commercially-derived central place structure. Attempts are made to estimate the populations served and the efficiency of the patterns of facility location.

II. CENTRAL PLACE THEORY

2.1. Exposition of the Basic Christaller Model[1]

Central Place Theory is a deductive model which uses the principles of rational behavior to explain the spatial distribution of some kinds of economic activity. As a theory, it utilizes the familiar devices of simplification and assumption, in order to expose the underlying processes that govern its subject. However, it would be wrong to think of central place theory as being merely a static, idealized description of pure rationality. While the idealized aspects of the theory have certainly received the most currency among later scholars, Walter Christaller was well aware of the artificiality of his assumptions, and he took pains in his work to demonstrate the consequences of relaxing them. Christaller's *Central Places in Southern Germany* (1966) shows this by being organized into "The Theoretical Part," "The Connecting Part," and "The Regional Part"—the last being an empirical study of the title region. Thus, from the beginning, central place theory has had an element of real-world applicability as an important adjunct to the idealized rational landscape.

2.1.1. Basic Concepts

"The theoretical part" follows a deductive procedure that is familiar in economics. Christaller starts with certain basic assumptions about behavior and

[1]This section is based primarily on the 1966 Baskin translation of Christaller's work (Christaller, 1966). I would also like to acknowledge Marshall (1969), which was greatly helpful in the preparation of this section.

economic relationships and weaves them into the fabric of his theory. It is useful to review some of the more important of these concepts.

2.1.1.1. Centrality

Central place theory is intended to uncover systematic reasons why some settlements develop into great cities, some into towns, and others cannot be said to develop much at all. "Centrality" is related to the factors that make a settlement relatively important in a region, in a way that is systematically important. This regional focus is what distinguishes a central place from a community established to take advantage of mineral deposits or recreational attractions. As Christaller (1966, 18) puts it:

> Let us in this sense speak simply of the centrality of a place, and understand centrality to mean the relative importance of a place with regard to the region surrounding it, or the degree to which the town exercises central functions.

Thus, even though a mining colony may grow to substantial size, unless it takes on functions that are important to the service of the surrounding region, it would not be considered a central place.

Christaller (1966, 19) makes a similar distinction between central and dispersed goods:

> Central goods and services are produced and offered at a few necessarily central points in order to be consumed at many scattered points. Dispersed goods and services are necessarily produced and offered at many scattered points (or at a few points, but not at central points), preferably in order to be consumed at a few points.

The goods in question are mostly "tertiary" goods. They do not require concentrations of specific natural resources, nor are they agricultural goods. In short, the goods which are the concern of central place theory are the ones which are primarily dependent on the location of the general population. Christaller's favorite example is that of a physician. Clearly, most retail trade would be considered central goods, as would many services. Heavy manufacturing, which is oriented more towards the location of raw materials, would not be a central function, but the distribution of the output of industry would be.

2.1.1.2. F.O.B. pricing

Christaller does not use the term "F.O.B. pricing." However, it is clear that the same concept is used in his discussions of consumer behavior and his numerical examples. Simply put, consumers are assumed to include the cost of transportation in the price of a good when they make their consumption decisions. The further a consumer lives from a source of a good, the higher the total price (i.e., including transportation) is, and the less he will purchase. In *Central Places in Southern Germany*, the consumer is assumed to travel to the source of the good, but it is clear that the principle applies equally well if he has to pay the freight on goods that are delivered to his home. In any case, demand decreases with distance, and this is of fundamental importance in determining the range of a good.

2.1.1.3. The range of a good

The range of a good is the critical concept that links the normal theories of the firm and consumer behavior with the locational patterns of central places. Because purchasing a good from a distant source is costly, for every good there will be a maximum distance, beyond which none of the good will be purchased. This is the maximum range of the good. Note that it is transportation cost, rather than distance per se, that is the deciding factor. (However, in the idealized model, transportation is assumed to be proportional to distance in every direction, so the distinction is moot.) In addition to the maximum range, every good has a minimum range. This range is based on the smallest market area that can support one firm providing this good. It is presumably based on normal profit, although Christaller does not address that directly. Again, distance per se is not the issue. In the case of minimum range, the area that encompasses enough demand to yield normal profits would determine the minimum range. (As with the maximum range, the assumptions of the idealized model allow this concept to be collapsed into simply the minimum radius of the market area.)

2.1.1.4. Economies of scale

One of the factors contributing to the development of central places is the existence of economies of scale. Larger firms are able to extend their hinterlands by virtue of their lower average costs. Thus, economies of scale encourage centralized production of goods and services, rather than the dispersal of small firms across the landscape.

2.1.1.5. Economies of agglomeration

The economies of agglomeration that are most relevant to central place theory are the ones that relate to consumer behavior rather than, for example, ones that reduce production costs. Consumers will economize on transportation costs by concluding several transactions in a single trip. Thus, someone might go shopping in the town that he has to visit to see the dentist. This increases the advantage of the central places that offer a wide variety of central goods. It also increases the maximum range of all the goods offered at the larger place. Of course, if an economy of agglomeration reduced production costs (e.g., through the development of specialized subcontractors), this would benefit the central place in the same way as economies of scale.

2.1.2. The Idealized Model

The most familiar version of the central place model is here referred to as "the idealized model." Like the perfect competition model, it is deliberately unrealistic in its assumptions, in order to most easily lay bare the salient features of a central place system. It is not intended to be immediately applicable to a real-world region without modification.

2.1.2.1. The idealized region

The region envisioned by the idealized model assumes away all of the geographic, demographic, and economic variations that make life so interesting and regional theory so difficult to apply. Geographically, the region is an "isotropic plain." It is completely flat and featureless, with transportation equally easy (or difficult) in every direction. The inhabitants of this endless steppe are appropriate for their environment. They are identical. The population density is absolutely even. This applies to their economic behavior as well. Each has the same income as the next person. Their tastes and preferences are also, presumably, identical.

A consequence of this drastically simplified environment is that specifying the radius of a circle around a supply source also specifies the population, buying power, and demand in that circle. The maximum range of a good defines a circular region around a supply source. The minimum range of a good is the radius that encompasses the smallest number of consumers that will still allow the firm to exist.

Thus, there is a doughnut-shaped region, between the minimum and maximum ranges, which may or may not be part of the place's market area for that good, depending on the competition from other central places. To the extent that the place's market area does extend into this ring, the supplying firms will enjoy economic profits.

2.1.2.2. The system of central places

Christaller develops his description of the system of central places by beginning with the highest-order good and working his way down to the lowest. The order of a good is determined by its minimum range. Thus, the highest-order good is the one that requires the largest number of consumers (and hence the largest geographic area) in order for a firm to survive. Since we begin with a region that is absolutely homogeneous with respect to every relevant variable, the placement of the first center, supplying the highest-order good, is completely arbitrary. Consumers within the maximum range of the center will be able to purchase the good, and everyone else will remain unsupplied.

Other centers, also supplying the highest-order good, will be established to take advantage of the opportunity represented by the unsupplied consumers. If we accept the usual condition that competitive firms will enter a market as long as there are economic profits to be made, then eventually the market areas will be crowded together in such a way that the circles defined by their minimum ranges will be tangent (see Figure 2.1). The resulting configuration, with respect to the original center, is that six competing centers will be located around it, each two competing centers forming the vertices of an equilateral triangle (with the original center as the third vertex). This arrangement, of six circular market areas tangent to a central circular market area, leaves roughly triangular regions, between the circles. Since the circles are defined by the minimum range of the good, the "leftover" areas will be still be supplied by one of the centers. If consumers simply go to the nearest center, we can divide up the leftover areas equally, transforming each market area into a regular hexagon.

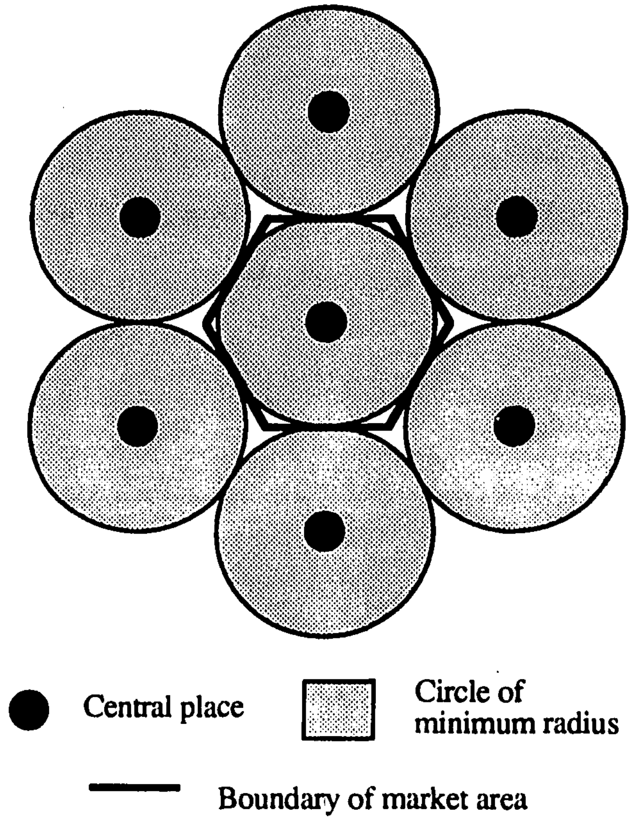

Figure 2.1. Formation of Hexagonal Market Area

The above description is one of several ways that the standard hexagonal market area can be derived. Under this explanation, the extra space in the "leftover" areas results in the firms earning economic profits. If we insist on normal profits, then the centers will be squeezed together, distorting the circular market areas into hexagons (albeit somewhat smaller ones than under the first explanation.) Marshall (1969, 18) is of the opinion that Christaller "seems to have arrived at the hexagonal shape by just... [the] process of tidying up the diagram." However, Mills and Lav (1964) demonstrate that the hexagonal area depends on the assumption that market areas must be space filling, i.e., that there be no gaps between markets. They relax that assumption and demonstrate that, given free entry and profit maximization it is possible to have market areas which are circular, triangular, rectangular, or hexagonal, depending on the relationships among demand and cost parameters.

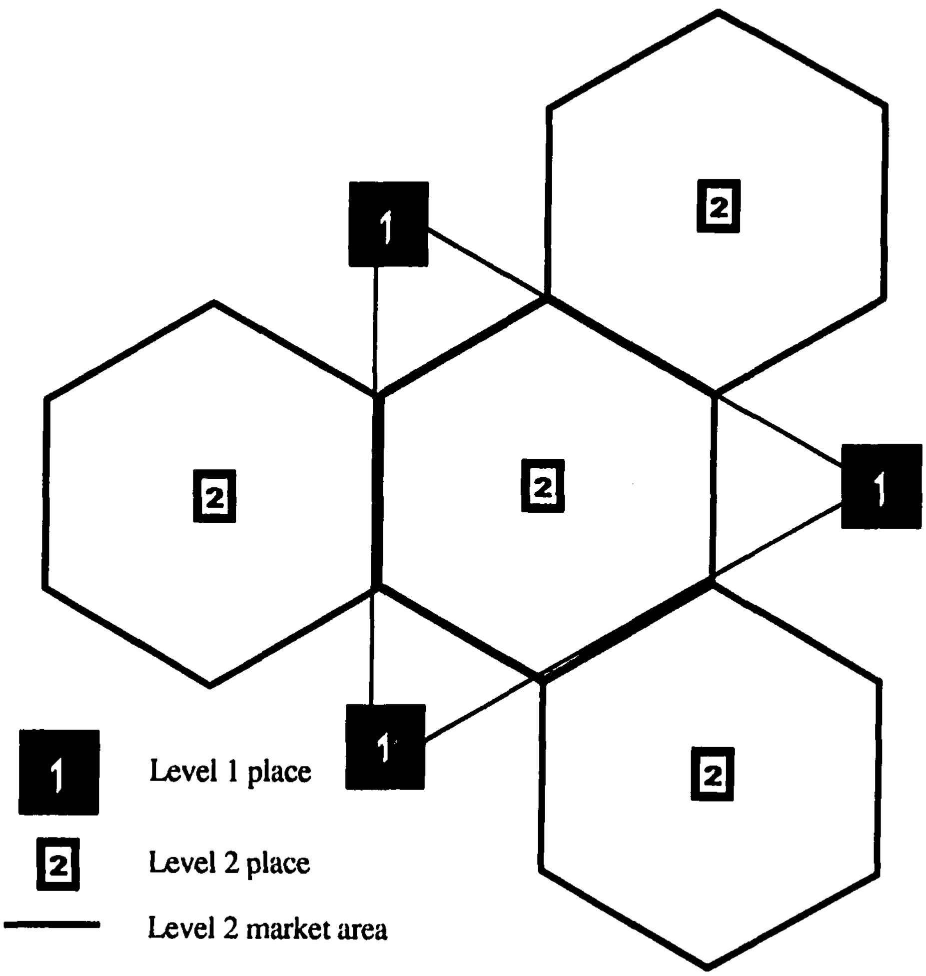

Figure 2.2. Placement of Level 2 Places Relative to Level 1 Places

The location of firms supplying lower-order goods is dependent on the pattern established by the higher-order firms. (Recall here that a "lower-order" good is simply one which has a smaller minimum range than a "higher-order" good.) Let us call the high-order centers "level 1 centers." Because consumers prefer to combine trips in order to minimize transportation cost, the level 1 centers will be attractive sites for the location of firms supplying the lower-order goods as well. Whether this second wave of firms locates anywhere else, in addition to at the level 1 centers, depends on the minimum ranges of the goods they sell.

Consider the case of an entrepreneur contemplating the establishment of a new center to supply a lower-order good (call it a "level 2" center). The adjacent existing (level 1) places enclose areas in the shape of equilateral triangles (see Figure 2.2). The entrepreneur can only hope to sell to customers attracted by lower transportation costs, which means that he will be able to sell his goods to consumers who are closer to the newly established level 2 place than they are to any level 1 place. Clearly, the location that maximizes the distances to all possible competitors is at the center of the triangle, as is shown in Figure 2.2. Thus, his market area will include that part of the triangle that is closer to the center than to any vertex[2]. Since (in long run equilibrium) there will be level 2 centers springing up in the other adjacent triangular areas, the market of the place in question will also be limited by competition with these, as is shown in Figure 2.2. If the minimum

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[2]The sides of the triangle are determined by the distance between level 1 centers. Each side is twice the minimum range of the higher-order good. Since the distance from the center of a triangle to a vertex is one-half its altitude , the radius of the level 2 center's market area is one-fourth this altitude. It follows by the geometry of triangles that if the radius of the level 1 center is "R" and the radius of the level 2 center is "r," then

$$r = \frac{\sqrt{3}}{4} R \approx 0.433 R.$$

range of a good is less than the distance to the edge of the hexagon thus derived, then it could be profitably supplied at a level 2 place. If not, then this good can still only be supplied from the level 1 centers. (Note, however, that the suppliers of goods with smaller minimum radii would make economic profits in the second case, because each would sell to a market which is larger than this minimum.) Note that each level 1 place also functions as a level 2 place and has a level 2 market area (or *umland*, to use Christaller's term) which is smaller than the area to which it supplies level 2 goods.[3]

If there are goods with sufficiently small minimum ranges to allow for the establishment of level 2 centers, then it is possible that the whole process will be repeated in the establishment of level 3 centers, level 4 centers, and so on, until all central goods are supplied. In each case, the lower-order center will be located at the center of a triangle formed by three higher-order centers, and each center will have a hexagonal market area greater than its minimum range. Figure 2.3 shows a 4-level system based on these principles. Each center is surrounded by six competing centers. Except for the highest-order centers, three of these competing centers are of the same order, and three are of higher order. Closer in to all but the lowest-level places, each is surrounded by another ring, this time of six centers of the next lower order.

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[3]For purposes of simplicity, this discussion assumes that the level 2 market area is the same for all places which supply level 2 goods. However, if the level 1 places are more attractive to consumers, because of their preference for "one stop shopping," then the level 1 places will be able to extend their level 2 areas at the expense of the strictly level 2 places. In that case, the hexagonal lattice will be distorted, with the areas of the strictly level 2 places being squeezed and those of the level 1 places, expanded. This may affect whether a marginal good can be offered at a level 2 place at all.

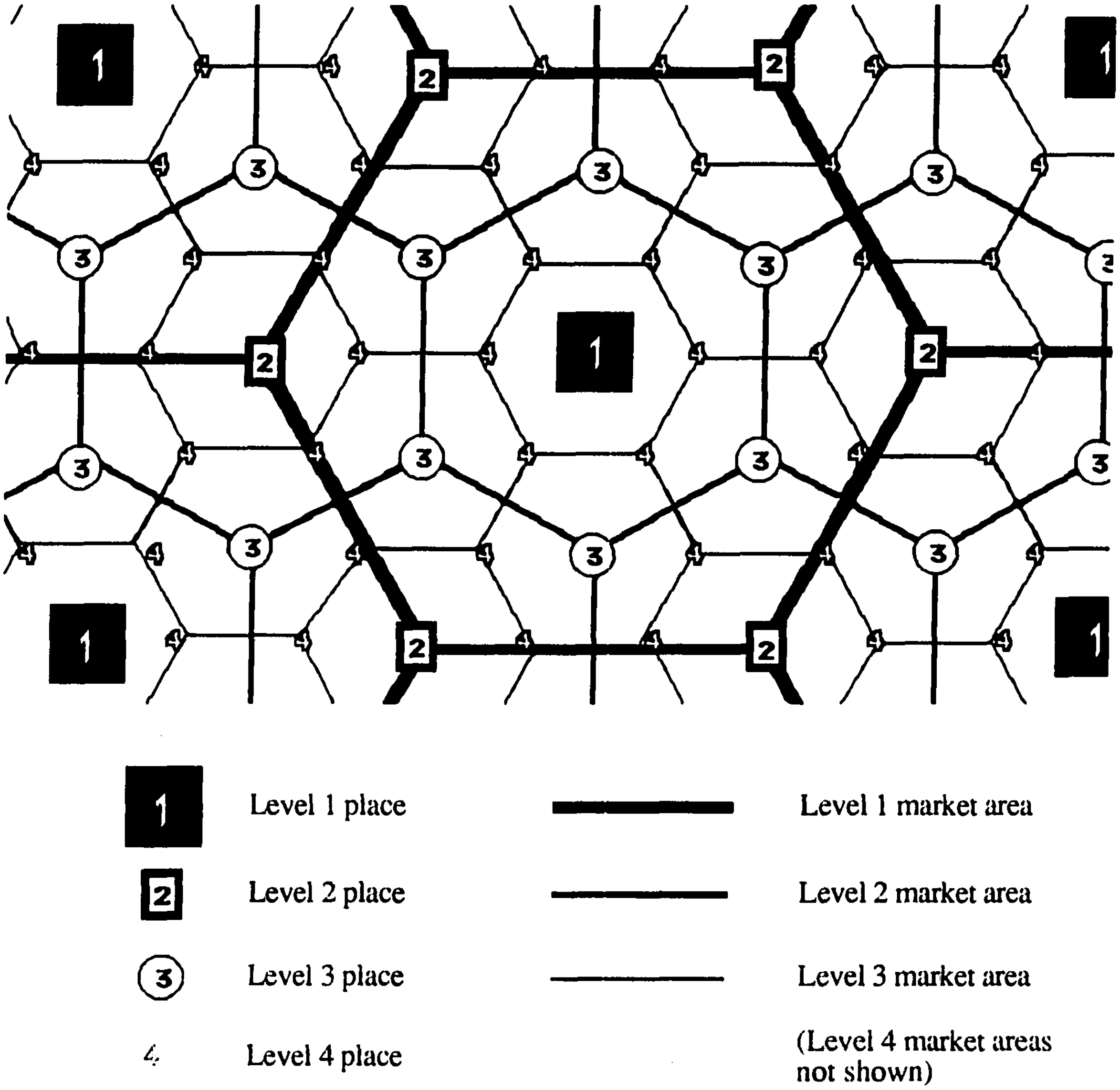

Figure 2.3. A Four-Level Central Place System, According to the Marketing Principle

2.1.2.3. Combination of geographic and functional ordering

The central place pattern is hierarchical in both its spatial arrangement and the functions performed by each central place. The spacing of the level 1 centers is determined by the good which has the largest minimum radius. Goods whose minimum radius is less than the maximum but still greater than the radius of level 2 markets will only be offered at level 1 places. Since the level 1 place also functions as a lower-level place, it will supply all goods. The level 2 place will supply all those goods whose minimum radius is less than or equal to the radius of the place's market area, and so on down the hierarchy.

Table 2.1. Numerical Example of Goods Hierarchy
(• = good is supplied by place at this level)

	Place Level:	1	2	3	4	
	Market Radius:[a]	100.00	43.30	18.75	8.12	
Good	Minimum Radius[b]					Good Level
A	100.00	•				1
B	90.40	•				1
C	70.90	•				1
D	66.30	•				1
E	38.90	•	•			2
F	36.00	•	•			2
G	17.80	•	•	•		3
H	13.80	•	•	•		3
I	4.30	•	•	•	•	4
J	1.60	•	•	•	•	4

[a]The market area of level 1 places is set arbitrarily at 100. Each lower-level market has a radius which is 0.433 times the previous one. (See footnote 2, above.)

[b]These numbers were generated randomly and sorted in order. They are for illustrative purposes only.

Table 2.1 gives a numerical example of the goods hierarchy in a central place system. Functionally, each kind of good is offered by every central place above a certain level. Thus, we can speak of "level 1 goods," "level 2 goods," and so on, categorizing a good by the lowest-order center that offers it. Each center offers all goods of its own level, plus all of the lower-level goods. in Table 2.1, goods "A" through "D" are level 1 goods, and each lower level happens to have two goods in its bundle[4]. Thus, central place theory describes a definite, discrete regularity to the distribution of central places across the landscape and to the distribution of central goods among the places.

2.1.2.4. Numerical relationships among the levels

In the idealized central place system, the number of central places of a particular order will be in a fixed ratio with those of the other orders. There will, of course, be more central places as one goes down the hierarchy. Each level 1 place is surrounded by six level 2 places (see Figure 2.3). However, each of these level 2 places is also in the level 1 market area of two other level 1 places. If we count each of these level 2 places as $\frac{1}{3}$ of a place (with respect to the original level 1 place), there are twice as many level 2 places as level 1 places ($6 \times \frac{1}{3} = 2$). Moving down to the level 3 places, there are a total of six, all of which lie totally inside the market area of the level 1 place. Of the level 4 places, 12 are on the periphery, split between two level 1 places each, while an additional 12 are completely contained in the level 1 center's market area. This makes 18 level 4 places per level 1 place (12 plus 12 x 0.5 for the shared places). Thus, the ratio of the number of places for the first four levels is (level 1:level 2:level 3:level 4) 1:2:6:18. Each set of lower-level places is twice as numerous as the sum of the number of higher-level places, and three times as numerous as the next higher level by itself.

[4]This is just the outcome of this particular example. There is no theoretical basis for determining the relative numbers of different goods which will be classified to each specific level.

Since each higher-level place also performs the functions of all places at lower levels, there is an alternative way to express the ratios among levels. If by "the number of level 2 places," we mean all those central places that provide level 2 functions, then we must include the level 1 centers in the total. Counting this way, the level 1:level 2:level 3:level 4 ratio becomes 1:3:9:27. For every source of level 1 central goods, there are 3 sources of level 2 goods, one of which is the level 1 place. There are 9 sources of level 3 goods, including the level 1 and level 2 places, and so on.

2.1.3. Variations on the Model

The central place system that has been described as the "idealized model" is what Christaller refers to as the *versorgunsprinzip* or "marketing principle" landscape. It is based on the assumptions that travel is equally easy in any direction, and that there is nothing wrong with having the market areas of some central places split among the market areas of several higher-level places (as is the case with level 2 places, for example). Christaller recognizes two variations on this model, in which these assumptions are changed.

2.1.3.1. The traffic principle

The *verkehrsprinzip*, or "traffic principle" introduces transportation lines (roads or railroads) into the model. The emergence of central places and the construction of transportation routes follow an iterative process. Since there are no settlements to begin with, there are no places to build roads or railroads between. Thus, the establishment of the level 1 places proceeds as described above. Roads are then constructed linking these centers. This changes the topography of the economic landscape. Now, the most accessible sites are along the roads. Firms which locate on the roads will have access to larger populations than those which do not, since the total cost of obtaining goods from them will be lower. The level 2 places will be established on the roads, midway between the level 1 centers, as is shown in Figure 2.4. If secondary lines are built linking the level 2 centers, then the level 3 centers will be established on these, as well as between the level 2 and level 1 centers on the primary rail line. A four-level system based on this principles is illustrated in Figure 2.5.

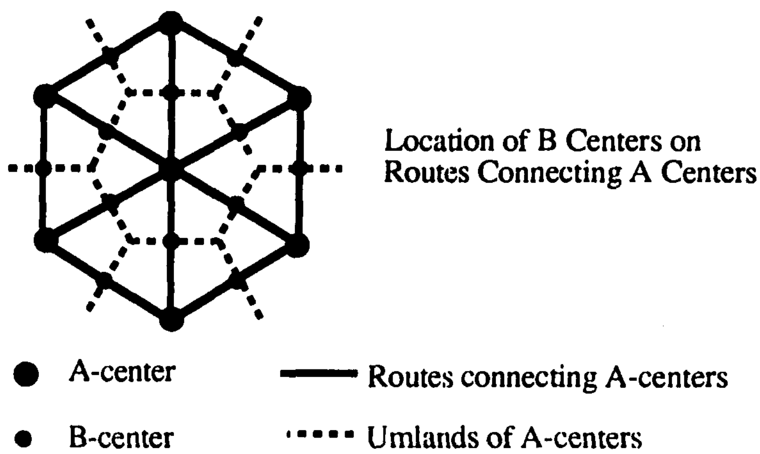

Figure 2.4. The Placement of Lower-Level Centers, According to the Traffic Principle[a]

[a]Source: Marshall (1969, 30)

As is shown in Figures 2.4 and 2.5, under the traffic principle the lower-level places are located in the centers of the sides of the hexagonal market areas, rather than at the vertices (which was the case under the marketing principle). This means that the numbers of lower-level places relative to higher-level places is different from the previous case. For example, each level 2 place is now on the border with only two level 1 places, instead of the three under the marketing principle. The ratio of individual places will be 1:3:12:48, and the ratio of functional places will be 1:4:16:64. Thus, the traffic principle requires more central places than does the marketing principle.

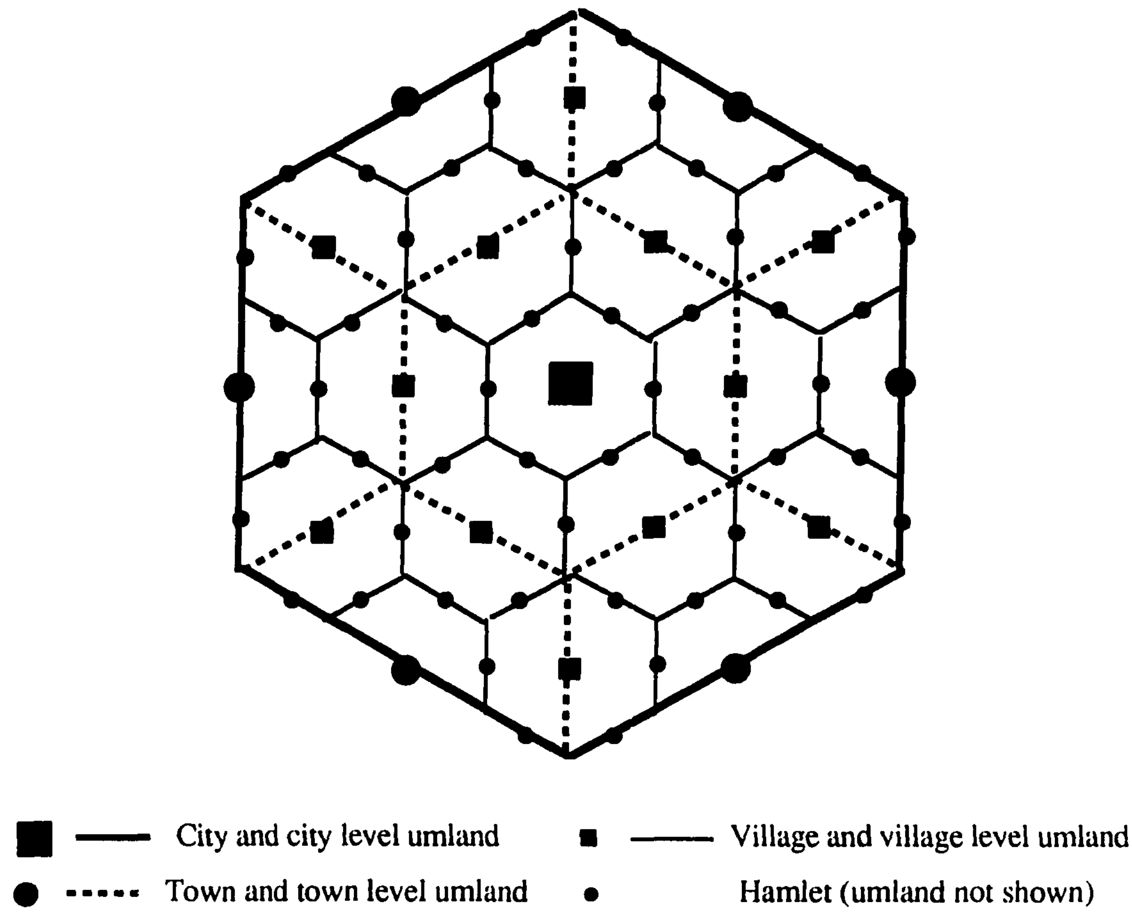

Figure 2.5. Four-Level Central Place System, According to the Traffic Principle[a]

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[a]Source: Marshall (1969, 30)

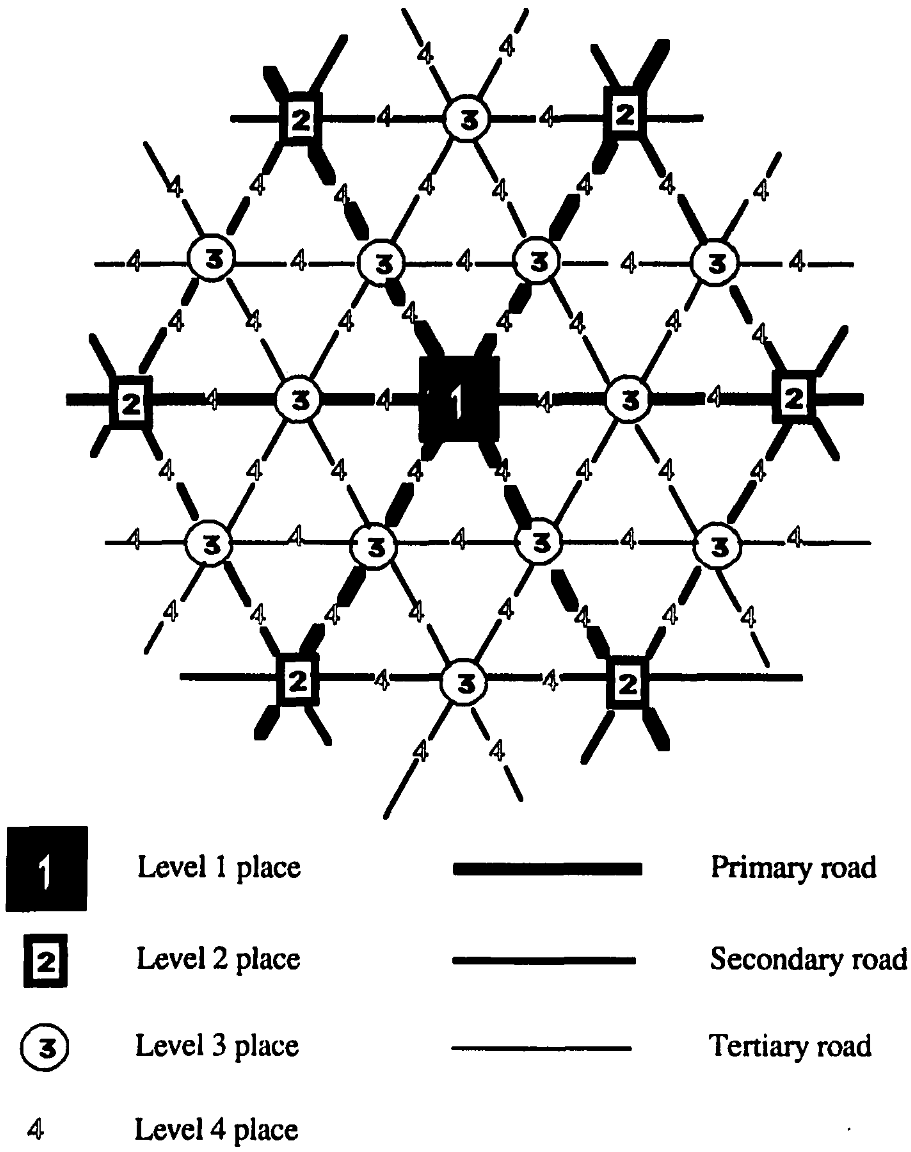

Figure 2.6. The Road Network, According to the Traffic Principle

Figure 2.6 shows the road network which results from the process of building roads between places of the same central place level. One question which is not addressed in this literature is the purpose of these roads. Under central place theory, each level 1 place supplies exactly the same goods as each other level 1 place. If that is the case, why would the residents of one such place want to travel to another? One can, of course, imagine social reasons for travelling to large population centers, or one could argue that these places would be the production points for noncentral (i.e., export) goods, but these explanations are all ad hoc and incidental to the theory. This particular road-building strategy is an assumption of the traffic principle. The consequence of the assumption is that lower-level central places will tend to locate on the roads between two higher-level places.

2.1.3.2. The separation principle

The traffic principle and the marketing principle both result in the market areas of lower-order places being split among the market areas of the higher-order places. For example, the market area of each level 2 place under the marketing principle straddles the hinterlands of three level 1 centers each (see Figure 2.3). Under the traffic principle, each level 2 area is divided between two level 1 areas. In both of these cases, the lower-level place itself is located on the border of two or more higher-level places. This poses no problems when we are dealing with private businesses. The baker does not care that some of his customers visit a physician in one city while others go to a different city. Nor do the doctors fret about where their patients buy baked goods. However, a difficulty may occur if the functions are provided by government agencies. Bureaucratic organizations, such as governments, have difficulties with divided loyalties. The chain of command is simplified if every subsidiary agency is wholly contained in a higher-level organization. We would think it strange if a county straddled two different states, for example. Similarly, the overlapping school districts, townships, municipalities, mosquito abatement districts, and transit districts of urban areas are usually pointed to as evidence of inefficiency in government—the so-called "balkanization of the suburbs." Thus, from a bureaucratic or administrative point of view, it would be preferable if each lower-level center serviced an area entirely within the boundaries of the next-higher-level center.

The "separation principle," or *absonderungsprinzip*, imposes this condition on the system of central places. Christaller himself (1966, 77-80) had a good deal of trouble with this principle, and the shapes of the market areas had to be considerably distorted from the hexagonal. Marshall (1969, 31-33) does include a diagram of a central place system following the separation principle which still maintains the regular shapes of the hinterlands (see Figure 2.7). However, while Marshall's arrangement of places is such that none is on the border between two higher-level jurisdictions,[5] and all the jurisdictions are regular hexagons, it is not the case that each lower-level jurisdictions is completely contained within a higher-level jurisdiction. This can be seen in Figure 2.7. The level 2 (called "Village" in this case) jurisdictions on the edges of the level 1 ("Town") jurisdictions. One could say that the "county seats" are all in their respective states, but parts of some of the "counties" are in neighboring states. To avoid this, either the level 1 jurisdictions would have to be modified to conform with the hexagonal level 2 jurisdictional boundaries, or the shape of the level 2 places would have to be modified to fit into the level 1 hexagons. In any case, it is not possible to nest hexagons in such a way that their boundaries line up, so some levels of jurisdiction would have to have shapes which were not regular hexagons.

Under the separation principle, no lower-level places are shared by upper-level places. Thus, there are six times as many places of a given level as there are

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[5]The term "jurisdictions" is used here because "market area" is not appropriate when discussing government administration.

places of higher levels. The ratio of individual central places (level 1:level 2:level 3:level 4) is 1:6:42:294, and the ratio of functional central places is 1:7:49:343. Thus, while a system of central places can be organized on the separation principle, it will require more central places than when organized on the marketing or traffic principles.

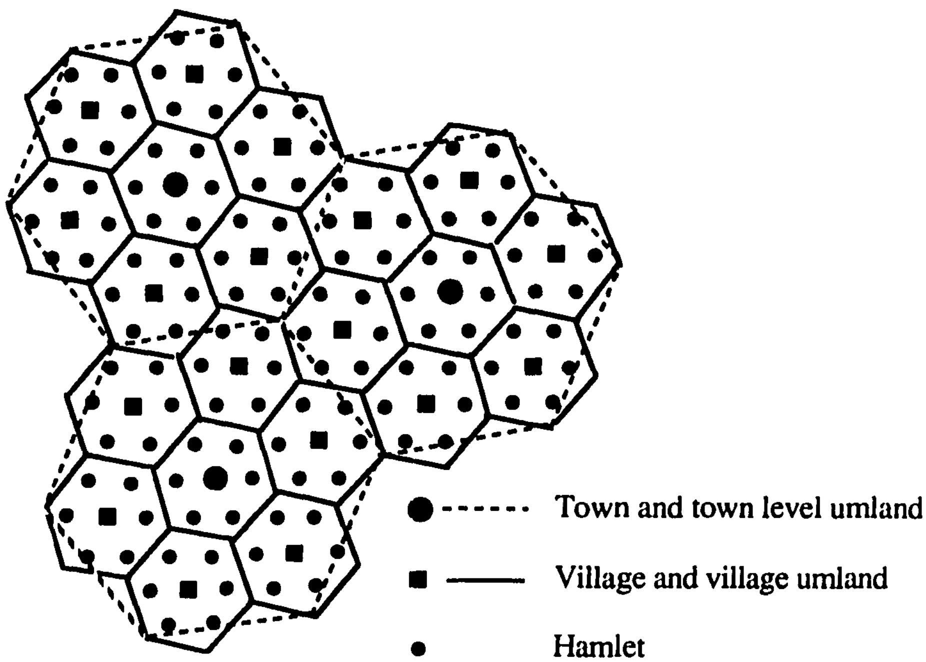

Figure 2.7. Marshall's Version of a Central Place System, According to the Separation Principle[a]

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[a]Source: Marshall (1969, 32)

The central place system of the separation principle differs from those of the other two principles in a more fundamental way than the arrangement or ratios of places. This principle is normative and prescriptive, rather than positive and descriptive. The marketing and traffic principles are based on concepts of long-run equilibrium locational choice, given the assumptions (of either no roads or roads built to connect places of the same level). The separation principle is implicitly about how a government should lay out a system of cities if it is to serve the population as efficiently as possible while still maintaining self-contained jurisdictions and subjurisdictions. There is no mechanism proposed to account for this pattern of central places coming about through an impersonal process of equilibration.

2.1.4. Departures from the Idealized Models

In a sense, we have already begun departing from the idealized model, with the traffic principle and the separation principle. Both of these introduce extra considerations that modify the "pure" theory of the marketing principle. However, the resulting systems are still geometrically and functionally regular enough to seem extremely artificial. But, as was stated previously, the purpose of an ideal model is to isolate the essential elements of a process, not to predict all the detail of the real world. The time has now come to consider some of the causes of divergence between the two worlds.

2.1.4.1. Competition among "principles"

There is nothing to prevent the various "principles" from operating simultaneously. The traffic and marketing principles implicitly operated that way even in the previous discussion, since the off-road travel, would be governed by the rules of the marketing principle, even if roads were built. It not hard to imagine how the separation principle would also be active. Commercial enterprises may well locate themselves according to the traffic or marketing principles, but the government might site its agencies according to the separation principle. Of course, if the government places a cluster of high-level services in a central place which, according to the commercial system, would be a low-level center, that place will be more attractive to consumers, because they have to go there to conduct their government business. This attractiveness will probably attract higher-level commercial services as well. Conversely, a government facility may be located in a (commercially) high-level central place, because it already had a concentrated population or was at the center of a transportation network. Thus, the principles can interact and produce a pattern of activity that is dependent on all of them. This pattern is hard to predict in general, but it will probably be different than the regularity of the single-principle systems.

2.1.4.2. Noncentral economic activity

Another source of disturbance to the central place system as described by the ideal model is the fact that a great deal of economic activity is not the "footloose," tertiary activity with which the model is designed to deal. Coal mines must be where the coal is. Manufacturing benefits from concentrated, large-scale production and is comparatively insensitive to the location of the ultimate consumers, especially in national or international markets. The locations of firms engaged in these activities will be determined by different principles than those of central place theory. However, primary and secondary industries employ a lot of people, and these workers want to consume central goods. The concentration of buying power caused by noncentral activity alters the economic topography of the landscape. Firms offering central goods will find a ready market in places of industrial concentration, and these will develop into central places in the Christallerian sense. Such central places, being (from the point of view of the ideal model) randomly imposed on the landscape, will influence the placement of competing centers, and so the whole network will be altered.[6]

2.1.4.3. Noneconomic forces

The modifications mentioned thus far have all dealt with the "economic topography" of the region, i.e., ways in which the uniform distribution of buying power or the uniform transportation cost will be altered by more realistic circumstances. These alterations cause the "economic map" of the region to be different from the geographic map, and so the market areas, drawn on a geographic map, appear distorted.[7] It is of course possible that the direction of alteration will be reversed. If the geographical topography is not a uniform plain, then there will be economic ramifications. Areas of the region that are less attractive to residents, because of low fertility, high water table, or whatever reason, will have a lower amount of buying power per square mile than more attractive areas. Swamps, rivers, mountains, and similar obstacles will cause transportation costs to be nonuniform. This will in turn modify the shape of the market areas from hexagons to something less regular.

Figure 2.8 reproduces Marshall's (1969, 35) example of the distribution of central places of a particular level, assuming the marketing principle but uneven population distribution. The population density is assumed to decrease with distance from the coast. Decreasing density means that market areas must be

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[6]Richard L. Morrill (1979) examines this effect in more depth in his reconciliation of Christaller's and von Thunen's locational models.

[7]This is analogous to the "rubber mat" image of relativistic physics, in which the presence of concentrations of mass distort the even geometry of space.

larger in order encompass the minimum amount of demand to maintain a firm. Thus, the central places must be spread further apart. At the limit, the radius necessary to encompass the population may be larger than the maximum range of the good.[8] If this occurs, the good cannot be offered at all.

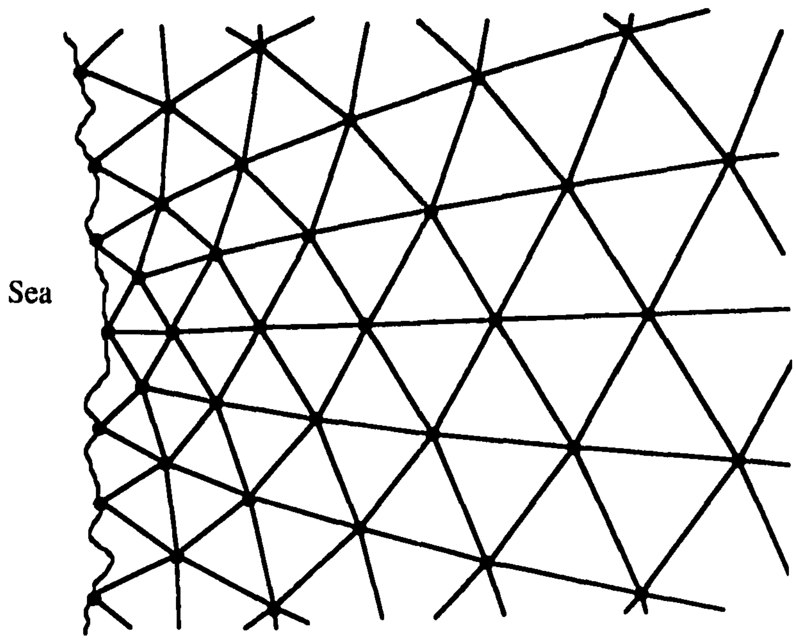

Figure 2.8. Distribution of Centers as Population Density Decreases[a]

[a]Source: Marshall (1969, 35)

Of course, some terrain features, such as rivers and valleys, are facilitators of transportation in particular directions, even as they are obstacles in others. They will have the same effect on a system of central places as roads in the direction of travel. In the direction in which they are barriers, these features will reduce the maximum ranges of central places on one side of the barrier and give competitive

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[8]Recall that the maximum range is the maximum distance consumers are willing to travel in order to obtain the good.

advantages to those on the other. These effects may be mutual: two places on opposite sides of a river will have advantages on their own sides but be disadvantaged on the other.

The essential consideration is that central place theory deals with economic and geographical space simultaneously, and the regularities of behavior in the one may appear irregular in the other. It is not distance per se which is a barrier but the cost of transportation. Terrain features which affect this cost will stretch or shrink the "economic distance," and this will influence the advantages and disadvantages of a place as a supply point for goods. Increases in population density or per capita income will increase the effective demand within a given distance from a place, thereby reducing the minimum ranges of the goods offered there.

2.1.4.4. Dynamic considerations

A final source of deviation between the idealized model and a real region is that the idealized model is static, while the world is not. Demographic change may allow for the establishment of new central places, or render old ones redundant. Technological change may increase the maximum range of a good, through lower production or transportation cost. The minimum range may increase because of technology that requires large-scale production, or it may decrease because of miniaturization (e.g., the data processing industry no longer requires the huge mainframe computers that it once did). These changes may mean that a good can now be offered at a lower-level center than before, or that it must be offered at fewer centers. A real system of central places will be subject to all sorts of changes over time. There is, however, an inertia that must be overcome. New settlements are not established overnight. Settlements that are no longer competitive may linger for decades. Established firms in the declining settlements may be reluctant to move, or they may relocate only partially. Government agencies, subject to bureaucratic inertia and political pressure, may be quite insensitive to the changed conditions (note, for example, the many military bases that outlast their usefulness, or the way that state capitals are moved with extreme reluctance). We should expect, then, that any study of a central place system will find it in partial transition. It would be most surprising if all central functions clustered in the exact hierarchy predicted by the idealized model.

2.2. Correspondence with Economic Base Models

Regional science has many models which, to one extent or another, cover the same ground. All attempt to characterize economic activity while explicitly considering the importance of space, distance, and location. These models differ in the variables they emphasize, but they very often say essentially similar things. One example of this convergence is the correspondence between central place theory and economic base models. Closely related to these models is the rank-size rule, which is a statistical regularity that has been often observed empirically and interpreted in various ways.

2.2.1. Brief Review of Economic Base Theory

The "base" in economic base theory refers to the sector of the local economy which produces the exports that "drive" the activities of the place or region (whichever is the subject of the study). The assumption is that the factors of production in this "basic" sector, which provide income from the rest of the world, are the economic lifeblood of the community. The factors of production employed in the nonexporting sector exist to provide those in the exporting sector and themselves with necessary local services. Thus, this "nonbasic" sector is dependent on the prosperity of the basic sector for its own prosperity. A point worth emphasizing, so as to avoid confusion later, is that the adjective "basic" refers to the economic base. One is tempted to interpret "basic" as meaning the everyday goods and services that everyone needs, but this is exactly the wrong way around. Everyday services are nonbasic, i.e., they are dependent on and exist to serve the segment of the population engaged in producing for export.

In its simplest form, economic base theory says that there is a fixed relationship between the number of persons engaged in basic activities and the number needed for nonbasic production. This relationship is variously expressed, as the ratio of basic population to nonbasic population, or sometimes as simply a fraction denoting the number of persons needed to supply one person with nonbasic goods. "Persons" here may refer either to employment or to population.[9] The workers in the nonbasic sector must themselves be supplied with nonbasic goods, and so must the workers who supply them, and so on, yielding a diminishing infinite series:

$$P_N = \sum_{i=1}^{\infty} k^i P_B \tag{2.1}$$

where P_N is the population engaged in nonbasic activities, P_B is the population engaged in basic activities, and k is a fraction, $0 < k < 1$, the number of persons required to supply one person with nonbasic goods.

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[9]If the latter, there is an implicit assumption that the labor force participation rate is fixed, so that each worker represents a certain additional number of additional persons (perhaps family members) who are not in the labor force.

This relationship is often formulated somewhat differently, to emphasize the fact that the nonbasic population must be large enough to supply the basic population and itself:

$$P_N = k(P_B + P_N) \tag{2.2}$$

This reduces to

$$P_N = P_B\left(\frac{k}{1 - k}\right) \tag{2.3}$$

The $\frac{k}{1 - k}$ factor is very similar to the Keynesian multiplier of macroeconomics and is sometimes called the "economic base multiplier." It shows that a change in the basic population will have a multiplied effect on the population of the region or place[10].

2.2.2. Interpreting Central Goods in Economic Base Terms

Economic base theory is generally used to predict the impact that exogenous changes in demand for a region's exports will have on the total employment of the region. The version described in the previous section is the "bare bones" of the model. A major concern, which was glossed over above, is the difficulty of defining exactly what employment is basic and what is nonbasic. The techniques for doing this are varied and ingenious, but they will not be discussed here[11]. What is of interest to the current study is that the central place model as developed by geographers such as Christaller can be interpreted in economic

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[10]The similarity to Keynesian macroeconomics is not accidental; both multipliers are based on the same mathematical relationship, in which a total is based on taking an infinite sum of constant being multiplied by a fraction taken to higher and higher powers. Indeed, yet another regional economic model applies explicitly Keynesian concepts to regional income flows.

[11]There are many regional economics works that provide such detail. One standard reference is Isard et al. (1960).

base terms. Early work in this area was done by Beckmann (1958) and, in a somewhat different form, by Dacey (1966). They recognized that the rural population could be considered to be basic, since they were presumably producing agricultural products for export. Central goods, which are purchased by the rural population, are nonbasic. Thus, the population of the lowest-level central place is

$$p_1 = r\left(\frac{k}{1 - k}\right) \qquad (2.4)$$

where p_1 is the population of the lowest-level central place, and r is the rural population served by that central place.

Note that the size of the rural population, r, would depend on the size of the market area, which in turn is dependent on the range of the good in question. What the economic base interpretation adds is the consideration of the size of central places, depending on the rural population and the proportionality factor, k.

The populations of higher-order central places depends on the populations of the lower-order places as well as the rural population, since they need to provide higher-order goods to all of those people. Here the formulation gets complicated, since each nth order center is also a 1st, 2nd, . . ., (n -1)th order center.[12] The second order centers have a population of

$$p_2 = k(sr + sp_1 + p_2) + k(r + p_2) \qquad (2.5)$$

where s is the number of 1st order centers served by each second order center.[13]

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[12]Note that the numbering of the levels is reversed from the discussion of central place theory. In other words, a level 1 place is the <u>lowest</u>- level place. This notation is used because economic base theory works from the lowest level upwards, whereas central place theory works from the highest level downwards.

[13]For example, under the marketing principle s=2, since each higher-order place serves 1/3 of each of 6 lower-order places.

The first term on the right-hand side of equation (2.5) is the population necessary to provide the residents of the market area with second order goods. The second term is the population needed to supply the first order goods to the second order center, plus its first order market area. If equation (2.4) is substituted into (2.5), and the latter is solved for p_2, we eventually arrive at

$$P_2 = \left(\frac{k(s-k+1)}{(1-3k+k^2)}\right)r \tag{2.6}$$

Note that the population of second-order places is determined by the rural population (r), the nesting factor (s), and the basic-nonbasic proportionality factor (k). It would be possible, though tedious, to calculate the populations of higher-order centers by the same method. Beckmann (1958, 244), Beckmann and McPherson (1970, 26), and Dacey (1966, 27) all derive general formulas for both the central place population and the population of the complementary region, for any order of place. They use different notation and somewhat different assumptions concerning the structure of the system, but Parr, Denike, and Mulligan (1975) demonstrate that all three can be reconciled.

The economic base interpretation of central place theory can be further articulated by viewing each order of goods as a separate industrial sector. We can then examine the basic and nonbasic components of each sector. Also, the implications of different "k" values (essentially, production coefficients) for each sector. This is done by Mulligan (1979, 60). He finds that the basic-nonbasic ratio (i.e., $\frac{P_{Bm}}{P_{Nm}}$, where m is the level of place) declines as the order of place (m) increases. Also, this ratio is independent of the topology of the central place system (i.e., the value of s). This talk of sectors and production coefficients naturally reminds one of input/output analysis, and Mulligan (1979, 61-63) goes on to show that an economic base model developed for a central place system can be reformulated as an inter-regional input/output model (the "regions" in this case being the individual central places).

2.2.3. The Rank-Size Rule

The rank-size rule is a statistical regularity concerning the distribution of city size, usually associated with Zipf (1949)[14]. The rule says that if all cities are ranked in descending order of population (i.e., the most populous city is "1," etc.), then, using Zipf's (p. 366) notation,

$$r\,P^q = K \tag{2.7}$$

where r is the city's rank (positive integer), P is the city's population,and q and K are positive constants.

This relationship is customarily expressed in logarithmic terms:

$$\ln P = -\left(\frac{1}{q}\right)\ln r + \left(\frac{1}{q}\right)\ln K \tag{2.8}$$

Equation (2.8) states that the population of a city is log-linearly related to its rank. In the special case where q=1, the product of rank and population is constant, and K is the population of the largest city.

Central place theory, per se, is not concerned with population, but with the location of services in a region. However, even the most casual observer would notice that higher-order central places are almost always places with larger populations. The economic base interpretation of central place theory explicitly concerns itself with predicting the populations of different order centers. The distribution of population thus generated turns out to be consistent with the rank-

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[14]However, Zipf (1949, 374, n.) credits Auerbach (1913) with the first use of the principle.

size rule[15]. Thus, a common empirical test for a valid central place system has been whether the distribution of sizes of central places is log-linear. While this is a fairly simple test to make, note that it is at best an indirect one. It depends on the economic base interpretation, and not on the essential hierarchy of functions and places that is the main theme of the theory.

2.2.4. Basic-Nonbasic Reversal in Developing Countries

The assumption of economic base theory is that basic production takes place in the rural areas and that the urban centers exist to provide nonbasic services to the basic sector. This is clearly based on an agricultural export economy, as one might find in the interior of the United States or the coastal plantation areas of Guatemala. In some regions of developing countries, such as the Western Highlands of Guatemala, the roles of the rural and urban workers may be reversed. The primary exports of the *altiplano* is seasonal labor, which is provided to the plantations, and tourism. Most agriculture in the *altiplano* itself is for household subsistence or sale to the residents of local towns. Tourism is an urbanized industry, centered on the towns and villages near important archaeological or natural attractions. While it may be reasonable to view the seasonal migration of the *campesinos* to the coffee and banana harvests as being a rural export sector, the same cannot be said of the production of corn and beans in the Highlands themselves. To the extent that they are not simply household production, these are service nonbasic industries, supporting the basic industries of the towns.

[15]See, for example, Beckmann (1958, 245-6) and Beckmann and McPherson (1970, 28-30).

The current study is concerned with classical central place theory, rather than economic base theory, and the purpose of this discussion is merely to note the similarities and differences in the two approaches. Thus, this is not the place for a detailed discussion of how rural nonbasic employment and basic urban employment would affect the structure of an urban hierarchy. However, it would seem that the amount of basic employment would be limited by the ability of the rural population to sustain it, as well as by the demand for basic output. Probably only one of these constraints would be binding at a particular time. There may be higher-level urban services which are nonbasic, so that the outputs of the towns may be a mixture of exports and local services. The implications of such an arrangement do not seem to have been addressed in the economic base literature.

2.3. Marshall's Identification Criteria

Since a central place system can follow a variety of patterns, even on a theoretical landscape, and since there are many deviations from theoretical assumptions that are found in real systems, we must have a set of criteria that identify the most important features that a real central place system should exhibit. Without such criteria, it is impossible to tell if a given pattern of settlement is consistent with the pattern predicted by central place theory. Since we can be absolutely confidant that the empirical pattern will be different from the theoretical one,it is necessary to "boil down" the theory to some easily identifiable and empirically testable features.

The current study relies heavily on the criteria developed by Marshall (1969, 23-28). They are as follows:

1. spatial interdependence of centers
2. functional wholeness of the system

3. discrete stratification of centrality
4. interstitial placement of orders
5. incremental baskets of goods
6. a minimum of three orders
7. numerical pyramid in order membership

The first two criteria insure that the places of the system belong together and that no places are wrongly excluded. This is important, because the theory applies only to an interdependent set of central places, not to a random collection. It is also important to include all of the places, since any exclusions will disturb the already delicate procedures for identifying the orders of places and goods.

Marshall's third and fifth criteria refer to the most visible characteristic of the Christallerian scheme, the development of discrete, hierarchical orders of goods and places. It is not enough that larger places offer simply more services than smaller ones; the theory requires that this increase occur in discontinuous jumps. In many ways, this requirement is the heart of central place theory, and it is very difficult to verify. Entrepreneurs are normal human beings and will sometimes establish their firms at locations that are not optimal, either through mistake or for reasons that we (as regional scientists) can read as random noise (e.g., to be in the same town as one's aged parents). Even if the location is not viable in the long run, we have no way of foreseeing that the business will move or close, two years after the study has been completed. A more systematic source of difficulty is the natural and gradual adjustment of a central place system responding to changes in population, technology, tastes, etc. Both the random and the systematic elements will tend to "blur" the discrete hierarchies predicted by the theory. Yet it remains vital that the discreteness of the central place order be verified, if we are to be sure that the places under study constitute a valid Christallerian hierarchy.

The fourth criterion is included because regional economics is always concerned with the use of geographical space. It is not sufficient for there to be certain specified numerical relationships between the central places in the region. There must also be a spatial structure governing the relative locations of these places. As has already been discussed, the ideal structure, of hexagonal market areas and so on, will be difficult to uncover because of the differing topography of theoretical and geographical spaces. Even so, the attempt must be made. Space is the sine qua non of regional science, and the primary appeal of Christaller's theory is that it integrates the functional and the spatial elements of the hierarchies of cities. Thus, it is important to examine the locations of the various orders of places in geographical space.

The final two criteria are more general, and in some respects more arbitrary. While it is conceivable that there would be only two orders in the hierarchy, such a simple division may not be interesting enough to be studies as "a central place system." However, as Marshall (1969, 27) says, this is "partly a matter of aesthetics," and partly to insure that the economic relationships are complex enough for Christaller's theory to be applicable. The requirement for a numerical pyramid in order membership is included because of the emphasis that the literature puts on the ratios between places of various orders. Note that we would not, however, hope to observe the strict ratios that the theory yields.

To the extent that an observed distribution of cities satisfies the above criteria, we can say that it approaches the "ideal" Christallerian system. While we expect that there will be imperfections in the system, for reasons already discussed at length, major deviations from several of the criteria would lead us to conclude that the region is not organized as central place theory would predict.

III. DELINEATION OF THE SYSTEM OF CENTRAL PLACES

This chapter deals with the work of using the Guatemalan survey data to determine the structure of the system of central places tributary to Quetzaltenango, the central or focal city of this study. The work is divided into several stages. It is first necessary to make a preliminary determination of the places that are tributary, directly or indirectly, to the central city. Once these places are identified, we must solve the double problem of separating them into their hierarchical classes as well as identifying the functions that characterize each class. Finally, the geographical arrangement of the places needs to be examined and interpreted.

3.1. The Importance of Identifying an Integral System

A matter that has received increasing attention in the recent literature is the importance of making very sure that the collection of places under study actually form an organic whole. Both Marshall (1969) and Smith (1972) put great emphasis on this, as we have seen. To recapitulate, the theory of central place systems applies to an economically integrated region, and not to an arbitrarily circumscribed piece of the earth's surface. In the idealized plane of the theoretical model, this is not a particularly important criterion, since the simplifying assumptions insure that there will be a single integrated system encompassing all places. Clearly, though, political and topographic divisions do exist and bring about a less than fully integrated world economy. Since we expect that even a well-integrated region will depart from perfect hierarchical regularity, it is important to minimize the disturbances caused by either excluding parts of the organic system or including places which do not, in truth, belong.

Thus, the first task is to determine which of the places in the Guatemalan survey data are actually part of the Quetzaltenango system, and which are not. This poses something of a chicken-and-egg problem: we must first have a collection of places in a system in order to identify that very system. Fortunately, we do not need the full-blown central place hierarchy to tell whether a place is tributary to the center city or not. We have only to trace the connections to Quetzaltenango well enough for these preliminary purposes. We will do this by using a classification system developed by Marshall (1969, 72-78).

3.2. Identification of Spatial Links

The procedure we will use is to begin at the central city and to find all places that rely on it more than they do on any other place. We will then take those places and find all the places that rely primarily on them. This procedure can be repeated until it reaches a natural stopping place—i.e., when an iteration adds no additional places. In practice, a total of three passes were necessary to trace all the connections.

3.2.1. Description of Relevant Questionnaire Data

A chronic problem in regional science is that while we can easily state what information we need in principle, obtaining that information is frequently hideously expensive or simply impossible. In this case, however, we do have questions from the survey which tell us almost exactly what we need to know. Question 20 is, "What is the most important nearby place accessible by road?" It provides for three levels of importance. "Importance" here is certainly subjective and may not be related to economic activity, and the stipulation of a road connection is also restrictive in the terrain of the *altiplano*, but at this stage, the intention is to separate those places in the data which are not at all related to Quetzaltenango from those which might be. An even more useful set of questions includes the ones which ask where the people in the place go to obtain various consumer items, commercial services, educational facilities, and government services (questions 105, 118, 130, 135, 142, 149, and 158). Most of these questions have several parts to them, and the total number of possible answers (some of which may be missing) is 38. Thus, we are in a position to directly determine the outside places that a given town or village relies on for things not supplied in that town or village.

3.2.2. Preliminary Partition

In order to try out the procedure outlined above, a preliminary partition of the sample was attempted, using question 20, the one about the most important nearby place. If an observation listed Quetzaltenango as the most important place, it was included on the first pass. The second pass scanned for the observations that listed places found in the first pass as the most important place, and so on. After three passes, no further places were identified. The preliminary partition of places is shown in Table 3.1.

3.2.3. Detailed Partition

The preliminary partition established the soundness of the technique, but it is not entirely satisfactory from an operational point of view. The question, "What is the most important nearby town connected by road?" suffers from being too vague (what makes a town "important"?) and from the stipulation of being connected by road. While the highway network is important for transport of certain types of goods in Western Guatemala, there is still considerable movement of goods by peddlers moving cross-country on foot. Fortunately, the detailed questions (noted above) provide us with the means for a partition of the region based on the trips that the inhabitants make to obtain a wide variety of items. Table 3.2 lists the questions included in the detailed partition.

The method used was essentially the same as for the preliminary partition. In the first pass, the data for each place were examined to find all references to Quetzaltenango. Places which listed that city as the answer to a majority of questions were considered directly linked. In the second pass, all connections were found to places selected in the first pass, and so on, until no new connections were found. There were, however, a few problems that arose to modify this mechanical process.

3.2.3.1. Missing values

Many of the answers to the questions listed in Table 3.2 were coded as "missing." Consultation with people who were familiar with how the survey had been administered in Guatemala revealed that a "missing" value could have two interpretations. In some cases it was a bona fide unreported item, but it could also indicate that the inhabitants of the place in question did not go anywhere for the specified good or service. Thus, if they bought corn locally, the question about where they went to buy corn was not applicable, and this generated a "missing value" code. If a service was not available at all (as in the case of many of the cooperatives), a similar result ensued. Consequently, allowances had to be made for these practices in making the detailed partition. The method used was to include a place if the majority of nonmissing values linked a place to one already in the system. Since the whole detailed partition was made by manually examining the raw data, it was possible to confirm that most of the missing values were encountered in connection with survey items concerning cooperatives or second or third most important locations of a given type. Since cooperatives are relatively uncommon in the region, and since many places would arguably have only one major source for a particular good, these missing value do not appear to invalidate the method employed.

3.2.3.2. Departamento capitals

The problem of missing value codes was particularly acute for the observations of departamento capitals. Because these places are the largest central places in the region, they are more nearly self-sufficient. Thus, inhabitants of departamento capitals have to travel elsewhere for very few goods and services. As was indicated above, this means that most of the answers to the questions used in the partition were coded as missing. This made deciding whether or not to include the places in the Quetzaltenango system more difficult. The importance of making the decisions correctly is magnified by the fact that there are many smaller places linked to each departamento capital, and so adding or subtracting one of these places would effectively mean adding or subtracting a large subsystem of central places. The places which were finally included were selected on the basis of consultation with the field experts and examination of published descriptions of the region, such as Smith (1972).

Table 3.1. Distribution of Preliminary Partition by Subsystem

Departamento[a]	Number of Places
Sololá	38
Totonicapán	50
Quetzaltenango	157
San Marcos	71
Huehuetenango	84
El Quiché	75
Total	75

[a]This listing is of the number of places linked to the departamento capitals. Some of these places are actually in neighboring departamentos.

Table 3.2. Source Questions for Detailed Partition

Question Number	Part Number(s)[a]	Description
105	1	Nearest corn market
	3	Nearest bean market
	5	Nearest rice
	7	Nearest coffee market
	9	Nearest produce market
	11	Nearest egg market
	13	Nearest meat market
	15	Nearest poultry market
	17	Nearest vegetable oil market
	19	Nearest clothing market
	21	Nearest dry goods (*merceria*) market
118	1,3,5	Sources of meat
130	1,3,5	Outside governmental locations[b]
135	1,4,7	Destination of primary students
	10,13,16	Destination of basic students

[a] Where several parts are indicated, it is because that question asked for the first, second, and third most important locations of the indicated type.

[b] "Outside" government locations are those outside of the village in question.

Table 3.2 continued

Question Number	Part Number(s)	Description
135	19,22,25	Destination of vocational students
	28,31,34	Destination of university students
142	1,3,5	Outside medical assistance
158	1	Saving & credit cooperative
	3	Agricultural cooperative
	5	Consumer cooperative
	7	Housing cooperative
	9	Commercial cooperative
	11	Transport cooperative
	13	Artisan's cooperative
	15	Other cooperative

3.2.3.3. The southwestern fringe

The survey area covered only about three-fourths of Guatemala. One region not surveyed was the coastal area to the southwest of the Quetzaltenango system. The lack of data on this region posed an "edge of the world" problem. Data from the northeast and east permitted finding a natural limit for the Quetzaltenango system in those directions. On the northwest the border with Mexico sets the limit of the system. Due north of the study region is the sparsely settled departamento of Petén, which could be ignored. However, the southwestern fringe of the study area was truncated more closely than one would have liked. A number of places on that border showed strong links to places that were not included in the survey. These were excluded from the Quetzaltenango system. It is thus possible that the system is incomplete on its southwestern edge, and that some of the excluded places would have been included, had observations been available all the way down to the coast. However, the coastal plain has a rather different orientation than the central highlands, being a region of large plantations rather than small peasant farms. Thus, it seems unlikely that much of the southwest would be oriented inwards, towards Quetzaltenango. It is more likely that these places would be linked to the port cities, whence the output of the plantations is exported.

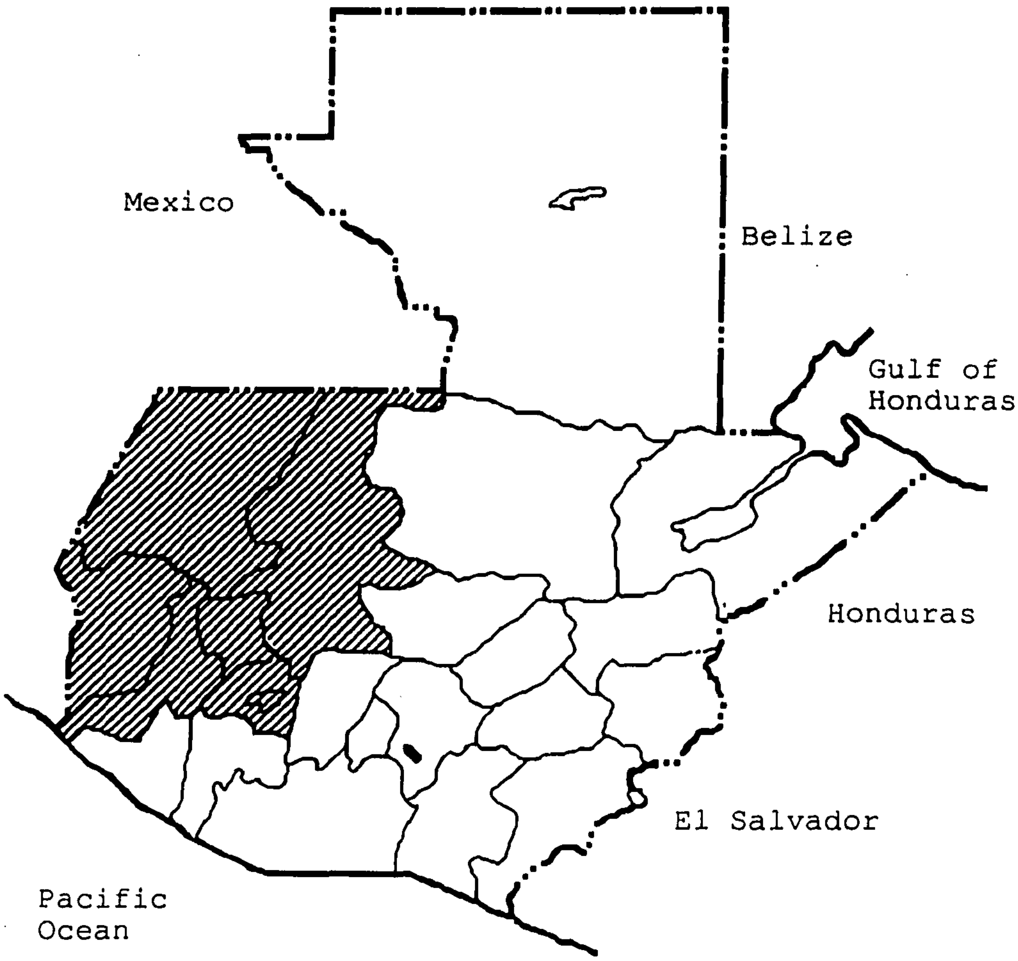

Figure 3.1. Map of Guatemala, Showing the Study Area

3.2.3.4. Summary of the detailed partition

The composition of the full system, as determined by the detailed partition, is summarized in Table 3.3, and Table 3.4 shows a comparison of the systems generated in the detailed and the preliminary partitions. The detailed partition includes about twice as many places as does the preliminary partition. This is mainly because the former includes many smaller places that the latter was not sensitive enough to detect. The geographical extent of the two partitions is approximately the same, including most of the departmentos of Sololá, Totonicapán, Quetzaltenango, San Marcos, El Quiché, and Huehuetenango (See Figure 3.1).

Table 3.3. Distribution of Detailed Partition by Subsystem[a]

Subsystem	Number of Places
Quetzaltenango	273
San Marcos	175
Huehuetenango	278
El Quiché	88
Total	914

[a]Note that in the detailed partition, the central places in Sololá and Totonicapán are part of the Quetzaltenango subsystem.

Table 3.4. Crosstabulation of Detailed and Preliminary Partitions

	Frequency Percent Row Percent Column Percent	Preliminary Partition: Out	In	Total
Detailed Partition	Out	1065 53.63 99.35 70.48	7 0.35 0.65 1.47	1072 53.98
	In	446 22.46 48.80 29.52	468 23.56 51.20 98.53	914 46.02
	Total	1511 76.08	475 23.92	1986 100.00

Only seven places were included in the preliminary partition but not in the detailed. Of these, one is in the departmento of Alta Verapaz, to the northwest of the study area; two are on the southeast fringe where the Quetzaltenango central place system merges with the one dominated by Guatemala City; three are in the far north of the region; and one is on the southwestern fringe. All of these places had some link to a place in the Quetzaltenango system, but the majority of their links were to places outside the study area.

3.3. The Preliminary Structure of the Quetzaltenango Subsystem

The entire study region contains 914 places. Cluster analysis, the most important statistical technique used to identify the central place hierarchy, requires a large amount of data manipulation. Even mainframe computers limit the number of observations which may be clustered to around 250.[1] In the case of this study, certain practical difficulties resulted in the cluster analysis being carried out on a microcomputer with only 64K of memory, using programs written by the author.[2] In order to reduce the data processing load, the study region was divided into four subsystems of manageable size. Each subsystem was named for the departamento capital which was its focal point: Quetzaltenango, Huehuetenango, San Marcos, and El Quiché. The Quetzaltenango subsystem consists of the central places in the departamentos of Quetzaltenango, Sololá, and Totonicapán, plus those places in San Marcos which were linked (during the detailed partition) to

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[1]For example, SAS (1979, 157-161) is limited to clustering a maximum of 250 observations.

[2]This was in 1984, when such machines were, while not state-of-the-art, at least second-line computers. In any case, each run of the cluster analysis program took literally about three days for the Kaypro II computer to complete.

places in Departamento Quetzaltenango. In addition, the outlying departamento capitals (i.e. the primary cities of the other subsystems) were included as part of the Quetzaltenango subsystem, on the grounds that they are the places immediately below Quetzaltenango city in the central place hierarchy. (Each of these departamento capitals was also included in the analysis of its own subsystem.) Most of the methods were developed using the Quetzaltenango subsystem by itself and then applied to the other subsystems in the study region.

3.3.1 Determination of the Place Hierarchy

3.3.1.1. The method employed

The original intention was to identify the various levels of the place hierarchy by the often-used technique of computing a centrality or "Davies" index for each place[3]. This index can be written as

$$D_i = \sum_k \left[\frac{t_{ik}}{\sum_i t_{ik}} \right] \tag{3.1}$$

where D_i is the index for place i and t_{ik} is the number of establishments[4] offering function k at place i. The is a weighed sum of the establishments offering central goods at a particular place, the weights being inversely proportional to the number of establishments of a particular type in the entire region. Thus, the presence of

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[3]See Davies (1967), Smith (1972), and Marshall (1969, 80-93, 161-168) for examples of this index being used.

[4]The number of establishments measures the level of function provision in a place. A common alternative measure is the number of persons employed in providing the central place function.

rare establishments (which presumably offer higher-level goods) give a central place a higher centrality rating than do common ones. Since the number of establishments of all types is positively correlated with population, the centrality index is usually plotted against place population. Sharp breaks in the scattergram are interpreted as representing changes in central place level.

This technique is computationally simple and makes a certain amount of intuitive sense. The increasing scarcity of establishments providing higher-level goods is probably the best theoretical clue we have for identifying such goods. However, the primary weakness of the method is that it relies on "eyeballing" the breaks in the scattergram. What one person perceives as a significant discontinuity, another will see as a minor jog. Since we have no theoretical basis for predicting how many separate levels a system of central places will have, we must rely entirely on how well an analyst can judge a geometric pattern.[5] While this element of professional judgment cannot be entirely eliminated (nor should it be), more quantifiable criteria would clearly assist in achieving reproducible results.

It was important to retain the essential idea behind the centrality index, which is that the hierarchy of central places can be identified by the distribution of services among the places in the region, with the most rare services being assumed to be of the highest level. Cluster analysis was used to provide a more rigorous way of identifying the important discontinuities. There are a few precedents for this approach. Beavon (1977) uses two different types of cluster

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[5]Beavon (1977) discusses this problem extensively.

analysis in his study of Cape Town.[6] Berry and Garrison (1958, 152-53) describe their criteria for classifying central places in terms that could be easily translated into cluster analysis, although it appears that they did not use any formal cluster analytic algorithm. The advantage of using cluster analysis is that it provides a somewhat less subjective procedure for uncovering the central places which are most similar to one another and for measuring the differences among the groups so identified. This hardly implies that the printout from a computer programmed to perform cluster analysis will simply list the Christallerian place hierarchy. Such a program will, after all, produce some kind of output, no matter what the data represent. However, cluster analysis is a fruitful method of generating a "rough-cut" central place hierarchy, which can be polished by further examination and analysis. That is the method which has been used: first, clustering the central places on the basis of services offered; second, examining the "fringes" of each tentative level for misclassified places; and third, using information gleaned from other subsystems and the goods hierarchy to feed back and iteratively improve the place classification.

This is not the place to present a full introduction to cluster analysis[7], but a brief summary is in order. Cluster analysis is used to identify groups or "clusters" of observations which are "similar" to one another in some respect. Unlike, for example, linear regression, cluster analysis is an algorithm or procedure, rather than a closed-form calculation. There are a wide variety of algorithms which fall

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[6]Beavon's study was primarily a study of intraurban service location, after Losch, but he includes an extensive criticism of central place theory in his introductory material.

[7]There are many such introductions available in the statistical literature. One useful one is Anderberg (1973).

under this general heading. Each takes a set of observations on some group of variables and begins grouping the observations which are most similar (however the particular algorithm defines similarity). Generally, the procedure continues this grouping process until all observations have finally been grouped into a single cluster that spans the data[8]. Thus, the output of cluster analysis consists of N sets of clusters, beginning will all observations separate and ending will all of them in one group. In between, the sets of clusters will represent more or less "natural" or "clean" partitions of the data. Depending on the algorithm employed, these sets of clusters may or may not be hierarchical. In a hierarchical clustering scheme, once a cluster is formed, the elements of the cluster can never again be separated. Succeeding clusters are formed by merging existing clusters. In nonhierarchical clustering, the criteria for determining the "closest" elements may allow for breaking up existing clusters. The second major problem of cluster analysis, after the choice of the algorithm, is how to evaluate which of these sets of clusters is best for the purpose at hand. With as many sets of clusters as there are original observations, some will be meaningful in terms of the research questions, while most will represent intermediate stages, in which "natural" classes are spread out across several different clusters.

In the case of a system of central places, the observations represent.the different places. The variables are measures of the amount of each central place function which is provided. (The details of how these are measured for this study are discussed below.) The lower-level places, being less complex, are apt to be clustered with each other first. There may be some intermediate places which

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[8]A less-used alternative procedure is to begin with a single cluster and break it down into smaller groups by separating the <u>least</u> similar elements.

happen to be very similar, and they also will be brought into clusters at an early stage. The higher-level places, which offer a wider variety of functions, are more likely to have significant differences from one another, and thus will tend to remain as isolated observations or perhaps small clusters until very late in the procedure. Since the lower-level places are more numerous, we should see a single large cluster absorbing most of the observations, with the more heterogeneous upper-level places being scattered in small clusters. As the procedure progresses, the single large cluster will by turns absorb places of higher and higher levels. The highest-level place, having functions duplicated nowhere else, should be the last observation to be absorbed.

The type of cluster analysis used in this study is of the "hierarchical agglomerative" type. This is to say that the analysis begins with all observations in separate ("singleton") clusters. The algorithm makes N-1 passes through the data, combining the two most similar existing clusters into a single new cluster. Thus, the analysis "agglomerates" the observations into larger and larger groups, ending when they are all members of a single cluster. The method is "hierarchical" because clusters are treated as indivisible units once they are formed. Each given cluster can be traced back to a set of earlier clusters.

The similarity measure used in this study is the multivariable Euclidean distance measure:

$$d_{ij} = \sqrt{\sum_{k=1}^{M}(x_{ik} - x_{jk})^2} \qquad (3.2)$$

where d_{ij} is distance measure between observations i and j, x_{ik} is the (normalized) number of establishments of type k at place i, and M is the total number of kinds of establishments. This is a “distance” type measure, which means that the larger d_{ij}

is, the less similar the two observations are. For cluster analysis, we must also define how we measure the similarity between nonsingleton clusters. This study employs the "complete linkage" method. This means that the similarity between two clusters is the similarity measure between the least similar pair of observations:

$$d_{ab} = \underset{i \in a,\ j \in b}{\mathrm{MAX}} [d_{ij}] \tag{3.3}$$

where d_{ab} is the distance between clusters a and b. The complete linkage method means that the distance between two clusters is the greatest distance between any two observations, one from each cluster. Thus, the distance between any pair of observations in a cluster formed by merging a and b will be less than or equal to d_{ab}.

3.3.1.2. Interpreting the cluster analysis

The algorithm proceeds by merging the two closest ("most similar") clusters at each iteration. This is an entirely mechanical process. It is the researcher's problem to determine which clusters are important to answering the question at hand. How to go about making this determination is one of the ongoing controversies of cluster analysis. The method chosen for this study is to examine the clusters where a statistic called the "clustering ratio" peaks with sufficiently large values.

The clustering ratio is based on the "cluster diameter", which is the maximum distance between any two observations in the same cluster. Using the complete linkage method, the diameter of each newly-formed cluster is the same as the distance between its parent clusters, d_{ab}. Since the algorithm merges the two existing clusters which are the smallest distance apart (i.e., are the most similar), it also minimizes the diameter of the next cluster formed. This means that the new cluster's diameter is the maximum of all current cluster diameters. By definition, all distances inside clusters are smaller than the maximum cluster diameter. The number of such within-cluster distances can be calculated by a combinatorial formula, since the number of elements inside each cluster is known. The "clustering ratio" is this count of within-cluster distances, divided by the total number of distances in the entire dataset which are less than the maximum cluster diameter:

$$R_m = \frac{\text{\# of } d_{ij}\text{'s within clusters}}{\text{total \# of } d_{ij}\text{'s} < d_{ab}} \tag{3.4}$$

where R_m is the clustering ratio after the mth merge. Since all of the d_{ij}'s for elements inside the same cluster will be less than the maximum cluster diameter (d_{ab}), R_m will always be less than or equal to unity. If R_m is less than unity, some of the distances between observations that are less than d_{ab} are distances <u>across</u> clusters, rather than within them. In other words, some elements are closer to observations which are <u>not</u> members of their clusters than they are to their own cluster members. If each of the elements <u>within</u> a cluster is closer to its fellow cluster members than to any observations <u>not</u> in that cluster, and this is true across all clusters, the clustering ratio will be equal to unity. If there are many cluster members which are closer to nonmembers than to members, the clustering ratio will be low. Thus, the ratio is a measure of how "clean" a partition of the dataset a given set of clusters is. It is a useful guide to which clusters may represent some "natural" grouping of the observations.

As shown in Figures 3.2 through 3.9 and the tables in Appendix B, the clustering ratio follows a partially predictable pattern over the course of an analysis. It generally rises at first, especially if there are many identical observations in the dataset (since the distance between these is zero). After all identical observations have been clustered with one another, the ratio decays and then enters an erratic phase where it fluctuates up and down. Eventually, as more and more observations are included in a single large cluster, the clustering ratio will rise again. It will always be equal to unity at the end of the analysis, since the maximum cluster diameter will be equal to the maximum distance between any two observations. It is in the "erratic phase" that peaks in the clustering ratio are most interesting. As the number of clusters decreases, the clustering ratio must peak at higher and higher levels to be of any significance. In this study, clustering ratios above 0.95 were considered interesting, with more "9s" being added after the first one as the number of clusters decreased. The dotted lines in the figures show the critical merges that were used to define the hierarchy.

3.3.1.3. Choice of variables

Since central place theory is concerned with the provision of private, market-oriented goods and services, all public service facilities were excluded from the data used in the cluster analysis. All of the private facilities, with the exception of educational and health facilities, were included. (The health and educational facilities will be examined in Chapters V and VI.) In some cases, several kinds of similar establishments were combined into aggregate variables. This was done for a variety of reasons. Some variables represented supplied essentially the same good under different institutional arrangements. For example, the survey data include variables for the number of booths selling the same various items at both the marketplace and the plaza of each place. These variables were combined on the grounds that what was important was the availability of a good at a place, and not where in the place it was available. In some cases goods were combined which were less similar (but still related to one another) into larger aggregates, such as "store food" and "private agricultural services." The larger categories were constructed in order to reduce the data processing load. The variables included in the aggregates were selected if they had reasonably high intercorrelations (see Table 3.6). Some of the aggregate variables had to be broken up or discarded later, when it was discovered that they did vary by central place level (see Section 3.4.2, below). The variables used in the initial cluster analysis of the Quetzaltenango subsystem are listed in Table 3.5.

Table 3.5. Variables Used in Initial Analysis of Quetzaltenango Subsystem

Simple variables:

Question Number	Part Number(s)	Description
94	04	Marketplace prepared food
	08	Marketplace various articles
95	10	Plaza plastic vendors
	19	Maize-cake (*panela*) vendors
	22	Plaza ceramics vendors
	25	Plaza *jarcia* vendors[a]
95	31	*"Ventas tipicas"* (i.e., handicrafts)
	34	Plaza "other vendors"
104	02	General stores (*pulperias*)
	03	Cantinas
	06	"Low-class" restaurants (*comedores*)
	09	Tailor shops
	11	Carpentry workshops
	16	Cafeterias
	17	Bars and restaurants

[a] "Jarcla" and "merceria" seem to have a special meanings in the Guatemalan highlands. Standard Spanish dictionaries translate both as "dry goods" or "haberdashery." "Merceria" seems to be related to the English "mercer," which refers to cotton products, as in the phrase, "mercerized thread." The distinction between these goods in the Guatemalan context is not clear, but establishments selling these two goods to have distinct distributions among the central places.

Table 3.5 continued

Simple variables continued:

Question Number	Part Number(s)	Description
104	19	Barber shops
	20	Gasoline stations
	21	Billiard parlors
	22	Construction materials
	24	Electrical equipment
	25	Hardware shops
	28	Fireworks
	29	Stationary and book stores
	31	Undertakers
	32	Blacksmiths
	33	Chandlers
	36	Palm article vendors
	38	Saddleries
	39	Pita article shops[b]
	41	Machine shops
	42	Veterinarians
	43	Hat shops
	44	Nonalcoholic beverages
	45	New and used auto dealerships
	46	Paint stores
	47	Nightclubs
	48	Watchmakers
	50	Propane sellers
	51	Photography
	52	Electricians
	53	Liquor
	54	Coffee shops
	55	Banks or agencies
	56	Musical groups
	57	Radio and television stores
	58	Ice cream stores
	59	Photocopy shops
	60	Locksmiths
	61	Furniture stores
	71	Other stores

[b] Pita is a type of vegetable fiber used for making baskets, etc.

Table 3.5 continued

Simple variables continued:

Question Number	Part Number(s)	Description
145		Lawyers and notaries
171	03	Weekly periodicals
	05	Monthly periodicals
	07	Wall periodicals[c]

Aggregate variables:

Question Number	Part Number(s)	Description
CLOTHING		Ready-made clothing
94	5	Marketplace clothing sellers
95	16	Plaza clothing sellers
104	10	Clothing stores
FOOTWEAR		Shoes, shoe repair, etc
94	6	Marketplace footwear sellers
95	13	Plaza footwear sellers
104	12	Shoe workshops
	13	Shoe stores
LODGINGS		Hotels and boarding houses
104	14	Boarding houses
	49	Hotels
MEAT		Total meat sellers
94	2	Marketplace meat sellers
	3	Marketplace pig sellers
104	4	Butcher shops
	18	Pig butchers
	62	Chicken/egg stores
106		Municipal slaughterhouse

[c] "Wall periodicals" are newspapers which are posted on walls rather than being sold to individual readers.

Table 3.5 continued

Aggregate variables continued:

Question Number	Part Number(s)	Description
MERCERIA[a]		Market and store merceria
95	28	Market merceria sellers
104	15	Store merceria
MKT_FOOD		Marketplace unprepared food
94	7	Marketplace food sellers
95	1	Plaza food sellers
	4	Plaza grain vendors
	7	Fruit and vegetable sellers
MOVIE		Public and private movie theatres
165	1	Private movie theatres
165	4	Public movie theatres
PR_AG_SV		Private agricultural. services
104	23	Seed stores
	26	Agrichemical stores
	27	Fertilizer stores
	37	Grain mills (commercial)
153		Agricultural storage facilities
PUBLISH		Printing and daily periodicals
104	35	Printing and editing
171	01	Daily periodicals
STR_FOOD		Total unprepared store food
104	01	Food stores (*tiendas*)
	05	Corn mills (consumer)
	07	Bakeries
	08	Misc. food stores
	34	Supermarkets
	40	Dairies
THEATRE		Theatres and exhibition halls
165	07	Other exhibition halls
166		Legitimate theatres

Table 3.6. Correlation Coefficients Among Aggregate Variable Components

CLOTHING Ready-made Clothing

	Market+Plaza[a]	Store
Market+Plaza	1.000	0.597
Store	0.597	1.000

FOOTWEAR Shoes, shoe repair, etc.

	Workshops	Store	Market+Plaza
Workshops	1.000	0.808	0.470
Store	0.808	1.000	0.544
Market+Plaza	0.470	0.544	1.000

LODGINGS Hotels and boarding houses

	Boarding Houses	Hotels
Boarding Houses	1.000	0.729
Hotels	0.729	1.000

MEAT Total meat sellers

	Market	Market pig	Butcher	Pig butcher	Chic.& Egg	Slaughter
Market	1.000	0.799	0.679	0.276	0.713	0.469
Market pig	0.799	1.000	0.512	0.246	0.818	0.364
Butcher	0.679	0.512	1.000	0.495	0.555	0.516
Pig butcher	0.276	0.246	0.495	1.000	0.282	0.417
Chic.& Egg	0.713	0.818	0.555	0.282	1.000	0.271
Slaughter	0.469	0.364	0.516	0.417	0.271	1.000

MERCERIA Market and store *merceria*

	Market	Store
Market	1.000	0.067
Store	0.067	1.000

MKT_FOOD Marketplace unprepared food

	Market+Plaza	Plaza grain	Fruit & veg.
Market+Plaza	1.000	0.497	0.650
Plaza grain	0.497	1.000	0.709
Fruit & veg.	0.650	0.709	1.000

[a] The number of marketplace and plaza booths were added together before the correlation coefficients were calculated.

Table 3.6 continued

MOVIE Movie theatres

	Private	Public
Private	1.000	-0.012
Public	-0.012	1.000

PR_AG_SV Private agricultural services

	Seed	Agrichemical	Fertilizer	Grain mill	Storage
Seed	1.000	0.518	0.399	0.291	0.265
Agrichemical	0.518	1.000	0.580	0.477	0.245
Fertilizer	0.399	0.580	1.000	0.395	0.248
Grain mill	0.291	0.477	0.395	1.000	0.165
Storage	0.265	0.245	0.248	0.165	1.000

PUBLISH Printing and daily periodicals

	Printing & Editing	Daily periodicals
Printing & Editing	1.000	0.970
Daily Periodicals	0.970	1.000

STR_FOOD Total unprepared store food

	tiendas	Corn mills	Bakeries	Misc.	Supermarkets	Dairies
tiendas	1.000	0.547	0.447	0.353	0.496	0.448
Corn mills	0.547	1.000	0.698	0.513	0.745	0.695
Bakeries	0.447	0.698	1.000	0.643	0.814	0.807
Misc.	0.353	0.513	0.643	1.000	0.702	0.671
Supermarkets	0.496	0.745	0.814	0.702	1.000	0.953
Dairies	0.448	0.695	0.807	0.671	0.953	1.000

THEATRE Legitimate theatres and exhibition halls

	Theatre	Other exhibition
Theater	1.000	0.272
Other exhibition	0.272	1.000

To prepare the data for cluster analysis, all variables were normalized to zero mean and unit standard deviation. This has much the same effect as calculating a centrality index, since the presence of a rare establishment in a place will be reflected in a higher standardized value for that variable than will the presence of a relatively abundant kind of establishment. The similarity matrix for the cluster analysis was calculated on the basis of these normalized variables, using the Euclidean distance measure described above.

3.3.1.4. Cluster analysis of the Quetzaltenango subsystem

When this method was applied to the 276 places of the Quetzaltenango subsystem, it identified five sets of clusters with sufficiently high clustering ratios. As is shown in Table 3.7, The lowest clustering ratio which was accepted was 0.9776.[9] This defined the "rough cut" hierarchy. Figure 3.2 shows a graph of the changes in the clustering ratio as the clustering took place. Figure 3.3 shows a magnified view of the same information as Figure 3.2, near the end of the procedure when the clustering ratio was very high. In both figures, the dotted vertical lines show the critical merges which defined the hierarchy. The early peak of the graph is the point where all identical observations are clustered together.

Table 3.7. Critical Merges in Cluster Analysis of Quetzaltenango Subsystem

Merge No.	Maximum Diameter	Within Dists	Total Dists	Clustering Ratio
232	3.346	25886	26480	0.97757
253	10.469	31879	32397	0.98401
270	28.965	36585	36637	0.99858

Because low-level central places are those which have the smallest variety of services, most of the variable values for such are zero (before normalization). Low-level places have smaller distance values between one another and thus tend

[9]The details of the cluster merges are provided in Table B.1 of Appendix B.

to be clustered early. The pattern of the cluster analysis was to build up a single large cluster containing the bulk of the observations, with a smattering of smaller nonsingleton clusters and the rest of the places still in singletons. This pattern follows what we would expect if the lower-level places in each set of clusters are in the large cluster, while the higher-level places are still singletons. The small nonsingleton clusters have to be examined more carefully on an individual basis, but they are usually higher-level places as well.

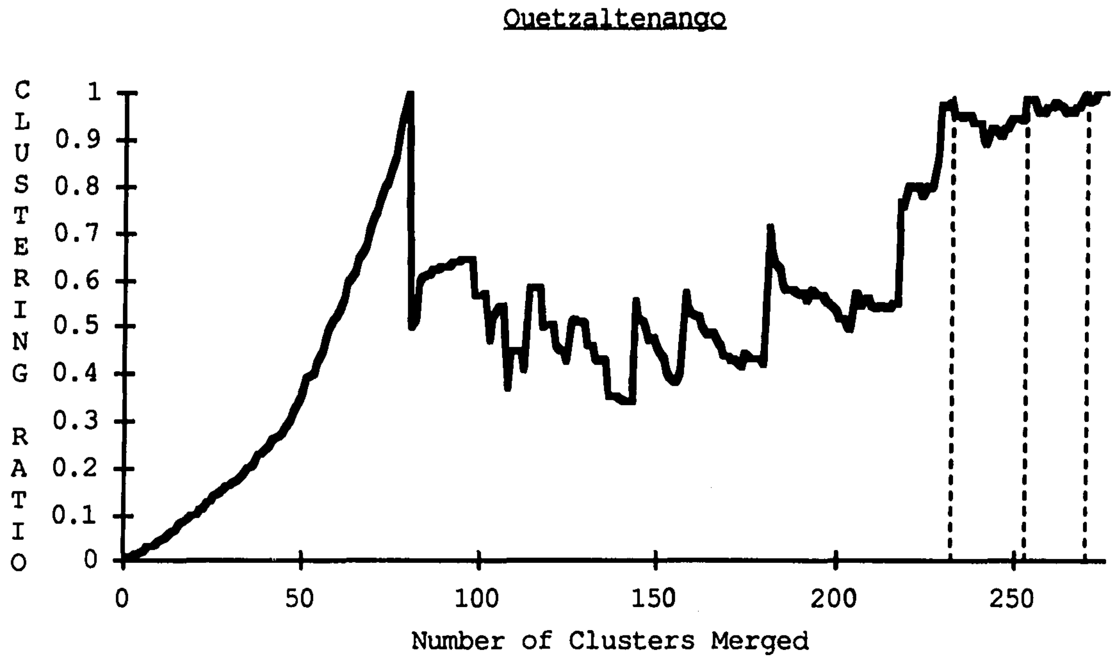

Figure 3.2. Clustering Ratios for Quetzaltenango Subsystem

The lowest level of the hierarchy was defined by the earliest set of clusters with a high clustering ratio, by assigning all the places in the largest cluster to the lowest central place level. These would become the level 5 central places, once the total number of levels had been determined. The remaining places were tentatively classified as being at least of level 4. For the next set of clusters with a high ratio, all of the places which had been merged into the largest cluster were classified as level 4 places. Classifying the level 3 and level 2 places was done in the same manner. The level 1 place is, by plan, Quetzaltenango itself.

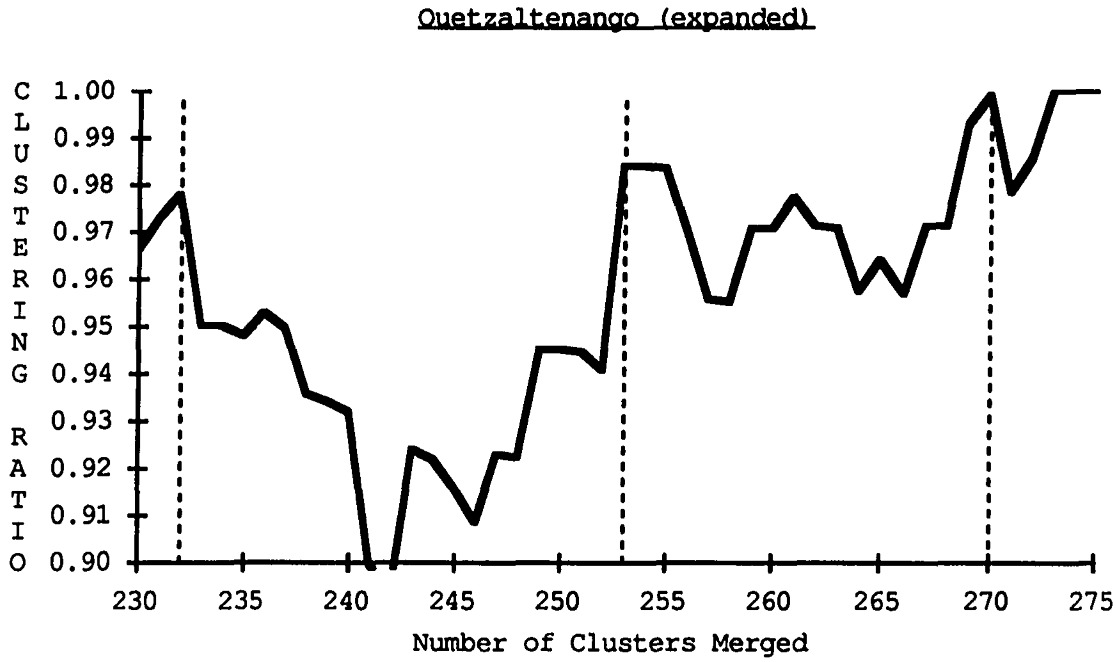

Figure 3.3. Magnified View of Clustering Ratios in the Quetzaltenango Subsystem

The next step was to check for misclassified places on the upper and lower fringes of each level. The sum over the normalized establishment variables for each place has essentially the same interpretation as the conventional centrality index, in that it is weighted in favor of places which have an abundance of rare (and hence high level) functions. Let us call this sum the "normalized centrality index" or NCI:

$$NCI_i = \sum_k \frac{t_{ik} - \bar{t_k}}{S_k} \tag{3.5}$$

where NCI_i is the index for place i, t_{ik} is the number of establishments of type k at place i, $\bar{t}_k$ is the mean number of establishments of type k over all places, and S_k is the standard deviation of t_{ik}. Some characteristics of the NCI values by level are shown in Table 3.8.

Table 3.8. NCI Characteristics of the "Rough-Cut" Hierarchy, Quetzaltenango Subsystem

Merge	NA	270	253	232	≤232
Level	1	2	3	4	5
Frequency	1	4	18	23	230
Standard Deviation	NA	33.570	25.010	5.368	1.258
Minimum	NA	116.523	1.579	-4.911	-8.745
First Quartile	NA	119.914	22.184	-3.003	-8.598
Mean	558.089	143.205	36.861	0.880	-7.890
Third Quartile	NA	177.703	53.483	3.488	-7.620
Maximum	NA	192.300	105.215	17.560	1.880

Table 3.9. Places Which Were Reclassified After NCI Examination, Quetzaltenango Subsystem

Place ID	Original Level	New Level	NCI
1201001	3	2	105.2150
914001	4	3	17.5604
904001	4	3	10.8296
714001	3	4	3.3541
803004	5	4	1.8795
801019	3	4	1.5794
804001	5	4	0.8571
914006	5	4	-3.0687
901019	5	4	-4.1041
701008	5	4	-4.7791

The places in each tentative central place level were sorted in order of their NCI values. If the upper range of one level's NCI overlapped the lower range of the next higher level, the places within the overlap were examined for possible reclassification. The rule used was that a place would be assigned to the level whose mean NCI was closer in standard deviations to the place's own NCI. In all, a total of 10 places (out of 276) changed central place level because of the application of this rule. Their NCI values are shown in Table 3.9.

3.3.2. First Approximation of the Goods Hierarchy

3.3.2.1. Method employed

Since a good is a "level n good" if the central places of "level n" or higher supply this good and those of lower level do not, what matters most is whether or not a good is available at a particular place. The number of establishments is not as important as the existence of any such establishments. Classifying a good is a matter of ascertaining how far down the hierarchy the good is generally available. To accomplish this, all the goods variables were recoded to dichotomous values, with "1" indicating that the good was available at a place, and "0" indicating that it was not. For each good, the mean of this dichotomous variable was computed, separately by central place level. Note that for this kind of variable, the mean is simply the proportion of places at a particular level which supply the good in question.

Ideally, a "level n" good should have a mean of 1.00 for all places at "level n" or higher, and 0.00 at lower levels. However, the world is not ideal. There are mislocations of services, which means that they may be missing at higher level places while present at those of a lower level. Thus, a certain amount of judgment is necessary in devising a cut-off proportion for deciding the level of a particular good. For this primary classification a base value of 0.67 was used. Thus, if at least two-thirds of the places of a particular central place level offered a good, it was classified as a good of at least that level. This was not a rigid line, however.

Allowances were made for special circumstances where warranted. A trivial example of these was the fact that there were only five second-level places, which meant that the cut-off level had to be 0.60 rather than 0.67. In some cases, goods which did not quite meet the cut-off at a particular level (generally 3 or 4) but which had substantial (40-50%) occurrences at even lower levels were classified at the higher level anyway. Finally, there was such a lack of any services at the lowest levels that anything over 0.50 was examined carefully. The first approximation of the goods hierarchy is listed in Table 3.10.

Table 3.10. Functional Levels Using 67% Cut-Off[a]

Level 1 functions	
Chandlers (weak)	Hat shops (weak)
Palm article vendors	Nonalcoholic beverages (weak)
Saddleries (weak)	New and used auto dealerships
Pita article shops	Nightclubs
Veterinarians	Locksmiths (weak)
Level 2 functions	
Plaza "other vendors"	Grain mills[b] (agricultural)
Cafeterias	Banks or agencies
Bars and restaurants	Musical groups
Gasoline stations	Radio and television stores
Billiard parlors	Ice cream stores
Construction materials (weak)	Photocopy shops
Electrical equipment	Furniture stores
Hardware shops	Chicken/egg stores[c]
Fertilizer stores[b] (weak)	Other stores
Stationary and book stores	Lawyers and notaries (weak)

[a] The comment "(weak)" indicates that there was substantial occurrence of this function at lower levels, although at less than the cutoff percentage.

[b] This function was formerly part of PRV_AG_SV.

[c] This function was formerly part of MEAT.

Table 3.10 continued

Level 2 functions continued	
Undertakers	Monthly periodicals
Blacksmiths	LODGINGS (weak)
Liquor	MEAT
Machine shops	MERCERIA (weak)
Paint stores	MOVIE (weak)
Watchmakers	PUBLISH
Propane sellers	STR_FOOD
Photography (weak)	THEATRE
Electricians	
Level 3 functions	
Market place prepared food	Barber shops (weak)
Plaza plastic vendors	CLOTHING
"Low-class" restaurants (*comedores*)	FOOTWEAR
Carpentry workshops	MKT_FOOD
Level 4 functions	
General stores (*pulperia*) (60%)	Butcher shops[c] (61%)
Cantinas (but level 5 is 36%)	Tailor shops
Level 5 functions	
Grocery stores (tiendas)[d]	Corn mills (consumer)[d] (59%)
Functions dropped from the analysis	
Mkt various articles	(not central good)
Maize-cake (panela) vendors	(not central good)
Plaza ceramics vendors	(not central good)
Plaza Jarcia vendors	(not central good)
"Ventas tipicas"	(not central good)
Seed stores[b]	(no hierarchical pattern)
Agrichemicals[b]	(no hierarchical pattern)
Fireworks	(not central good)
Coffee shops	(too few to be analyzed reliably)
Agricultural storage[b]	(no hierarchical pattern)
Weekly periodicals	(too few to be analyzed reliably)
Wall periodicals	(too few to be analyzed reliably)
PR_AG_SV	(broken into component variables)

---

[d] This function was formerly part of STR_FOOD.

3.3.2.2. Changes in the selected variables

Some problems with the original set of central functions (i.e., good or service provision) came to light when their distribution could be examined over the central levels. Three of the functions (indicated in Table 3.10) were present in such small numbers in the subsystem that they could not be reliably analyzed. Rare occurrences are not necessarily a mark of data problems, since we expect that the higher-level functions will be rare. However, the functions in question did not exist at the level 1 place, but were scattered in different places which otherwise offered low-level services. These functions were dropped from the analysis of the outlying subsystems.

A group of six goods do not appear to meet the Christallerian definition of central goods at all. Central place theory is primarily about the location of tertiary services dependent on the distribution of the population they serve. All of the goods listed as "not central good" in Table 3.10 exhibit a pronounced concentration of establishments in single places (one for each good). These places are primarily level 3 places in other respects. It appears that these goods are produced at specialized manufacturing centers, either as export goods (through the tourist trade) or for distribution to the other places in the region (possibly by peddlers).

Another group of functions consists of components of the PR_AG_SV (private agricultural services) aggregate variable. Some of these components were found to have no discernible pattern with respect to the central place hierarchy. All such functions are present in the level 1 place, but their occurrence in level 2 places is only 40%. Even so, some lower-level places have as many establishments or more than the level 2 places. The functions were dropped from the analysis. Two of the private agricultural service variables (grain mills and fertilizer) did follow a central place pattern, and these were entered into hierarchy by themselves.

Some of the goods that had been included in aggregates were found to differ substantially from the goods with which they were aggregated. The variables, "grocery stores" and "grain mills (consumer)[10]" are found virtually everywhere, making them level 5 goods. They had been included in STR_FOOD (store unprepared food), which consists of level 2 goods, except for those two goods. They were taken out of the aggregate and treated separately. Similarly, "butcher shops," part of the MEAT aggregate, was found to be a level 4 good, while the rest of the elements of that aggregate are level 2 goods. The variable was removed from the aggregate and treated separately.

3.4. Identifying the Central place Structure of the Full System

3.4.1. The Place Hierarchies of the Outlying Subsystems

The method described above was applied to the places of the other three subsystems in the study region. For these places, the distance matrix was computed using all of the functions which are given a level rank in Table 3.10. Each subsystem's set of variables was normalized separately. The cluster analysis was used to order the places in a rough pattern, and then the NCI computation was used to refine this pattern.

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[10]"Consumer" grain mills are small establishments where families take corn to be ground for their own use. "Agricultural" grain mills are larger establishments where farmers take grain to be ground for sale.

3.4.1.1. The San Marcos subsystem

The sequence of merges in the cluster analysis of the San Marcos subsystem are detailed in Table B.2 of Appendix B. Figure 3.4 below shows the graph of the clustering ratio as the clustering procedure progressed, and Figure 3.5 shows a magnified view. The most interesting difference between Figure 3.4 and the corresponding graph for the Quetzaltenango subsystem (Figure 3.2) is that the San Marcos subsystem exhibits some very "clean" clusters early in the procedure, as is indicated by the peaks in the graph at the 75th and 83rd merges. This made it more difficult to determine where to partition the places in order to determine the hierarchy. At this stage, the working assumption was that the level 5 places found in the Quetzaltenango subsystem represented the lowest level of the hierarchy. This was later found to be an error, as is explained below. In the next chapter, it will be demonstrated that San Marcos has the largest population of these sub-level-5 places. This would account for the significant early merges, but it was not realized until later.

Table 3.11 shows the critical merges of the cluster analysis and their corresponding clustering ratios. Since the presumed top level of this subsystem was represented by the city of San Marcos (ID 1201001), which was a level 2 place in the Quetzaltenango subsystem, the problem was how to differentiate among the central places below this level. This was done on the basis of NCI values, which are shown in Table 3.12.

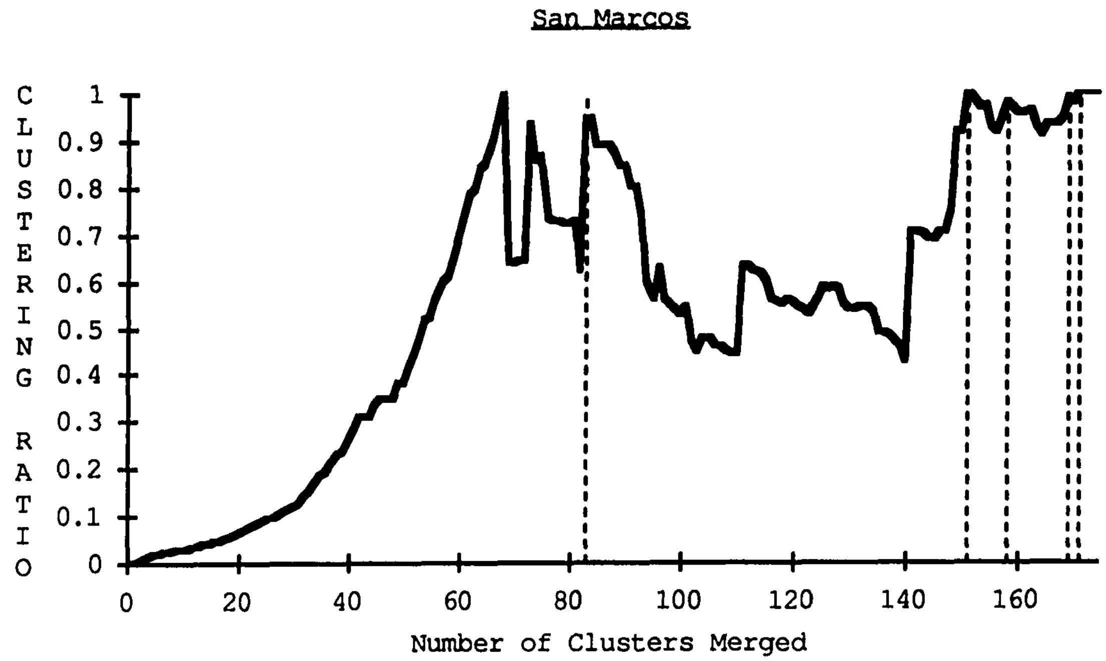

Figure 3.4. Clustering Ratios for San Marcos Subsystem

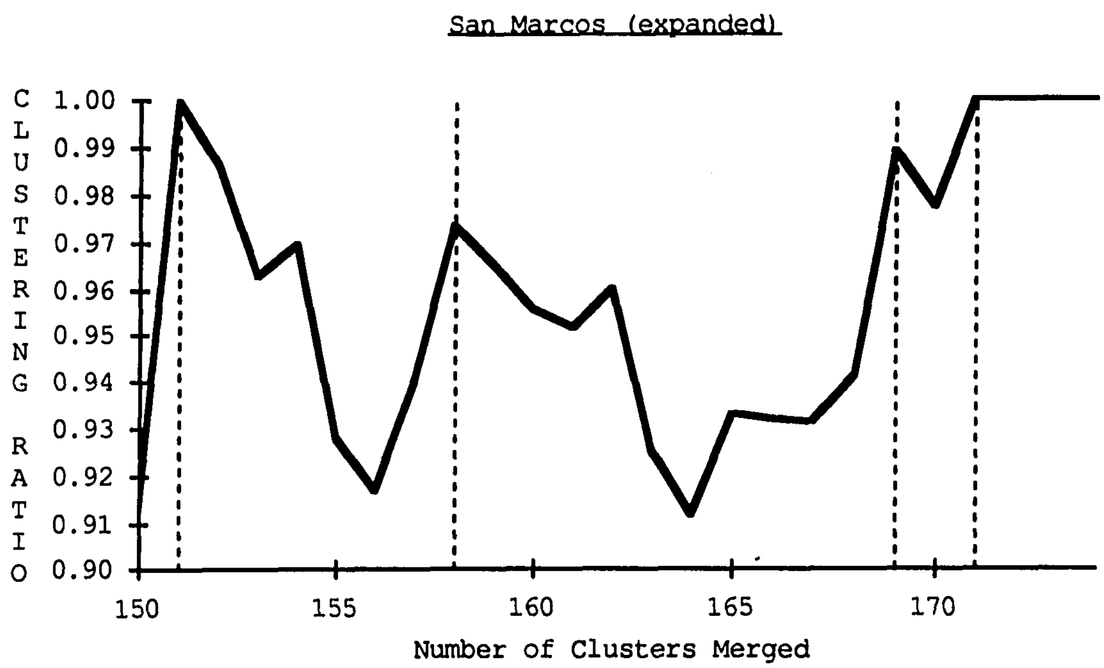

Figure 3.5. Magnified View of Clustering Ratios for San Marcos Subsystem

Table 3.11. Critical Merges in Cluster Analysis of San Marcos Subsystem

Merge No.	Maximum Diameter	Within Dists	Total Dists	Clustering Ratio
83	0.287	1629	1726	0.94380
151	5.433	11476	11478	0.99983
158	11.182	12561	12903	0.97349
169	20.217	14365	14527	0.98885
171	25.034	14706	14706	1.00000

In Table 3.12, the merge numbers are the significant points in the cluster analysis. The partition proceeded from the top down. Thus, the two places listed under 171 were the only places which were singletons after the 171st merge. The three places under 169 were singletons after the 169th merge, but were not still singletons after the 171st, and so on. The places accounted for in the "<83" column were already merged into the largest cluster by the time of the 83rd merge. The level numbers indicated are the preliminary levels to which each of these groups of places were assigned, on the basis of comparing NCI characteristics. The places partitioned by the 151st and 158th merge have a considerable amount of overlap, and they were classified as both representing level 4. The places from the 83rd merge and below are all have very low NCI values, considerably lower than the next partition, and thus were classified as level 5.

At the 83rd merge, there were seven nonsingleton clusters, apart from the largest one. Some of their NCI characteristics are shown in Table 3.13. The "cluster numbers" are the merge at which these particular clusters were formed. Thus, cluster 27 was formed by the 27th merge, and remained unchanged through the 83rd, while cluster 82 was formed by the 82nd merge, and so on. Since all of these clusters had NCI characteristics of the level 5 places already classified, they were also classified as level 5.

Table 3.12. NCI Characteristics for "Rough-Cut" Partition of San Marcos Subsystem

Merge	≤ 83	83	151	158	169	171
Level	5	5	4	4	3	2
Frequency	56	60	7	11	2	3
Standard Deviation	0.090	2.584	6.024	13.411	14.564	144.134
Minimum	-9.9025	-9.2942	1.188	2.1769	73.3225	117.217
First Quartile	-9.9025	-8.1863	2.535	10.7795	NA	404.775
Mean	-9.8367	-6.2672	8.622	21.0404	83.6209	266.838
Third Quartile	-9.7504	-4.9771	13.457	31.5054	NA	404.774
Maximum	-9.5591	2.3908	17.114	43.0255	93.9193	404.775

Table 3.13. NCI Characteristics of Nonsingleton Clusters after the 83rd Merge, San Marcos Subsystem

Cluster Number	Frequency	Minimum	Mean	Maximum
27	2	-9.2658	-9.2658	-9.2658
70	4	-9.1998	-9.1798	-9.1198
75	8	-9.5983	-9.5033	-9.4462
78	7	-9.3598	-9.2018	-8.7513
80	4	-9.5026	-9.4646	-9.4227
81	9	-9.1356	-9.0307	-8.9521
82	2	-8.9665	-8.9226	-8.8787

Finally, the tentative partition had to be examined for unusually high or low NCI values at each level, and extreme cases had to be adjusted up or down a level as a consequence. This was done using the same procedure as was used for the Quetzaltenango subsystem. Table 3.14 summarizes the places which were moved.

Table 3.14. Places Which Were Reclassified after NCI Examination, San Marcos Subsystem

Place ID	Original Level	New Level	NCI
1206001	2	3	117.217
1208001	5	4	2.391

3.4.1.2. The Huehuetenango subsystem

The clustering ratios of the Huehuetenango subsystem are graphed in Figure 3.6, and Figure 3.7 shows the magnified view.[11] This subsystem is more like that of Quetzaltenango than San Marcos, in that its clustering ratios show no important early peaks, except for a minor one that barely reaches to 0.7. The critical merges which were used to partition the subsystem are shown in Table 3.15.

Table 3.16 shows the NCI characteristics of the Huehuetenango subsystem partition. On the basis of these characteristics, the same adjustment procedure was followed as for the two previous subsystems. The places which changed level as a result of this procedure are shown in Table 3.17. An unusual characteristic of this subsystem is that the merge which defined the division between the levels 4 and 5 (i.e., the 252nd merge) left the tentative level 5 places with such a high maximum. The mean and even the third quartile values are reasonably low, but a number of extreme values were included in the rough-cut partition. This accounts for the relatively high number of places which had their levels adjusted on the basis of their NCI values.

[11] See Table B.3 in Appendix B for the complete sequence of merges, cluster diameters, and clustering ratios for this subsystem.

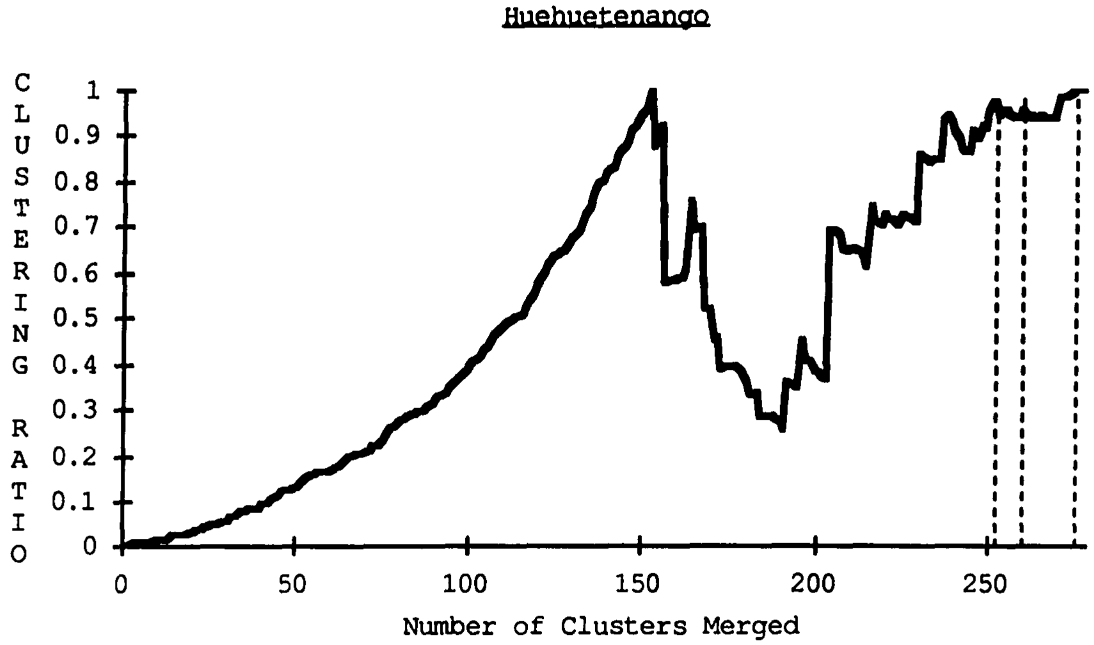

Figure 3.6. Clustering Ratios for Huehuetenango Subsystem

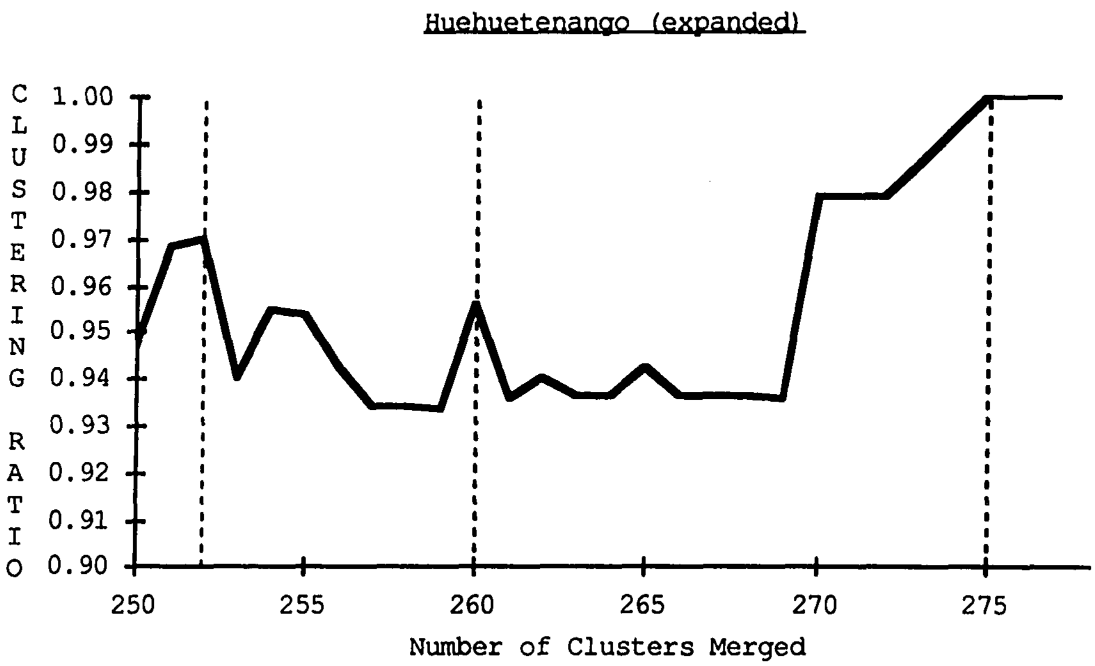

Figure 3.7. Magnified View of Clustering Ratios for Huehuetenango Subsystem

Table 3.15. Critical Merges in the Cluster Analysis of the Huehuetenango Subsystem

Merge No.	Maximum Diameter	Within Dists	Total Dists	Clustering Ratio
252	9.2014	31128	32103	0.96963
260	14.670	33156	34688	0.95584
275	35.671	37950	37950	1.00000

Table 3.16. NCI Characteristics for "Rough-Cut" Partition of Huehuetenango Subsystem

Merge	≤252	252	260	275
Level	5	4	18	2
Frequency	250	8	3	2
Standard Deviation	2.5022	6.5865	22.7294	263.7474
Minimum	-7.4990	-1.7549	5.5720	184.513
First Quartile	-7.2471	0.9376	27.8237	NA
Mean	-6.1047	7.3934	40.2776	371.011
Third Quartile	-6.1277	12.3885	49.1104	NA
Maximum	8.9228	17.7951	85.5689	557.508

Table 3.17. Places Which Were Reclassified after NCI Examination, Huehuetenango Subsystem

Place ID	Original Level	New Level	NCI
1326001	2	3	184.513
1312010	5	4	-2.1094
1301037	5	4	-1.6943
1304109	5	4	-1.4570
1301015	5	4	-1.4024
1302005	5	4	-1.4024
1206022	5	4	-0.4321
1328001	5	4	-0.3927
1306056	5	4	0.7335
1330001	5	4	0.7859
1326136	5	4	1.3327
1310001	5	4	1.7286
1323001	5	4	2.2742
1331001	5	4	4.5035
1304003	5	4	4.5363
1322001	5	4	4.9245

Table 3.17 continued

Place ID	Original Level	New Level	NCI
1315001	5	4	5.3186
1319001	5	4	5.3422
1301003	3	4	5.5720
1303061	3	4	6.8995
1316001	3	4	12.1074

3.4.1.3. The El Quiché subsystem

The final subsystem to be analyzed was that centered on Santa Cruz del Quiché, including, for the most part, places in Departamento El Quiché. The clustering ratios are graphed in Figure 3.8, with the magnified view in Figure 3.9.[12] This subsystem shows the usual early peak when all identical places have been clustered (after the 54th merge), but after that there are no large clustering ratios until late in the analysis, beginning with the 169th merge. The critical merges of the cluster analysis are shown in Table 3.18.

The NCI characteristics of the central place partition for this subsystem are shown in Table 3.19. In this table, the characteristics for the groups defined by the 54th merge and below are also shown, although the high clustering ratio for this merge was an artifact of the clustering procedure, rather than an indication of a critical merge. Thus, the 169th merge defines the division between the level 5 and level 4 places. Since the two places partitioned by merge 181 were fairly close to the maximum of the level 4 places and farther from the minimum of the places in the 183rd merge, they were classified as level 4. The last place to be merged into the large cluster was the departamento capital, which was classified at level 2 during the analysis of the Quetzaltenango subsystem.

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[12]See Table B.4, in Appendix B, for the sequence of merges, cluster diameters, and clustering ratios.

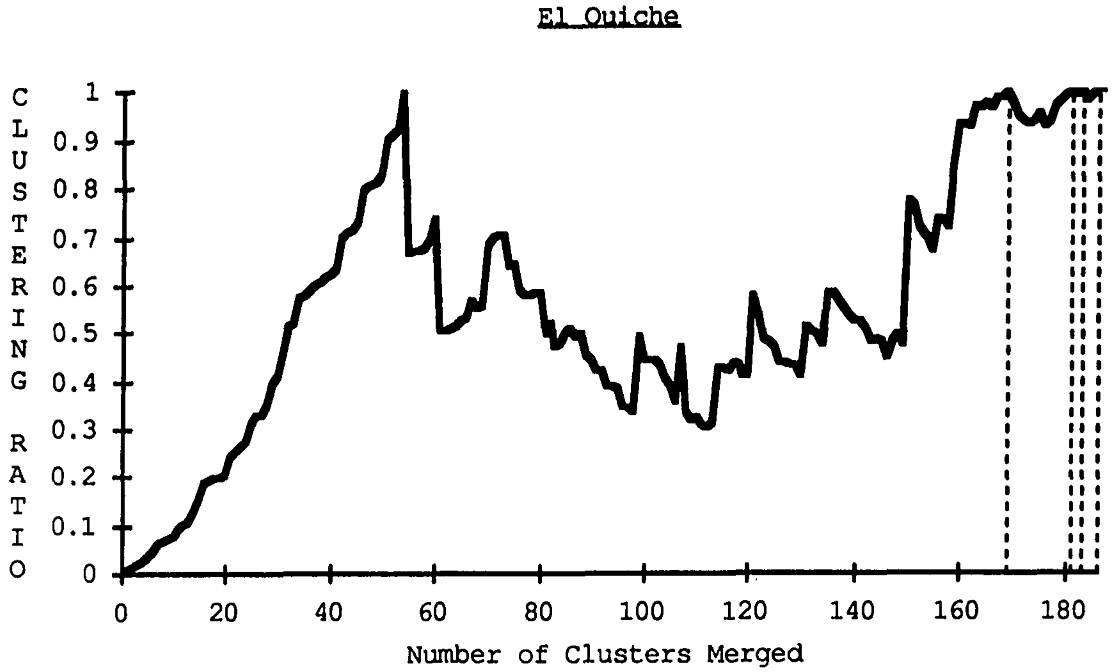

Figure 3.8. Clustering Ratios for El Quiché Subsystem

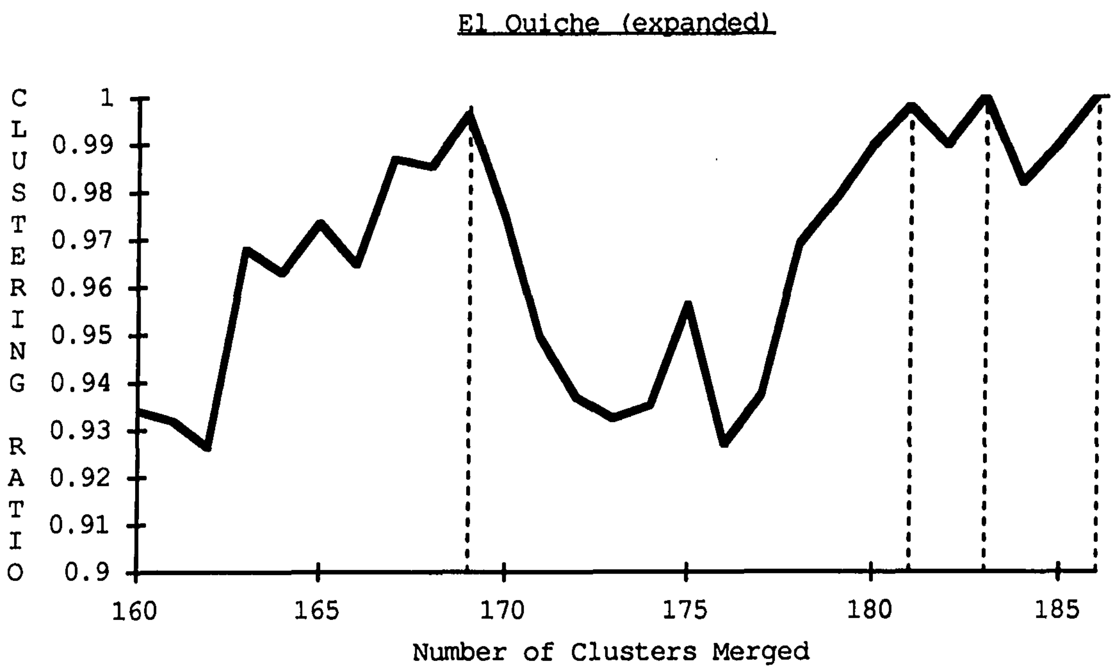

Figure 3.9. Magnified View of Clustering Ratios for El Quiché Subsystem

Table 3.18. Critical Merges in Cluster Analysis of El Quiché Subsystem

Merge No.	Maximum Diameter	Within Dists	Total Dists	Clustering Ratio
169	8.0782	14365	14421	0.9961
181	1.9832	16471	16504	0.9980
183	2.5320	16836	16836	1.0000
186	4.1729	17391	17391	1.0000

Table 3.19. NCI Characteristics for "Rough-Cut" Partition of El Quiché Subsystem

Merge	<54	54	169	181	183	186
Level	5	5	4	4	3	2
Frequency	72	98	12	2	3	1
Std Deviation	0.3572	3.9344	10.6452	27.1293	11.929	NA
Minimum	-9.0669	-8.5669	0.7136	41.8782	122.545	NA
First Quartile	-9.0390	-7.5395	9.1146	NA	122.545	443.924
Mean	-8.6754	-5.4897	17.2134	61.0615	130.005	NA
Third Quartile	-8.7406	-4.9559	24.1905	NA	143.763	NA
Maximum	-7.8182	16.7305	36.6732	80.2448	143.763	NA

Table 3.20. Places Which Were Reclassified after NCI Examination, El Quiché Subsystem

Place ID	Original Level	New Level	NCI
1418006	5	4	-1.6884
1401012	5	4	-1.5371
1410008	5	4	-1.2090
1416055	5	4	0.8071
1403001	5	4	1.9532
1410001	5	4	5.8885
1417001	5	4	9.6626
1407001	5	4	9.8390
1408001	5	4	17.9312

The level 5 places, as defined by the places merged before the 169th merge, have a rather high maximum, although their third quartile value is fairly small. This extended "upper tail" was closer to the level 4 mean NCI than to that of level 5. Following the same procedure as was used with the other subsystems, these were reclassified, as shown in Table 3.20.

3.4.2. Adjustment of the Full System

Once the preliminary partitions for the individual subsystems had been established, the full system was refined further. Each place was assigned five "level scores" which indicated the percentage of all goods of a particular level which were offered at that place:

$$L_{ik} = \frac{\sum_{j=1}^{N_k} e_{ij}}{N_k} \qquad (3.6)$$

where L_{ik} is the kth level score for place i ($k = 1...5$, $i = 1...914$), e_{ij} is a dummy variable, equal to 1 if place i offers the jth central good, and N_k is the number of k-level central goods (i.e., for each k, $j = 1...N_k$). For example, Santa Cruz del Quiché, the capital of the Departamento El Quiché, has level scores of 0.385, 0.943, 1.00, 1.00, and 1.00 (using the final version of the goods hierarchy). This indicates that this central place offers 38.5% of all level 1 goods, 94.3% of all level 2 goods, and 100% of all lower-level goods.

The level scores were used to detect anomalies and inconsistencies in the assignment of central places to levels. A discriminant function was estimated which classified the places on the basis of their level scores. Places which the discriminant analysis indicated as misclassified were examined more carefully on an individual basis. Discriminant analysis is a set of related procedures designed to aid in the classification of objects among a set of groups.[13] It is different from

[13]See James (1985) for a good introduction to discriminant analysis and the various forms it can take.

cluster analysis, in that the latter is intended to identify "natural" groupings in a set of observations. In discriminant analysis, the set of groups is taken as given, and the object is to develop a set of functions or rules which efficiently assign objects to those groups, on the basis of measurements taken on each observation. Thus, cluster analysis was used to identify how many central place levels there were and the approximate membership of each. Discriminant analysis will be used to flag those places which do not seem to belong to the levels to which they are assigned.

The discriminant analysis was performed by the SAS computer package's PROC DISCRIM (SAS Institute, Inc. 1982, 381-396). It estimates a linear discriminant function for each group and assigns each object to the group which has the highest posterior probability. The procedure automatically tested the covariance matrices of the groups and determined that a pooled covariance matrix could be used. This procedure assumes that the distribution of the variables is at least approximately multivariate normal. In particular, the procedure defines the generalized squared distance from an observation, represented by a vector of measurements, x, to a particular group, t, as

$$D_t^2(x) = (x - m_t)' S^{-1} (x - m_t) - 2\ln(q_t) \tag{3.7}$$

where $D_t^2(x)$ is the generalized squared distance from x to group t, m_t is the vector containing the means of group t, S is the pooled covariance matrix, and q_t is the prior probability for group t. The posterior probability of x belonging to group t is

$$p_t(x) = \frac{e^{\left[-0.5\, D_t^2(x)\right]}}{\sum_u e^{\left[-0.5\, D_u^2(x)\right]}} \tag{3.8}$$

3.4.2.1. First-pass discriminant analysis

For the central place partition, the prior probabilities were assumed to be proportional to the percentage of all observations classified at each level, as shown in Table 3.21. Note that the level 1 place could not be considered in the discriminant analysis, since a group must have more than a single member before covariances can be calculated. The generalized squared distances between the mean vectors of the groups are shown in Table 3.22. The general pattern of increasing distance as the groups are separated more in the hierarchy is consistent with what we would expect. For example, the distance level 2 to level 4 is greater than the distance from level 2 to level 3, and so on.

Table 3.21. Prior Probabilities for First-Pass Discriminant Analysis

Level	Frequency	Prior Probability
2	6	0.0066
3	39	0.0427
4	99	0.1084
5	769	0.8423
Total	913	1.0000

Table 3.22. Distance Matrix for First-Pass Discriminant Analysis

From Level	Generalized Squared Distance to Level 2	3	4	5
2	10.0500	329.6622	526.1928	578.6607
3	333.4058	6.3063	39.9659	68.6536
4	531.7996	41.8290	4.4432	8.5960
5	588.3674	74.6166	12.6960	0.3433

The estimated coefficients for the individual discriminant functions are shown Table 3.23. They are calculated by

$$\text{Constant} = -0.5\, m_t'\, S^{-1}\, m_t \tag{3.9}$$

$$\text{Coefficient Vector} = S^{-1}\, m_t \tag{3.10}$$

Table 3.23. Discriminant Function for First-Pass Discriminant Analysis

Level	2	3	4	5
Constant	-297.5519	-39.9000	-8.9674	-1.3876
SCORE1	335.5728	27.1504	4.0338	-1.3063
SCORE2	505.2672	131.6200	12.4867	0.4085
SCORE3	-9.3286	36.1682	17.0205	-2.1593
SCORE4	0.6785	4.4538	6.5106	3.1184
SCORE5	6.8185	3.2236	3.9347	3.5837

When the discriminant functions were used to classify the central places, 76 places were indicated as being misclassified. These are shown in Table 3.24. The computed reclassifications were not all accepted, however. The level scores of each individual place were examined, and levels were changed only when the place clearly offered a large proportion of higher level goods (in the case of increasing the level) or clearly did not offer a large proportion of goods at its putative level (in the case of decreasing the level). The "Actual" column of Table-3.24 shows the actual disposition of each of the questionable observations.

In addition to those marginal adjustments generated by the discriminant analysis, the level scores revealed two anomalous sets of places at the low end of the hierarchy. One set consists of places which have level scores of zero for level 5 goods, but nonzero scores between for level 4 goods (none of the level 4 scores were over 0.50). Because they offer some higher-level goods, they should be considered central places of a sort, but they cannot really be considered intermediate-level places (as they would at level 4), because they offer none of the lowest-level bundle. They are, in effect, a different sort of low-level place from the more common level 5 places. These unusual places were given a separate level number (level 6) to make them easier to keep track of in subsequent analysis[14].

There are also 95 places in the study region which have scores of zero on all five levels. These places hardly should be called "central places" at all, since they perform no central functions. A new level, 7, was created to accommodate such places. Also, some places with one or two very small level scores were assigned to level 7.

Table 3.24. Places Indicated as Misclassified by First-Pass Discriminant Analysis

				First Line: Posterior Probabilities Second Line: Level Scores			
ID	Original	Discrim	Actual	2	3	4	5
701001	3	2	3	1.0000 0.6486	0.0000 1.0000	0.0000 1.0000	0.0000 0.5000
704001	3	4	4	0.0000 0.1892	0.2937 0.5000	0.7059 1.0000	0.0003 0.0000
706001	4	5	4	0.0000 0.0541	0.0000 0.1250	0.1407 0.7500	0.8593 0.5000
707001	4	5	4	0.0000 0.0811	0.0000 0.1250	0.1849 0.7500	0.8151 0.5000
709006	5	4	4	0.0000 0.0541	0.0000 0.2500	0.6820 0.7500	0.3180 1.0000
710004	5	4	4	0.0000 0.0000	0.0000 0.3750	0.9115 0.7500	0.0885 0.5000
711001	4	5	5	0.0000 0.0270	0.0000 0.0000	0.0046 0.5000	0.9954 0.5000

[14]The peculiar characteristics of level 6 places are explored in more detail in the next chapter.

Table 3.24 continued

ID	Original	Discrim	Actual	2	3	4	5
				First Line: Posterior Probabilities Second Line: Level Scores			
714001	4	5	5	0.0000 0.0000	0.0000 0.0000	0.0017 0.2500	0.9983 1.0000
717001	5	4	4	0.0000 0.0270	0.0000 0.3750	0.9445 0.7500	0.0555 1.0000
801005	5	4	4	0.0000 0.0000	0.0000 0.3750	0.9247 0.7500	0.0753 1.0000
801015	4	5	4	0.0000 0.0000	0.0000 0.1250	0.0691 0.5000	0.9309 1.0000
803021	4	5	4	0.0000 0.0000	0.0000 0.1250	0.0922 0.7500	0.9078 1.0000
805184	4	5	5	0.0000 0.0270	0.0000 0.0000	0.0020 0.2500	0.9980 0.5000
805251	5	4	4	0.0000 0.0270	0.0000 0.3750	0.9709 1.0000	0.0291 0.5000
806001	3	4	3	0.0000 0.1351	0.3795 0.8750	0.6205 1.0000	0.0000 0.5000
806082	4	5	4	0.0000 0.0000	0.0000 0.1250	0.0352 0.5000	0.9648 0.5000
808001	3	4	3	0.0000 0.1081	0.0168 0.8750	0.9832 1.0000	0.0000 1.0000
901019	4	5	5	0.0000 0.0270	0.0000 0.1250	0.0569 0.5000	0.9431 1.0000
905001	5	4	4	0.0000 0.0541	0.0000 0.3750	0.9593 0.7500	0.0407 1.0000
912001	5	4	5	0.0000 0.0541	0.0000 0.5000	0.9794 0.2500	0.0206 1.0000
913001	4	3	4	0.0000 0.1892	0.9742 0.6250	0.0258 0.7500	0.0000 1.0000

Table 3.24 continued

ID	Original	Discrim	Actual	2	3	4	5
				First Line: Posterior Probabilities Second Line: Level Scores			
914012	5	4	5	0.0000 0.0270	0.0000 0.3750	0.8594 0.5000	0.1406 0.5000
916019	4	5	4	0.0000 0.0811	0.0000 0.1250	0.1849 0.7500	0.8151 0.5000
923001	4	5	4	0.0000 0.0541	0.0000 0.0000	0.0075 0.5000	0.9925 1.0000
923006	5	4	4	0.0000 0.0541	0.0000 0.2500	0.6820 0.7500	0.3180 1.0000
924001	4	3	3	0.0000 0.1622	0.6209 0.7500	0.3791 0.7500	0.0000 1.0000
1201023	5	4	5	0.0000 0.0541	0.0000 0.3750	0.9099 0.5000	0.0901 1.0000
1201036	5	4	3	0.0000 0.0270	0.0000 0.6250	0.9998 1.0000	0.0002 1.0000
1202044	4	3	4	0.0000 0.1892	0.9742 0.6250	0.0258 0.7500	0.0000 1.0000
1204021	4	5	5	0.0000 0.0270	0.0000 0.2500	0.2211 0.2500	0.7789 1.0000
1204043	5	4	4	0.0000 0.0000	0.0000 0.2500	0.6863 1.0000	0.3137 0.5000
1205047	4	5	5	0.0000 0.0000	0.0000 0.1250	0.0079 0.0000	0.9921 1.0000
1206022	4	5	5	0.0000 0.0000	0.0000 0.2500	0.2518 0.5000	0.7482 0.0000
1206048	4	5	5	0.0000 0.0270	0.0000 0.1250	0.0675 0.5000	0.9325 0.0000

Table 3.24 continued

				First Line: Posterior Probabilities Second Line: Level Scores			
ID	Original	Discrim	Actual	2	3	4	5
1209001	5	4	4	0.0000	0.0000	0.6428	0.3572
				0.0541	0.2500	0.7500	0.5000
1211001	4	3	3	0.0000	0.9876	0.0124	0.0000
				0.2162	0.6250	1.0000	0.5000
1227001	5	4	4	0.0000	0.0000	0.7520	0.2480
				0.0270	0.2500	1.0000	0.5000
1228001	5	4	5	0.0000	0.0000	0.9877	0.0123
				0.0270	0.5000	0.5000	1.0000
1229015	4	5	4	0.0000	0.0000	0.0336	0.9664
				0.0541	0.0000	1.0000	0.5000
1301003	4	5	5	0.0000	0.0000	0.0010	0.9990
				0.0000	0.0000	0.0000	0.5000
1301015	4	5	5	0.0000	0.0000	0.0014	0.9986
				0.0000	0.0000	0.2500	0.5000
1301016	4	5	6	0.0000	0.0000	0.0010	0.9990
				0.0541	0.0000	0.0000	0.0000
1301037	4	5	5	0.0000	0.0000	0.0154	0.9846
				0.0000	0.1250	0.2500	0.5000
1302005	4	5	5	0.0000	0.0000	0.2863	0.7137
				0.0000	0.2500	0.5000	0.5000
1303001	3	4	3	0.0000	0.0044	0.9956	0.0000
				0.1081	0.7500	0.5000	1.0000
1303061	4	5	5	0.0000	0.0000	0.0020	0.9980
				0.0270	0.0000	0.2500	0.5000
1304003	4	5	5	0.0000	0.0000	0.0655	0.9345
				0.0541	0.1250	0.5000	0.5000

Table 3.24 continued

ID	Original	Discrim	Actual	2	3	4	5
				First Line: Posterior Probabilities Second Line: Level Scores			
1305001	3	4	4	0.0000 0.1622	0.0001 0.2500	0.9393 1.0000	0.0606 0.5000
1306001	3	5	3	0.0000 0.1892	0.0001 0.1250	0.4994 0.7500	0.5005 1.0000
1306056	4	5	5	0.0000 0.0270	0.0000 0.0000	0.0020 0.2500	0.9980 0.5000
1308001	3	4	3	0.0000 0.1081	0.0000 0.5000	0.9976 0.7500	0.0024 0.5000
1312010	4	5	5	0.0000 0.0270	0.0000 0.0000	0.0008 0.0000	0.9992 0.5000
1314001	3	4	3	0.0000 0.0811	0.0001 0.7500	0.9998 0.7500	0.0000 0.5000
1315038	4	5	5	0.0000 0.0270	0.0000 0.0000	0.0023 0.2500	0.9977 1.0000
1316001	4	5	5	0.0000 0.0000	0.0000 0.1250	0.0260 0.2500	0.9740 0.5000
1317001	3	4	3	0.0000 0.1351	0.0916 0.6250	0.9082 0.5000	0.0002 1.0000
1319001	4	5	4	0.0000 0.0541	0.0000 0.1250	0.1208 0.7500	0.8792 0.0000
1324006	4	5	5	0.0000 0.0000	0.0000 0.1250	0.0183 0.2500	0.9817 1.0000
1325001	5	4	5	0.0000 0.0541	0.0000 0.5000	0.9756 0.2500	0.0244 0.5000
1326118	4	5	5	0.0000 0.0000	0.0000 0.2500	0.1700 0.2500	0.8300 1.0000

Table 3.24 continued

ID	Original	Discrim	Actual	2	3	4	5
				First Line: Posterior Probabilities Second Line: Level Scores			
1326136	4	5	5	0.0000 0.0000	0.0000 0.2500	0.1700 0.2500	0.8300 1.0000
1326152	4	5	5	0.0000 0.0000	0.0000 0.1250	0.0079 0.0000	0.9921 1.0000
1328001	4	5	4	0.0000 0.0541	0.0000 0.0000	0.0123 0.7500	0.9877 0.0000
1330001	4	5	5	0.0000 0.0000	0.0000 0.0000	0.0039 0.5000	0.9961 1.0000
1401012	4	5	5	0.0000 0.0000	0.0000 0.1250	0.0079 0.0000	0.9921 1.0000
1401059	4	5	4	0.0000 0.0270	0.0000 0.2500	0.3986 0.5000	0.6014 1.0000
1401062	4	5	5	0.0000 0.0000	0.0000 0.1250	0.0183 0.2500	0.9817 1.0000
1408013	4	5	5	0.0000 0.0270	0.0000 0.1250	0.0356 0.2500	0.9644 0.5000
1409001	4	5	4	0.0000 0.0541	0.0000 0.1250	0.3947 1.0000	0.6053 0.5000
1409006	4	5	5	0.0000 0.0000	0.0000 0.0000	0.0017 0.2500	0.9983 1.0000
1413001	4	3	3	0.0000 0.2703	1.0000 0.6250	0.0000 0.7500	0.0000 0.5000
1414001	4	5	4	0.0000 0.1081	0.0000 0.1250	0.2726 0.7500	0.7274 1.0000
1415001	4	3	3	0.0000 0.3243	1.0000 1.0000	0.0000 0.7500	0.0000 1.0000

Table 3.25 summarizes the changes in classifications caused by the results of the discriminant analysis and the creation of levels 6 and 7. Broadly speaking, there are two high-level (1 and 2), intermediate-level (3 and 4) and low-level classes (5 and 6). Whether level 6 should really be considered as being "below" level 5 is a question which will be discussed later. The level 7 places are not truly members of the central place hierarchy at all, since they offer no central goods.

Table 3.25. Reclassifications after First-Pass Discriminant Analysis

Frequencies and Row Percentages
Zero-Frequency Cells Shown as Blank
Nonzero Off-Diagonal Cells shown in **Boldface**

From	To Level							
Level	1	2	3	4	5	6	7	Total
1	1 100.00							1 100.00
2		6 100.00						6 100.00
3			37 94.87	**2** **5.13**				39 100.00
4			**17** **17.17**	50 50.51	**31** **31.31**	**1** **1.01**		99 100.00
5			**1** **0.13**	**46** **5.98**	508 66.06	**122** **15.86**	**92** **11.96**	769 100.00
Total	1 0.11	6 0.66	55 6.02	98 10.72	539 58.97	122 13.35	93 10.18	914 100.00

3.4.2.2 Second-pass discriminant analysis

After each rearrangement of the place hierarchy, the goods hierarchy was re-examined to see if any goods appeared to be misclassified. As the place hierarchy became better defined by the rearrangement of marginal places, the level structure of the goods hierarchy was also subject to change. The basis for the alteration was the same as the original classification scheme: the percentage of places at a given level which offered the good in question. In some cases, goods moved up or down a level, but no goods were added or dropped after the preliminary examination, nor were any levels were added to the hierarchy after this point. The tables below show the details of the second discriminant function and the consequent reclassifications.

Table 3.26. Prior Probabilities for Second-Pass Discriminant Analysis

Level	Frequency	Prior Probability
2	6	0.0066
3	47	0.0515
4	102	0.1117
5	543	0.5947
6	123	0.1347
7	92	0.1008
Total	913	1.0000

Table 3.27. Distance Matrix for First-Second Discriminant Analysis

From Level	Generalized Squared Distance to Level 2	3	4	5	6	7
2	10.0500	252.7282	335.6860	378.8482	396.7175	404.8062
3	256.8449	5.9332	46.7700	74.4078	83.0483	91.7937
4	341.3524	48.3196	4.3836	16.5164	24.8759	37.2713
5	387.8589	79.3018	19.8607	1.0393	14.6181	15.2182
6	402.7584	85.0085	25.2504	11.6483	4.0091	7.4638
7	410.2663	93.1370	37.0649	11.6675	6.8830	4.5899

Table 3.28. Discriminant Function for Second-Pass Discriminant Analysis

Level	2	3	4	5	6	7
Constant	-205.1331	-46.5685	-18.5325	-5.8338	-3.4415	-2.2949
SCORE1	197.9819	-12.8066	-16.3418	-5.8600	-0.5497	0.0000
SCORE2	297.6864	47.3450	16.1003	3.5085	-2.5365	0.0000
SCORE3	4.3953	64.5967	6.5001	-3.2366	-2.2820	0.0000
SCORE4	16.4156	17.2167	25.5319	5.1561	10.1793	0.0000
SCORE5	16.6789	9.4283	12.7244	13.8185	-0.4223	0.0000

Of note in Table 3.27 is that the distances between levels, relative to the distances within levels, get dramatically smaller at the low end of the hierarchy. For the original five levels, the generalized distance to the closest adjacent level is 5 to 25 times larger than the distance from each level to itself. However, the distances between levels 6 and 7 are less than twice the within-level distances. This is part of the reason that these levels were not detected in the original cluster analysis. It also underscores the unusual nature of level 6, which appears to be closer to the "noncentral" places of level 7 than to the recognizable (if very low-level) central places of level 5.

In Table 3.28, one should note that the classification is still on the basis of the level scores for the five main central place levels. There are no goods which are classified as level 6 or level 7. The status of level 7 as the level containing no central place function is made clear by the fact that the coefficients for all the level scores are zero for this level. As one might expect, the coefficients for each of the top five levels are highest for each level's own level scores. Also, the SCORE4 coefficients for levels 2 and 3 are roughly equal, as are the SCORE5 coefficients for levels 2 through 4. This reflects the fact that higher-level places must also function as "full service" lower-level places.

Table 3.29. Places Indicated as Misclassified by Second-Pass Discriminant Analysis

First Line: Posterior Probabilities
Second Line: Level Scores

ID	Prv	Dsc	Act	2	3	4	5	6	7
701001	3	2	2	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000
				0.7222	1.0000	1.0000	0.5000		
704001	4	3	3	0.0000	0.9223	0.0776	0.0000	0.0001	0.0000
				0.1667	0.5714	1.0000	0.0000		

Table 3.29 continued

ID	Prv	Dsc	Act	2	3	4	5	6	7
				First Line: Posterior Probabilities Second Line: Level Scores					
718001	4	3	3	0.0000	0.9999	0.0001	0.0000	0.0000	0.0000
				0.5000	0.5714	1.0000	1.0000		
801015	4	5	5	0.0000	0.0000	0.0465	0.9533	0.0001	0.0000
				0.0000	0.1429	0.5000	1.0000		
805001	4	3	3	0.0000	0.9954	0.0046	0.0000	0.0000	0.0000
				0.3333	0.5714	0.7500	1.0000		
806082	4	5	5	0.0000	0.0000	0.1433	0.7588	0.0948	0.0031
				0.0000	0.1429	0.5000	0.5000		
904001	4	3	3	0.0000	0.9399	0.0601	0.0000	0.0000	0.0000
				0.2778	0.5714	1.0000	1.0000		
913001	4	3	3	0.0000	0.9545	0.0455	0.0000	0.0000	0.0000
				0.2500	0.5714	0.7500	1.0000		
914012	5	4	5	0.0000	0.0000	0.5847	0.3752	0.0380	0.0020
				0.0556	0.2857	0.5000	0.5000		
923001	4	5	5	0.0000	0.0000	0.0529	0.9471	0.0001	0.0000
				0.0556	0.0000	0.5000	1.0000		
1201023	5	4	4	0.0000	0.0000	0.5637	0.4362	0.0000	0.0000
				0.0833	0.2857	0.5000	1.0000		
1202044	4	3	3	0.0000	0.9185	0.0815	0.0000	0.0000	0.0000
				0.2222	0.5714	0.7500	1.0000		
1206022	5	6	6	0.0000	0.0000	0.0071	0.0054	0.9521	0.0354
				0.0000	0.2857	0.5000	0.0000		
1206048	5	6	6	0.0000	0.0000	0.0005	0.0068	0.9701	0.0227
				0.0556	0.0000	0.5000	0.0000		
1208001	5	3	3	0.0000	0.7497	0.2394	0.0095	0.0013	0.0001
				0.0556	0.5714	0.5000	0.5000		
1210001	3	2	3	0.9970	0.0030	0.0000	0.0000	0.0000	0.0000
				0.6944	0.8571	1.0000	0.5000		

Table 3.29 continued

ID	Prv	Dsc	Act	2	3	4	5	6	7
				First Line: Posterior Probabilities / Second Line: Level Scores					
1211006	5	4	4	0.0000	0.0000	0.9995	0.0002	0.0003	0.0000
				0.0000	0.1429	1.0000	0.5000		
1228001	5	4	3	0.0000	0.1835	0.7434	0.0731	0.0000	0.0000
				0.0278	0.5714	0.5000	1.0000		
1301006	6	7	7	0.0000	0.0000	0.0000	0.0242	0.2226	0.7532
				0.0278	0.0000	0.0000	0.0000		
1301016	6	7	7	0.0000	0.0000	0.0000	0.0271	0.2098	0.7631
				0.0556	0.0000	0.0000	0.0000		
1304109	5	3	3	0.0000	0.4778	0.0466	0.4325	0.0195	0.0236
				0.0278	0.5714	0.2500	0.5000		
1317035	6	7	7	0.0000	0.0000	0.0000	0.0242	0.2226	0.7532
				0.0278	0.0000	0.0000	0.0000		
1319001	4	6	4	0.0000	0.0000	0.2206	0.0020	0.7755	0.0019
				0.0556	0.1429	0.7500	0.0000		
1322001	5	4	4	0.0000	0.0000	0.6383	0.3617	0.0000	0.0000
				0.0000	0.4286	0.5000	1.0000		
1323001	5	3	3	0.0000	0.4778	0.0466	0.4325	0.0195	0.0236
				0.0278	0.5714	0.2500	0.5000		
1325001	5	3	3	0.0000	0.7569	0.0302	0.1958	0.0074	0.0096
				0.0556	0.5714	0.2500	0.5000		
1328001	4	6	4	0.0000	0.0000	0.0747	0.0027	0.9209	0.0016
				0.0556	0.0000	0.7500	0.0000		
1401059	4	5	5	0.0000	0.0000	0.1833	0.8167	0.0001	0.0000
				0.0556	0.1429	0.5000	1.0000		
1406001	4	3	3	0.0000	0.9913	0.0087	0.0000	0.0000	0.0000
				0.3333	0.5714	1.0000	1.0000		

Table 3.30. Reclassifications after Second-Pass Discriminant Analysis

Frequencies and Row Percentages
Zero-Frequency Cells Shown as Blank
Nonempty Off-Diagonal Cells Shown in **Boldface**

From Level	To Level 1	2	3	4	5	6	7	Total
1	1 100.00							1 100.00
2		6 100.00						6 100.00
3		**1** **1.82**	53 96.36	**1** **1.82**				55 100.00
4			**3** **3.06**	91 92.86	**4** **4.08**			98 100.00
5			**2** **0.37**	**2** **0.37**	533 98.89	**2** **0.37**		539 100.00
6						119 97.54	**3** **2.46**	122 100.00
7							93 100.00	93 100.00
Total	1 0.11	7 0.66	58 6.02	94 10.72	537 58.97	121 13.23	96 10.50	914 100.00

3.4.2.3. Third-pass discriminant analysis

Only one place was reclassified on the basis of the third-pass discriminant analysis. This was Tejutla (1210001), a municipio capital in Departamento San Marcos. It had been indicated as misclassified in the previous passes of the discriminant function, but its low level 2 score of 0.6944 resulted in the discriminant function's reclassification being overruled. After the third instance of misclassification, it was decided that this persistence indicated that the place should be considered level 2. It is the weakest of the level 2 places, a fact which will be examined in more detail in the next chapter.

Table 3.31. Prior Probabilities for Third-Pass Discriminant Analysis

Level	Frequency	Prior Probability
2	7	0.0077
3	58	0.0635
4	94	0.1030
5	537	0.5882
6	122	0.1336
7	95	0.1041
Total	913	1.0000

Table 3.32. Distance Matrix for Third-Pass Discriminant Analysis

From	Generalized Squared Distance to Level					
Level	2	3	4	5	6	7
2	9.7417	259.1037	399.9226	433.8510	445.3014	447.7613
3	263.3328	5.5126	54.5610	81.9073	87.4924	95.5387
4	405.1174	55.5267	4.5469	17.4050	24.0308	36.7725
5	442.5311	86.3584	20.8904	1.0615	15.3611	15.3579
6	451.0176	88.97952	24.5522	12.3972	4.0254	7.6801
7	452.9773	96.5256	36.7937	11.8937	7.1798	4.5257

Table 3.33. Discriminant Function Coefficients for Third-Pass Analysis

Level	2	3	4	5	6	7
Constant	-226.8751	-48.3146	-18.4064	-5.9484	-3.5824	-2.2634
SCORE1	238.4025	25.2029	-27.9522	-10.1198	-1.7812	-0.7806
SCORE2	321.7340	43.5833	8.4234	1.7952	-5.7814	0.9644
SCORE3	44.41319	76.7519	9.8290	-4.2453	-1.3996	-0.0984
SCORE4	6.5774	15.3136	25.7695	4.6377	10.7156	-0.0222
SCORE5	9.8140	7.6565	11.9432	14.2078	-0.7220	0.0075

Table 3.34. Places Indicated as Misclassified by Third-Pass Discriminant Analysis

First line: Posterior Probabilities
Second Line: Level Scores

ID	Prv	Dsc	Act	2	3	4	5	6	7
701002	4	3	4	0.0000	0.8453	0.1547	0.0000	0.0000	0.0000
				0.1111	0.5714	1.0000	1.0000		
802001	3	2	3	0.9620	0.0380	0.0000	0.0000	0.0000	0.0000
				0.6111	0.8571	1.0000	1.0000		
912001	5	3	5	0.0000	0.8923	0.0286	0.0791	0.0000	0.0000
				0.0556	0.5714	0.2500	1.0000		
914012	5	4	5	0.0000	0.0000	0.7679	0.1940	0.0362	0.0019
				0.0556	0.2857	0.5000	0.5000		
916001	4	3	4	0.0000	0.6807	0.3193	0.0000	0.0000	0.0000
				0.1389	0.5714	1.0000	0.5000		
924004	5	4	5	0.0000	0.0000	0.5134	0.4865	0.0001	0.0000
				0.0278	0.2857	0.5000	1.0000		
1203001	4	3	4	0.0000	0.6508	0.3492	0.0000	0.0000	0.0000
				0.1944	0.5714	1.0000	1.0000		
1210001	3	2	2	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000
				0.6944	0.8571	1.0000	0.5000		
1228001	3	4	3	0.0000	0.4518	0.5391	0.0092	0.0000	0.0000
				0.0278	0.5714	0.5000	1.0000		
1302005	5	4	5	0.0000	0.0000	0.6761	0.2495	0.0717	0.0026
				0.0000	0.2857	0.5000	0.5000		
1319001	4	6	4	0.0000	0.0000	0.2458	0.0008	0.7518	0.0016
				0.0556	0.1429	0.7500	0.0000		
1328001	4	6	4	0.0000	0.0000	0.0615	0.0014	0.9354	0.0016
				0.0556	0.0000	0.7500	0.0000		

3.4.3. Summary of the Final Hierarchy

Table 3.35 summarizes the final place hierarchy, after the iterative process with the goods hierarchy reached completion. It has the expected pyramidal structure, although the ratios of the places do not follow a regular pattern. The small number of level 7 places is not a violation of this pattern, since they are not central places. Similarly, the level 6 places represent an unusual type of low-level place, rather than a true class below level 5. Except for the division between levels 3 and 4, the number of succeeding places increases by a factor of between 6 and 8 as one moves down the hierarchy, if one treats levels 5 and 6 as a single group of low-level places. The details of the relationships among the different levels of the hierarchy, their markets, populations, and so on, will be discussed in the next chapter.

Table 3.35. Average Level Scores for the Final Version of the Place Hierarchy

Level	Frequency	SCORE1	SCORE2	SCORE3	SCORE4	SCORE5
1	1	1.000	1.000	1.000	1.000	1.000
2	8	0.333	0.865	0.893	1.000	0.875
3	57	0.060	0.219	0.797	0.789	0.763
4	94	0.004	0.052	0.208	0.824	0.734
5	537	0.001	0.004	0.028	0.177	0.713
6	122	0.001	0.001	0.011	0.295	0.000
7	95	0.000	0.001	0.000	0.000	0.000

The goods hierarchy in its final form is listed in Table 3.36. It is rather difficult to account for some of the differences between level 1 and level 2 goods. "Pita Articles" and "Palm Articles" may well be for the tourist trade, in which case they would more properly be termed export goods rather than central goods. Weekly periodicals probably require a large population to support them, particularly in a region where literacy is so low and disposable income so small. In a region as poor as the Central Highlands, theatres[15], auto sales, and even radio and television sales may be such luxuries as to be level 1 goods. However, chandlers, hat shops, saddleries, and (perhaps) locksmiths seem very mundane functions to bo rated level 1. It is possible that these items are supplied to rural dwellers by traveling peddlers or general stores, which would account for their lack of appearance at the lower levels.

The level 2 places include most of the ordinary business and commercial services which (in developed countries) one would associate with a local consumer service center. It should be kept in mind that in Guatemala the ladino population is much more commercially oriented than the indiano. As was discussed in Chapter I, the Central Highlands have the highest population of indanos of any region in Guatemala, but the ladinos are more urbanized. Thus we find that "stores" (as opposed to market booths) tend to be rare and concentrated in the higher level places. Below level 2, one generally finds necessities and the most minor of luxuries (such as cantinas). Clothing, plastics, and prepared food can be found in the level 3 places. Below this level, one finds only establishments related to food, except for general stores and tailor shops. The general stores no doubt function as substitutes for the more specialized shops and stores of the higher-level places.[16] Exactly what these "tailor shops" do is not known. One suspects that they make simple work clothes and perform mending, rather than produce the made-to-measure luxury clothing we might associate with the term.

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[15]These are "legitimate" theatres, i.e., with live actors. Cinemas are level 2 goods. It is also possible that these theatres also exist for the benefit of tourists, if they show traditional dances, etc.

[16]General stores (*pulperias*) are a prominent characteristic of the level 6 places, as will be discussed in the next chapter.

Table 3.36. Summary of Final Goods Hierarchy
(Proportion of places offering each good, by place level)

Level 1 goods:

	Central Place Level						
Description	1	2	3	4	5	6	7
Chandlers	1.000	0.500	0.211	0.011	0.000	0.000	0.000
Palm articles	1.000	0.125	0.000	0.000	0.002	0.000	0.000
Saddleries	1.000	0.500	0.088	0.011	0.004	0.000	0.000
Pita articles	1.000	0.250	0.000	0.000	0.000	0.008	0.000
Veterinarians	1.000	0.125	0.035	0.000	0.000	0.000	0.000
Hat shops	1.000	0.250	0.035	0.000	0.000	0.000	0.000
New and used autos	1.000	0.375	0.018	0.000	0.002	0.000	0.000
Nightclubs	1.000	0.125	0.000	0.000	0.000	0.000	0.000
Radio & television[a]	1.000	0.500	0.123	0.011	0.000	0.000	0.000
Locksmith	1.000	0.375	0.000	0.000	0.000	0.000	0.000
Weekly periodicals[a]	1.000	0.500	0.035	0.011	0.000	0.000	0.000
THEATRE[a]	1.000	0.375	0.175	0.011	0.000	0.000	0.000

Level 2 goods:

Description	1	2	3	4	5	6	7
Plaza other vendors	1.000	0.875	0.404	0.043	0.002	0.000	0.000
Cafeterias	1.000	1.000	0.175	0.021	0.000	0.000	0.000
Bars and restaurants	1.000	0.750	0.070	0.000	0.000	0.000	0.000
Barber shops[a]	1.000	1.000	0.474	0.330	0.041	0.008	0.000
Gasoline stations	1.000	1.000	0.228	0.043	0.000	0.000	0.000
Billiard shops	1.000	0.750	0.105	0.011	0.000	0.000	0.000
Constr. materials	1.000	0.875	0.158	0.043	0.009	0.000	0.000
Electrical equipment	1.000	1.000	0.193	0.021	0.000	0.000	0.011
Hardware stores	1.000	1.000	0.193	0.011	0.000	0.000	0.000
Fertilizer stores	1.000	0.750	0.404	0.128	0.004	0.000	0.000
Stationary and books	1.000	1.000	0.123	0.011	0.000	0.000	0.000
Undertakers	1.000	1.000	0.193	0.021	0.002	0.000	0.000
Blacksmiths	1.000	0.875	0.298	0.043	0.006	0.000	0.000
Grain mills (agri.)	1.000	0.625	0.123	0.043	0.006	0.000	0.000
Machine shops	1.000	1.000	0.158	0.011	0.002	0.000	0.000
Nonalcoholic bev.[a]	1.000	1.000	0.211	0.032	0.002	0.000	0.000
Paint stores	1.000	0.625	0.070	0.000	0.000	0.000	0.000
Watchmakers	1.000	0.750	0.140	0.032	0.002	0.000	0.000
Propane sellers	1.000	0.750	0.070	0.000	0.000	0.000	0.000

[a] Changed level between preliminary and final goods hierarchies.

Table 3.36 continued

Level 2 goods continued:							
	Central Place Level						
Description	1	2	3	4	5	6	7
Photography stores	1.000	1.000	0.246	0.032	0.002	0.000	0.000
Electricians	1.000	0.750	0.140	0.032	0.000	0.000	0.000
Liquor	1.000	0.875	0.105	0.011	0.000	0.000	0.000
Banks or agencies	1.000	0.875	0.000	0.000	0.000	0.000	0.000
Musical groups	1.000	1.000	0.193	0.053	0.004	0.008	0.000
Ice cream	1.000	0.875	0.193	0.021	0.002	0.000	0.000
Photocopying	1.000	0.875	0.035	0.000	0.000	0.000	0.000
Furniture stores	1.000	0.625	0.035	0.000	0.002	0.000	0.000
Chicken/egg stores	1.000	0.875	0.158	0.000	0.000	0.000	0.000
Other stores	1.000	0.750	0.421	0.138	0.015	0.000	0.000
Lawyers and notaries	1.000	1.000	0.316	0.064	0.013	0.000	0.011
MOVIE	1.000	0.750	0.368	0.085	0.011	0.000	0.000
MEAT	1.000	1.000	0.947	0.436	0.026	0.008	0.000
LODGINGS	1.000	1.000	0.404	0.096	0.002	0.000	0.000
PUBLISH	1.000	0.625	0.000	0.000	0.000	0.000	0.000
STR_FOOD	1.000	1.000	0.333	0.021	0.006	0.016	0.021
Level 3 goods:							
Description	1	2	3	4	5	6	7
Market prepared food	1.000	0.875	0.842	0.043	0.004	0.000	0.000
Mkt plastic vendors	1.000	0.625	0.754	0.085	0.002	0.000	0.000
Comedores	1.000	1.000	0.895	0.404	0.041	0.016	0.000
Carpentry workshops	1.000	0.875	0.614	0.394	0.117	0.041	0.000
CLOTHING	1.000	1.000	0.825	0.170	0.020	0.008	0.000
FOOTWEAR	1.000	1.000	0.719	0.213	0.009	0.000	0.000
MKT_FOOD	1.000	0.875	0.930	0.149	0.004	0.008	0.000
Level 4 goods:							
Description	1	2	3	4	5	6	7
General stores	1.000	1.000	0.737	0.851	0.264	0.992	0.000
Cantinas	1.000	1.000	0.982	0.968	0.236	0.074	0.000
Butcher shops	1.000	1.000	0.649	0.691	0.052	0.033	0.000
Tailor shops	1.000	1.000	0.789	0.787	0.156	0.082	0.000
Level 5 goods :							
Description	1	2	3	4	5	6	7
Grocery stores	1.000	0.750	0.702	0.500	0.793	0.000	0.000
Corn mills (consumer)	1.000	1.000	0.825	0.968	0.633	0.000	0.000

IV. THE QUETZALTENANGO CENTRAL PLACE SYSTEM

The previous chapter explained the methods that were used to identify the hierarchies of central places and central goods. This chapter examines the spatial system defined by that hierarchy.

4.1. Identifying the Geographical Structure

There are a total of 914 places in the study area. Each of these places is part of a web of distribution extending from Quetzaltenango down to the smallest level 7 place. In order to trace this web, we must examine each place individually and discover its spatial relationship with all neighboring places. If a central place is of level 4 or higher, it will have "tributary" lower-level places, which it supplies with all or part of their demand for higher-level goods. The extent of its market area will be determined by the proximity of other places which can also supply the goods in question. Except for the single level 1 place, each central place will be tributary to higher-level places.

The task of tracing out this web of overlapping, nested market areas was conducted from the top down. As a first approximation of market areas, each place was boxed by lines which enclosed the region that was closer to the place in question than to any other place of that level or higher. Starting with the highest-level places, each tributary place was assigned to one or more higher-level markets. These assignments were made on the basis of map distance to possible competing higher-level places, with the road grid and terrain of the region being taken into consideration. A weighting system was used to record these assignments, as follows: if a place was assigned to a single higher-level place, the assignment was give a weight of 1.00. If the place appeared to be tributary to two places, each assignment was give a weight of 0.5, and if three places were involved, each assignment was weighted 0.33. These weights were used when aggregating across market areas to produce the statistical results discussed below.

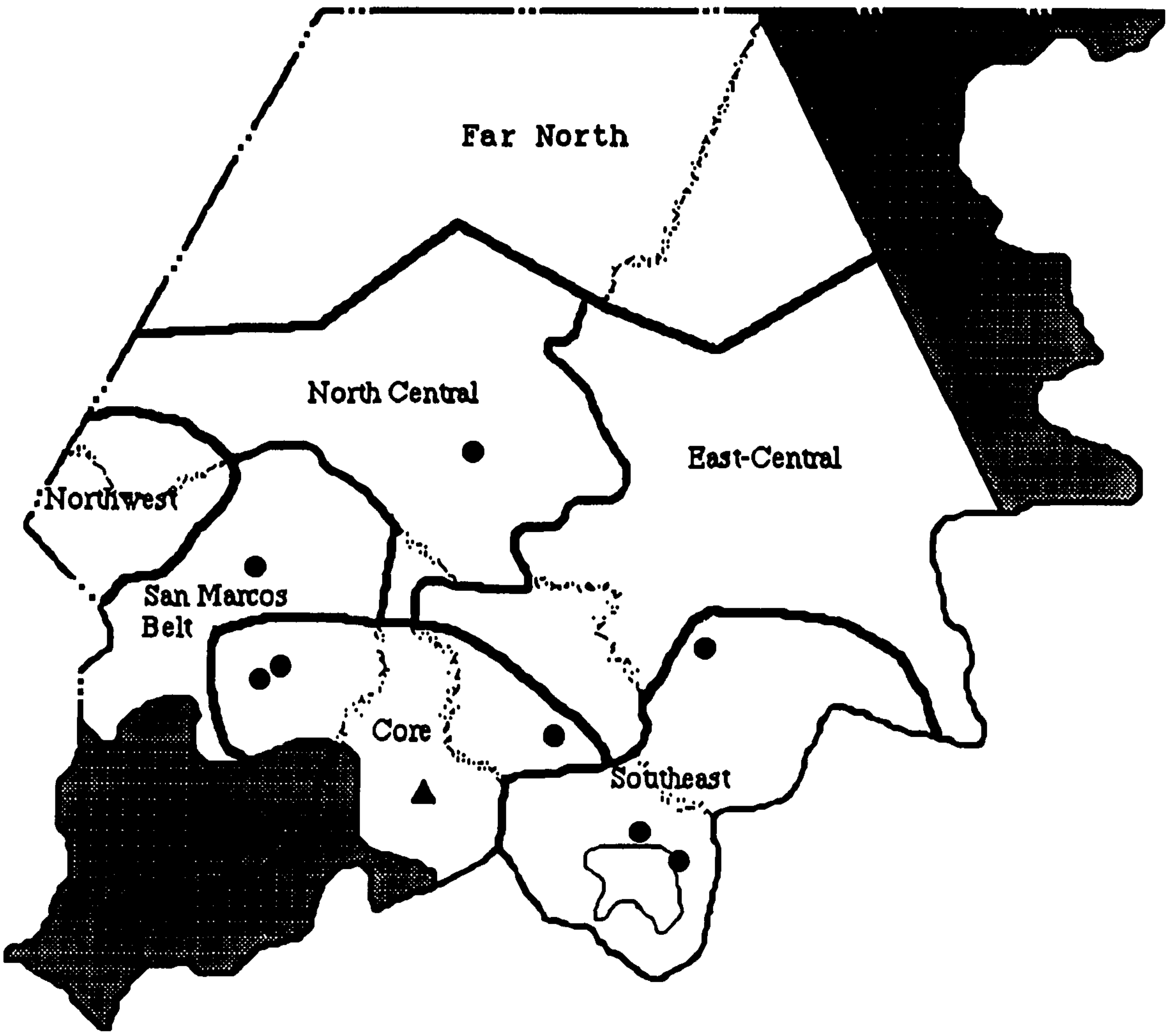

Figure 4.1. Subregions in the Study Area

The study region can be thought of as a central core of dense settlement in the vicinity of Quetzaltenango, surrounded by a relatively sparsely settled periphery. This periphery is far from homogeneous, however. To the south and east of Quetzaltenango lies Guatemala City (outside the study area). The part of the study region in between, consisting of the Municipio Chichicastenango in Departamento El Quiché plus all of Departamento Sololá, still exhibits relatively dense settlement. Settlement density tends to be higher in the vicinity of each of the departamento capitals. In broader terms, however, as one moves to the west, north, or northeast from Quetzaltenango, the pattern of settlement becomes more diffuse.

An examination of the physical distribution of central places in the study region shows four distinct subregions, as is listed in the table below and shown in Figure 4.1. In addition, three more subregions were defined to include the transitional areas between the functionally distinct subregions.

Table 4.1. Distinct Subregions in the Study Area

Core	The central area of the study region which has the densest settlement. It consists of most of Departamento Quetzaltenango, plus the eastern municipios of Departamento San Marcos and the western municipios of Totonicapán, including the capitals of those departamentos.
Northwest	The part of Departamento San Marcos near the Mexican border, north and west of Tejutla, plus Municipio Tectitán, in Huehuetenango. The central places are not as diffuse as those of the Far North subregion, but they have consistently low levels. The low-level places in the northwest are typically level 6 or 7, with the level 5 places that are the backbone of the rest of the system being relatively rare.

Table 4.1 continued

Far North	The northern half of Departamento Huehuetenango, plus the northernmost municipios of El Quiché. In this region, the well-articulated market system of the core gives way to a two-level pattern, with only level 3 and level 5 places in much evidence. This is highly mountainous country (even for Guatemala), and the towns and villages are widely scattered.
Southeast	The comparatively well-settled region between the core and Guatemala City. This region encompasses all of Departamento Sololá, plus the part of El Quiché directly south of the departamento capital. The central place system of this subregion is quite well developed, with all intermediate-level places being represented.

Table 4.2. Transitional Subregions in the Study Area

San Marcos Belt	The thin band of municipios between the core and the northwestern subregion. This region is not as dense as the core, but it is better articulated than the northwest. The belt subregion includes a level 2 place, the anomalous Tejutla.
North-Central	The southern portion of Huehuetenango, including the departamento capital. This subregion also includes the northernmost municipio of Quetzaltenango (Cabricán) and two level 5 places of Municipio San Carlos Sija, a long, irregularly shaped municipio in Quetzaltenango. Both this subregion and East-Central have lower settlement densities than the core but still maintain distinct intermediate-level markets.
East-Central	The parts of Totonicapán which are not in the Core subregion, plus the parts of El Quiché which are not in the Southeast subregion. This subregion also includes the single central place in Baja Verapaz, which is part of the Quetzaltenango system.

4.2. Level 2 Markets

There are nine places in the region which offer level 2 goods. However, there are two instances of paired places which are so close together as to be essentially a single supplier of level 2 goods. In Departamento San Marcos, the departamento capital (San Marcos) and San Pedro Sacatepéquez are virtually adjacent to one another and seem to form twin cities. They were treated as a single central place for the rest of this study. In Departamento Sololá, there is an odd situation in which two level 2 places, Sololá and Panajachel are only about 5 kilometers apart. These are not close enough to be considered the same place, but they are much closer together than any other pair of level 2 places. This pair is treated as a single level 2 central place, but as different lower-level places.

Treating the two pairs as single markets, there are a total of six level 2 market areas. Except in Departamento San Marcos, each level 2 market area is dominated by a departamento capital, and the areas themselves are roughly contiguous with the departamentos themselves. The major exception to this pattern is in San Marcos, which has two distinct but weak level 2 markets: San Marcos/San Pedro and Tejutla.[1] The former dominates the more densely settled southeastern part of the departamento, while the latter's market area extends northwest, to the Mexican border, and even to parts of western Departamento Huehuetenango.

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[1] The closest any other pairs of level 2 places are to one another is approximately 20 km. San Marcos/San Pedro is this distance from Tejutla, but there is a substantial mountain range in between. Quetzaltenango and Totonicapán are also approximately this distance apart, but this is in the dense core of the study region.

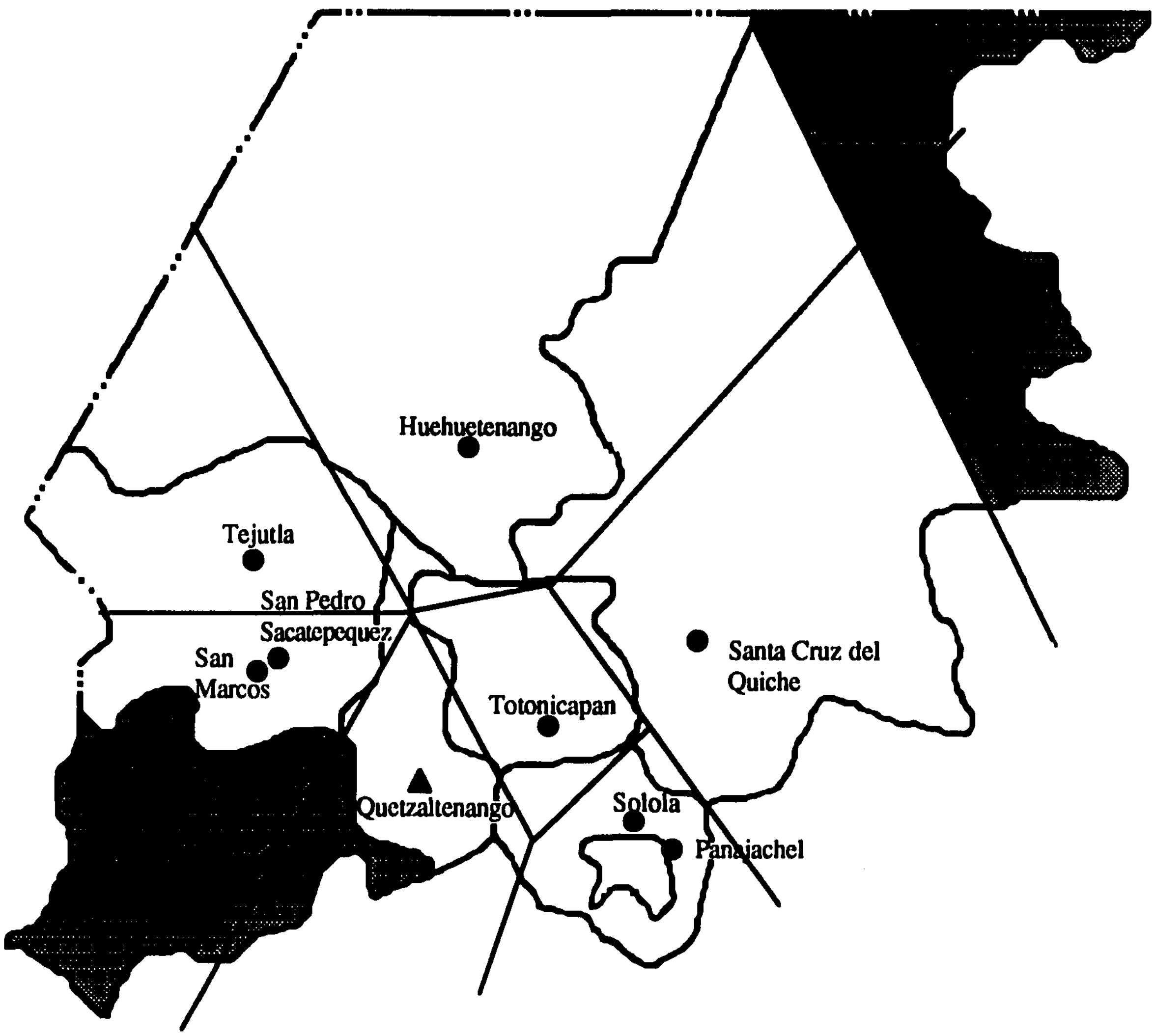


Figure 4.2. Level 2 Market Areas in Study Region

The level 2 market areas conform to the core-periphery pattern described earlier. Most of the core region is tributary to Quetzaltenango, but it also includes some parts in the market areas of Totonicapán or San Marcos/San Pedro. The southeast is supplied by the relatively compact market area of Sololá/Panajachel, and the large areas of the periphery look to the outlying level 2 places: Santa Cruz del Quiché, Huehuetenango, and Tejutla. These "central" places are not located in the centers of their market areas. Instead, they form a ring close to the core of the region, with pie-shaped market areas extending outward to the edges of the study region.

4.2.1. Central Places

Table 4.3 shows some basic information for the nine places which have level 2 markets. These places have the largest populations of the region, but they vary considerably among themselves, from 77,554 for Quetzaltenango to only 1,727 for Tejutla. Even discounting Quetzaltenango (the level 1 place), the largest level 2 place is over 20 times as populous as the smallest.

Table 4.3. Place Data for Level 2 Markets

Place Name	Level	Subregion	Population (1979)	Level 1 Score	Level 2 Score
Sololá	2	Southeast	5,578	0.167	0.722
Panajachel	2	Southeast	2,647	0.500	0.861
Totonicapán	2	Core	13,027	0.417	0.861
Quetzaltenango	1	Core	77,554	1.000	1.000
San Marcos	2	Core	7,532	0.167	0.917
San Pedro Sacatepéquez	2	Core	15,265	0.583	0.972
Tejutla	2	NW Belt	1,727	0.083	0.694
Huehuetenango	2	N. Central	18,481	0.417	0.944
Santa Cruz Del Quiché	2	Southeast	12,897	0.333	0.944

A clue to the reason for this can be seen if we examine the top two level scores for these places. Tejutla, the smallest level 2 place, is the weakest in terms of the goods it offers. Tejutla offers only 69.4 percent of the level 2 bundle. It essentially straddles the borderline between level 2 and level 3 places. It was classified as level 3 in some preliminary lists. The geographical position of Tejutla is also important. The town is a municipio capital in the belt subregion, and most of its market area is in the northwestern subregion. This subregion is the least developed of all areas in the Quetzaltenango system. Thus, Tejutia occupies a marginal niche, certainly stronger than most level 3 central places, but very weak as a level 2 central place.

The pair of "twin city" level 2 markets also show a certain amount of weakness. This is particularly true for the noncore example of a twin city market, Sololá/Panajachel. For both this market and for San Marcos/San Pedro the city which is not the departamento capital has the larger level score—even to offering half the level 1 goods bundle. It appears that the noncapitals may be in better positions as "natural" commercial centers, but the historical and political advantages of the departamento capitals allow these to still compete in offering level 2 goods. As casual evidence, note that the noncapital components of the twins are further from the competing market of Quetzaltenango. Panajachel is also further from Santa Cruz del Quiché than is Sololá.

The other two peripheral level 2 markets, Huehuetenango and San Marcos del Quiché, are well established, with large populations and 94.4 percent of the complete level 2 goods bundle. They are sufficiently far from the competing places in the core of the region, and each has its own hinterland stretching out to the edges of the study area. Note that both also offer a large fraction of the level 1 goods bundle.

Totonicapán, the nontwin level 2 place in the core, has a population, level 2 score, and level 1 score which are in the middle of the distributions for level 2 places. It is in the core, which gives it access to the buying power of the dense population, but at the same time it must compete with Santa Cruz del Quiché, Sololá/Panajachel, and Quetzaltenango. This is the best example in the study area of a pure level 2 place whose market is constrained primarily by competing centers, rather than by international borders or unpopulated spaces.

Quetzaltenango sits in the center of the core and is the only place which offers all the level 2 goods. By definition, it also offers all level 1 goods. It is by far the largest place in the region, as expected.

4.2.2. Market Areas

Table 4.4 shows some selected measures of the extent of the level 2 markets. The most striking thing about this table is the way the peripheral centers serve much larger markets than the core centers. This is probably an illusion, in the sense that many of the outlying places in the peripheral market areas are simply not supplied with level 2 goods, or are at least supplied only irregularly and inadequately.

Table 4.4. Market Data for Level 2 Markets

Market Name	Places Served Unwght	Places Served Wght	Pop. (1979)	Area (km^2)	Density	Level 2 Score
Sololá/Panajachel	102	82.33	116,226	917	126.7	0.971
Totonicapán	115	78.70	172,373	882	195.3	0.943
Quetzaltenango	116	86.85	215,631	831	259.2	1.000
San Marcos/San Pedro	104	82.19	124,674	854	145.9	1.000
Tejutla	143	121.59	163,609	1,677	97.5	0.807
Huehuetenango	338	300.34	452,992	8,291	54.6	1.000
Santa Cruz del Quiché	198	160.50	273,005	3,572	76.4	1.000

We can obtain a rough approximation of the the effective markets served by the peripheral level 2 places by reducing the radius of their market areas to something closer to the observed distances between the other level 2 places. The average distance between adjacent level 2 places is 31.25 km, which means a market radius of half that, or 15.63 km. This, however, is probably too short a radius, since the distances among the core centers is probably the minimum rather than the maximum. If we take the third quartile of the distribution, we get a distance between centers of 47.25 km, yielding a radius of 23.63 km.

Table 4.5. Market Data for Reduced Level 2 Markets

Market Name	Places Served Unwght	Places Served Wght	Pop. (1979)	Area (km^2)	Density	Level 2 Score
Tejutla	90	77.09	106,283	1,018.02	104.40	0.7857
Huehuetenango	104	92.85	121,006	1,571.24	77.01	0.9714
EL Quiché	127	103.83	129,141	1,827.68	66.4	1.0000

Table 4.5 shows the same measures as the previous table, but for the reduced peripheral market areas. Comparing the two, we can see that within the smaller area the peripheral centers serve approximately the same number of places as the other centers. The population figures tell a similar story. The market area is still large, but this is to be expected, since even the reduced markets were predicated on a larger-than-average radius from the level 2 place. The fact that the population served is roughly equal but the area is larger leads to the lower market density figures. In order to encompass a large enough population to support a level 2 market, the geographical size of the market has had to be extended, compared with the more densely populated parts of the study area.

We can also see a decrease in the level 2 area score in the reduced market areas. Since this score is the percentage of all level 2 goods which are available in at least one place in the market area, a smaller score for fewer places is not surprising. The El Quiché reduced market still shows the maximum score of unity, indicating that the deficiencies of Santa Cruz (which itself has a level 2 score of 0.944) are made up by lower-level places close enough to be within the reduced area. Tejutla, the weakest of the level 2 markets, also shows the largest decline in area score from reducing its market area. This indicates that some level 3 or lower places at a far remove from Tejutla are supplying level 2 goods which are not available at the "central place" of the market area.

Since it is not unusual for some level 2 goods to be supplied by level 3 places, it is possible that in the periphery these lower-level places, far from the nearest level 2 place, take on some of the burden of supplying at least part of the level 2 bundle. On the other hand, the fact that these parts of the study region are unable to support an additional level 2 place suggests that the demand for such goods might be insufficient to allow such "enhanced level 3 places" to exist. To test these alternative hypotheses, we need to examine the level 2 scores of the level 3 places, to see if those distant from a level 2 place have higher scores.

To simplify the terminology, we define the "complementary region" of a level 2 place as that part of its market area which is not in its reduced market area. It is the level 3 places in the complementary regions which we want to test for supplying level 2 goods.

Table 4.6 shows some descriptive statistics for the percentage of level 2 goods (i.e., the "level 2 score") offered by level 3 places in the complementary regions, not in the complementary regions, and all such places. The mean for all *complementary* regions is somewhat lower than for places *not* in complementary regions, but the difference is well within one standard deviation. The pattern of lower scores is not consistent among the three complementary regions. Tejutla's mean score is much lower than the noncomplementary level 3 places, but El Quiché's is slightly higher.

Table 4.6. Level 2 Score Descriptive Statistics for Level 3 Places in Complementary Regions

Region	N	Mean	Standard Deviation	Minimum Value	Maximum Value
Tejutla Complementary	4	0.0694	0.0661	0.0278	0.1667
Huehuetenango Complementary	17	0.1961	0.1455	0.0278	0.6389
El Quiché Complementary	4	0.2986	0.1641	0.0833	0.4722
All Complementary[a]	24	0.1887	0.1519	0.0278	0.6389
Not Complementary	33	0.2416	0.1514	0.0278	0.6111
All Level 3 Places	57	0.2193	0.1526	0.0278	0.6389

[a] One level 3 place is shared by two of the complementary regions. Thus, the total number of level 3 places in the complementary regions is 24, not 25.

The highest level 2 score (0.639) for any level 3 place in the study area is Barillas, in the Huehuetenango complementary region. Barillas is a municipio capital in the northeastern corner of the study region. This is a heavily mountainous area and about as far from a level 2 place as it is possible to be. It is the only level 3 place in the peripheral level 2 areas which offers half or more of the level 2 goods bundle. No such strong level 2 score is observed in the northwestern corner of the study area. This is a bit surprising, since that section has more central places and is even further from Huehuetenango, the nearest level 2 place. Perhaps the nearness of the Mexican border reduces the ability of the northwest to support level 2 central functions. Barillas is on the edge of the study area which borders on the rest of Guatemala. It may receive a certain amount of demand from Guatemalan places on the other side of this edge.

Table 4.7 shows the results of an analysis of variance test of the hypothesis that the mean level 2 score of level 3 places is different in the complementary level 2 markets compared with the rest of the study area. The resulting F-value, 2.17, is not significant at the 95% confidence level, but the p-value of 10.24% indicates that this test is not entirely conclusive. Table 4.8 shows the results of pairwise comparisons between the means for each of the complementary markets and the rest of the study area. Only the level 3 places of the Tejutla complementary market area show a mean level 2 score that is significantly different, and this mean is lower than the mean for the rest of the study area. Thus, the evidence does not indicate that level 3 places far from level 2 places "pick up the slack" by offering additional level 2 goods.

Of the 889,606 persons seemingly served by the three peripheral level 2 places, only 356,430 live in the reduced market areas. Thus 533,176 people are probably too far from a level 2 place to receive an adequate supply of the places' central goods. This number is subject to a large amount of error and should only be used as the roughest approximation. Even so, this figure represents 35 percent of the population of the study area. More than a third of the inhabitants of western Guatemala have at best doubtful access to higher-level goods.

Table 4.7. Examination of Level 2 Scores for Level 3 Places

(ANOVA Comparison of Complementary Regions with Rest of Study Area)

Source	DF	Sum of Squares	Mean Square	F-Value	PR > F
Model	3	0.1404	0.0468	2.17	0.1024
Error	54	1.1664	0.0216		
Corrected Total	57	1.3068			

Table 4.8. Examination of Level 2 Scores for Level 3 Places Comparing Complementary Markets with Rest of Study Area

T-Tests for Differences in Mean Level 2 Scores

Alpha=0.05 Confidence=0.95 DF=54 MSE=.0216001
Comparisons significant at the 0.05 level are indicated by '***'

Reduced Region	Lower Confidence Limit	Difference Between Means	Upper Confidence Limit	
Tejutia	0.0161	0.1721	0.3281	***
Huehuetenango	-0.0424	0.0455	0.1334	
El Quiché	-0.2130	-0.0570	0.0989	

4.2.3. Summary

The pattern of level 2 places conforms to the expectations of central place theory, given the uneven terrain and population distribution of western Guatemala. Quetzaltenango, the level 1 place, has a much more populous level 2 market area than the purely level 2 places, considering only the reduced market areas of the periphery. The peripheral level 2 places must extend their areas in order to reach populations large enough to sustain them. Although there is no direct evidence, it seems likely that many of the places in the outlying municipios of the study region have incomplete or nonexistent access to level 2 central goods.

4.3. Intermediate-Level Markets

The level 3 and 4 markets follow patterns similar to the level 2 markets: densely packed in the center and southeast of the region, but larger and less numerous on the periphery. Most municipio capitals are level 3 markets, and vice versa. On the edges of the study region, in northern Huehuetenango and northwestern San Marcos, level 4 markets per se disappear entirely. The only sources of level 4 goods in those regions are the level 3 places—again, usually the municipio capitals.

4.3.1. The Market Area Lattice

It is too much to expect that the market areas of the central place system in a real (and mountainous) region will conform to Christaller's simple diagrams. However, we do find that there is a general resemblance in the arrangement of the lower-level central places in western Guatemala. Table 4.9 shows the frequency distribution of the number of sides in the polygons which comprise the rough market areas of the level 3 and 4 places in the study region.[2] Since the borders of these areas are drawn so as to perpendicularly bisect the line between a place and a competing place, the number of sides is the same as the number of competing markets which set a limit on the territorial reach of the market at the center of the polygon.

In a perfect Christallerian system organized on "the marketing principle," there would be six sides to every market area. If the dominant principle of the system of central places is one of the alternatives that Christaller suggested, there should be three or four competing places. Since a real-world system may well be the result of several of these organizing principles operating simultaneously, we might expect to see fewer than six competitors in some cases. The system in Guatemala illustrates this rather well. The average number of competing markets for level 3 market areas is 5.33, while for level 4 market areas there are 5.38. These

[2] Only those places which were surrounded on all sides by other markets in the study region were included in constructing this table.

numbers are virtually equal, given the size of the samples, and they err on the expected side of six. Only 16.3 percent of the level 3 markets and 11.4 percent of the level 4 markets have more than six competitors.

Table 4.9. Distribution of Polygon Sides for Market Areas

Level 3 Market Areas:

No. of Sides	Frequency	Percent	Cumulative Frequency	Cumulative Percent
3	1	2.3	1	2.3
4	9	20.9	10	23.3
5	15	34.9	25	58.1
6	11	25.6	36	83.7
7	7	16.3	43	100.0

Level 4 Market Areas:

No. of Sides	Cumulative Frequency	Cumulative Percent	Frequency	Percent
3	1	0.8	1	0.8
4	15	12.3	16	13.1
5	59	48.4	75	61.5
6	33	27.0	108	88.5
7	12	9.8	120	98.4
8	2	1.6	122	100.0

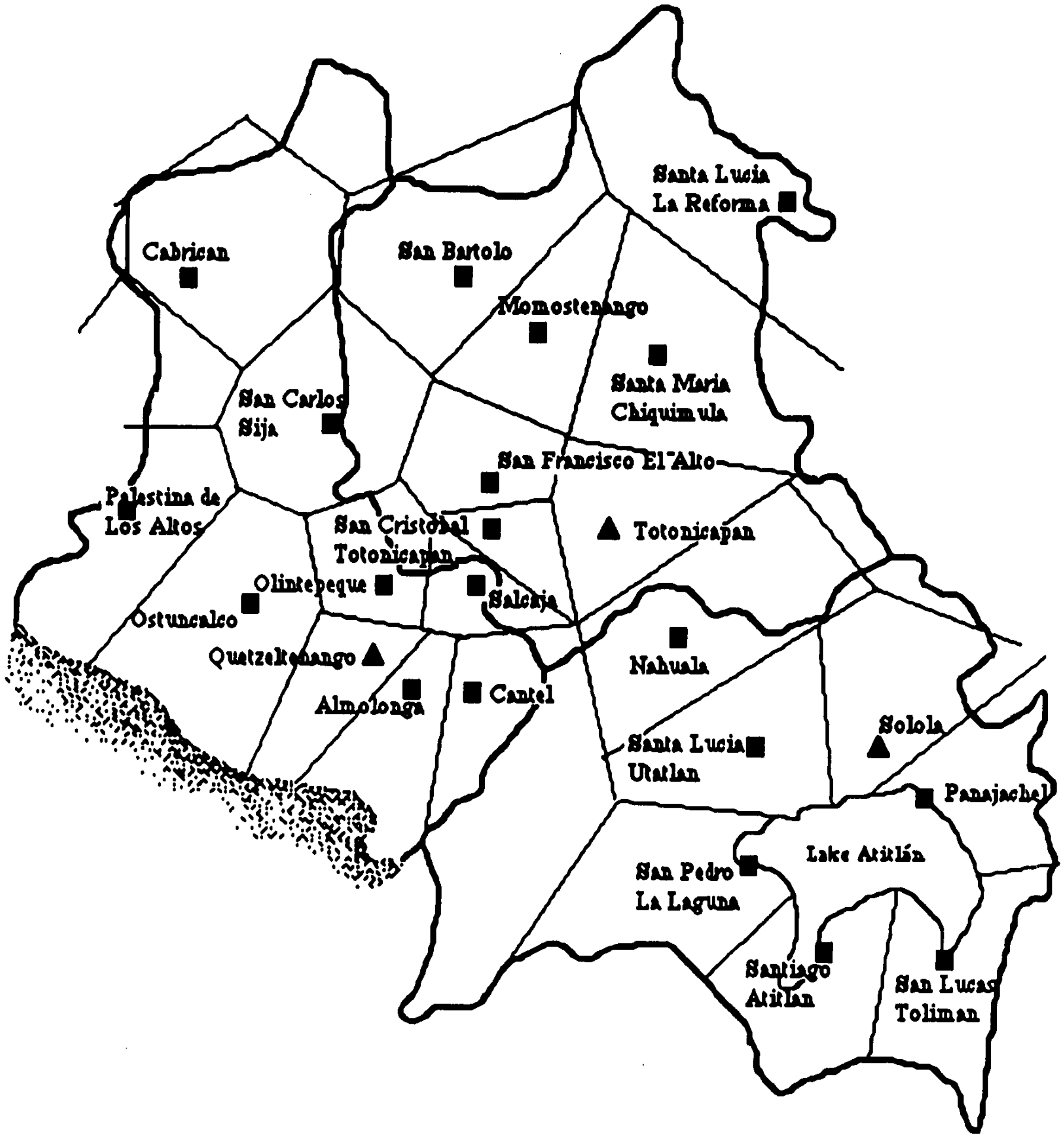


Figure 4.3. Level 3 Market Areas in Quetzaltenango, Totonicapán, and Sololá

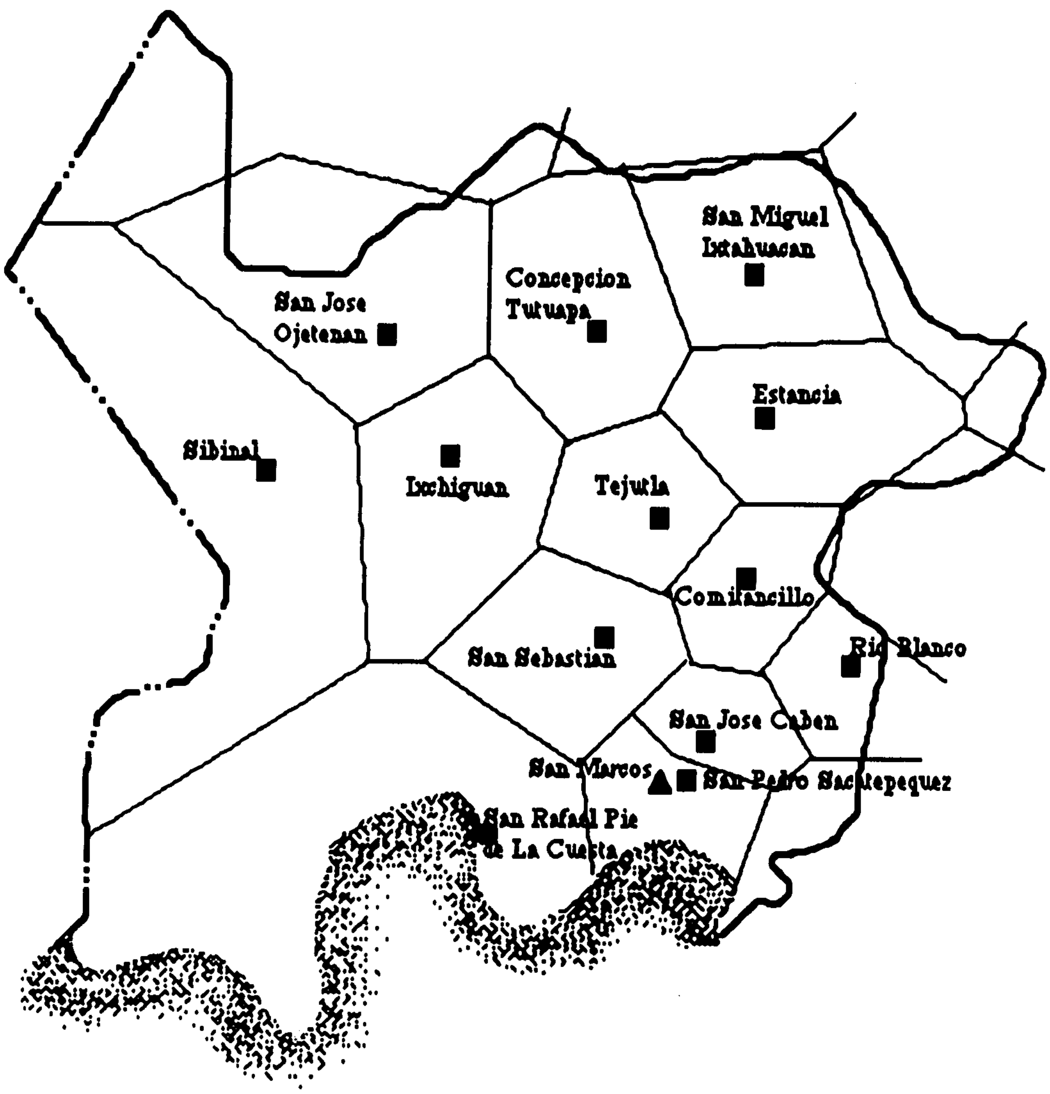
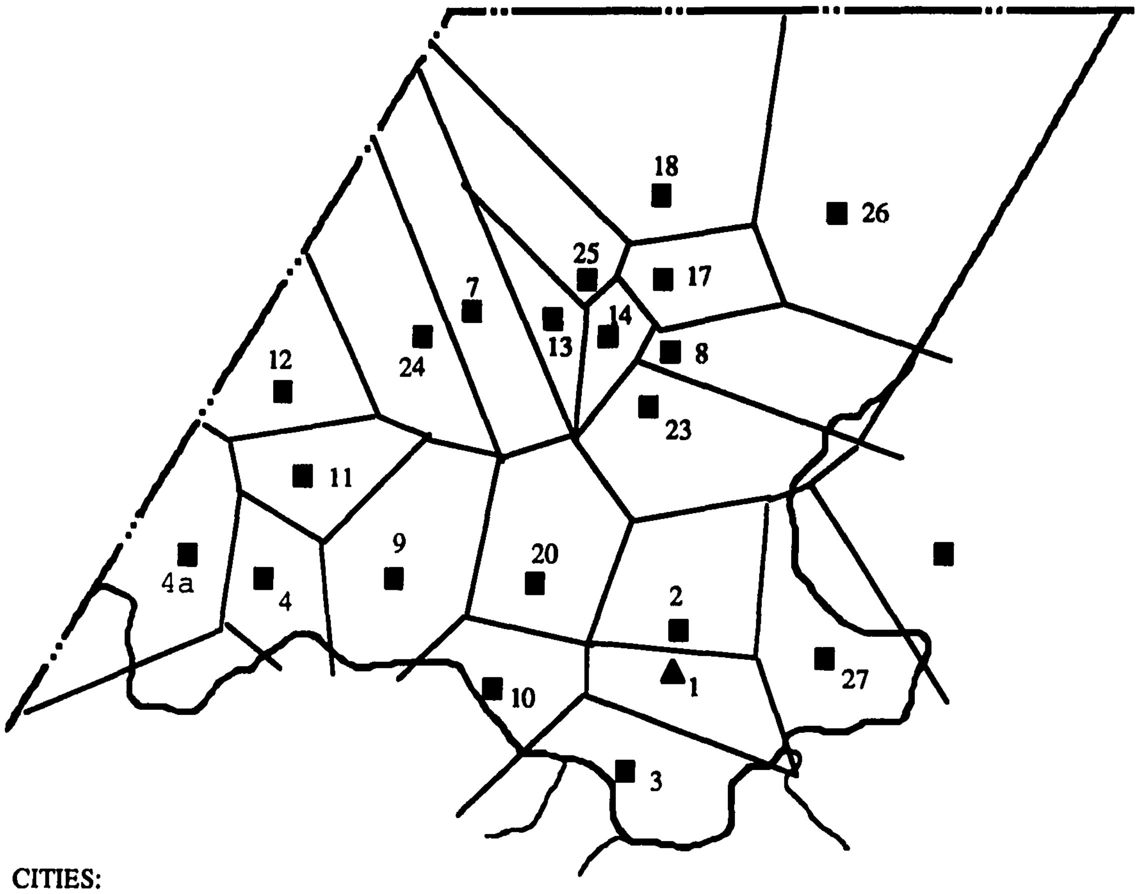


Figure 4.4. Level 3 Market Areas in San Marcos



CITIES:

1 Huehuetenango
2 Chiantla
3 Malacatancito
4 Cuilco
4a Yerbabuena
7 Jacatenango
8 San Pedro Soloma
9 Ixtahuacan
10 Santa Barbara
11 La Libertad
12 La Democracia
13 San Miguel Acatan
14 San Rafael La Independencia
17 Santa Eulalia
18 San Mateo Ixtatan
20 San Sebastian Huehuetenango
23 San Juan Ixcoy
24 San Antonio Huista
25 San Sebastian Coatan
26 Barillas
27 Aguacatan

Figure 4.5. Level 3 Market Areas in Huehuetenango

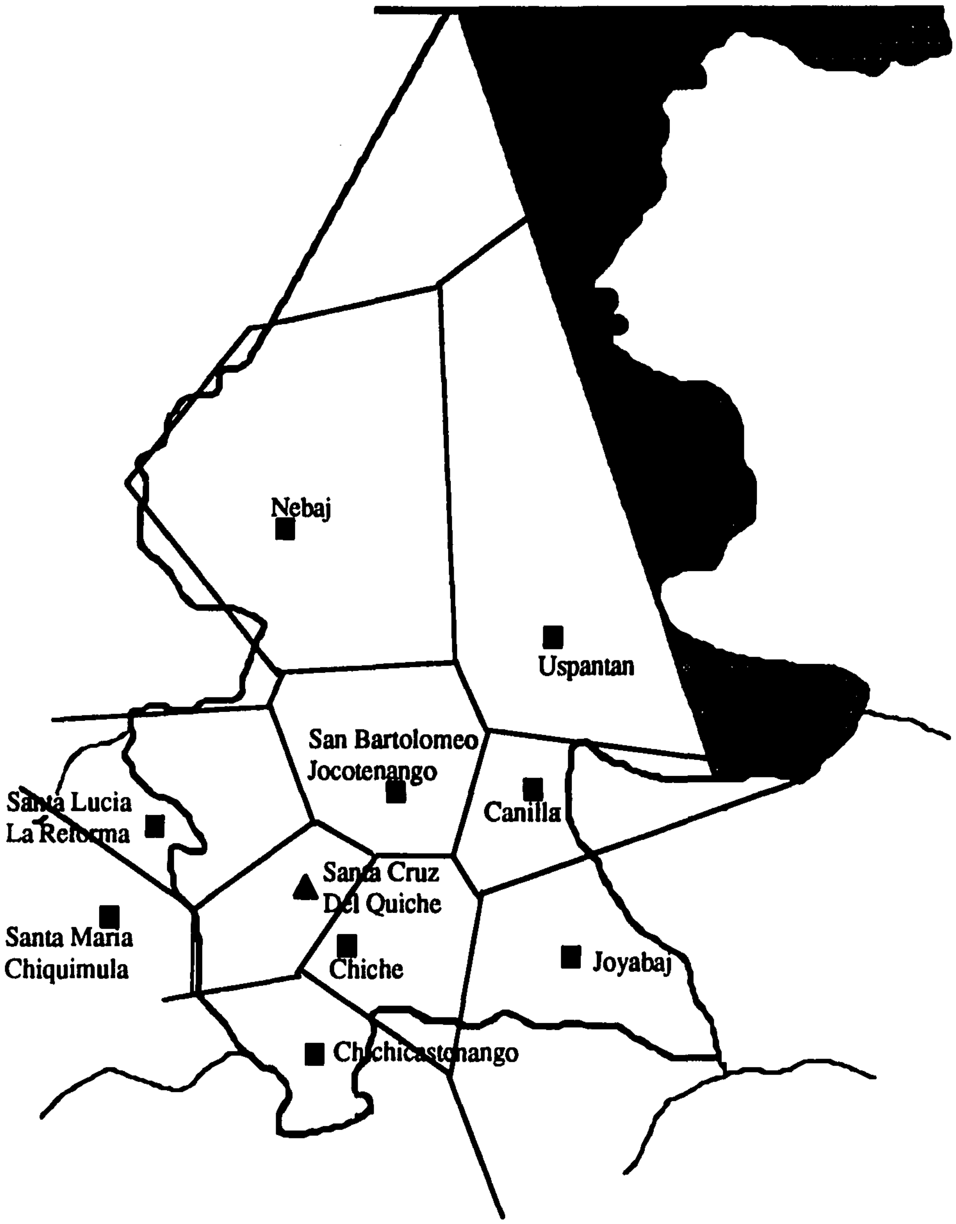


Figure 4.6. Level 3 Market Areas in El Quiché

4.3.2. Central Places

There are a total of 151 mid-level central places. Of those, 57 (37.75%) are level 3 places, and 94 (62.25%) places are level 4. Since there are only six distinct level 2 places, we see that the ratios of each level to the next lower level are not constant, being approximately 1:9.5:13.9. The distribution of level 3 goods requires far more places than level 2 goods.[3] On the other hand, the low ratio of approximately 1.6 level 4 places for every level 3 place has to be viewed with some caution. This is the average over the entire study area, and if parts of the area have an insufficiently well developed system of central places, there may be fewer level 4 places than expected.

Table 4.10 shows the distribution of mid-level central places among the subregions described earlier. This distribution is not uniform, as is demonstrated by the variation in the level 4:level 3 ratio, also shown in the table. In the two most developed subregions, the core and the southeast, the ratio is 3 or more. As we move further into the periphery, the ratio continues to fall. In the east central and belt subregions, the ratio is still fairly high, but beyond that the ratio drops below unity, indicating that level 3 places are more numerous than level 4 places. This is particularly true in the Northwest region, where even level 5 places tend to be under-represented. In the well-articulated portion of the region, approximately three level 4 places are required for every level 3 place. As the settlement density dwindles, level 4 places tend to disappear. The level 3 places must then take on the entire burden of supplying level 4 goods. In the discussion below, it is

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[3]This evidence again suggests that level 2 goods do not reach all of the population in the study area.

hypothesized that the two intermediate levels essentially merge into a single level in the least developed areas of the study region. If, following this hypothesis, the Northwest, Far North, and Northwest Belt regions are excluded from consideration, the level 4:level 3 ratio is 2.2:1 for the remainder of the study region.

Table 4.10. Distribution of Mid-Level Places by Subregion

Frequency Percent Row Percent Column Percent	Central Place Level 3	 4	 Total	Ratio: 4:3
Core	13 8.61 25.00 22.81	39 25.83 75.00 41.49	52 34.44	3.00
Northwest	4 2.65 80.00 7.02	1 0.66 20.00 1.06	5 3.31	0.25
Far North	12 7.95 70.59 21.05	5 3.31 29.41 5.32	17 11.26	0.42
Southeast	7 4.64 23.33 12.28	23 15.23 76.67 24.47	30 19.87	3.29
East-Central	8 5.30 30.77 14.04	18 11.92 69.23 19.15	26 17.22	2.25
North-Central	10 6.62 66.67 17.54	5 3.31 33.33 5.32	15 9.93	0.50
San Marcos Belt	3 1.99 50.00 5.26	3 1.99 50.00 3.19	6 3.97	1.00
Total	57 37.75	94 62.25	151 100.00	1.65

4.3.2.1. Populations

Tables 4.11 and 4.12 show place population and level-score statistics for the level 3 and level 4 central places, respectively. These tables illustrate that while there is a general correlation between central place level and population, the former does not determine the latter. The mean population of level 3 places is 3152.3, almost twice that of level 4 places (1742.8). However, the range of population for level 3 places is so much greater that the smallest level 3 place has a population of 149, compared with a minimum of 232 for the level 4 places. Indeed, the normal pattern is reversed for two subregions, northwest and north-central, and a third subregion, the far north, has near-equal populations for its level 3 and level 4 places.

Table 4.11. Place Data for Level 3 Places

		Place Population			Mean Place Level Scores		
Subregion	Freq	Mean	Max	Min	Level 3	Level 4	Level 5
Core	13	3882.2	9816	698	0.7692	0.9039	1.0000
Northwest	4	832.0	1337	548	0.7500	0.8125	0.5000
Far North	12	3107.8	6418	708	0.7857	0.6250	0.5833
Southeast	7	7460.6	26382	1023	0.7959	0.9643	0.7143
East-Central	8	2645.4	9456	149	0.8929	0.8750	0.9375
North-Central	10	1177.6	2358	456	0.8000	0.6500	0.7000
San Marcos Belt	3	1141.7	1986	514	0.7619	0.7500	0.6667
All Subregions	57	3152.3	26382	149	0.7970	0.7895	0.7632

The population of fully 47% of the level 3 places is less than the mean level 4 place population (see Table 4.13). The proportions of level 3 central places which are this small are unusually high in the northwest and north-central subregions. The northwest subregion also has an unusually high proportion of places in the lowest quartile of the population distribution, at 75%. On the other hand, the southeast has no places this small, and the far north has only 1, or 8% of its total. The two smallest level 3 places in the core subregion are San Sebastian, in Municipio San Marcos, and Comitancillo, a municipio capital, also in Departamento San Marcos. These are right on the edge of the core subregion and could arguably be considered part of the San Marcos belt.

Table 4.12. Place Data for Level 4 Places

		Place Population			Mean Place Level Scores		
Subregion	Freq	Mean	Max	Min	Level 3	Level 4	Level 5
Core	39	1867.0	5393	665	0.1868	0.8141	0.7436
Northwest	1	1913.0	1913	1913	0.2857	1.0000	0.5000
Far North	5	2964.8	5203	1736	0.4571	0.7500	0.8000
Southeast	23	1656.0	4829	232	0.1801	0.8261	0.8044
East-Central	18	1471.4	2657	319	0.2460	0.8750	0.6944
North-Central	5	1550.0	2501	1023	0.1429	0.7500	0.5000
San Marcos Belt	3	650.3	841	537	0.1429	0.8333	0.6667
All Subregions	94	1742.8	5393	232	0.20821	0.8245	0.7340

The distribution of smallest level 3 places does not suggest a strong pattern, other than to emphasize the underdeveloped nature of the northwest and the the greater density of the southeast. The far north's low percentage may be related to the fact that that subregion has very few level 4 places and is far from the level 2 places. Thus, level 3 places are the locally dominant centers. The very smallest level 3 place is San Bartolome Jocotenango, a municipio capital in Departamento El Quiché. At 149 persons, it is barely a third of the size of the second smallest place (San Sebastian Huehuetenango, population 456). Even so, the place has a level 3 score of 0.8571, and both of its lower-level scores are 1.0000. Thus, it is a more solid level 3 place than many with larger populations.

The far north and northwest subregions have both the highest proportion of unusually small level 3 places and of unusually large level 4 places. Both of these subregions are characterized by under-articulation of the central place hierarchy: The far north has a paucity of level 4 places, and the northwest has unusually high proportions of low-level places of all types. It appears that in these circumstances, the distinction between level 3 and level 4 places essentially disappears, and the two levels merge into one. This effect is particularly visible in the northwest subregion, where the single level 4 place, Sibinal, has the highest population in the subregion and offers 19.44% of the level 2 goods bundle, 28.57% of the level 3 bundle, and as much of the level 4 and 5 bundles as any level 3 place in the subregion.

Table 4.13. Distribution of Small Level 3 Places

	Places with populations less than the average level 4 place:		Places in lowest quartile of level 3 place populations:	
Subregion	Freq.	Percent of Subregion	Freq.	Percent of Subregion
Core	4	30	3	23
Northwest	4	100	3	75
Far North	3	25	1	8
Southeast	1	14	0	0
East-Central	4	50	3	38
North-Central	9	90	3	30
San Marcos Belt	2	67	1	33
All Subregions	27	47	14	25
Mean		54		29
Standard Deviation		31		22

In the far north, too, the level 3 and 4 places are quite similar. The level 3 places have a larger range of populations, but their mean is only 4.82% larger than the mean population of the level 4 places. The level 3 scores of the level 4 places are, of course, lower than for the level 3 places, but they are still quite high, averaging 0.4571. The level 4 places in the far north actually have higher level 4 and 5 scores than the level 3 places.

Table 4.14. Level 4 Places Larger than the Mean Level 3 Place

Subregion	Frequency	Percent of Subregion
Core	4	10
Northwest	1	100
Far North	5	100
Southeast	3	13
East-Central	0	0
North-Central	0	0
San Marcos Belt	0	0
All Subregions	13	14

4.3.2.2. Level scores

Central places are classified on the basis of the goods offered, not their populations. Thus, by definition, the level 3 places have a much higher level 3 score than do the level 4 places. The level 3 places offer, on the average, 79.7% of the total level 3 goods bundle, compared with only 20.82% for the average level 4 place. There is much less variation in the level 3 score by subregion than there is in place populations, illustrating that while in general higher level places tend to have larger populations, it is the goods bundle offered which determines central place levels. Both kinds of intermediate places score high on supplying level 4 goods, with the strictly level 4 places averaging somewhat better than the level 3 places (which, of course, are also level 4 places). Some of the level 3 places show remarkably low level 4 scores, in the far north and the north-central subregions.

The average level scores for supplying the lowest-level goods, level 5, is very similar for both levels 3 and 4 places. There is considerable subregional variation, however. Some of this variation occurs because there are only two goods in the the level 5 bundle. This means that the absence of one good will reduce a place's level 5 score by half. Even so, it does appear that the northwest—a subregion quite weak in many ways—is rather tenuously supplied with level 5 goods, as both the level 3 and the level 4 places in that subregion average only 50% of the level 5 goods bundle.

Table 4.15. Mean Market Statistics for Intermediate Areas

Level 3:

Central Place Level	Places Served: Freq	Places Served: wght	Places Served: unwght	Persons Served (1979)	Market Area (km^2)	Density (persons per km^2)	Area Level Score
1	1	8.17	13.00	73583.2	113.50	648.30	1.0000
2	7	18.00	26.29	33180.9	204.97	167.15	0.8980
3	57	13.52	21.09	21357.0	270.12	113.16	0.8601
All	65	13.92	21.52	23433.8	260.69	127.21	0.8663

Level 4:

Central Place Level	Places Served: Freq	Places Served: wght	Places Served: unwght	Persons Served (1979)	Market Area (km^2)	Density (persons per km^2)	Area Level Score
1	1	3.34	6.00	69409.2	57.26	1212.24	1.0000
2	7	6.74	11.57	19203.3	69.27	322.59	0.8750
3	57	7.39	11.98	12883.3	158.28	158.66	0.8757
4	94	4.51	7.14	6169.4	77.41	145.67	0.8679
All	159	5.63	9.06	9547.8	105.92	164.82	0.8718

4.3.3, Market Areas

Level 3 markets are much smaller than level 2 markets, whether measured by territorial extent or population served. This is an arithmetic consequence of the fact that there are 66 places functioning as level 3 central places, as opposed to the 6 which act as level 2 places. Thus, the average level 3 market population is 23,434 persons, as opposed to the average of 216,768 for level 2 markets (see Table 4.15). Similarly, the mean number of places served by each level 3 place is approximately 14, an order of magnitude less than the level 2 mean of 130. Level 3 markets are much more local in character, encompassing a municipio, or perhaps two, while the level 2 markets span departmentos. The reason for this can be seen in the list of goods in the previous chapter (Table 3.10). Level 3 goods are everyday items, such as food, clothing, and footwear. Three of the the seven categories are specifically marketplace (as opposed to store) goods, and two others, FOOTWEAR and CLOTHING, include some marketplace vendors. Level 2 goods tend more towards luxuries,entertainment, and business services.

The higher-level places also have advantages as suppliers of lower-level goods, as can be seen from Table 4.15. The level 1 and 2 places serve larger market populations in smaller areas than do the strictly intermediate places. This is primarily because the higher-level places have large local populations (i.e., in the places themselves) to supply. However, this does not completely account for the disparity. Table 4.16 shows the mean "nonlocal" populations served by different levels of places in their capacities as level 3 and 4 markets. While the differences in population and market population density are less marked when only the nonlocal portion is considered, they are not extinguished. Level 2 places still provide level 3 goods to 23% more persons, with a 12% greater density, than do level 3 places. Both level 2 and 3 places have larger level 4 market populations and densities than do the strictly level 4 places, although it is interesting to note that the average nonlocal level 4 market population is slightly greater for level 3 places than for level 2 places.

Table 4.16. Mean Nonlocal Market Populations[a]

Level 3 Markets:

Place Level	Freq	Place Pop	Market Pop	Nonlocal[b] Pop	Area (km^2)	Market Density	Nonlocal Density
2	7	11022	33181	22159	205.0	167.1	115.0
3	41	3391	21303	17911	208.8	131.3	102.3
ratio (2:3)		3.25	1.56	1.23	0.98	1.27	1.12

Level 4 Markets:

Place Level	Freq	Place Pop	Market Pop	Nonlocal Pop	Area (km^2)	Market Density	Nonlocal Density
2	7	11022	19203	8181	69.3	322.6	138.1
3	1	3392	11851	8460	108.0	190.1	108.2
4	88	1671	5503	3832	58.4	152.0	83.2
ratio (2:4)		6.60	3.49	2.13	1.19	2.12	1.65
ratio (3:4)		2.02	2.15	2.21	1.84	1.25	1.30

[a]The figures for level 3 and 4 places in this table exclude the places in the far north and northwest subregions.

[b]The "nonlocal" population of each market was calculated by subtracting the place population from the market population. Note that the table excludes the intermediate central places in the far north and northwestern subregions, because of the blurring that occurs between the level 3 and 4 centers in those parts of the study region.

There are two reasons why this pattern might be expected. One is that locations which are easily accessible and in well-populated areas are more likely to become higher-level places. By definition, high-level goods are those which require large populations to support the firms producing them. Firms which locate in more accessible places will tend to be more successful competitors than those with less favorable locations. Thus, these more accessible locations will be the ones which evolve into high-level central places. The advantages of the location will apply to lower-level goods as well, giving these places larger market populations, even for the lower-level goods.[4].

The second reason is that places which offer high-level goods are more attractive to consumers, who can acquire both high-level and low-level goods with a single trip to the high-level centers. This would increase the population served by the high-level places, at the expense of the lower-level centers. While this second effect probably occurs, it would not be detected by the methods used in this study. The method of estimating market populations (as described in Section 4.1) was based on allocating tributary places to nearby centers and then allocating rural municipio populations in proportion to place populations. Thus, the market populations are inferred on the basis of residence, and do not reflect data on actual trips to specific market centers.

4.3.3.1. Level 3

The strictly level 3 places show a remarkable consistency across subregions in their market populations, as can be seen in Table 4.17. With a single exception, all market populations are within 25% of the global mean, and all but one of these are within 7% of this mean. The main outlier is the northwest belt subregion. This

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[4]It is quite possible that the firms in such places will benefit to the extent of making economic profits. On the other hand, it may simply result in a larger number of individual firms in the higher level places, each making normal profits.

subregion was defined as the "leftover" strip between the core and northwest subregions. The usually low mean population is probably a result of this arbitrary specification. This consistency of population comes with considerable variation in market area and population density. The markets of the far north average nearly 500 km^2, while those in the core require less than a quarter as much area to reach the same number of persons.

Table 4.17. Market Statistics for Level 3 Central Places.by Subregion

Subregion	Places Served Frq	Places Served wght	Places Served unwght	Persons Served (1979)	Market Area (km^2)	Density (persons per km^2)	Area Level Score
Core	13	12.42	19.23	20547.8	115.99	190.10	0.8699
Northwest	4	17.42	28.00	21798.1	223.64	103.65	0.9046
Far North	12	11.65	18.50	21394.8	494.97	54.37	0.8571
Southeast	7	15.56	21.14	22120.7	193.18	118.45	0.8367
East-Central	8	12.60	19.50	26762.4	316.63	127.93	0.8989
North-Central	10	16.38	26.90	20002.2	276.91	76.11	0.8191
San Marcos Belt	3	8.72	15.00	12443.1	133.39	99.57	0.8571
All Subregions	57	13.52	21.08	21357.0	270.12	113.16	0.8601

The area level scores also vary little by subregion, but this is to be expected, since each market is based on a level 3 place. What is notable is the fact that the level scores are so low. On the average, 14% of the level 3 goods bundle is unavailable to consumers in the market areas of level 3 places. The same goods would not be missing in each area, of course, and it is probable that consumers could obtain the whole bundle by patronizing several level 3 places, at least in the more densely populated regions. Even so, there does seem to be a certain amount of weakness in the distribution of these goods.

4.3.3.2. Level 4

There is much less uniformity in the market statistics for the strictly level 4 places (Table 4.18). In particular, the northwest and far north subregions show much higher mean market populations, roughly two to five times the global mean. The north-central subregion also has an unusually large mean for the market population. All of these subregions are characterized by small numbers of level 4 places and large numbers of tributary (low-level) places. Thus, it is the scarcity of intermediate places relative to low-level places which is inflating the market populations. In fact, ranking the subregions from lowest to highest in terms of mean market population also ranks them from lowest to highest in terms of mean weighted number of places served, except that the northwest belt is out of order.

Table 4.18. Market Statistics for Level 4 Central Places

Subregion	Places Served: Frq	Places Served: wght	Places Served: unwght	Persons Served (1979)	Market Area (km^2)	Density (persons per km^2)	Area Level Score
Core	39	3.58	5.67	5313.8	36.43	198.89	0.8450
Northwest	1	22.66	30.00	28379.2	265.21	107.01	1.0000
Far North	5	8.96	14.60	13457.4	374.81	41.81	0.7915
Southeast	23	3.69	6.13	4141.0	33.97	134.92	0.8677
East-Central	18	4.27	6.50	6461.3	124.98	85.65	0.9213
North-Central	5	8.00	13.20	9824.0	78.38	136.56	0.8250
San Marcos Belt	3	5.00	7.67	5450.7	97.95	97.57	1.0000
All Subregions	94	4.51	7.14	6169.4	77.41	145.67	0.8679

The area level scores average 0.8679, which is quite similar to the 0.8601 mean for level 3 markets. As with population, there is more variation among subregions for level 4 markets than for level 3. However, the extremes are found in the subregions with the smallest numbers of places, and is possible that this is simply a random effect. For both the level 3 and level 4 places, the low area scores suggest that there may be gaps in the supply of goods to some consumers.

4.4. Low-Level Places

The lowest tier of the central place system is made up of the level 5, 6, and 7 "central places." That term is used cautiously because, strictly speaking, only level 5 places meet the Christallerian criteria of a central place, that of being a supply source for central goods. Level 7 places are those places that offer none of the goods in the hierarchy developed in the previous chapter. Level 6 places offer none of the level 5 goods but do offer very small and incomplete portions of the higher-level goods bundles. Thus, the level 7 places are simply "names on the map," small settlements that offer no private services of any kind (although public services have not yet been addressed). Level 6 places are anomalies which bear further investigation. The true bottom of the Christallerian hierarchy is the level 5 central place, which offers the most basic necessities only.

4.4.1. Distribution by Subregion

The distribution of these lowest level places is shown in Table 4.19. The 754 central places in the lowest three categories represent 80% of the 941 individual places in the study region. Of these, 537, or 71.22%, are level 5. The remainder are divided roughly equally between level 6 and level 7 places. The level 7 places are very small indeed, with a mean population of 602.5 (see Table 4.20) and a minimum recorded size of only 62 persons. It is easily conceivable that such small places, with no services, would be overlooked by the survey that generated this study's data. With that caution in mind, the differences in proportions of places among subregions are still rather interesting.

Table 4.19. Distribution of Lower-Level Places by Subregion

Frequency Percent Row Percent Column Percent	Central Place Level 5	6	7	Total	Ratio: 5:6:7
Core	137 18.17 87.26 25.51	12 1.59 7.64 9.84	8 1.06 5.10 8.42	157 20.82	17.1:1.5:1
Northwest	14 1.86 18.67 2.61	31 4.11 41.33 25.41	30 3.98 40.00 31.58	75 9.95	0.5:1.0:1
Far North	74 9.81 67.27 13.78	26 3.45 23.64 21.31	10 1.33 9.09 10.53	110 14.59	7.4:2.6:1
Southeast	107 14.19 91.45 19.93	6 0.80 5.13 4.92	4 0.53 3.42 4.21	117 15.52	26.8:1.5:1
East-Central	75 9.95 65.79 13.97	20 2.65 17.54 16.39	19 2.52 16.67 20.00	114 15.12	3.9:1.1:1
North-Central	107 14.19 71.33 19.93	23 3.05 15.33 18.85	20 2.65 13.33 21.05	150 19.89	5.4:1.2:1
San Marcos Belt	23 3.05 74.19 4.28	4 0.53 12.90 3.28	4 0.53 12.90 4.21	31 4.11	5.8:1.0:1
Total	537 71.22	122 16.18	95 12.60	754 100.00	5.7:1.3:1

Table 4.20. Place Data for Lower-Level Places

Subregion	Freq	Population Mean	Population Max	Population Min	Mean Level Scores Level 3	Mean Level Scores Level 4	Mean Level Scores Level 5
All Lower-Level Places:							
Core	157	1057.7	4275	72	0.0328	0.2213	0.6688
Northwest	75	680.2	1995	112	0.0229	0.1833	0.1200
Far North	110	772.1	7090	61	0.0312	0.1295	0.4455
Southeast	117	1035.3	6360	42	0.0244	0.2585	0.7863
East-Central	114	684.2	3527	75	0.0125	0.1864	0.4342
North-Central	150	750.5	5445	62	0.0067	0.0833	0.4000
San Marcos Belt	31	599.7	1973	76	0.0276	0.1452	0.5968
All Subregions	754	838.6	7090	42	0.0218	0.1741	0.5080
Level 5 Places:							
Core	137	1107.7	4275	73	0.0375	0.2263	0.7664
Northwest	14	825.4	1398	249	0.0612	0.2500	0.6429
Far North	74	847.4	7090	61	0.0444	0.0980	0.6622
Southeast	107	1064.6	6360	42	0.0254	0.2617	0.8598
East-Central	75	759.1	3527	156	0.0171	0.2033	0.6600
North-Central	107	810.6	5445	71	0.0093	0.0631	0.5607
San Marcos Belt	23	683.6	1973	76	0.0373	0.1522	0.8043
All Subregions	537	929.8	7090	42	0.0282	0.1774	0.7132
Level 6 Places:							
Core	12	893.9	2162	241	0.0000	0.3125	0.0000
Northwest	31	686.9	1995	112	0.0276	0.3306	0.0000
Far North	26	555.7	1205	157	0.0055	0.2692	0.0000
Southeast	6	417.8	1048	86	0.0238	0.3750	0.0000
East-Central	20	644.1	1851	97	0.0071	0.3000	0.0000
North-Central	23	553.2	1381	88	0.0000	0.2500	0.0000
San Marcos Belt	4	291.5	434	204	0.0000	0.2500	0.0000
All Subregions	122	620.8	2162	86	0.0105	0.2951	0.0000
Level 7 Places:							
Core	8	447.5	844	72	0.0000	0.0000	0.0000
Northwest	30	605.5	1782	126	0.0000	0.0000	0.0000
Far North	10	777.0	1496	215	0.0000	0.0000	0.0000
Southeast	4	1179.0	2812	174	0.0000	0.0000	0.0000
East-Central	19	430.9	1040	75	0.0000	0.0000	0.0000
North-Central	20	656.0	2041	62	0.0000	0.0000	0.0000
San Marcos Belt	4	425.0	661	312	0.0000	0.0000	0.0000
All Subregions	95	602.5	2812	62	0.0000	0.0000	0.0000

The subregions with the highest proportions of level 5 places (relative to levels 6 and 7) are the more developed core and southeast subregions. In these two, the 6:7 ratio is the same, but the southeast has a much higher proportion of level 5 places. The reason for this is mysterious. It seems to stem from an unusually high number of level 5 places in the southeast, rather than a paucity in the core subregion. In Table 4.10, we can see that the southeast has roughly half as many intermediate central places as the core, with this proportion holding true (again, roughly) for both the level 3 and level 4 places taken individually. In Table 4.19, this pattern also holds for level 6 and 7 places, but the southeast has almost as many level 5 places as does the core itself. Why the southeast should require these extra level 5 places is not apparent. The terrain in the southeast is somewhat less mountainous than the core, which means that the level 5 places should be able to extend their market ranges, due to the lower cost of transportation. But this would result in fewer level 5 places, rather than more. Nor is it a matter of the southeast having more but smaller places. The mean populations of level 5 places in the core and southeast are roughly equal, as can be seen in Table 4.20. It would seem, then, that either the level 5 places in the southeast are less efficient, or that the population in the southeast is better supplied with level 5 goods, but for reasons which are not known.

On the other end of the distribution, the chronically underdeveloped northwest subregion has by far the lowest 5:7 ratio of the study region. The northwest is the only subregion in which there are more level 6 or 7 places than level 5, and here the latter outnumber the former by more than four to one.

The other subregion that showed marked underdevelopment in the intermediate level central places was the far north. However, we do not see a corresponding under-representation of level 5 places. To the contrary, the proportion of level 5 to lower-level places is higher than the area-wide average. Since the weakness of the intermediate central places in this subregion caused a disappearance of the level 4 places, with their functions being assumed by the level 3s, it is possible that the larger number of level 5 places is another form of compensation. Free of competition from better-situated level 4 centers, some firms offering level 4 goods could survive in level 5 centers. The mean level score data in Table 4.10 do not bear out this hypothesis. In fact, the mean level 3 scores for level 5 central places in the far north are lower than the average for this level of central place in the study area as a whole. Even their mean level 5 scores are on the low side. The large number of level 5 places is not a sign of strength, but of weakness. The sparse population, convoluted topography, and long distances in the far north reduce the competitive forces among market centers. The result is that a large number of centers survive, many of which provide substandard levels of service.

4.4.2. Place Populations

The central place and economic base theories have often been linked by a formal model which relates the population of a place to its central place level. The basis for this relationship is that higher-level places (which provide more goods) afford more employment opportunities, both to provide the central goods and to provide for the needs of those providing the central goods. However, there are many other reasons for people to settle or not settle in a place. These other factors can be expected to dominate at the low end of the central place hierarchy when the places in question offer only a few staple goods and the employment effects of the central place aspects are consequently muted.

Table 4.21. Test of Population Mean Equality for Low-Level Central Places

Source	DF	Sum of Squares	Mean Square	F-Value	PR > F
Model	2	15549403	7774701	17.32	0.0001
Error	751	337166780	448957		
Corrected Total	753	352716184			

Table 4.20 shows the breakdown of place populations by level and subregion. The mean populations of both the level 6 and level 7 places are virtually the same, at slightly more than 600 persons per place. Level 5 places are about 50% larger, around 900 persons. However, the variation around these mean figures is quite large. The extreme values of the level 5 places straddle those of both lower levels. Table 4.21 shows the results of an analysis of the variance of population among the three lowest levels of central places. The F-statistic of 17.32 is highly significant, indicating that one should reject the hypothesis that all levels have the same place population distribution. A further pairwise t-test, in the following table, shows that while the population of level 5 places is significantly different from that of the level 6 and 7 places, the latter pair of levels do not differ significantly at the 95% confidence level.[5] Thus, it appears that while even the very basic services offered by level 5 central places tend to increase the incomes of such places, the same cannot be said for the miscellany of services offered at level

[5]The t-test controls the significance for pairwise comparisons. An additional test was run using Scheffé's multiple comparison method (which controls experimentwise significance levels). This test yielded the same conclusions with respect to the significance of differences in mean populations.

6 places. These places are essentially the same as level 7 places (which have no private services).

Table 4.22. Pairwise T-Tests (LSD) of Low-Level Place Population Means

Alpha=0.05 Confidence=0.95 DF=751 MSE=448957
Critical Value of T=1.96313
Comparisons significant at the 0.05 level are indicated by '***'

Level Comparison	Lower Confidence Limit	Difference Between Means	Upper Confidence Limit	
5 - 6	177.06	308.98	440.91	***
5 - 7	180.91	327.32	473.73	***
6 - 7	-161.65	18.34	198.33	

Another question is whether the populations of each level of central place differ by subregion. Table 4.23 examines this, again using an analysis of variance F-test. In this case, the null hypothesis is that the mean place population is equal across subregions. Two tests were run: one for level 5 places and one for levels 6 and 7 places (since the previous test indicated no difference in population between the latter). The F-statistic is significant for the level 5 places, indicating that there is a difference in population across subregions. For the lowest levels, however, the F-statistic is not significant, and the null hypothesis is accepted.

Table 4.23. Test of Population Mean Equality Across Subregions

Level 5 Central Places
Number of Observations = 537

Source	DF	Sum of Squares	Mean Square	F-Value	PR > F
Model	6	12036318	2006053	3.70	0.0013
Error	530	287681788	542795		
Corrected Total	536	299718106			

Table 4.23 continued

Level 6 and 7 Central Places
Number of Observations = 217

Source	DF	Sum of Squares	Mean Square	F-Value	PR > F
Model	6	1130644	188440	1.09	0.3700
Error	210	36335992	173028		
Corrected Total	216	37466636			

Table 4.24 examines the pairwise differences in population means for the level 5 places. There are essentially two groups of subregions: the relatively developed core-and-southeast, and all the peripheral subregions. The main source of population differences seems to be related to general development in the subregions.

Two subregions are anomalies on Table 4.24. The mean population of the northwest subregion is not significantly different from that of any other subregion. The far north is significantly different from the core but not from the southeast. These two subregions (northwest and far north) are the least developed in terms of higher-level places, but their level 5 place populations have means which are within 10% of the mean for the study area (see Table 4.20). The subregions' lack of development does not seem to have hurt the level 5 places. Indeed, it seems likely that the lack of competition from level 4 places may have helped the level 5 places in these least developed regions. In the rest of the periphery, however, the intermediate central places are still well articulated. In those, the level 5 places suffer from the general low population density but still must compete with the existing level 3 and 4 places. All of these other peripheral subregions have mean level 5 populations which are lower than those of the northwest and far north.

Table 4.24. Differences in Mean Place Populations for Level 5 Places.Across Subregions

Alpha=0.05 Confidence=0.95 DF=530 MSE=542796
Critical Value of T=1.96445
Comparisons significant at the 0.05 level are indicated in **boldface**

	Core	SE	NW	FN	NC	EC	Belt
Core	N.A.	-43.15	-260.30	**-282.29**	**-297.13**	**-348.67**	**-424.11**
Southeast	43.15	N.A.	-217.15	-239.14	-253.98	-305.52	-380.96
Northwest	260.30	217.15	N.A.	-21.99	-36.83	-88.37	-163.81
Far North	282.29	**239.14**	21.99	N.A.	-14.84	-66.38	-141.82
North-Central	**297.13**	**253.98**	36.83	14.84	N.A.	-51.54	-126.98
East-Central	**348.67**	**305.52**	88.37	66.38	51.54	N.A.	-75.44
San Marcos Belt	**424.11**	**380.96**	163.81	141.82	126.98	75.44	N.A.

Weak corroboration of the hypothesis that the level 5 places in the least developed subregions benefit from the lack of competition can be seen in the mean level scores listed in Table 4.20. The level 3 scores for both the northwest and far north subregions are higher than the all-area mean. This indicates that the level 5 places are picking up more of the level 3 functions than is usual. For the northwest subregion, the level 4 level score is also above the mean, but this is not true for the far north. The far north does have a network of intermediate places, although the level 3/level 4 distinction tends to blur. One does not want to read too much into a few means, but the evidence at least suggests that the intermediate places in the far north supply level 3 but not level 4 goods with relative adequacy. On the other hand, in the northwest, the absence of a well developed intermediate tier forces more reliance on level 5 central places, inadequate though they may be at supplying higher-level goods.

The population patterns of the low-level places illustrate the interactions among the central place place hierarchy, topography, and general development which combine to determine a place's population. While it is generally true that level 5 places are larger than level 6 or 7 places, there is an area of overlap in the two size distributions. The level 5 places also show sensitivity to the general development of the subregions and the development (or lack of it) of the intermediate level central places. The level 6 or 7 places do not show significant subregional variation, perhaps because these are all such small and intensely local hamlets that the broad regional effects are too diffuse to matter.

4.4.3. Level 6 Central Places

The 122 "level 6" places identified in this study do not constitute a true level of the hierarchy. They are the places which do not fit anywhere. They offer no level 5 goods, nor do they offer a sufficient percentage of any of the higher-level goods bundles to be classified as a higher-level place. On the other hand, they do offer some goods, so they cannot be classified as level 7. The populations of these places do not differ significantly from those of the level 7 places. Are the level 6 places simply level 7 places which have acquired the odd central function, or is there something special about these places?

All but one of the level 6 places have one or more general stores (pulperias, variable P104002), which was classified as a level 4 good in the previous chapter. Almost 83% (101) of the places offer only this type of central good. Most places have three or fewer establishments of this type, but the number goes as high as 25 in a single place. This suggests that most of the level 6 places may be acting as substitutes or alternatives to level 5 places. The level 5 goods bundle consists of only two goods, grocery stores (tiendas) and (consumer) corn mills. No level 6 place has either of these, by the way the level was defined. The general stores that virtually all of the level 6 places have may be substitutes for these establishments. A disproportionately large number of these places are found in the underdeveloped northwest and far north subregions. Just over a quarter (31) of the level 6 places are found in the northwest, which contains only 8.75% of the total number of places in the study area. The far north contains 20.47% of the level 6 places but only 13.89% of all places. The only other subregion to possess a higher proportion of level 6 places than its proportion of all places is the northwest belt subregion, which is the transitional zone between the northwest and the core. Level 6 places are thus associated with the same subregions which are deficient in intermediate-level places. Since pulperias are ordinarily found in such places, their prevalence in separate level 6 places also suggests that these are an adaptation of the system of central places to the depressed conditions in the north and west of the study area.

The 21 level 6 places which offer goods other than pulperias do not differ notably from the 101 pulperia-only places in either size or location. The mean population of the former is 623.43, and of the latter, 620.31—identical, for all intents and purposes. Table 4.25 shows the distribution of these 21 places by subregion. The places are strongly concentrated in the northwest, where eleven places are to be found. Lesser concentrations are in the far north and east-central subregions, each of which has around 14% of the total.

Table 4.25. Distribution of Multiple-Good Level 6 Places by Subregion

Subregion	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Core	1	4.8	1	4.8
Northwest	11	52.4	12	57.1
Far North	3	14.3	15	71.4
Southeast	2	9.5	17	81.0
East-Central	3	14.3	20	95.2
North-Central	1	4.8	21	100.0

Table 4.26. Non-Pulperia Goods Offered at Level 6 Places

Variable	Description	No. of Places	Total Vendors	Max. Vendors
Level 1 Goods:				
P104039	Pita articles	1	10	10
Level 2 Goods:				
P104019	Barber shops	1	1	1
P104056	Musical groups	1	1	1
Meat	Meat sellers	1	1	1
STR_FOOD	Store unprep. food	2	11	10
Level 3 Goods:				
P104006	Restaurants (comedores)	1	2	2
P104011	Carpentry Shops	5	16	7
CLOTHING	Ready-made clothing	1	9	9
MKT_FOOD	Market unprep. food	1	32	32
Level 4 Goods:				
P104003	Cantinas	9	12	3
P104004	Butcher shops	4	4	1
P104009	Tailor shops	10	25	5

Twelve different kinds of goods are offered by these 21 "multiple-good" level 6 places.[6] Of these twelve, seven are offered at only one level 6 place (See Table 4.26). Four of these seven involve only one or two vendors.

There are four categories of goods offered by the level 6 firms:

1. **General stores** (pulperias), the most numerous good.
2. Goods offered at a **single place** by only **one or two vendors**: barber shops, musical groups, meat sellers, and restaurants (comedores). These are probably simple flukes with no special significance.

[6] Only one of these places has no pulperias. This place (ID number 1301038) is in the same municipio as Huehuetenango city and offers a large number of vendors in the STR_FOOD aggregate good. It is the only level 6 place in the north-central subregion.

3. Goods offered at a **single place** by **many sellers**: pita articles, ready-made clothing, and market unprepared food. These suggest specialized production centers and will be examined more closely below.
4. Goods which are offered at **more than one level 6 place**: store unprepared food, carpentry shops, cantinas, butcher shops, and tailor shops. Three of these are level 4 goods, and one (STR_FOOD) is level 3. These intermediate-level goods may be simply "misplaced" for essentially random reasons, or they may represent regionally specialized production. In any case the spatial distribution of the vendors of these goods also bears closer examination.

4.4.3.1 Single place, multiple sellers

One must be very tentative in drawing any conclusions about these anomalies. It is always possible that individual values are simply errors, particularly in the case of survey data. All three level 6 places with multiple sellers are in the same municipio, Concepción Tutuapa, in the northwest subregion of Departamento San Marcos. The three places in question and associated goods are Tutuapa (place #1206048, pita articles), La Laguna (1206022, ready-made clothing), and Belajuyape (1206002, marketplace unprepared food). Their grouping adds further weight to the suspicion that this is all caused by an inaccurate field or data entry worker.

If we accept the data as genuine, what can be inferred? The three places are not grouped together; they are between 13 and 17 kilometers apart, distances which virtually span the municipio. All three have many places considerably closer to them than they are to each other. Only Tutuapa appears on the road map, on a vehicular trail. Because of differences in scale among maps, it is difficult to be certain, but it appears that Belajuyape may also be on a vehicular trail, although this is less likely for La Laguna. The position of these places is thus not particularly favorable, although no worse than many low-level places in the study region.

The goods offered by the three places include one level 1 good, pita articles, and two level 3 composite goods, ready-made clothing and market unprepared food. The only other place in the study region which contains any large quantity of pita sellers is Quetzaltenango City, the level 1 place. The tentative conclusion concerning the sellers of Quetzaltenango is that they are part of the tourist trade. Tutuapa, however, is far from any known archaeological site or similar tourist attraction. The place may be a center for specialized production of these articles, but the reason for this is not clear from the evidence available to this study.

The other two places also seem to be specialized producers, but again there is no immediately available explanation. La Laguna contains nine sellers of ready-made clothing. Smith mentions that most peasant clothing in Guatemala is produced at such specialized centers, and this may be one of them. Belajuyape contains a variety of food sellers, dominated by market place fruits and vegetables (20 sellers), but also including plaza grain (eight sellers) and market and plaza other food (four sellers). It is not a location where we would expect to find many bulk agricultural sales, since it is off the transportation net and at an altitude of 2100-2700 meters. Yet again, the reason for this concentration is mysterious.

While the particular places where these specialized centers have located are not subject to explanation by the evidence available, the fact that they occur in the least developed subregion suggests that a principle of compensation may be involved. These unbalanced centers may be supplying goods which are not obtainable elsewhere, because there are so few higher-level central places in the northwest. In a more well-developed subregion, these places would either have developed into level 5 (or higher) places, or they would not have developed any special functions at all.

Table 4.27. Goods Found at Several Level 6 Places

Place	ID	STR_FOOD	P104011 Carpentry	P104003 Cantinas	P104009 Tailors
Los Tabiones	702002		1		
Rio Nondo	1204034				2
Tutuapa	1206048			3	
Cua	1207010				1
Chininxac	1207026				4
Chichum	1207028				1
San Andrés Cheoj	1208017		1		
Choanla	1224005		7	1	
Esquipulas	1224008		6		3
Zaculea El Llano	1301038	10			5
Yac	1315072	1		2	
Teninquim	1321011				1
El Pericon	1410016		1		
El Potrera	1401019				1
Xeabaj	1414048				5

4.4.3.2. Goods found at more than one place

Table 4.27 shows the distribution of the 15 places and four goods which make up this category. Seven of the places (those with ID numbers in beginning with 1206 through 1224) are in the northwest subregion. This again shows the disorganized nature of this subregion's central place structure. Of the remaining places, only two, Zaculea El Llano in Departamento Huehuetenango, and Xeabaj in Departamento El Quiché, have more than one or two vendors in any of the the four goods categories. The former is not far from the Departamento capital and is near an archaeological site sharing the place's name (Zaculea). It seems likely that the unusually high number of food vendors may be a response to tourists. The large number of tailors is more puzzling, but this, too, may be connected with visitors (especially if the term "tailor" was interpreted loosely by the survey workers). The reason why Xeabaj should have 5 tailor shops is not clear. It is located on the edge of an east-west valley, off the vehicular track. There is no obvious tourist attraction nearby.

4.5. Summary

The system of central places in western Guatemala illustrates the ways that settlement patterns adjust to the economic and topographical circumstances of a region. The essential features of a Christallerian system are preserved, but with many deviations from the mathematically perfect regularity of simple theoretical treatments. There are clearly the dual nested hierarchies of goods and places which are at the core of central place theory. However, the clean break between places of different levels cannot be observed. Instead, there is a blurring of roles, with some lower places taking on isolated higher-level functions, and some service gaps among the higher-level places.

Market areas and populations follow expectations, in that they shrink noticeably as place level decreases. However, the market areas are not regularly shaped, nor is there a simple system of ratios relating the number of places of one level to those of the next. Major differences in area and population are to be found among markets at the same level. This is particularly true if one contrasts the core with the periphery, particularly in the northern and western parts of the study region. The densely settled areas have a fine pattern of numerous intermediate subregions have much smaller numbers of Intermediate places, and these must serve considerably larger areas and smaller populations.

The level 2 places form a ring around the level 1 place. Their market areas are pie-shaped, widening out towards the periphery of the study region. It is likely that consumers on the far edges of the region are simply not supplied with higher-level goods, because of the distances to the level 2 places.

The level 2 places also show a number of individual peculiarities. Although there are eight such places, there are only six market areas, because of the existence of two pairs of "twin cities." In each instance, one of the twins is a departamento capital, and the other is a municipio capital. The evidence suggests that the municipio capitals may be superior locations, but the fact of the departamento capitals' governmental dominance prevents either place in the pair from developing into a strong level 2 supplier. This is corroborated by the only "singleton" level 2 place which is not a departamento capital, Tejutla. Tejutia is by far the weakest level 2 place and could arguably be called an enhanced level 3 place instead. It is on the edge of the northwestern subregion, the least developed of the entire study area.

It is at the intermediate level (levels 3 and 4) that the effects of demographic and topographical variation is most clearly seen. As was mentioned above, the intermediate places are numerous and closely packed in the populous southeastern and core subregions. In the periphery, however, they are spread out much more thinly. In the far north, the two intermediate levels are effectively collapsed into one, as the level 4 places completely disappear. In the less developed northwest, even the level 3 places are scarce and undeveloped.

This study has paid less attention to the lowest-level places, levels 5 through 7. This is the level which is most vulnerable to small disturbances in local conditions, factors which would not be detectable with the data available. However, the level 5 places follow the same general pattern as the intermediate places, being more numerous in the core and southeast, and less numerous (and more thinly spread) on the periphery.

The very lowest places, levels 6 and 7, have a different distribution. These can hardly be called "central places" at all, since they either offer no private goods (in the case of level 7) or offer only a fragmentary bundle (level 6). They are numerous in the northwest, and, to a lesser extent, in the far north. Although similar in population to the level 7 places, the level 6 places do have some commercial function. Most offer only general stores, perhaps allowing them to operate as surrogate level 5 places in those areas where even such low-level central places are lacking. There are a few level 6 places which offer other goods, sometimes with relatively large numbers of sellers. In some cases, these concentrations can be related to nearby tourist attractions, but in others there is no clear reason for their having higher-level functions.

V. HEALTH FACILITY LOCATION IN A SYSTEM OF CENTRAL PLACES

This chapter examines the spatial distribution of public facilities in the Quetzaltenango central place system. The emphasis is on two public goods which are provided through hierarchical systems of facilities: education and health care. The approach is to examine how closely the centers offering these goods match the central place structure of the region. The important variables affecting facility placement appear to be the subregion, political capital status, and central place level of each place.

5.1. Principles of Facility Location

5.1.1. Cost of Mislocation

There are certain costs associated with mislocating public service facilities. These costs can be categorized by their effects on the static and dynamic efficiency of a system of central places. The static inefficiencies are those which occur, given the current state of the central place structure. These would include the inadequate provision of the good provided by the public facility, the increased transportation costs incurred by persons travelling to a badly-sited facility, and the losses incurred by private establishments when the previous traffic patterns are disrupted by the facility's construction. The dynamic inefficiency arises because the central place system will adapt itself to the exogenous placement of a government facility. Persons travelling to that facility to obtain the public good will prefer to obtain other goods in the same trip. Thus, private establishments in the same central place will gain an advantage over establishments which might have been efficiently located before the change. If the facility employs large numbers of persons (and in the villages of Guatemala, "large" may not be all that many), there will also be economic base effects which will encourage the site of the new facility to grow and accommodate the demand for service goods by the public employees. At the same time, other places may be losing employees and population, as consumer traffic favors the site of the new facility. Since buildings are the least mobile of capital, the adaptation of the central place system will require the investment of resources to construct and expand establishments in the vicinity of the public service facility, while useful buildings are abandoned or under-utilized as other central places decline.

5.1.2. Central Place Levels and Public Facilities

A public facility can be said to have a central place level. This level is determined by the same concepts as for private establishments, the minimum and maximum ranges. The maximum range of a central good is the longest distance that consumers are willing to travel to obtain the good. Since distance translates into time and money costs, the maximum range is inversely related to the elasticity of demand for the good. A related factor is the number of trips required to maintain the desired supply of the good. The more trips, other things being equal, the more expensive obtaining the good will be, and, hence, the maximum range will be less. The minimum range for a private central good is the radius of the smallest market area that will still afford a normal profit to an establishment providing the good. This range is dependent on the costs of production, the population density, and per capita quantity demanded.

In central place theory, the minimum range is generally more important, because competition will squeeze market areas to that minimum. Christaller assumes that the minimum range of the highest-level good determines the distance between the highest-level central places. Once these are established, they are appealing places to locate establishments of all types. However, goods which have minimum ranges of half (or less) the minimum range of the highest-level goods will be able to profitably locate in the interstices of the high-level market areas, thus establishing the second level of the hierarchy. The process repeats itself, generating incrementally smaller places, until even the lowest-level goods are provided in market areas that just allow for normal profit.

For a local public good, the maximum range will be determined in the same way as for private goods, since this is a matter of individuals' choices. Goods which require frequent trips, such as primary schools, will have smaller ranges than those which require less frequent trips, such as universities or hospitals. The minimum range is more difficult to specify, because public facilities do not maximize profit. The essence of the minimum range for private facilities is that it encompasses the smallest population which can support one firm. In the simple case of a public facility which is supported by local taxes, the minimum range could be defined as the radius of a service area which contains the smallest population willing to pay for a facility through taxes. Given the cost, as the range (and population) increased, the per capita tax would decrease. Very closely packed facilities would be supported by small numbers of persons, and these would have to bear larger individual burdens. The maximum acceptable tax rate would depend on the residents' marginal rates of substitution between public and private goods, and on the prices of private goods. As with private goods, the minimum range depends on the cost of producing the public good, the population density, and the amount of consumption per capita. A university would have a large minimum range because of its high fixed costs and low consumption per capita. A primary school could draw on a much more limited market area and still be efficient, particularly if all children attend school.

If the facilities are not funded locally, the situation is more complicated. Poorer areas (such as the current study region) would presumably be receiving a subsidy from the central government, in order to provide a level of service which the residents of the region could not afford. The goal of the central government would be to equalize the services across the population. In this case, the minimum range becomes less important. The government would wish to build sufficient facilities in order to provide the desired level of service to the entire population. This level of service would depend on what the country as a whole was willing to pay. The location of facilities, particularly in the poorer areas, would be designed to insure that as many persons as possible received at least the minimum amount of the public good. This is accomplished by making sure that everyone is within the maximum range, not the minimum.

5.1.3. Efficient Facility Placement

If we wish to minimize the amount of disturbance which a public facility will cause, we should place it so as to mimic the placement of private facilities. In other words, we should determine the smallest level of place whose market radius is greater than or equal to the facility's minimum range. Places of this level or larger should receive the facility, and lower-level places should not. This will ensure maximum access to the good and provide for an efficient scale of operations. The implementation of this principle is very difficult. Measuring the minimum range of a local public service requires a knowledge of the population's marginal rates of substitution between the public good and private goods and of the public good's cost function. These and the market radius of a level of central place are subject to variation within the same system of cities, due to uneven population densities, incomes, and transportation networks.

A less ambitious but more achievable alternative to identifying the optimal locations of public service facilities is to evaluate the efficiency of an existing system. The number and size of the facilities can serve as a measure of the level of effort of the government to provide the services to its population. We can ask the question, "Could a rearrangement of the locations of the facilities, given the level of effort, result in an increase in efficiency?" This increase in efficiency could be realized through a decrease in cost (particularly transportation cost on the part of the population), level of service provided, or both. This is the approach taken here.

5.1.4. Measuring Efficiency

A key variable in the following analysis is the number of places possessing one or more facilities of a of a particular type. This determines the network of supply through the region. It is the same variable which was used to determine central place levels for private facilities. It is also the most reliable measurement of effort in the data of the current study. In some cases, more detailed data are available, such as numbers of teachers or medical personnel, but these are not as trustworthy as the presence or absence of a school or health center in a particular central place. By examining the number of places which have a facility, we can estimate the level of effort in providing that kind of good. The percentage of all places with such a facility will be the major indicator of that facility's central place level. We can compare the facility with private facilities having a similar degree of ubiquity and whose central place levels have already been determined. If the public facilities are primarily found in places of that level or higher, we can conclude that the location of the facilities seem to be as efficient as the private establishments. On the other hand, if we find that the public facilities are often found in lower-level places, this would necessarily imply gaps in the higher-level coverage (since the percentage distribution is given). This implies an inefficient locational pattern.

Note that this comparison with the private central place system is only meant to investigate the relative efficiency of the given level of effort by the government. It cannot evaluate whether the level of effort is appropriate. As we will see, the general access to health and educational facilities which the people of western Guatemala "enjoy" is far less than what would be considered acceptable in the United States. (Which is not to imply that the situation is "acceptable" to Guatemalans who must suffer under it.) We can, however, ask whether what is available is being distributed in an efficient manner.

5.2. Public Health Statistics for Guatemala[1]

The poor state of health care in rural Guatemala is a contributing factor in the unrest and low quality of life in the region. In the late 1970s, the life expectancy of Guatemalans generally was approximately 60 years. However, even this low number underestimates the difficulties of rural Guatemalans, particularly the

[1] Information in this section from Nyrop (1983, 77-80).

indianos which make up the majority of the population of the central highlands. These persons can expect to live 10 to 15 years less their the urban or ladino compatriots. Most deaths occur early in childhood. Rural infant mortality rates are estimated at 100 to 160 per 1,000, which is about 20 percent higher than the national average. For indianos, infant mortality rates are 70 percent above those of ladinos.

A main theme of this chapter is the extremely limited access that the residents of the study area have to even the most rudimentary of health care facilities. However, it should be noted that there are more fundamental problems for rural Guatemalans than medical care, and these also affect their health. Many of the diseases which are principle causes of death are themselves caused or at least exacerbated by poor sanitation and malnutrition. Only 14 percent of rural Guatemalans had potable water in the 1970s. The poor of Guatemala could afford only about half of the calories and protein necessary to meet minimum requirements. Again, the young suffered particularly badly in this respect, beginning with a 40 percent rate of low-birth-weight babies (compared with 7 percent in the United States).

Such medical facilities as exist in Guatemala are highly concentrated in the capital. In the early 1980s Guatemala City had 20 percent of the population but 80 percent of the doctors, and "more than 40 percent of the dentists, nurses, and laboratory technicians" (Nyrop 1983, 79). We are thus examining the distribution of facilities in a region characterized by extreme scarcity. However, given this level of effort, what can be said about the locational pattern?

5.3. Guatemalan Health System

5.3.1. Hierarchy of Public Facilities

The public health system of Guatemala involves a hierarchical structure of health facilities. At the lowest level is the health post (puesto de salud) which provides minimal facilities and is staffed on a periodic basis. The next higher level is occupied by a set of health centers (centro de salud) rated "A," "B," and "C," in decreasing order of sophistication. At the top of the hierarchy are the hospitals.

5.3.2. Other Facilities in Dataset

While the main focus of this study is on the hierarchical health facilities, it should be noted that data on several other types are available and used to some extent. These include IGSS (Guatemalan Institute of Social Security) facilities, private hospitals, medical clinics, dental clinics, clinical laboratories, opticians, pharmacies, and "other health facilities." The distribution of these facilities by central place level will be discussed below. The extent of the data varies from facility to facility. For hospitals, IGSS, and "other health facilities," there are questions in the survey about the number of establishments, the number of beds existing and occupied, and the number of medical and paramedical personnel. (The same information is collected for health posts and centers, and for public hospitals.) For most other facilities, only the number of establishments is recorded. For clinical laboratories, only the existence of such a facility in a place is known--not the number. Unfortunately, most of the more detailed information is either missing or unreliable. It is used where possible as an indication of conditions, but its accuracy is not to be relied upon.

In addition to the facility information, the survey also includes questions on the patients' places of origin and the destinations of outside medical help. For each of these, three choices are recorded, in order of importance. For the origins of patients, the place ID, distance, and number of patients is given. For the destinations, only the ID and distance are recorded. However, in many cases only one of the three choices is not missing, and the patient (and, in some cases, even the distance) data are not considered to be reliable.

5.4. Distribution of Facilities

5.4.1. Distribution by Central Place Level

In previous chapters, the central place levels of the various places were identified by means of cluster analysis of the services offered. The central place levels of the goods offered were then determined by the proportion of the places of each level offering each particular good. The same procedure is followed to determine the central place level of the public facilities. The expected pattern is that a good will be offered by all higher-level places, and all places at its own level. Lower-level places will not offer the good. This is, of course, the ideal situation. Some higher-level places may fail to offer a good, and some lower-level places may offer a good, because of errors in placement. For publicly provided goods, where the question is the efficiency of placement, we should expect larger deviations from the idealized pattern. The distribution of all health facilities in the study region by central place level is shown in Table 5.1.

Table 5.1. Distribution of Health Establishments by Central Place Level (Percentage of places having at least one establishment)

	Hospitals			Health Centers				Health
Level	Pub.	Priv.	Any	A	B	C	Any	Post
1	100.00	100.00	100.00	0.00	100.00	0.00	100.00	0.00
2	62.50	75.00	87.50	12.50	75.00	12.50	100.00	0.00
3	0.00	8.77	8.80	5.26	36.84	10.53	52.60	42.11
4	1.06	0.00	1.10	0.00	4.26	8.51	12.80	37.23
5	0.00	0.37	0.40	0.00	0.19	0.56	0.70	9.87
6	0.00	0.00	0.00	0.82	0.00	0.00	0.80	4.10
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.32
All	0.77	1.53	1.80	0.55	3.61	1.97	6.10	13.46

	Clinics					
Level	Medical	Dental	Labs	Optician	Pharmacy	Other
1	100.00	100.00	100.00	100.00	100.00	100.00
2	100.00	75.00	62.50	37.50	100.00	12.50
3	26.32	28.07	5.26	3.51	71.93	5.26
4	6.38	3.19	1.06	0.00	20.21	2.13
5	1.68	0.74	0.00	0.00	2.05	1.86
6	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	1.05	0.00
All	4.27	3.28	1.09	0.66	8.86	1.86

Based on Table 5.1 above, the approximate central place levels of the health facilities are as follows.

Table 5.2. Central Place Levels of Health Facilities

Facility	Level
Hospitals	2
Health centers	3
Health posts	3/4
Medical clinics	2
Dental clinics	2
Labs	1/2
Opticians	1
Pharmacies	3
Other	1

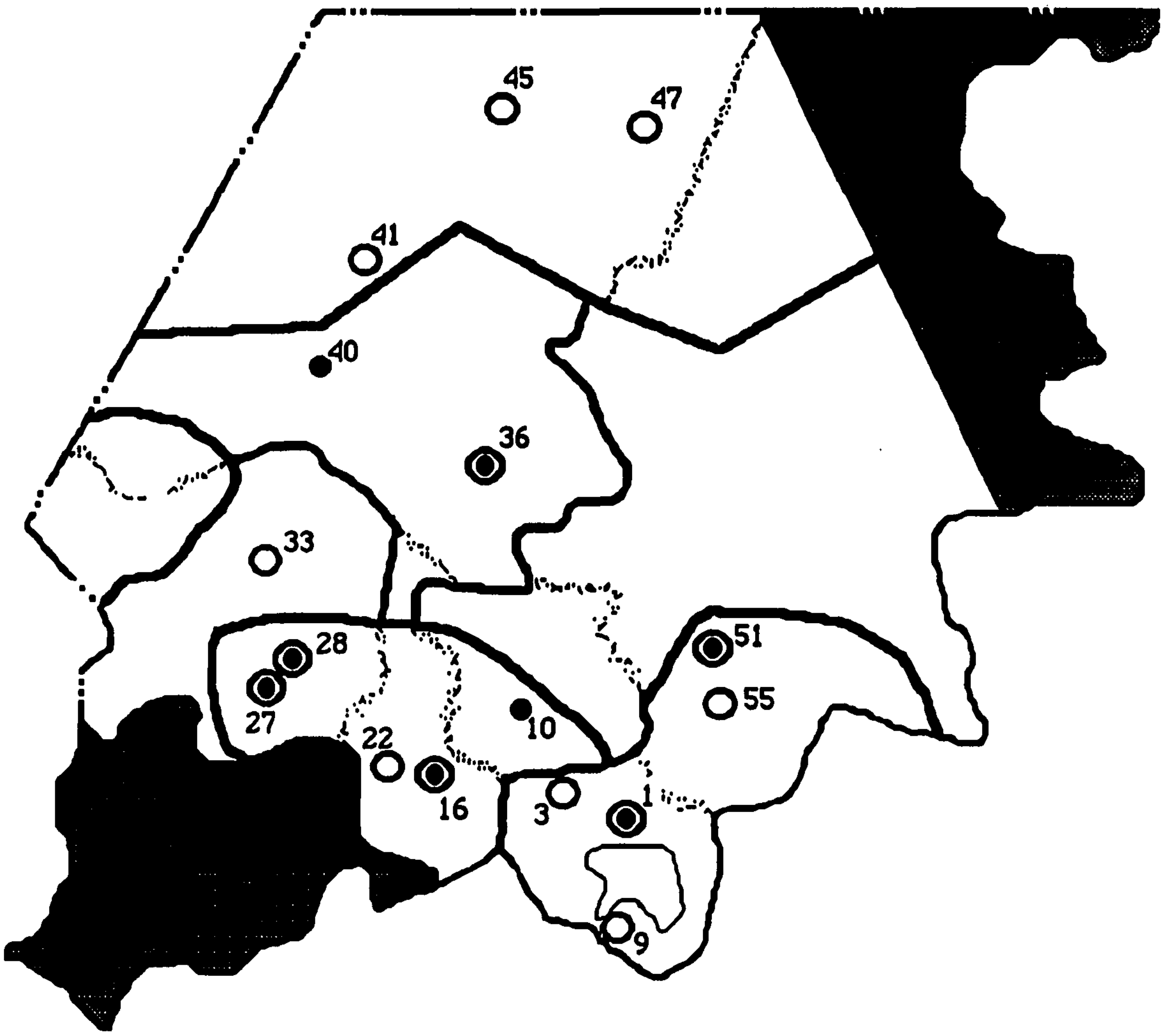

Figure 5.1. Hospitals in the Study Region (See Table 5.3 for key)

Public hospitals are only found in level 2 places, except for a single level 4 place (Place ID 1306001, San Pedro Necta, a municipio capital in Huehuetenango). There are five non-level 2 places which have private hospitals, including five level 3 places and two level 5 places. Most of the level 3 places are in the northern reaches of Huehuetenango (see Figure 5.1), but one is in Chicastenango (ID 1406001), the capital of a rather densely settled corner of southwestern El Quiché. There is also a private hospital in Nahualá (ID 705001), in northwestern Sololá, another heavily settled area. The level 5 places are in Quetzaltenango (Buena Vista, ID 909005) and Sololá (Panabaj, ID 719012). These exceptions, particularly the ones in Huehuetenango, extend the reach of the hospital network into areas which are distant from the main centers. However, based on the percentage of places with hospitals, we must conclude that this is a level 2 central good.

Table 5.3. Distribution of Hospitals and Health Centers by Place

Fig. ID Number	Place ID	Place Name	Numbers[a] of Hospitals: Public	Hospitals: Private	Health Centers
1	701001	Sololá	1	1	1
2	704001	Santa Lucia Utatlán			1
3	705001	Nahualá		2	1
4	706001	Santa Catarina Ixtahuacán			1
5	710001	Panajachel			1
6	703001	San Lucas Tolimán			1
7	714001	Santa Cruz La Laguna			1
8	719001	Santiago Atitlán			1
9	719012	Panabaj		1	
10	801001	Totonicapán	1		1
11	802001	San Cristóbal Totonicapán			1
12	803001	San Francisco El Alto			1
13	805001	Mosmotenango			1
14	806001	Santa Maria Chiquimula			1
15	808001	San Bartolo			1
16	901001	Quetzaltenango	2	6	1
17	902001	Salcajá			1
18	904001	San Carlos Sija			1
19	905001	Sibilia			1
20	907001	Cajolá			1
21	909001	Ostuncalco			1
22	909005	Neuva Concepción		1	
23	912001	San Martin Sacatepéquez			1
24	916001	Zunil			1

[a] Zeros shown as blanks.

Table 5.3 continued

Fig. ID Number	Place ID	Place Name	Numbers of Hospitals Public	Numbers of Hospitals Private	Health Centers
25	923001	La Esperanza			1
26	924001	Palestina de los Altos			1
27	1201001	San Marcos	1	1	1
28	1202001	San Pedro Sacatepéquez		1	1
29	1204001	Comitancillo			1
30	1206001	Concepción Tutuapa			1
31	1207001	Tacaná			1
32	1208001	Sibinal			1
33	1210001	Tejutla		1	1
34	1211001	San Rafael Pie de la Cuesta			1
35	1229001	San Lorenzo			1
36	1301001	Huehuetenango	1	1	2
37	1301038	Zaculeu El Llano			1
38	1302001	Chiantla			1
39	1304001	Cuilco			1
40	1306001	San Pedro Necta	1		
41	1307001	Jacaltenango		1	
42	1308001	San Pedro Soloma			1
43	1313001	San Miguel Acatán			1
44	1317001	Santa Eulalia			1
45	1318001	San Mateo Ixtatán		1	
46	1324001	San Antonio Huista			1
47	1326001	Barillas		2	1
48	1327001	Aguatán			1
49	1327056	Tuixcox			1
50	1331001	Santa Ana Huista			1
51	1401001	Santa Cruz del Quiché	1	2	1
52	1402001	Chiché			1
53	1403001	Chinique			1
54	1404001	Zacualpa			1
55	1406001	Chichicastenango		2	1
56	1407001	Patzité			1
57	1412001	Joyabaj			1
58	1413001	Nebaj			1
59	1414001	San Andrés Sajcabajá			1
60	1415001	Uspatán			1
61	1416001	Sacapulas			1

The individual grades of health centers do not show a very strong central place structure. There are none present in the level 1 place (Quetzaltenango), and the "A" and "C" centers are not present in a majority of places at any level. However, if we take health centers as a group, there is a sharp drop-off in incidence below level 3 places. Health centers are assigned a central place level of 3, although their representation at level 3 is somewhat weak.

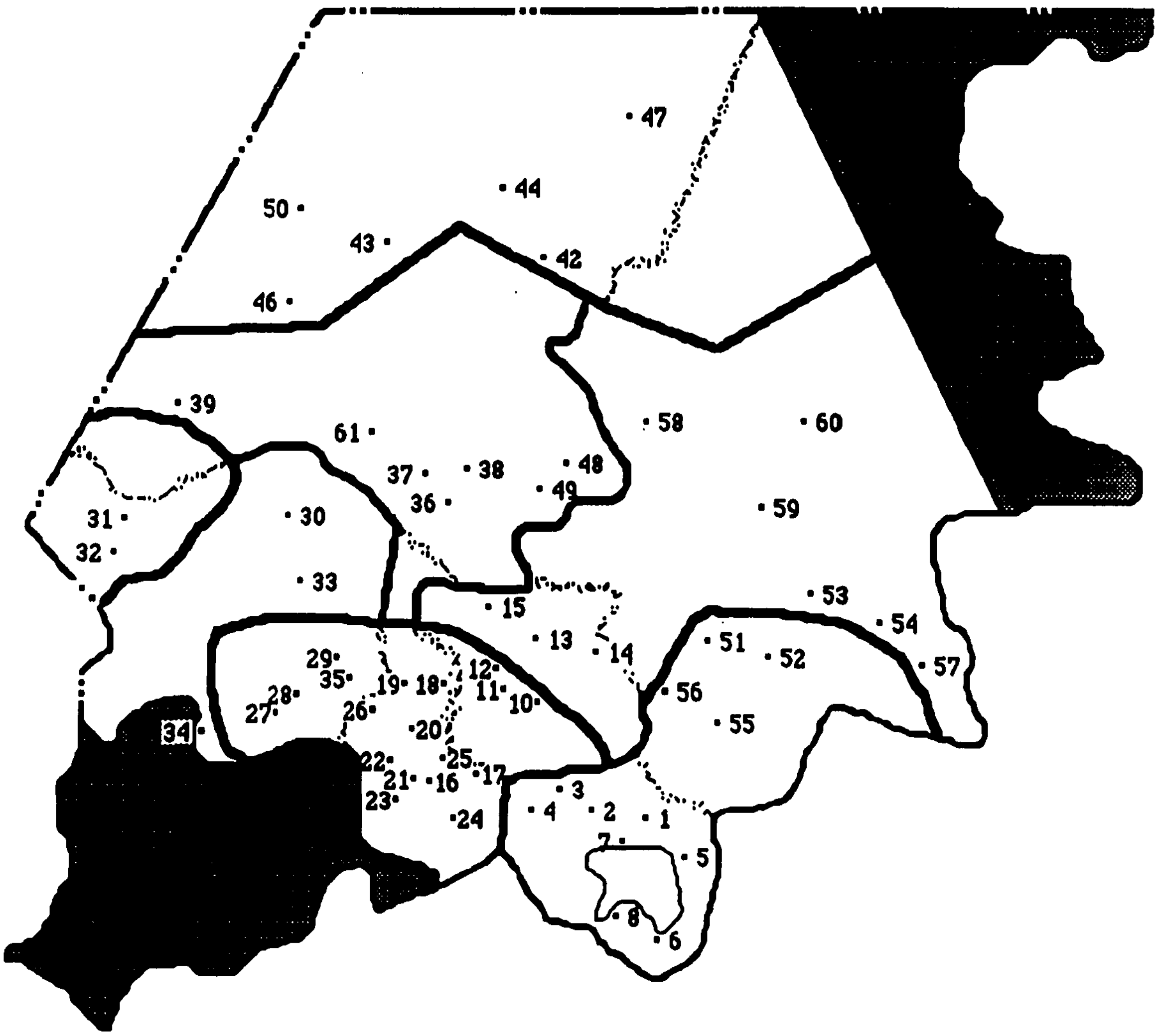

Figure 5.2. Health Centers in the Study Region (See Table 5.3 for key)

Health posts are also too diffusely distributed to be given a definite central place level. They are proportionally most numerous at levels 3 and 4. They seem to make up a low-end substitute for health centers in some central places. The absence of health posts and (to a lesser extent) centers at levels 1 and 2 is probably because hospitals are able to provide all of the services of those lower-level facilities.

The other health facilities are, for the most part, only found in the level 2 or higher places. The exceptions are opticians, which are found in only about a third of the level 2 places (and are thus classified as level 1) and pharmacies, which are common even in level 3 places. Clinical laboratories are present in a majority of level 2 places, although the proportion is a little low for definite classification as a level 2 good.

5.4.2. Maximum Facilities by Place

An alternative way of examining the distribution of facilities is to determine the highest kind of establishment in a place, using the hierarchy, of hospitals, medical clinics, health centers, and health posts (in descending order) Of the 914 places in the study area, 725 (79.3%) have no facility. The majority of the rest (113 places, 12.4%) have only health posts. Health center places number 45 (4.9%). The smallest number of places, 15 (1.3%), have medical clinics but no hospital. An almost equal number of places, 16 (1.8%) have hospitals. This puts the distribution of health care in Western Guatemala in a different light. Four out of five places have virtually no local access to health care. Of the rest, most have the minimal amount, a health post with its part-time staff. Only a small percentage have reasonably adequate facilities.

5.4.3. Subregional Variation

Table 5.4 shows the results of several analyses of variance on the existence of the more common health facilities by subregion, controlling for central place level. The central place level factor was significant to four decimal digits in all cases. The table shows the significance levels for subregional variation. The only facilities which seem to have differences in distribution by subregion are health posts and dental clinics. Even for these, the results are rather weak, in the neighborhood of 92% confidence.

Table 5.4. Summary of ANOVA of Facility Existence by Subregion, Controlling for Central Place Level

Facility	P-Level
Health Centers (all)	0.708
Health Posts	0.080
Medical Clinics	0.932
Dental Clinics	0.085
Pharmacies	0.979

5.5. Measures of System Efficiency

How well does the system of health facilities perform? While many important aspects of this question are beyond the reach of the available data, it is possible to examine some items which have a particular importance in terms of the spatial distribution of services. These include the distance people must travel in order to obtain medical help, the spatial hierarchy of facilities, the extent to which the political or central place systems dominate the choice of facility, and the populations served by each place.

5.5.1. Distance to Nearest Facility

Since most places have no medical facility, and most of those that do have minimal ones, most people must travel to obtain medical services. The survey included questions about the three most important locations of outside medical assistance. Many of these responses are missing, however. There are many duplicate entries and references to nonexistent places (i.e., places with clearly erroneous ID codes). In order to bring some consistency to this information, the closest destination named was chosen for each, with its corresponding distance. The analysis which follows was conducted in terms of these "minimum-distance destinations," which has been abbreviated to the variable name, "MINDEST." the corresponding distance is called "MINDIST." It was possible to determine these variables for 903 of the places, with 11 places yielding no useful survey data for these questions.

Table 5.5. MINDIST Variation by Political Status of MINDEST and Maximum Health Facility of Origin Place

	Mean	Std. Dev.	Cases
For Entire Population	19.2802	26.7507	903
MINDEST not a Departamento Capital			
All Places	9.6934	13.6159	574
No Facility	9.0838	8.2745	549
Health Post	13.7778	10.0209	18
Clinic	6.2500	4.6458	4
Health Center	18.5000	4.9497	2
Hospital	267.0000	0.0000	1

Table 5.5 continued

	Mean	Std. Dev.	Cases
MINDEST is a Departamento Capital			
All Places	36.0061	34.6783	329
No Facility	33.6629	37.7010	175
Health Post	38.4681	30.6597	94
Clinic	31.8000	23.9527	10
Health Center	38.4884	27.9552	43
Hospital	52.2857	54.6129	7

The mean distance to MINDEST is 19.28 km. Table 5.6 below shows the results of an analysis of variance on this distance, by the facilities at the origin and destination places and whether the destination is a departamento capital. Distance is significantly related to the capital status of the destination, as indicated by the high F-value and low p-value. The type of facilities at the origin and destination places are at best marginally significant, with the influence of the destination (p-value 0.059) being more certain than that of the origin (p-value 0.084). Table 5.7 shows the changes in distance to MINDEST which can be attributed to the various factors. Origins which do not name a departamento capital are over 19 kilometers closer to their destinations than those which do. Worse facilities at either end generally decrease distance travelled. This makes sense, since the residents of places with poor facilities would have to travel to a place with slightly better facilities for even routine care. On the other hand, places with better facilities would only travel to places with even better ones, and these are more rare (and thus further away). This effect is not as consistent for the type of origin facility as it is for the destination facility. That is to be expected, given the lower confidence for origin factor, as measured by the ANOVA results.

Table 5.6. ANOVA on Distance to MINDEST

by: MAXHLTH (maximum health facility code)
DESTHLTH (destination health facility)
MD_DCAP (MINDEST departamento capital flag)

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F
Main effects	157676.118	9	17519.569	36.530	0.000
MAXHLTH	3956.451	4	989.113	2.062	0.084
DESTHLTH	4379.380	4	1094.845	2.283	0.059
MD_DCAP	26609.574	1	26609.574	55.484	0.000
Explained	157676.118	9	17519.569	36.530	0.000
Residual	425394.727	887	479.588		
Total	583070.845	896	650.749		

Table 5.7. Deviations from Mean Distance to MINDEST

by: MAXHLTH (maximum health facility code)
DESTHLTH (destination health facility)
MD_DCAP (MINDEST departamento capital flag)

Variable	N	Unadjusted Dev.	Adjusted for Independents Dev.
MAXHLTH			
0 No Facility	719	-3.99	-0.87
1 Health Post	112	15.42	3.32
2 Clinic	14	5.42	-3.47
3 Health Center	45	18.52	3.98
4 Hospital	7	33.21	17.51
DESTHLTH			
0 No Facility	7	-14.79	-6.91
1 Health Post	178	-11.49	-3.88
2 Clinic	25	-10.00	-2.18
3 Health Center	256	-10.73	-2.97
4 Hospital	431	11.94	3.61
MD_DCAP			
1 Departamento Capital	329	16.93	12.10
0 Not Dept. Capital	568	-9.81	-7.01

A surprisingly large number of MINDESTS, 329 out of 903 (36.4%) are departamento capitals. A particularly high proportion of the places in Departamento Huehuetenango name their departamento capital as their only health destination. Many of the origin places are actually closer to other health facility locations than they are to these capitals. This raises some questions about the reliability of this information. Since the survey was conducted of village mayors, it is conceivable that many of them simply said, "oh, we go to the capital." On the other hand, the capital is often the only place in the departamento which has a hospital. It may be that people go to the hospital for serious cases and simply get no other medical attention, unless there is a facility in their village or town.

Of the MINDESTS which are not departamento capitals, the median distance from origin to destination is 6 kilometers. 81 percent of these MINDESTS are within 14 km. The maximum recorded distance (for destinations which are not departamento capitals) is 71 km. Clearly, Some of these larger distances are questionable. It is difficult to say exactly what it means to say that the people in a highland village travel so far for medical assistance. Surely this can not be a very frequent occurrence.

Of the places which claim their departamento capitals as their minimum distance destinations, the mean distance is 36 km, with the median being 24 km. The maximum recorded distance is a staggering 122 km!. There is considerable variation in the mean distance among the different departamento capitals, as shown in Table 5.8.

Table 5.8. Mean Distance to MINDESTS Which Are Departamento Capitals

Capital	Distance (km)	Cases
Sololá	22.89	36
Totonicapán	16.49	37
Quetzaltenango	21.48	52
San Marcos	32.02	49
Huehuetenango	58.46	100
Santa Cruz del Quiché	34.18	55
All such cases	36.01	329

The striking difference is the distance and number of cases for Huehuetenango. When this place is excluded, the mean distance drops to 26.02 km, a reduction of 28%. Huehuetenango is considerably larger than the other departamentos, and its central places are more evenly distributed than those of El Quiché, the other large departamento. Even so, one has to wonder if the data recording for Huehuetenango was subject to an unusual amount of error. In any case, these are all very long distances for poor peasants to be travelling. The conclusion, of course, is that most medical facilities are too far away to do the villagers much good.

5.5.2. Origin vs. Destination Facilities

Table 5.9 shows a crosstabulation of the maximum health facility in the origin and destination places. There is an almost-clean upper-triangular crosstabulation of the origin facilities vs. destination facilities. Only one place (0.1%) has a MINDEST which has worse facilities than itself. 48.1% of the places name destinations with hospitals (this explains part of the predominance of departamento capitals). The order of frequency is in the expected direction:

Hospitals, health centers, and health posts with decreasing frequencies. Only 25 (2.8%) name clinics (which have no health center), and 7 (0.8%) name places with no health facilities. Thus, the direction of travel is what one would expect: people go to places which have better facilities than in their home villages. Places which have better facilities are more attractive as destinations than those with worse.

Table 5.9. Cross Tabulation of Maximum Health Facilities at Origin and Destination Places

	Count Row Percent Column Percent Total Percent	Destination Health Facility: No Facility	Health Post	Clinic	Health Center	Hospital	Row Total
Origin Health Facility	No Facility	7 1.0 100.0 0.8	177 24.6 98.9 19.7	23 3.2 92.0 2.6	246 34.2 96.1 27.4	267 37.1 61.8 29.7	720 80.1
	Health Post		1 0.9 0.6 0.1	1 0.9 4.0 0.1	7 6.3 2.7 0.8	103 92.0 23.8 11.5	112 12.5
	Clinic			1 6.7 4.0 0.1	2 13.3 0.8 0.2	12 80.0 2.8 1.3	15 1.7
	Health Center		1 2.2 0.6 0.1		1 2.2 0.4 0.1	43 95.6 10.0 4.8	45 5.0
	Hospital					7 100.0 1.6 0.8	7 0.8
	Column Total	7 0.8	179 19.9	25 2.8	256 28.5	432 48.1	899 100.0

5.5.3. Comparison of Level 3 and Political Hierarchies

The pattern of travel for medical services conforms to the hierarchy of political capitals, rather than to the central place hierarchy. Since health centers are level 3 central goods, the closest source of medical assistance will generally be a place's level 3 market. The large number of places naming departamento capitals as their MINDEST has already been noted. These capitals are all level 2 places, and as such are generally further away than the closest level 3 places. Of the 583 places which do **not** name a departamento capital as their MINDEST, 256 (43.9%) have MINDESTS which are outside their level 3 market areas. Most of these are to their own municipio capitals (72.3%) or to another municipio capital (13.3%). Only 38 (6.5%) name noncapitals. Only 5 (0.9%) are outside their own municipios.

Table 5.10. Cross Tabulation of MINDEST and Municipio Capitals for MINDESTS Which Are Not Departamento Capitals

Count Row pct Col pct Tot pct	Not Capital	Other Capital	Own Capital	Row Total
MINDEST	37	34	185	256
not a	14.5	13.3	72.3	43.9
level 3	97.4	49.3	38.9	
market	6.3	5.8	31.7	
MINDEST	1	35	291	327
is a	0.3	10.7	89.0	56.1
level 3	2.6	50.7	61.1	
market	0.2	6.0	49.9	
Column	38	69	476	583
Total	6.5	11.8	81.6	00.0

Those places which **do** name one of their (nondepartamento-capital) level 3 markets as MINDESTS include 291 (89.0 percent) which name their own municipio capital, 35 (10.7 percent) which name other municipio capitals, and only 1 (0.3) which names a place which is not a capital of any municipio.

The dominant factor in determining where people say they go for medical care seems to be the political status of the destination. It should be noted that most municipio capitals are level 3 central places. Thus, most of the 56.1 percent name their own municipio capitals, which also happen to be their level 3 markets.

One cannot completely discount the possibility that the village leaders who answered the survey simply indicated that the residents went to a prominent place, such as the municipio or departamento capital, for their medical assistance. On the other hand, there is no direct evidence to indicate that this was so. We must conclude, at least tentatively, that the distribution of medical care is based on a political hierarchy, rather than a market hierarchy. This is hardly unknown in central place theory. Christaller's "separation principle" was designed to describe this sort of situation. However, since the level 3 market areas were identified on the basis of the closest such markets to each place, it must be the case that any other basis for the distribution of a service will require travelling longer distances than if that service were integrated with the system of market areas. This is particularly true if travel for medical purposes could be combined with trips that people were making to their level 3 markets in any case.

5.5.4. Populations Served

5.5.4.1. Direct population served

The service population of each place named as a MINDEST was estimated using the allocated municipio populations that were used in computing the service populations for private services in the previous chapter. These populations were summed across origin places for each MINDEST, including the population of the MINDEST itself. These are "direct" populations served only. In other words, the possibility that there is a chain of places linking a place with an advanced facility (e.g., a hospital) was not taken into consideration. The "full" population served takes such indirect links into account and is discussed below.

The mean direct population served per MINDEST is 10,779. This is considerably smaller than the mean population served per level 3 market, 23,433.8 (see Table 4.15 in the previous chapter). This, in part, is due to the fact that so many lower-level places are named as MINDESTS, particularly the municipio capitals which are level 4 places. The mean population served by all level 4 places is 9,547.8, which is roughly similar to the mean population per MINDEST. Considering that the some places have considerably larger service populations, there is inefficiency at both ends of the distribution. On the one hand, there are some places which serve too small a population and are unable to offer reasonably adequate services. On the other hand, the large centers with hospitals are so few in number that people must travel long distances to reach them. Their large service populations are measures of the long "reach" these places have into the hinterlands.

An analysis of variance on the population served by a place shows that it is significantly related to the destination place's political status (as a municipio or departamento capital), the kind of facility present, and the subregion in which the place is located. The p-level of facility and capital status are zero to three decimal places. For subregion, the p-level is 0.077, indicating that it is significant at the 92.3% confidence level or lower. The importance of these variables is in the order listed. The mean values for population and number of places served by the various criteria are given in Table 5.11.

Table 5.11. Direct Populations Served by Political, Facility, and Subregional Status

	Mean Population	Mean No. of Places	Frequency
Grand Mean	10,779.20	7.02	128
Political Status			
Not a capital	1,130.42	1.13	24
Municipio capital	6,617.10	5.53	98
Departamento capital	117,355.33	55.00	6
Facility			
None	716.82	1.00	7
Health Post	3,041.94	3.11	57
Clinic	3,638.88	3.57	7
Health Center	7,516.14	6.10	42
Hospital	57,345.29	28.93	15
Subregion			
Core	13,752.58	7.94	31
Northwest	8,398.41	7.11	9
Far North	6,475.61	4.53	19
Southeast	14,346.59	8.32	22
East-Central	6,610.39	4.84	19
North-Central	10,863.37	8.52	23
San Marcos belt	8,141.13	6.40	5

While all of these categories are significant in an ANOVA of population, when the number of places served is introduced as a covariate, only the political status has a significant effect. The p-value of political status is still zero to three decimal places, but that of maximum facility rises to 0.445, and subregion, to 0.835. Thus, differences in facility and subregion only affect population served insofar as they affect the number of places served. The mean number of places served is significantly influenced by the type of facility and, to a lesser extent, by subregion. Tables 5.12 and 5.13 show the ANOVA results and the multiple classification effects of these variables on places served. As facility level increases, the number of places served also increases, as one might expect. Similarly, the political capitals, and particularly the departamento capitals, attract more tributary places than noncapitals. The large increase in places for departamento capitals may be an exaggeration caused by the kinds of data problems discussed above. However, it is plausible that these places, with their higher central place ranks and their political importance, would have larger numbers of tributary places in any case.

5.5.4.2. Number of tributary places.

The number of places served by each MINDEST ranges from 1 to 100, with median of about 3.6. The departamento capitals dominate the top end, with 36-100 places served (Huehuetenango is the top) Only three other places serve more than 14. Two of these, Jacaltenango (ID 1307001, 18 places) and Tacaná (ID 1207001, 21 places) are in the remote areas near the Mexican border. The third, Chichicastenango (ID 1406001, 33 places), is the capital of a densely settled municipio just south of Santa Cruz del Quiché. It is a major center of tourism and Mayan culture.

Table 5.12. ANOVA of Number of Places Served per MINDEST

by: MAXHLTH (maximum health facility code)
CAPITAL (political status)
SBREGION (subregion code)

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F
Main Effects	15878.800	12	1323.233	40.839	0.000
MAXHLTH	666.363	4	166.591	5.142	0.001
CAPITAL	6726.009	2	3363.005	103.793	0.000
SBREGION	498.891	6	83.148	2.566	0.023
Explained	15878.800	12	1323.233	40.839	0.000
Residual	3726.130	115	32.401		
Total	19604.930	127	154.370		

Table 5.13. Multiple Classification Analysis of.Number of Places Served per MINDEST

by: MAXHLTH (maximum health facility code)
CAPITAL (political status)
SBREGION subregion code

Grand Mean = 7.02

Variable	N	Unadjusted Deviation	Adjusted for Independents Deviation
MAXHLTH			
No Facility	7	-6.02	-2.68
Health Post	57	-3.92	-1.99
Clinic	7	-3.45	-1.93
Health Center	42	-0.93	0.96
Hospital	15	21.91	7.03
CAPITAL			
Not a capital	24	-5.90	-4.89
Municipio capital	98	-1.49	-1.37
Departamento capital	6	47.98	41.91

Table 5.13 continued

Variable	N	Unadjusted Deviation	Adjusted for Independents Deviation
SBREGION			
Core	31	0.91	-1.98
Northwest	9	0.09	3.71
Far North	19	-2.50	-1.24
Southeast	22	1.29	-1.44
East-Central	19	-2.18	0.56
North-Central	23	1.50	3.09
San Marcos Belt	5	-0.62	0.34

As Table 5.12 shows, the maximum facility, political status, and subregion all have significant effects on the number of origins which name a place as their MINDEST. The p-level for subregion is a bit lower than the other two, but it is still significant at the 97.7% confidence level. The deviations which these factors cause to the grand mean number of places is shown in the multiple classification analysis in Table 5.13.

The deviations caused by facility type and political status are about what one would expect. As the facility improves, there are more places which use the center as their MINDEST. The adjusted deviations are smaller than the unadjusted because better facilities are usually found in political capitals, which have their own positive effects. The political status works in a similar way, with increasing numbers of tributary places for municipio and then departamento capitals. Note the large jump for the latter. This probably overstates the importance of departamento capitals, based as it is on the somewhat suspect survey data. Even so, the general pattern is probably correct.

The subregional effects are more difficult to interpret. The most well developed systems of cities are to be found in the core and southeastern subregions. These have negative adjusted deviations but positive unadjusted deviations. The difference is caused by the fact that the places in this subregion generally have better facilities, leading them to have more tributary places. On the other hand, the higher numbers of such places means that potential origin places have more choice. The result is that there are fewer tributary places, given facility type, but there are more tributary places overall. Thus, the residents of the core and southeast have the benefit of better facilities and greater accessibility to those facilities.

The other subregion showing negative adjusted deviations is the far north. It also has negative unadjusted deviations, but these are somewhat greater than the adjusted ones. The far north consists of the upper tier of municipios in Huehuetenango. This is a region of sparse settlement and inadequate facilities. As was noted earlier, Huehuetenango is the departamento capital which has the largest number of places claiming it as the MINDEST, and the largest distances to the MINDEST are also found among those looking towards Huehuetenango. With the low density of places and the (real or perceived) attraction of the capital in the survey data, the number of tributary places in the far north are bound to be reduced. Thus, the unadjusted deviation is large and negative. However, when one accounts for the fact that this subregion contains no departamento capitals and few higher-level facilities, this negative deviation is reduced somewhat, giving the smaller adjusted reduction.

The northwest was noted in the last chapter as having the least developed system of central places. However, the unadjusted deviation shows that those places which do provide medical services have close to the average number of tributary places. This necessarily means that the adjusted deviation is quite high, since there are few capitals and no hospitals in this subregion. There is in fact a fairly high density of places in this subregion, although most of them are of central place level 5, and not a few are of level 7. Given the remoteness of the subregion, the existing facilities seem to get a lot of traffic.

The other three subregions are referred to as "transitional" in the beginning of the previous chapter. They do not have distinct characteristics as central place systems but instead are the "leftovers" not included in the more distinct subregions. The east-central subregion consists of the northeastern portion of Totonicapán and the less populated parts of El Quiché. It is an area of low-level central places and sparse settlement. It appears that these are the characteristics which are most important in determining the number of places served by each medical supply place. The unadjusted deviation is negative, but the adjusted deviation puts it close to average.

The north-central subregion includes the parts of Huehuetenango which are not in the far north or northwest, plus a few villages in Quetzaltenango. Its most important characteristic is that it includes the city of Huehuetenango, which has by far the largest number of places claiming it as their MINDEST. Thus, even accounting for the fact that it has a departamento capital and hospitals, the adjusted deviation is still large and positive. This is probably the effect of Huehuetenango itself.

The San Marcos belt subregion is simply that part of Departmento San Marcos which could neither be classified as part of the core or part of the northwest. It has only five places which are named as MINDESTS. They vary around the average, negative for the unadjusted and positive for the adjusted. There is little of substance which can be deduced from this.

5.5.4.3. Indirect ("full") population served

The "direct" population served by a central place, as discussed above, refers to those persons either living in the central place or living in other places which claim the central place as their nearest source of health services. The full population takes this a step further by summing over the direct populations of subsidiary places. For example, San José Chacayá (place ID 702001) is a municipio capital in Departamento Sololá. It has a health post, which is the lowest level of health facility. Two places, both in the municipio, list San José Chacayá as their MINDEST. The total allocated population of these two places is 361 persons. This is San José's "direct" population. However, San José lists the departamento capital, Sololá, as its MINDEST. The direct population served by Sololá includes the population of San José, but not that of its two tributary places. The full population of Sololá would include those indirectly tributary places, as well as those places directly tributary to Sololá. It took a total of four "passes" through the dataset to fully aggregate these indirect linkages. That is to say that a few places are tributary to another place, which is in turn tributary to another, and so forth, going up four times (involving a chain of five places, from the lowest to the highest). The top of the hierarchy is not a single place, however. There are several places which have no upward links. This is not really surprising, since it may well be that a central place which has its own hospital is not tributary to any other place in the region, at least as far as health services are concerned. Links outside the region (to Guatemala City, for example) were not traced.

Table 5.14. Full Populations Served by Political and Facility Status

	Population	Places	Frequency
Grand Mean	13,797.11	8.15	197
Political Status			
Not a capital	3,202.27	2.03	87
Municipio capital	9,352.80	5.45	104
Departamento capital	24,4456.86	143.50	6
Facility			
None	1,985.93	2.00	8
Health Post	4,451.94	3.01	113
Clinic	4,339.36	3.20	15
Health Center	11,487.14	6.00	45
Hospital	101,066.37	58.19	16

An ANOVA of the full population served, using subregion, the political status, and maximum facility as independent variables and the number of places served as a covariate, shows all except subregion to be significant. The p-values for political status and the covariate are zero to three decimal places, and that of the health facility variable is 0.056. The R^2 associated with this test is 0.980. The multiple classification effects of the significant factors are shown below. The signs of the deviations are not surprising: The worse the facility, the lower the population served. The population also falls as one goes down the political hierarchy. This political effect is most marked for departamento capitals, as might be expected. The raw regression coefficient for the covariate indicates that each place served adds 1,634.512 persons to the full population.

An ANOVA of the number of places served, using the same factors as independent variables, reveals that the political status is the only significant one. The p-value of the former is again zero to three decimal places, whereas that of the latter is 0.916. The R^2 for this test is lower for that of the populations, 0.839. The mean number of places served is 8.15. The adjusted deviation is -5.58 for noncapitals, -3.01 for municipio capitals, and 133.22 for departamento capitals.

Table 5.15. Multiple Classification Analysis of Full Allocated Health Population

by: MAXHLTH (maximum health facility code)
CAPITAL (political status)
SBREGION (subregion code)
with: FULLNUM (full health origin place count)

Grand Mean = 13797.11

Variable + Category	N	Unadjusted Deviation	Adjusted for Independents + Covariates Deviation
MAXHLTH			
No Facility	8	-11811.17	-1990.67
Health Post	113	-9345.17	-1016.25
Clinic	15	-9457.75	-1285.71
Health Center	45	-2309.97	1741.68
Hospital	16	87269.26	4479.46
CAPITAL			
Not a capital	87	-10594.84	-1669.72
Municipio capital	104	-4444.30	-1699.00
Departamento capital	6	230659.75	53660.30

The full population data confirm the story told by the direct data. The departamento capitals are the dominant sources of health services. Beyond that, sources of health care are favored according to the political hierarchy. The type of facility also has an effect, but this reinforces the political hierarchy's influence, because the location of better facilities, particularly hospitals, closely parallels this hierarchy. Subregional variation is more important for the direct population than for the full populations, as is the number of places served. This is probably because the local conditions affect the first destination more than it does subsequent ones.

As the populations are funnelled up the hierarchy, the higher-order centers provide services to several subregions. Thus, the particular subregion where the center is located is less important, and the subregion variable loses much of its explanatory power.

5.6. Summary of Health Findings

While it is possible to classify the health facilities of the study region on the basis of their central place levels, the results of this classification reveal the extreme scarcity of these facilities. Only the most rudimentary facilities are available outside of level 2 places—and this essentially means everywhere outside of departamento capitals, with a few exceptions. The coverage of the putative "level 3" facilities, health centers, is quite spotty, with only slightly over half of the level 3 places having them. The majority of those places which have any health facilities at all have health posts, and four-fifths of the places lack even these. Thus, compared with the distribution of private goods, health facilities are much more scarce, and unevenly distributed.

Given the scarcity of facilities, it is hardly surprising that the distances travelled to the nearest facility used by the residence of a central place are so long. The mean distance of 6 kilometers (3.7 miles) is a long enough walk in the mountains of the central highlands. There is an extensive if erratic bus system in Guatemala which may serve for the occasional trip for medical treatment. However, this is the figure for destinations which are not departamento capitals, and there are many distances which are larger than this mean. If we wish to consider the distance to major facilities (i.e., hospitals), then the distance traveled to departamento capitals, 36 km (22.4 miles) is a better measure. The maximum recorded distance is over 75 miles.

This region clearly shows the dominance of the political hierarchy at the expense of the central place hierarchy. The system of central places and their market areas which was identified in the previous chapters was based on minimizing the distance travelled to obtain central goods. Any deviation from this pattern necessarily means increasing the distance. The analyses of the choice of destination, populations served, and number of places served all show that the political hierarchy of municipio and departamento capitals is more important than central place levels. Villages will use their municipio capitals as sources of health services even if closer ones are available. Many villages seem to view the distant departamento capital as the only source of medical care, despite supply sources closer to home.

The health facilities of the Quetzaltenango central place system are too few in number and overly dependent on the political hierarchy. This leaves the periphery of the system in particular with inadequate access to any kind of medical care. While the level of effort is certainly inadequate, its distribution could be improved if the existing facilities and, more important, the travel patterns of the residents were adjusted to conform more closely with the system of intermediate (level 3 and 4) central places.

VI. EDUCATIONAL FACILITY LOCATION IN A SYSTEM OF CENTRAL PLACES

This chapter examines the school system of the study area, using similar techniques to those applied to the health facilities. The school system, in the form of primary schools, extends considerably further down the hierarchy than does the health system. Unfortunately, some serious data problems hampered calculation of service populations and cast some doubt on the reliability of the minimum distance data. However, the tentative results show the school system to be less dominated by the hierarchy of political capitals than was found for the facilities of the previous chapter.

Officially, Guatemala has a compulsory three-level educational system, with additional schooling at the preprimary and university levels. The compulsory portion consists of six years of primary school, divided into two three-year segments, plus six years of secondary education. The secondary education is also broken into two parts, with the second part being more specialized than the first. However, this official structure is moot, particularly in the rural areas. In the 1970s less than half of the adult population had completed primary school. About one-half the primary-school-age population was actually enrolled, and only a quarter of the students who enroll actually finish primary school.

It is hardly surprising, then, that the literacy rates in Guatemala are quite low. Nationally, about half of the population was illiterate in the mid-1970s. Following the same pattern as with health, the rural poor were considerably worse off in this respect than the urban: about 30 percent of the rural population was literate, as opposed to 70 percent of the urban population. The worst off were the indianos.

They were generally rural and poor, of course, but they also spoke non-Spanish native languages. Their literacy rate was only around 20 percent. The Quiché-speaking indianos, which includes most of the study region, had somewhat higher literacy than some of the other linguistic groups in Guatemala, around 30 per cent (Nyrop 1983, 76-77).

Table 6.1. Literate and Indiano Populations by Subregion

Subregion	Total Place Population	Indiano Persons	Indiano Percent	Literate Persons	Literate Percent
Core	402,723	280,144	69.56	153,714	38.17
Northwest	56,257	45,947	81.67	10,922	19.41
Far North	137,044	108,988	79.53	31,199	22.77
Southeast	232,562	211,675	91.02	45,131	19.41
East-Central	125,646	109,723	87.33	20,843	16.59
North-Central	150,583	81,221	53.94	40,729	27.05
San Marcos Belt	25,692	17,147	66.74	9,389	36.54
Total	1,130,507	854,845	75.62	311,927	27.59

As Table 6.1 shows, the literacy rate in the study region is approximately 27.6 percent, with a considerable amount of sub-regional variation. The rate is highest in the core and San Marcos belt subregions, and it is lowest in the east-central subregion. The inverse relationship between literacy and percent indiano population is notable but not perfect. One surprise is that the northwest subregion, one of the least developed, has the same, relatively low literacy rate as the southeast, which by most measures has been well developed. The southeast does have the highest percentage of indianos in the study region, which accounts for some of its low literacy rate. In general we can say that the subregion seems to reflect the national literacy trends in Guatemala.

6.1. School Distribution in the Study Region

Table 6.2 shows how many places in the study region have at least one school of each type. Primary schools are by far the most common, with 792 places (86.65 percent) having a primary school, either public or private. The public schools clearly predominate, but there are a few places which have only private schools. The other types of schools are much rarer. Only 65 places (7.11 percent) have basic schools, and 6 (0.77 percent) have diversified schools. The importance of public and private schools is about equal for these higher-level facilities. The hierarchy of schools is very clean, in that there are no places which have a basic school but no primary school. Similarly, every place with a diversified school has both a primary and a basic school. The number of schools in each place varies from 1 to 22 for public primary schools (15 for private). The maximum for the other levels varies from 7 to 10.

Table 6.2. Distribution of Schools in the Study Area
(Places with at least one establishment)

	Public		Private		Any	
Type	Places	Percent	Places	Percent	Places	Percent
Primary	790	86.43	29	3.17	792	86.65
Basic	37	4.05	37	4.05	65	7.11
Diversified	5	0.55	6	0.66	7	0.77

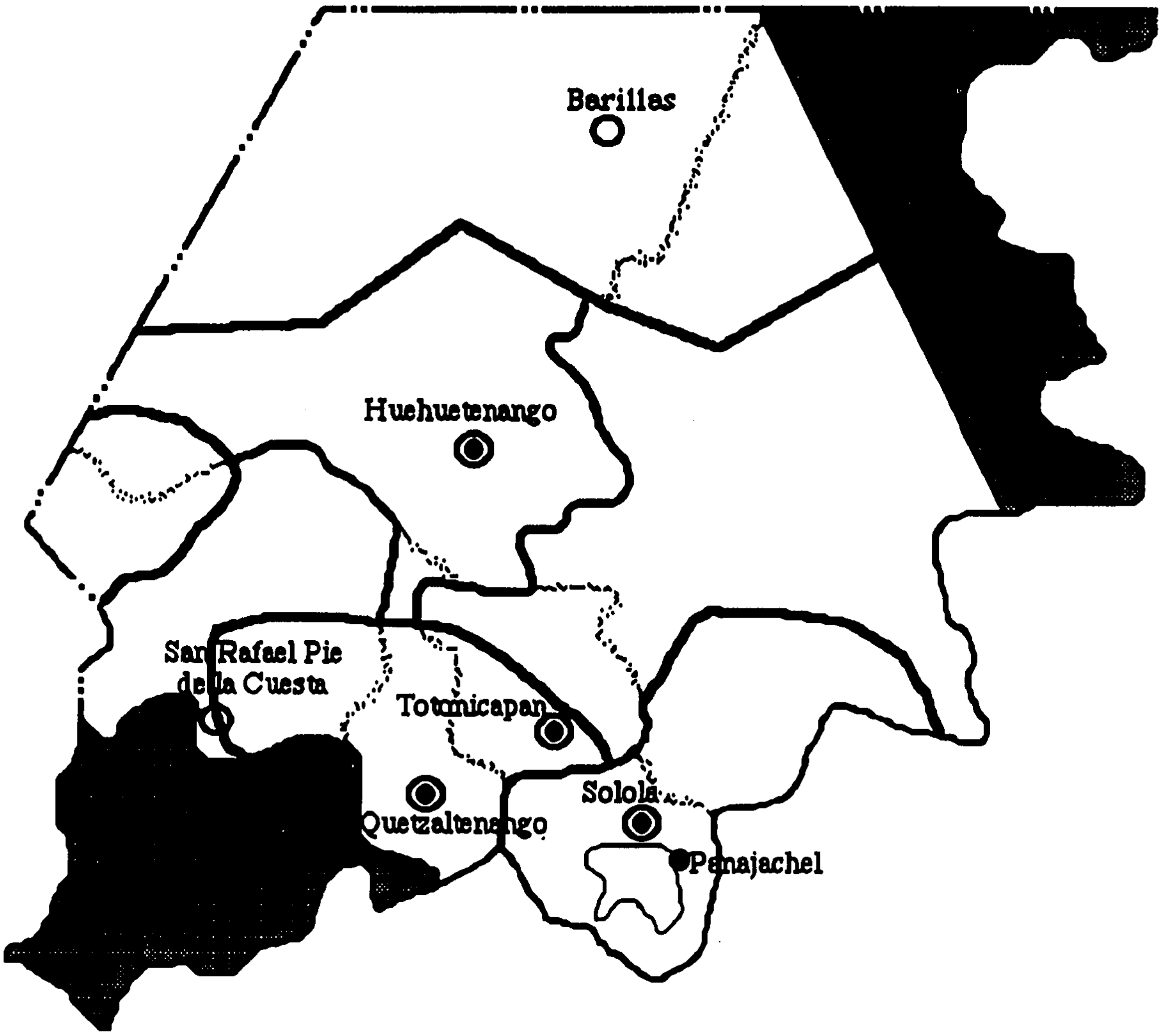

Figure 6.1. Diversified Schools in the Study Region (see Table 6.3 for key)

Table 6.3. Places with Basic and Diversified Schools

Fig. ID Number	Place ID	Place Name	Numbers[a] of Basic Pub.	Basic Priv.	Diversified Pub.	Diversified Priv.
1	701002	Chiquel		1		
2	704009	Novlitero		1		
3	707001	Santa Clara La Laguna	1			
4	713001	San Lucas Tolimán		1		
5	718001	San Pedro La Laguna	1			
6	719001	Santiago Atitlán	1			
7	802001	San Cristóbal Totonicapán		1		
8	803001	San Francisco El Alto	1			
9	805001	Mosmotenango	1			
10	902001	Salcajá		2		
11	903001	Olintepeque		1		
12	904001	San Carlos Sija	1			
13	905001	Sibilia		1		
14	906001	Cabricán		1		
15	909001	Ostuncalco	1			
16	914001	Cantel	1			
17	915001	Huitán		1		
18	918001	San Fransico La Union		1		
19	924001	Palestina de los Altos	1			
20	1201001	San Marcos	3	3		
21	1202001	San Pedro Sacatepéquez	1	4		
22	1203001	San Antonio Sacatepéquez	1			
23	1204001	Comitancillo	1			
24	1205001	San Miguel Ixtahuacán	1			
25	1206001	Concepción Tutuapa		1		
26	1207001	Tacaná	1			
27	1210001	Tejutla		2		
28	1223001	Ixchiguán		1		
29	1224001	San José Ojetenam		1		
30	1228001	Rio Blanco		1		
31	1229001	San Lorenzo	1			
32	1302001	Chiantla	1	1		

[a] Zeros shown as blanks.

Table 6.3 continued

Fig. ID Number	Place ID	Place Name	Numbers of Basic Pub.	Basic Priv.	Diversified Pub.	Diversified Priv.
33	1303001	Malacatancito		1		
34	1304001	Cuilco	1			
35	1305001	Nentón	1			
36	1306001	San Pedro Necta		1		
37	1307001	Jacaltenango		1		
38	1309001	Ixtahuacán	1			
39	1311001	La Libertad		1		
40	1312001	La Democracia	1			
41	1313001	San Miguel Acatán		1		
42	1317001	Santa Eulalia		1		
43	1319001	Colotenango	1			
44	1323001	San Juan Ixcoy		1		
45	1324001	San Antonio Huista	1			
46	1327001	Aguacatán	1			
47	1331001	Santa Ana Huista	1	1		
48	1401001	Santa Cruz del Quiché	1	3		
49	1403001	Chinique	1			
50	1404001	Zacualpa		1		
51	1406001	Chichicastenango	1	2		
52	1410001	Cunén	1			
53	1411001	San Juan Cotzal		1		
54	1412001	Joyabaj	1			
55	1413001	Nebaj		1		
56	1414001	San Andrés Sajcabajá		1		
57	1415001	Uspantán	1			
58	1416001	Sacapulas	1			
59	701001	Sololá	1		1	2
60	710001	Panajachel	1		1	
61	801001	Totonicapán	2	2	1	1
62	901001	Quetzaltenango	9	7	8	10
63	1211001	San Rafael Pie de la Cuesta		1		1
64	1301001	Huehuetenango	1	4	1	3
65	1326001	Barillas		2		1

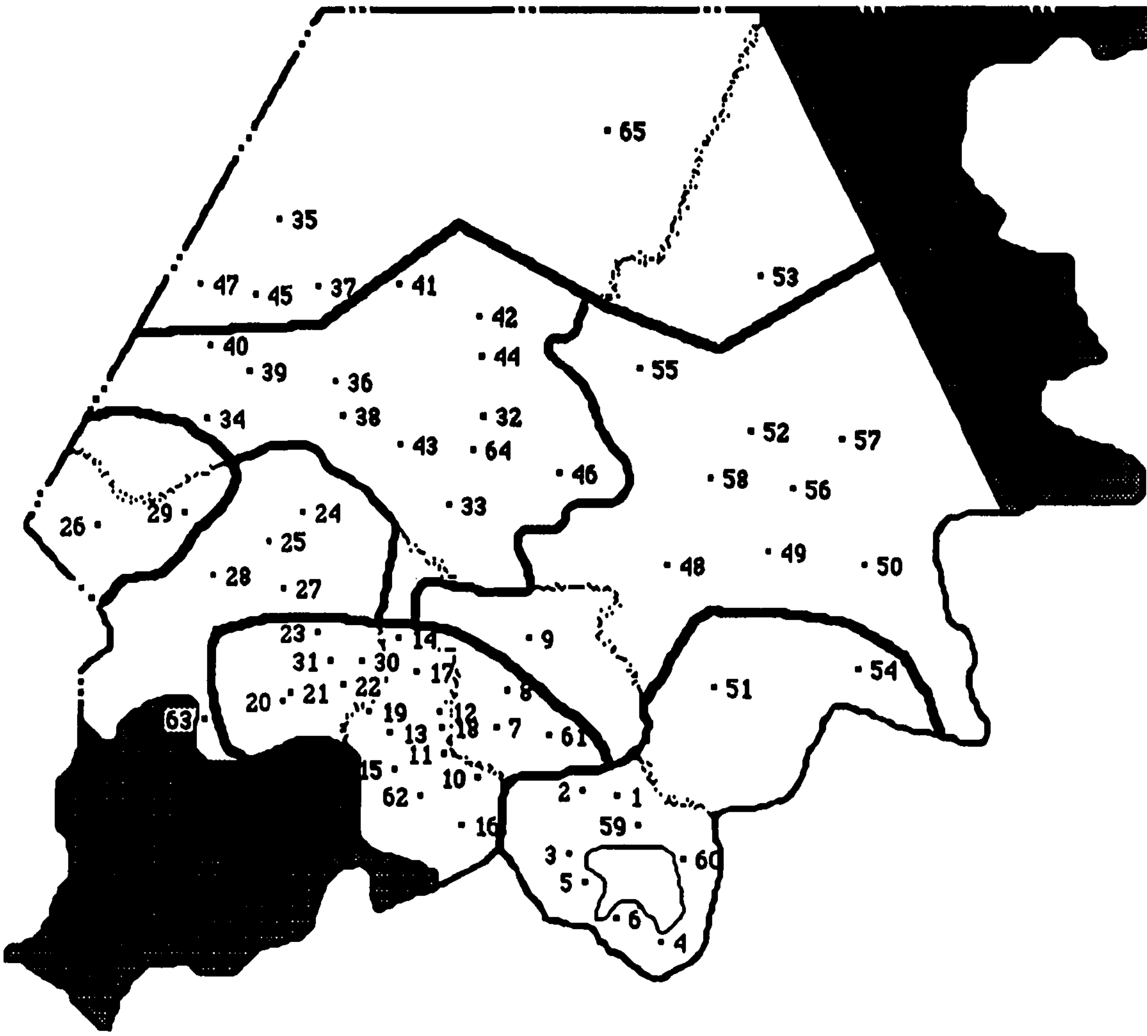

Figure 6.2. Basic Schools in the Study Region (see Table 6.3 for key)

6.1.1. School Existence by Central Place Level

The distribution of schools fits the pattern of central places fairly well. Primary schools are found all the way down the hierarchy. Even 66.32 percent of the level 7 places (which have no commercial services), have public primary schools. Basic schools appear to be level 2 services, with a sharp drop in incidence (from 87.50 to 33.33 percent) as one moves to level 3 places. Diversified schools are borderline between level 1 and level 2. Quetzaltenango has one, of course, but they are present in only half of the level 2 places.

Table 6.4. Percentage of Places with Schools by Central Place Level

	Primary		Basic		Diversified	
Level	Public	Private	Public	Private	Public	Private
1	100.00	100.00	100.00	100.00	100.00	100.00
2	100.00	62.50	87.50	75.00	50.00	37.50
3	100.00	26.32	33.33	35.09	0.00	3.51
4	98.94	3.19	10.64	10.64	0.00	0.00
5	86.59	0.44	0.00	0.00	0.00	0.00
6	84.43	0.00	0.00	0.00	0.00	0.00
7	66.32	1.05	0.00	0.00	0.00	0.00
All	86.43	3.17	4.05	4.05	0.55	0.66

The level 2 places are mostly departamento capitals. However, two departamento capitals, Santa Cruz del Quiché (1401001) and San Marcos (1201001) have no diversified schools. There are three level 2 places which are not departamento capitals: Panajachel (710001), in Departamento Sololá, and Tejutla (1210001) and San Pedro Sacatepéquez (1202001), both in Departamento San Marcos. Of these, only the first has a diversified school. Thus, while there is a strong correlation between locations of diversified schools and level 2 central places, it seems that this is because most such central places have political importance.

The distribution of diversified schools among the departamentos is highly uneven. There are no diversified schools in Departamento El Quiché at all. The only diversified school in Departamento San Marcos is the school in San Rafael Pie de la Cuesta (1211001). With the only 15 students and 6 faculty, this is the smallest of all the diversified schools. Surprisingly, Departamento Huehuetenango has two locations with diversified schools, one in the departamento capital and one in Barillas (1326001), one of the northernmost places in the study region. The Barillas school is small, with 17 students and 4 faculty.

6.1.2. Locational Differences Between Private and Public Schools

The survey data include separate information on private and public schools at all levels. However, they do not provide an explanation of the nature of these "private" schools. While it is natural to expect that at least some of these schools are church related, given the traditional strength of the Catholic Church and the recent expansion of evangelical protestantism in Guatemala, there is in fact nothing in the data which identify these schools as being affiliated with any religious organizations. *A priori,* private schools can function as substitutes or complements with respect to the public school system. Complementary schools extend the range of the educational system as a whole and are located in places which are not served by public schools. Substitute schools draw students from the same places as the public schools. These may deepen the educational resources available in parts of the central place system, rather than extending it into the periphery. An example of a complementary school would be a religious mission school established to educate the (mostly indiano) poor in the remote areas of the region. A substitute school would be be a higher quality private academy serving students from (mostly ladino) elite families in the population centers. Thus, to the extent that the private school system duplicates the public, we have evidence of substitution. If the distribution of private schools is different from that of public, we have evidence of complementarity. This is, of course, a simplification. A private school in a higher-level central place could function as a complement if it took pressure off the overcrowded public system or if it used the advantages of central location to draw in disadvantaged students from the periphery. However, the limits of the available data preclude investigating such possibilities.

6.1.2.1. Primary schools

Table 6.5 shows a crosstabulation of the existence of public and private primary schools, for all 792 places which have any of either. There are only two places which have a private school but no public school. These are Pasci (914007), a level 4 place in municipio Cantel, a few miles southeast of Quetzaltenango (and in that departamento) and, rather surprisingly, a level 7 place, Las Nubes (1207046). The latter is in the northwestern subregion (Municipio Tacaná, Departamento San Marcos), very near to the Mexican border. 93.1 percent of the places with private schools also have public schools. Further, 74.1 percent of the places which have private schools are of central place level 3 or higher (which are themselves mostly municipio or departamento capitals). By contrast, only 8.3 percent of the places which have public primary schools are level 3 or higher. Thus, it seems that for primary schools, at least, the private schools are substitutes for the public schools. The private schools duplicate the efforts of the public schools in the higher-level places.

A similar story is told by the distribution of places with schools by subregion (see Table 6.6). The private schools are more concentrated in the core subregion than are the public schools. However, there are a few anomalies. Just over a quarter of the places which have private schools are in the north-central subregion, in contrast to less than a fifth of the public schools. However the numbers of private primary schools are so small relative to the number of public schools that this is unlikely to make any difference.

Table 6.5. Crosstabulation of Public and Private Primary Schools

Count Row percent Column percent Total percent Public Schools	Private Schools Absent	 Present	 Row Totals
Absent		2 100.0 6.9 0.3	2 0.3
Present	763 96.9 100.0 96.3	27 3.4 93.1 3.0	790 99.7
Column Totals	763 96.3	29 3.7	792 100.0

Table 6.6. Subregional Distribution of Places with Primary Schools

	Public		Private		Any	
Subregion	Freq.	Percent	Freq.	Percent	Freq.	Percent
Core	189	23.9	10	37.0	190	24.0
Northwest	66	8.4	1	3.7	67	8.5
Far North	115	14.6	5	18.5	115	14.5
Southeast	124	15.7	3	11.1	124	15.7
East-Central	118	14.9	1	3.7	118	14.9
North-Central	141	17.8	7	25.9	141	17.8
San Marcos Belt	37	4.7	0	0.0	37	4.7
Total	790	100.0	27	100.0	792	100.0

6.1.2.2. Basic schools

The situation is quite different for the basic schools. There are 65 places which have at least one basic school of some type. Of these, 28 have only public and 28 have only private schools. Only 9 places (13.8 percent) have both types of basic school. Thus, it appears that the basic school systems supplement each other. However, the distribution of places with basic schools by central place level is virtually the same for both public and private schools. This means that while the private schools extend the geographic range of the basic schools, they do not extend services any further down the central place hierarchy. In effect, "basic schools" are a single central good, with a distinct central place level, although half of the services are provided by one sector, and half by the other.

Table 6.7. Crosstabulation of Public and Private Basic Schools

Count Row percent Column percent Total percent	Private Schools		
Public Schools	Absent	Present	Row Totals
Absent		28 100.0 75.7 43.1	28 43.1
Present	28 75.7 100.0 43.1	9 24.3 24.3 13.8	37 56.9
Column Totals	28 43.1	37 56.9	65 100.0

The differences in subregional distribution are also interesting. Of the four places with basic schools in the underdeveloped northwestern subregion, there is only one with a public school, but three have private schools. The far north, another region whose central place system is less developed, the places with private schools outnumber those with public by more than two to one, although there is some overlap. By contrast, the in core, which is relatively well endowed with public schools, there are more places with public schools than with private. Thus, the private schools are located in the remoter subregions on the periphery, which the public system covers less well.

Table 6.8. Subregional Distribution of Places with Basic Schools

	Public		Private		Any	
Subregion	Freq.	Percent	Freq.	Percent	Freq.	Percent
Core	12	32.4	11	29.7	19	29.2
Northwest	1	2.7	3	8.1	4	6.2
Far North	4	10.8	9	24.3	11	16.9
Southeast	7	18.9	5	13.5	10	15.4
East-Central	6	16.2	2	5.4	8	12.3
North-Central	6	16.2	5	13.5	10	15.4
San Marcos Belt	1	2.7	2	5.4	3	4.6
Total	37	100.0	37	100.0	65	100.0

6.1.2.3. Diversified schools

There are only seven places which have any diversified schools, which makes making firm judgments about them difficult. However, four of these places (all of them departamento capitals) have both private and public schools. Two of the places have only private schools, and one has only public. The two places which have only private schools are the only level 3 places which have diversified schools. They are both municipio capitals: Barillas (1326001), in the far north of

Departamento Huehuetenango, and San Rafael Pie de la Cuesta (1211001), which is just southwest of San Marcos (its departamento capital). These two places have the smallest number of students (17 and 15, respectively) of any places which have diversified schools. The student/teacher ratio for each (4.25 and 2.5) is quite low, which could be a sign of superior quality or of the minimum number of teachers necessary to staff such a school. The school at Barillas, small though it is, is much closer to many places in the far north subregion than any other diversified school. The school at San Rafael is in the San Marcos belt subregion and thus also out of the core, although its proximity to San Marcos city means it extends the reach of diversified schools by very little. Thus, the private diversified schools mostly act as substitutes for the public schools, with the significant exception of Barillas, and the less convincing one of San Rafael. The one place which has only a public school is Panajachel (701001) in Departamento Sololá. This place is also notable in that it is a level 2 place but not a departamento capital. In this case, one might argue that it was the public schools which were extending the range of this level of schooling, by locating outside of the capital.

The subregional distribution adds little to what has already been said. The far north and San Marcos belt have already been mentioned as being "served" by only a single small private school each. Two subregions have no diversified schools at all. The northwest, is again one of these least served subregions. The other subregion with no diversified schools is the east-central. This includes all of El Quiché, and is notable because it emphasizes the point that Santa Cruz del Quiché is a departamento capital and level 2 place, yet it has no diversified school.

Table 6.9. Crosstabulation of Private and Public Diversified Schools

Count Row percent Column percent Total percent Public Schools	Private Schools Absent	 Present	 Row Totals
Absent		2 100.0 33.3 28.6	2 28.6
Present	1 20.0 100.0 14.3	4 80.0 66.7 57.1	5 71.4
Column Totals	1 14.3	6 85.7	7 100.0

Table 6.10. Subregional Distribution of Places with Diversified Schools

	Public		Private		Any	
Subregion	Freq.	Percent	Freq.	Percent	Freq.	Percent
Core	2	40.0	2	33.3	2	28.6
Northwest	0	0.0	0	0.0	0	0.0
Far North	0	0.0	1	16.7	1	14.3
Southeast	2	40.0	1	16.7	2	28.6
East-Central	0	0.0	0	0.0	0	0.0
North-Central	1	20.0	1	16.7	1	14.3
San Marcos Belt	0	0.0	1	16.7	1	14.3
Total	5	100.0	6	100.0	7	100.0

6.2. Gross Measures of School Efficiency

6.2.1. Student and Teacher Data

Unfortunately, the survey data on the number of students and teachers at each place are not trustworthy. Thus, they would not be meaningful in any kind of sophisticated analysis. Some summary statistics are listed in Table 6.10. These statistics are for *places*, not schools. Some places have several schools of a particular type. The size of the student bodies and staffs are highly variable. For public schools, mean numbers of students increase as the level of school increases, but the maxima decrease. There are more individual primary schools in the larger places, which probably accounts for the large maxima. For private schools, on the other hand, the mean number of students is virtually the same for primary and diversified schools, but much lower for basic schools. The mean for primary schools is the only one of the three which is larger for private than for public schools. The private schools have the same pattern of decreasing maxima as the public schools.

The mean numbers of teachers per place increase with level for both private and public schools, but the effect is much more noticeable for the public schools. There are clearly some very small schools at all levels, some with only one teacher. Even some of the diversified schools have very small numbers of teachers. The student-teacher ratio drops as schools get larger. This is somewhat counterintuitive. One would expect that the proliferation of very small schools, all of which must, of course, have at least one teacher, would decrease the student-teacher ratio. Instead, it is the larger basic and diversified schools which have the low ratios. Indeed, a ratio of 8 or 9 students per teacher is quite low even by the standards of the United States. Perhaps this low value is due to the small number of these schools, allowing the concentration of trained personnel. Private primary and basic schools have lower student-teacher ratios than do public schools, but the ratio is slightly lower for the public schools at the diversified level.

Table 6.11. Descriptive Statistics for Student and Teacher Data

	Students			Teachers			Mean
	Mean	Min	Max	Mean	Min	Max	Ratio
Primary							
Public	169.79	2	7615	4.11	1	243	41.36
Private	399.63	20	2925	13.42	1	122	29.78
Basic							
Public	293.61	20	4205	20.58	3	344	14.26
Private	191.75	14	1325	17.94	4	197	10.69
Diversified							
Public	660.60	20	1843	78.60	6	344	8.40
Private	396.17	15	1417	44.83	4	197	8.84

6.2.2. Anomalies in Origin and Destination Data

It was originally intended that the analysis of the school system proceed along the same lines as that of the health care system, relying on the survey data concerning destinations, aggregating the populations served, and so forth. However, there are some disturbing anomalies in these data for the school system. Because of this, it is impossible to be confident about the meaningfulness of the higher levels of aggregation, and more simple statistics must suffice. The anomalies are characterized by contradictory evidence from different variables. There are places which have schools but claim to send students elsewhere, places which have no schools but name no destinations, and places which claim to send students to places which are recorded as having no schools.

6.2.2.1. Places with schools which name destinations

One hundred ninety central places which themselves have schools also name destinations where students from those places go to attend schools. This in itself is not very disturbing, since not all schools are alike and there may be reasons for students to go out of town, even when there is a school in the same place. In particular, we might expect that a place which had only private or only public schools would send some students to places which had schools of the type it lacked. However, the proportions of places with only public schools which send students to destinations which also have only public schools are disturbingly high, particularly in the case of primary schools. Even these are not damning, given the lack of qualitative information about the schools, but they contribute to the sense of uneasiness about the accuracy of these data.

Tables 6.12 through 6.15 give crosstabulations of the 190 places by types of schools in the origin and destination places. (Columns or rows in which all frequencies are zero have been omitted to save space.) In many cases the destinations coded "missing" are places outside the study area (for which there is no school inventory information). The most often-named such destination is Guatemala City, which presumably has schools of all kinds.

Table 6.12. Crosstabulation of Places with Primary Schools Which Name Destinations

Frequency Row percent Column percent Total percent Destination Schools	Origin Schools Public Only	 Private Only	 Row Totals
Public Only	107 98.17 68.15 67.30	2 1.83 100.00 1.26	109 68.55 68.55
Both Types	35 100.00 22.29 22.01		35 22.01 22.01
Missing	15 100.00 9.55 9.43		15 9.43 9.43
Column Totals	157 98.74	2 1.26	159

Table 6.13. Crosstabulation of Places with Basic Schools Which Name Destinations

Frequency Row percent Column percent Total percent Destination Schools	Origin Schools Public Only	 Private Only	 Both Types	 Row Totals
None		3 100.00 18.75 14.29		3 14.29
Public Only		1 100.00 6.25 4.76		1 4.76
Both Types	3 17.65 100.00 14.29	12 70.59 75.00 57.14	2 11.76 100.00 9.52	17 80.95
Column Totals	3 14.29	16 76.19	2 9.52	21

Table 6.14. Crosstabulation of Places with Diversified Schools Which Name Destinations

Frequency Row percent Column percent Total percent Destination Schools	Origin Schools Public Only	 Private Only	 Both Types	 Row Totals
None		2 100.00 50.00		2 20.00
Both Types	1 25.00 50.00 10.00	1 25.00 25.00 10.00	2 50.00 50.00 20.00	4 40.00
Missing	1 25.00 50.00 10.00	1 25.00 25.00 10.00	2 50.00 50.00 20.00	4 40.00
Column Totals	2 20.00	4 40.00	4 40.00	10

Table 6.15. Crosstabulation of All Places with Schools Which Name Destinations

Frequency Row percent Column percent Total percent Destination Schools	Origin Schools Public Only	 Private Only	 Both Types	 Row Totals
None		5 100.00 22.73 2.63		5 2.63
Public Only	107 97.27 66.05 56.32	3 2.73 13.64 1.58		110 57.89
Both Types	39 69.64 24.07 20.53	13 23.21 59.09 6.84	4 7.14 66.67 2.11	56 29.47
Missing	16 84.21 9.88 8.42	1 5.26 4.55 0.53	2 10.53 33.33 1.05	19 10.00
Column Totals	162 85.26	22 11.58	6 3.16	190

6.2.2.2. Places with no schools which name no destinations

As Table 6.16 shows, a large number of places which have no schools of a particular type name no destination for that type of school. The primary schools show a low incidence for this problem. In fact, the incidence for primary schools is even lower than first appears, since 86.65 percent of all places have a primary school. Thus, the 24 places listed in the first line of the table represent only 2.63 percent of the places in the region (but 19.67 percent of the 13.35 percent which have no primary school). Basic and diversified schools, however, are much less common. As the table shows, most of the places without such schools do not report any destination for their students. The destination data accounts for only 20 to 30 percent of those places which one would expect to send students somewhere. Considering the small proportion of Guatemalans who obtain education beyond primary school, it is likely that the reason for this poor response is that the places simply have no destinations for "higher" education. However, it means that any analysis of origin and destination data will be inconclusive at best. Most of the students that obtain primary education do so in their own villages. Most of the students do not obtain any more than this. If they do, we only have a small (and probably not random) sample of their destinations.

Table 6.16. Places with No Schools and No Destinations

School Type	Frequency	Percentage of Places without Schools	Percentage of All Places
Primary	24	19.67	2.63
Basic	584	68.79	63.89
Diversified	727	80.15	79.54

6.2.2.3. Destinations which are named but have no schools

Of those places which name destinations, there are 214 cases in which the place named cannot be confirmed to have a school of the proper type (see Table 6.17). Some destinations in fact have no schools, some are not in the survey dataset, some are not valid place ID numbers, and some are not in the current study region. These 214 cases "point to" a total of 78 separate destinations. (There are many cases of the same destinations being named by different origin places, particularly for the higher-level schools.) The breakdown by school type is shown in Table 6.17. By origin, about half of the problems involve diversified schools, and the other two levels account for about a quarter each. If these problems were caused by entirely random mistakes, one would expect the primary school destinations to account for smaller numbers, since so few places need to send their students elsewhere for primary schooling. The concentration of the destinations, particularly at the upper two levels is also interesting. One would expect random mistakes to name all sorts of different destinations (as we see for primary schools). Instead, the average number of times a place is named is about 4 for basic schools and 10 for diversified. Among the destinations named, the problems with them break down as shown in Table 6.18.

Table 6.17. Frequency Distribution of Destinations without Schools

School Type	Origins	Destinations
Primary	58	55
Basic	50	12
Diversified	106	11
Total	214	78

Table 6.18. Frequency Distribution of School Destinations by Type of Problem

Problem	Primary	Basic	Diversified	Total
Zero schools recorded	2	8	8	18
Not in study region	1	3	2	7
Not in survey dataset	49	0	0	49
Bad place ID	3	1	1	5
Total	55	12	11	78

The less frequent problems are not of great concern. A few coding errors which yield invalid destination ID numbers are to be expected. Similarly, it is not surprising that some students are sent to schools outside the Quetzaltenango central place system (one such place which was named quite often was Guatemala City). The other problems bear some additional examination.

The destinations which are not in the survey dataset have ID numbers which follow the pattern of valid places (at least there is nothing obviously wrong with them), but these places neither appear on the map of all places in the survey, nor do they have records in the master datasets (which are supposed to contain all the places in the survey, not just in the study region). In many cases, these ID codes are numbers which are bracketed by valid place IDs. For example, one of these missing destinations has a place ID of 1301005, which would put it in the capital municipio of Departamento Huehuetenango. There is a 1301004 (Canabaj) and a 1301006 (Chinaca), but no 1301005. The survey only sampled (rather than inventoried) the places with populations less than 50 persons, and one might hypothesize that the places referred to were left out. The fact that none are named as basic or diversified destinations lends some credence to this hypothesis, since such small places would be unlikely to have upper-level schools. However, the fact remains that they were named as destinations. If they actually do have schools, it means that the discussion of the distribution of schools in the study region is inaccurate. For primary schools, this inaccuracy probably does not amount to much. Seventeen out of twenty places in the dataset have primary schools. That some very small places have such schools is to be expected.

The second-most frequent problem by destination is that 18 places were named, despite their having no schools of the indicated type. This is a cause for concern, particularly since all but two of these destinations are those for basic or diversified schools. (These are all places which have valid IDs and can be found in the study region.) For most of these putative destinations, only one or two origins claim to send students to them. Perhaps these are clerical errors. On the other hand, 24 places claim to send basic, and 10 diversified, students to Santa Lucia Utatlán (704001). Similarly, 31 places claim San Marcos and 18 claim Santa Cruz del Quiché as destinations of diversified students, despite the fact that these places are recorded in the dataset has having no schools of this type. What sort of error is this? Are these destinations to be considered unreliable, or should one conclude that the inventory variables are faulty? If one assumes that all the places named as destinations for diversified schools actually have them, the number of places with such schools more than doubles, from 7 to 15. An additional 8 places having basic schools is an increase of 12.31 percent–not as large, but still significant. San Marcos and Santa Cruz del Quiché were notable in being the only two departamento capitals with no diversified schools. These data throw doubt on that statement. Similarly, Departamento El Quiché was noted as having no diversified schools at all. This, too, is somewhat questionable.

In the analyses of destination data below, the questionable destination data have been used to some extent. Since the survey data reports distances to destinations, they have been included in the analysis of distances, even if it is not certain that a school actually exists at a place. Clearly, it is impossible to compute any measures of school populations served by facility or per school when this information is not available. Places which name no destinations are not included in the analysis. Places which have schools but name destinations are included. The conclusions reached and statistics computed must be treated skeptically and not be subjected to stringent standards of proof.

6.2.3. Distance Travelled

For the most part, the distance information was supplied by the survey dataset; it is not based on map work. However, the survey seems to have coded any distance above 97 km as "98" ("99" is the value for missing data). These numbers were replaced with estimates taken from the map. Straight-line distances were used, which most probably underestimate the true travel distances. This reinforces the impression that the maximum distances are extraordinary.

As might be expected, the mean distance travelled to school destinations increases with the level of school. Table 6.19 summarizes some simple measures of this. As was the case with the health data, it is difficult to know what to make of the maximum reported values, which are extremely large. They could be reporting errors, or they could represent travel to boarding or residential schools. They are too large for daily commuting distances, even assuming that most people could afford daily bus fare, which is unlikely. The mean distance to primary schools is about the same as the mean distance to the minimum-distance health facilities (which was 6 km). In fact, of course, the distance to primary schools for most places is essentially zero, since most places have their own. The distances reported in the table only apply to places which name outside destinations.

Table 6.19. Distance Travelled to School Destinations (kilometers)

	Primary	Basic	Diversified
Frequency	184	67	15
Minimum	1.00	1.00	1.00
Mean	5.27	14.34	35.05
Maximum	117.00	172.00	193.00

The "frequency" line in Table 6.19 is the number of different places listed as destinations. These numbers are not the same as the number of places which have schools. In fact, the number of destinations is larger for two of the types of schools. This summary does include places which are outside the study region, which is part of the reason for the discrepancy. Another reason is some cases of places which have no schools being named as destinations, as was discussed above.

Table 6.20. Minimum Distance to School Destinations by Central Place Variables (ANOVA summary)

	Primary		Basic		Diversified	
Factor	F	Signif. of F	F	Signif. of F	F	Signif. of F
Main Effects	2.934	0.000	3.784	0.000	4.459	0.000
Subregion	1.540	0.162	6.994	0.000	8.194	0.000
Capital	0.069	0.933	0.099	0.906	0.329	0.720
Level	3.596	0.002	0.877	0.512	0.356	0.906

While some places have more than one school destination, the best simple measure of accessibility is the minimum distance. Places which have a school have a minimum distance of zero, while those which do not will have a positive distance. This distance was determined for each place and school level, on the basis of destinations claimed. Table 6.20 shows a summary of the analyses of variance which tested whether the minimum distance to a school was significantly related to subregion, central place level, or political status. Only one factor turns out to be significant for each type of school. For primary school destinations, the important factor is the central place level of the origin place. This is probably because so many places have their own primary schools. All places of level 3 or higher have these schools, and at least 84 percent of the places in levels 4 through

6 have schools. The proportion of places without schools rises as one goes down the hierarchy. Thus, for most places the minimum distance to a primary school is zero.

The upper-level schools show significant variation by subregion only. Neither central place nor political status help explain the differences among distances traveled to schools. The multiple classification analysis shows that the distances for both types of school are smallest for the well-developed areas of the study region, the core and southeast. The mean distances are the largest for the least developed area, the northwest. The east-central subregion, which consists mainly of El Quiché, also shows large positive deviations, reflecting the lack of schools in the departamento (in particular, the lack of any diversified schools at all). The far north does rather well in its accessibility to basic schools, but the deviation for diversified schools is the highest of all. There is in fact a diversified school in the far north (at Barillas), but it is also one of the smallest of such schools. Most diversified students in the far north must travel to Huehuetenango, at the extreme southern end of that departamento.

We can thus conclude that there is evidence of differences in accessibility, particularly with respect to basic and diversified schools. However, unlike the health facilities, schools are not as tied to the hierarchy of political capitals. They are more accessible to the residents of the parts of the study region which have better developed central place systems. In the case of primary schools, which are available almost everywhere, the central place system still exhibits a minor role, in that the lowest-level places are those least likely to have their own schools.

Table 6.21. Multiple Classification Analysis of Minimum Travel Distances to Basic and Diversified Schools by Subregion

		Basic		Diversified
Grand Mean		11.01		30.41
Subregion	N	Unadjusted Deviation	N	Unadjusted Deviation
Core	133	-5.19	85	-12.52
Northwest	17	15.23	5	27.59
Far North	29	3.61	16	31.53
Southeast	42	-4.72	22	-7.36
East-Central	40	5.87	17	18.18
North-Central	57	4.24	34	4.59
San Marcos Belt	12	4.08	8	14.84
Multiple R^2		0.144		0.266
Multiple R		0.379		0.516

6.2.4. Places Served

Table 6.22. Number of Origin Places per Destination Place

	Primary	Basic	Diversified
Minimum	1.00	1.00	1.00
Mean	1.51	5.79	16.93
Maximum	7.00	45.00	109.85
Total	278.00	388.00	254.00

The total number of origins for all levels of schooling (Table 6.22) attests to the number of missing values in the dataset. In fact, even this total exaggerates the number of places accounted for. The survey allowed each origin to name as many as three destinations, and a few places used all three slots. Thus, the 278 "origins" for primary schools are not distinct places. Table 6.23 shows the frequency of places indicating each number of definitions. About a quarter to a fifth of the places (depending on the school level in question) which named destinations named more than one. Most of these reported two places, with only a few percent reporting three. Between a fifth and a third of all places report at least one destination for a given level of school. Since 86 percent of all places have a primary school, it is not surprising that only 26.15 of them report a destination for primary students. The two percentages do not sum to 100 because of the anomalies discussed above. The small numbers of origins for the other two levels indicate that either a lot of information is missing, or many places simply stop at the primary level of education. Probably both are true. The data themselves show the expected pattern, with higher-level places having many more origins than lower-level places. Even so, there is a place with a diversified school which has only one place naming it as a destination.

Table 6.23. Tally of the Number of School Destinations Named per Place

Number of	Primary		Basic		Diversified	
Destinations	Freq	Percent	Freq	Percent	Freq	Percent
None	679		636		739	
1	197	82.43	216	71.52	137	74.05
2	38	15.90	62	20.53	38	20.54
3	4	1.67	24	7.95	10	5.41
Total	239	100.00	302	100.00	185	100.00
As Prop. of All Places		26.15		33.04		20.24

6.2.5. Populations Served

The survey includes questions about the number of students sent to each destination. While these are certainly unreliable, compounding the problem of where students go with the problem of accurately counting them, an aggregation of all students over the destinations may give us some idea of the amount of educational travel. The result of this aggregation is shown in Table 6.24.

Table 6.24. Aggregated Number of Students per Destination Place

	Primary	Basic	Diversified
Minimum	1.00	1.00	1.00
Mean	30.32	51.66	179.00
Maximum	214.00	578.00	1186.00
Total	5427.00	3461.00	2685.00

The numbers of students are those reported as going to the destinations. They do not include the resident student populations of the places that have schools. The only student information for each place is the number of students attending school, which includes both the students from outside and the local students. Given the many gaps in the destination data, the number of local students cannot be reliably obtained through subtraction. The measures of the ratio of aggregated students to reported students is shown in Table 6.25. The low mean values show that many students are not accounted for by the aggregation. This is hardly surprising, since the children in the same place as a school are most likely to attend there. However, it is impossible to separate measurement errors from this local population.

Table 6.25. Ratio of Aggregated to Reported Students per Place

	Primary	Basic	Diversified
Cases	117	32	4
Maximum	0.890	0.740	0.580
Mean	0.149	0.259	0.442
Minimum	0.000	0.020	0.150
Standard Deviation	0.173	0.194	0.195

An attempt was made to estimate the school-age service population of each place which has primary schools. Since most places have such schools and relatively few send their children elsewhere, for the most part this is simply the school-age population of the place and the surrounding rural area. To this local population was added the school-age population of those places claiming a school site as a destination. The population for those places which claim more than one destination was divided in proportion to the number of students sent to each place. It was hoped that these service populations could then be compared to the actual number of students reported, to measure the percentage of the population receiving primary education. It could also be analyzed on the basis of subregional variation, the central place hierarchy, the political hierarchy, and so on. Unfortunately, a series of serious data problems brought the reliability of this aggregation into such doubt that further analysis had to be abandoned.

Primary schooling in Guatemala consists of two three-year cycles. Appropriately, the survey dataset includes separate place population variables for the age groups, 7-9 years of age and 10-12 years of age. Unfortunately, the variable containing the latter population figures is entirely absent from existing copies of the survey dataset. However, the data do include the total place population and that of all other age groups. In principle, the missing figures can be reconstructed by subtracting all the known age groups from the total. This is hindered by the fact that one or more of the population values are missing for three places (including Quetzaltenango itself). The subtraction procedure yields negative values for two additional places, and for others the estimate represents a large proportion of the total population--as much as 91 percent in one case. The average ratio to total place population is 0.084, with a standard deviation of 0.035. (These figures exclude the missing and negative values.)

Despite these difficulties, the aggregation of school-age service populations was computed. Only those places whose upper primary (i.e., the 10-12 year old age group) estimates as a proportion of total population were within two standard deviations of the mean proportion were included. Any place for which any part of the upper primary population could not be computed, either for the place itself or origins sending students to that place, was excluded from the aggregation.

The student to population ratios resulting from dividing the number of students claimed by the estimated service population has a mean of 0.801 and a standard deviation of 0.549. The mean itself is implausibly high, given what is known about the percentage of Guatemalans who receive primary educations. The standard deviation is simply absurd, implying as it does that the student to population ratio for some places is greater than unity. This, unfortunately, is the case. In fact, the ratio has a maximum of 6.00, and 20.8 percent of the places in the study region have ratios greater than 1.00. One reason for this is that the age-classified population variables only measure the population of the place and not of the surrounding rural area. Unfortunately, similar data for the rural population is not available. However, in Chapter IV an attempt was made to allocate the total municipio populations to the places in each municipio, weighted by place population. If we assume that the proportion of school age children in the rural and place populations are the same, we can estimate the student to population ratio by taking the previous estimate and multiplying it by the ratio of total place population to total allocated municipio population. This is so because we have specific numbers on students, and only the service population (the denominator of the ratio) is uncertain. The corrected ratios are lower than the original estimates, with a mean of 0.604 and a standard deviation of 0.536. While this certainly moves the estimate in the direction it is expected to go, there is no reason to trust these figures very much. Indeed, despite the correction, 15.0 percent of the places have ratios greater than unity. One possible reason for this is that there may be older children or even adults still attending primary school, despite the official age classification for such schooling. There is no information available on the numbers of such older students. It thus appears to be impossible to adequately estimate the proportion of the school age population which are actually attending school, given the data available.

Table 6.26. ANOVA of the Estimated Ratio of Primary Students to Municipio School-Age Population

by: SBREGION (subregion code)
CAPITAL (political status)
NEWLEVEL (central place level)

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F
Main Effects	18.738	13	1.441	5.398	0.000
SBREGION	14.695	6	2.440	9.172	0.000
CAPITAL	0.523	2	0.262	0.980	0.376
NEWLEVEL	1.252	5	0.250	0.938	0.456
Explained	18.738	13	1.441	5.398	0.000
Residual	198.138	742	0.267		
Total	216.875	755	0.287		

As might be expected, given all the difficulties with the data, the student to population ratio shows little sensitivity to variation in central place variables. Of the usual central place variables, the subregion is the only one which is shown to be significant in explaining variations in the student to population ratio, as is indicated in the ANOVA results shown in Table 6.26. The R^2 is very low at 0.086. The multiple classification analysis (Table 6.27) shows that the highest ratios are found among the subregions which have the most developed central place structures, the core and southeast. Large negative deviations are found, predictably, in the least developed northwest and east-central, but also in the San Marcos Belt, which lies between the core and the northwest.

Table 6.27. Subregional Variation in the Mean Estimated Ratio of Students to Municipio School-Age Population

Grand Mean = 0.60

Subregion	N	Unadjusted Deviation
Core	185	0.10
Northwest	63	-0.18
Far North	109	-0.07
Southeast	115	0.27
East-Central	115	-0.16
North-Central	137	-0.04
San Marcos Belt	32	-0.20
Multiple R^2	0.086	
Multiple R	0.294	

6.2.6. Literacy and Central Place Variables

Despite the poor showing of the service population calculations, an attempt was made to explain variations in literacy rates on the basis of central place variables. The technique employed was to use analysis of variance on the proportion of place population which is literate. The explanatory variables were central place level, subregion, and political status. In addition to those categorical variables, the ratio of primary students to school age population, the number of origin places, and the percent of the place population which is ladino were entered in as covariates. Because the literacy rates were based on place populations only, the student to population ratio was used without the correction for municipio population. The number of origin places was also modified, by counting each place which had a school itself as having one more origin. (Thus, places with no outside origin but their own schools had values of "1" on this variable.) The results are shown in Tables 6.28 and 6.29.

Quite surprisingly, all of the explanatory variables are shown to be highly significant, with p-values of 0.000. Of the covariates, the regression coefficient of the student-population ratio is the smallest. Given the wide range of this variable, the meaning of the coefficient is difficult to interpret. The strongest effect is attributed to the proportion of ladinos. Ladinos (as opposed to indianos) are usually Spanish speakers and more oriented to commercial and urban society, which would help account for their higher literacy. The R^2 (shown in the multiple classification, Table 6.29) is 0.635, which is not extremely high but is respectable for this kind of data.

The multiple classification analysis shows the expected pattern for central place level and political status. Literacy rates increase with both, whether one looks at the adjusted or unadjusted deviations. The adjusted deviations are generally smaller, reflecting the fact that positive factors are generally found together. (Note that there is no level 1 because Quetzaltenango had missing population variables.)

Table 6.28. ANOVA of Literate Place Population Percentage

by: SBREGION (subregion code)
CAPITAL (Political status)
NEWLEVEL (central place level)
with: PRIRATIO (primary student-population ratio)
PCNT_LAD (ladino proportion of place pop.)
PORGNUM (primary origins count plus self)

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F
Covariates	6.547	3	2.182	260.679	0.000
PRIRATIO	0.510	1	0.510	60.976	0.000
PCNT_LAD	3.694	1	3.694	441.258	0.000
PORGNUM	1.495	1	1.495	178.585	0.000
Main Effects	2.438	13	0.188	22.403	0.000
SBREGION	1.022	6	0.170	20.337	0.000
CAPITAL	0.155	2	0.078	9.268	0.000
NEWLEVEL	0.378	5	0.076	9.029	0.000
Explained	8.985	16	0.562	67.079	0.000
Residual	5.174	618	0.008		
Total	14.159	634	0.022		

Covariate	Raw Regression Coefficient
PRIRATIO	0.053
PCNT_LAD	0.216
PORGNUM	0.073

The subregional variation shows that the core area has higher literacy rates, even after accounting for the other variables. This pattern is also found for the San Marcos belt, despite its poor showing in the student-to-population ratios. The southeast, which is the other region considered to have a well developed central place structure, shows literacy rates lower than average. This subregion has a very low proportion of ladinos in the population (around 7 percent, as compared to the regional average of around 26 percent). This goes a long way to explaining the negative deviation. On the other hand, the southeast does have two level 2 places, one of which is a departamento capital. That may have prevented the adjusted deviation from rising as much as the ladino covariate variable would have implied.

Table 6.29. Multiple Classification Analysis of Literate Place Population Percentage

by: SBREGION (subregion code)
CAPITAL (political status)
NEWLEVEL (central place level)
with: PRIRATIO (primary student-population ratio)
PCNT_LAD (ladino proportion of place pop.)
PORGNUM (primary origins count plus self)

Grand Mean = 0.23

Variable	N	Unadjusted Deviation	Adjusted for Categories and Covariates
SBREGION			
Core	169	0.07	0.05
Northwest	48	-0.02	0.02
Far North	93	-0.03	-0.02
Southeast	88	-0.05	-0.03
East-Central	91	-0.07	-0.05
North-Central	118	0.01	-0.02
San Marcos Belt	28	0.09	0.07
CAPITAL			
Not a Capital	533	-0.03	-0.01
Municipio Capital	97	0.14	0.06
Departamento Capital	5	0.38	0.01

Table 6.29 continued

Variable	N	Unadjusted Deviation	Adjusted for Categories and Covariates
NEWLEVEL			
2	8	0.37	0.22
3	53	0.15	0.06
4	82	0.05	0.03
5	373	-0.02	-0.00
6	76	-0.08	-0.05
7	43	-0.04	-0.05
Multiple R^2		0.635	
Multiple R		0.797	

The undeveloped northwest shows a negative unadjusted deviation but a positive adjusted figure, reflecting its lack of other positive factors (i.e.,. the positive adjusted deviation shows that literacy is not quite as low as one might expect on the basis of the other variables). Most of the other peripheral areas show a similar pattern, although the increase in the adjusted deviations are not large enough to change their signs. The one exception on the periphery is the north-central subregion, which shows a decrease in effect, from positive (if small) to negative. This is the region which includes Huehuetenango. Perhaps the presence of this level 2 departamento capital raises the expected literacy rate, but the large number of less developed places then pulls the actual number down again.

6.3. Summary of School Findings

6.3.1. Numbers of Facilities

Guatemala's educational system is certainly characterized by a lack of sufficient numbers of schools, particularly at the upper levels of education. This is its most pressing problem. Even an optimal locational pattern of facilities would not make up for the fact that there are too few to adequately supply the region at the level implied by the country's compulsory education laws. However, the primary school level is to an extent an exception to this. There are primary schools in the large majority of places, down to fairly small sizes. Unfortunately, the limits of this study preclude commenting on the qualitative adequacy of the institutions, rather than simply counting them.

Guatemala's private schools, to some extent, serve to supplement and extend the public school system. While this is not an accurate statement about the private primary schools, this level of schooling is the one in which the public sector is most successful in any case. There are as many places with only private basic schools as there are public, and these make up substantial fractions of the total places with such schools. There are more places with private diversified schools than with public, although for this level two-thirds of the places with any have both types. To be sure, the private schools are generally smaller, but they do extend the reach of the educational system into areas which the public system does not reach.

6.3.2. Placement of Facilities

While the locational distribution of schools is generally consistent with the central place hierarchy, it is inconsistent in the details. Primary schools extend down to the bottom of the hierarchy, even appearing in about two-thirds of the level 7 places, which have no private services at all. On the other hand, there are a few places as high as level 4 which have no primary schools. The distribution of basic schools extends into part of the level 3 places and even diffuses into a bit of level 4.

Expansion of the basic school system, if contemplated, should be geared towards filling in the gaps at level 3 (these are mostly municipio capitals, and as such are prominent places politically as well). The diversified schools are so few in number that their locational pattern is difficult to evaluate. However, they appear in only a fraction of the level 2 places. They are totally absent from El Quiché. While the private school at Barillas does provide an educational resource in the much-neglected northern tier of the study region, one might argue that placement in one of the level 2 centers which lack such a school, such as Santa Cruz del Quiché or San Marcos, might put it in range of a larger population of students.

The hierarchy of political capitals is considerably less influential in the educational system than it is in the health care system. Departamento capitals and, to a lesser extent, municipio capitals, are still more likely to have upper-level schools, but a larger proportion of schools are in noncapitals than is the case with health facilities. Of the six departamento capitals in the study region, a third do not have diversified schools, and a third of the noncapital level 2 places do.

The study of the distribution of private goods and services in the early chapters of this study identified certain parts of the region as having better access to these goods, a more complete and well-articulated system of central places, denser settlement, shorter travel distances. These subregions are the ones called the "core" and the "southeast." The advantages that these subregions enjoy also spill over into the provision of public services. On the other hand, certain subregions were identified as being particularly underdeveloped. The most extreme of these cases were the northwest and the far north. Here, too, we find the pattern repeated, with both of these regions having smaller percentages of places with schools at most levels. The northwest is considerably worse off than even the far north in this respect. Another region which is undersupplied with educational services is the San Marcos belt.

6.3.3. Efficiency

Because of the many problems and anomalies encountered in the school destination data, conclusions based on them must necessarily be tentative. The large number of missing destinations suggests that many places simply have no school destinations, because the school-age children are not attending school. Compared with health care, we can say that in this region of Guatemala, basic schooling is provided at roughly the same level of accessibility, diversified schooling is a considerably less accessible, and primary schooling is much more accessible. This is true because most places have their own primary schools, and these schools serve few (if any) other places. These are the characteristics of a low-level good. By contrast, the mean distances travelled to diversified schools are higher than the health system's mean MINDEST, (35.05 km vs. 19.28 km), while the mean distance to basic schools (14.34 km) is comparable, given the weakness of the data. The number of places served per health MINDEST was 7.02, while the mean for basic schools was 5.79 places served and for diversified schools was 16.93. Basic schools serve about the same sort of market area as MINDESTS, while the market areas of diversified schools is larger. On the other hand, places with hospitals serve a mean of 28.93 other places at a mean distance of 52.29 km. Thus, diversified schools serve smaller areas than does the top level of health care.

The political dominance of educational trips is not as marked as it is for health care. Capital status is not significant in explaining distance travelled for any of the school levels. It is possible that this is because medical care is more of a necessity when compared with education. Some people have to go to hospitals from any village, even if it means a long trip to the departamento capital. On the other hand, if schooling is not available locally, poor families will do without it. Thus, the missing values in the school destination data, but not in the health data, reflect the greater urgency of medical care. However, to the extent that can be discerned from the available information, trips for schooling are not as uniformly to political capitals as they are for health care, nor do political capitals have a longer "reach" into the countryside, again in contrast with what was found in the health care system.

The data problems with respect to the school system impinge most heavily on estimates of service populations, since there are doubts about the accuracy of the allocation of origins to destinations, the numbers of students, and the school age population–in other words, virtually all of the important information is of doubtful reliability. On the basis of what is available we can say that most of the students who attend school do so locally, in their places of origin. The proportion of outside students increases as one goes up the hierarchy, from a mean of 14.9 percent for primary schools, to 44.2 percent for diversified. The number of students served per place rises with schooling level, as one might expect. However, it has been impossible to get any reliable measure as to the proportion of the school-age population which is actually attending school.

By the standards of developed countries, literacy rates are extremely low in the study area, with a mean of 23 percent. Even so, there is considerable variation in literacy by place. The most important influence appear to be socioeconomic, particularly the proportion of ladinos in the place population. Higher-level urban centers, whether measured by central place level or political status, also contribute to higher literacy rates. The usual subregional variation between more and less developed parts of the region are also evident, with the major exception that the southeast (consisting of the heavily indiano areas of Sololá and southern El Quiché) has unusually low literacy. The educational variables seem to have the least influence, although, again, their inaccuracy makes firm conclusions unobtainable.

VII. SUMMARY AND CONCLUSIONS

7.1. The Quetzaltenango Central Place System

7.1.1. Methods

The essential principle used in identifying the central place structure was that the rarity of facilities supplying particular central goods is directly related to those goods' central place levels. This principle was employed by using cluster analysis to sort the places in the study region into a hierarchical set of classes. Those places which supplied only the most nearly ubiquitous goods were assigned to lower levels of the central place hierarchy. This hierarchy of places simultaneously defined the hierarchy of goods, since higher-level goods are only offered at higher-level places. A discriminant function was estimated which used the hierarchy of goods to predict the hierarchy of places. Misclassified places were detected by this function, and marginal adjustments were made to the "rough cut" produced by the cluster analysis.

After the structure was defined, market areas were approximated by drawing perpendicular bisecting lines between neighboring places of each central place level. Lower-level places were assigned to neighboring centers so as to minimize distances. Such places could be tributary to as many as three higher-level places if they were roughly equidistant, taking into account the road network where possible.

7.1.2. Characteristics

7.1.2.1. Places and goods

At the top of the hierarchy is the single level 1 place, Quetzaltenango. Just below are the eight level 2 places. The high-level places include all of the departamento capitals, plus three municipio capitals. Two of these three are close enough to a departamento capital to be considered a "twin city" for the purpose of supplying level 2 central goods. The remaining municipio capital in this group, Tejutla, is by far the weakest in that it supplies the smallest fraction of the total level 2 goods bundle. The strictly level 2 places are arranged in a rough ring around Quetzaltenango. This arrangement puts certain parts of the study region, particularly the far north, at a long distance from a source of level 2 goods.

The goods bundles comprising levels 1 and 2 encompass most business services. Many would be supplied by fairly low-level places in developed countries. Also in this category are the amusements and consumer goods of a commercially-oriented society, reflecting the lack of demand for such goods in the traditional (and economically impoverished) culture of the rural areas.

The middle tier of the hierarchy consists of the level 3 and 4 places. These are mostly the municipio capitals. As such, they are scattered across the entire study region. They supply basic goods, such as footwear, clothing, and food. An important distinction between the goods found in these levels and those higher up is that many of the mid-level goods are sold in market place booths, rather than in permanent commercial stores. The commercial establishments found at this level are the cantinas, general stores, and small restaurants.

At the lowest level of central places *per se* are the level 5 places. They are the most numerous and smallest of the central places. Level 5 central goods are concerned with the barest necessities: small grocery stores and mills which grind the families' corn supplies into meal. Below even these are the level 6 and 7 places. These cannot be reliably classified as central places at all because they are not the supply point for any significant amounts of central goods. Level 6 places do not supply even the level 5 bundle, but they do have an establishment or two, most likely a general store. The level 7 places have no commercial services at all.

7.1.2.2. Markets

The level 1 market area is, of course, the entire study region. As such, it includes the entire population. There is no basis of comparison between it and other markets of the same level. The level 2 markets vary in area between 831 and 8,291 km^2, and in population from 116,226 to 452,992 persons. These ranges are somewhat misleading, however, because it is likely that the outlying places of the large peripheral market areas receive few if any level 2 goods from the level 2 place in whose markets they putatively lie. It was estimated in Chapter IV that 533,176 people, or about 35 percent of the region's population, may be beyond the reach of higher-level central goods.

The middle-level markets (3 and 4) average about 5 ™ competing markets each, which is in the right neighborhood for a central place system based on the market principle but modified by the other principles. The market areas are much smaller than for level 2 markets, averaging 23,434 persons and 261 km^2 for level 3 and 9,548 persons and 106 km^2 for level 4. Peripheral middle-level markets also tend to increase in area and decrease in density when compared with similar markets in the core subregions.

Market areas were not estimated for the level 5 places, because they are so numerous and because in the more densely settled parts of the study region there are no lower-level places to include in these market areas. The places themselves have an average population of 929 persons, although the extremes vary from almost eight times this mean down to less than 50 persons. The level 6 and 7 places each have mean populations of around 600 persons, but again with very wide ranges.

7.1.3. Subregional Variation

The study region is not a homogeneous unit. Distinct subregions could be identified on the basis of the central place structure and demographic characteristics. The most general division is between the "peripheral" areas and the "core." The core is more densely settled and contains a well-articulated central place hierarchy, with all of the levels present. The core itself consists of two somewhat different subregions, the "core" proper, and the southeast. The southeast (Sololá and part of El Quiché) is densely settled but has a higher indiano population and considerably lower literacy. The core proper is centered on Departamento Quetzaltenango but spills across the borders to the east and the west, as far as the level 2 places of Totonicapán and San Marcos.

The periphery is the rest of the study region, to the east, north, and west. While all of it is less well settled and supplied than the core subregions, there are two areas which have special characteristics, the far north and the northwest. The far north, consisting of the upper tiers of municipios in Departamento

Huehuetenango, has a simplified central place structure. The two levels (3 and 4) of the middle ranks essentially collapse into a single level 3. It appears that the diffuse population and mountainous terrain prevent the development of as articulated a central place hierarchy as is found elsewhere. The other special subregion is the northwest. This subregion is in the corner of Departamento San Marcos which is on the Mexican border. It also includes a bit of the neighboring municipios in Huehuetenango. The unusual characteristic of this subregion is that it has a much higher proportion of level 6 and 7 places than any other part of the study region. It was consistently found to lag behind in access to services, both private and public. The other peripheral subregions are the east central, the north central, and the San Marcos belt. They do not have such distinct characteristics as the subregions already described. They are all less developed than the core and generally suffer in comparison with the core on most measures of services.

7.2. The Distribution of Public Services in Western Guatemala

7.2.1. General Characteristics

The most striking characteristic of the health and educational systems in the study region is their extreme scarcity. Except (perhaps) for primary schools, the number and size of existing facilities is too small for any gain in efficiency from locational changes to have much of an impact. That having been said, it is still true that the problems of inadequate health care and schooling are exacerbated by locational inefficiencies. Facility location and user travel are overly influenced by the political hierarchy of departamento and municipio capitals. More careful attention to the central place structure of the region would reduce travel time and increase accessibility. The core subregions receive the lion's shares of the few facilities which exist. This shuts out the periphery–the poor, rural, indiano populations who need health care as much and education even more than the comparatively well-off ladinos.

7.2.2. Health Facilities

The health care facilities in Guatemala are organized into a hierarchy of posts, centers, and hospitals. These could be easily applied to the existing hierarchy of central places, with the hospitals occupying the upper levels, the health centers in the middle levels, and the health posts at the lower levels. Depending on the amount of resources available, this hierarchy could be adjusted, preferably providing more access at the bottom than concentrating it at the top. To an extent, the existing distribution of facilities follows this pattern. Hospitals are certainly rare outside of level 2 places. Slightly more than half of the level 3 places have health centers. However, the coverage is too spotty, and too oriented to the core areas and political capitals. The other half of the middle-level central places should receive health centers, and health posts need to be extended deeper down the hierarchy.

While the existence of health centers and hospitals, *given central place level,* does not vary significantly by subregion, the peripheral subregions tend to have lower quality facilities because of their lack of higher-level places. If the destination data is to be believed, many people travel to their municipio or even departamento capital for health care, in preference to their level 3 central place. Since the construction of the level 3 market areas ensures that the central place is the closest possible, this means that many people are travelling further (in some cases much further) than they should. The reasons for this difference are not clear. They may be institutional (e.g., requiring villagers to go to their own capital) or it may be that political capitals have qualitatively better facilities. Whatever the reason, the evidence implies that a change in travel patterns would increase access and efficiency.

7.2.3. Schools

The distribution of primary schools is probably the best of all the public services examined in this study. Almost four-fifths of all places have at least one primary school. Unfortunately, not much more is known than that. Attempts at calculating the proportion of the school-age population which is actually attending school were defeated by the unreliability of the data. It also appears that most of the private schools in the study region are oriented towards the more urbanized ladino population, since they are concentrated in the upper-level central places.

Less can be said about the post-primary schools. They are certainly much scarcer. Places with any basic school are over twenty times scarcer than places with primary schools. Diversified schools are six times scarcer than that. No place lower than level 4 has a post-primary school of any kind. Although the private basic schools substantially increase the number of places with such schools, this cannot be claimed for the diversified schools, and in any case, the numbers of places are still quite small. The small numbers of post-primary schools means that most places are a long distance away from one. This is reflected in the poor response to the school destination questions of the survey: the children of most places in the study region simply do not attend any post-primary school. Even their attendance of primary school is doubtful.

This study has found a weak positive relationship between access to primary schools and literacy rates. Central place level and the proportion of ladinos in the place population are much stronger predictors of literacy than the ratio of primary students to the school age population. The effects of political capital status and subregion are of roughly the same importance as the school variables. To be sure, many of these variables are highly correlated, and it is difficult to separate the individual effects. However, the tentative conclusion is that the school system in the study region follows the social and political factors in importance.

7.3. Topics for Further Investigation

There are several directions that this study could be expanded, in "breadth" and "depth." The expansion of "breadth" involve widening the scope of the study to examine other regions than the Quetzaltenango central place region. Studies of increasing depth would examine additional public services or the same service in more depth. In addition, there are certain special aspects of the Guatemalan economics system, as it pertains to the residents of the central highlands, which bear further investigation.

7.3.1. Extraregional Comparisons

The general conclusions about the study region system are that it has a well developed central place system, but that the provision of public services is insufficient in scale and overcentralized in its geographical distribution. It would be interesting to examine whether this pattern is followed in other parts of Guatemala: in the east, in the Pacific coastal plain, and in the Petén to the north. Each of these regions has certain differences which may make for variation in central place structure or government interest. The Pacific coast is dominated by plantation agriculture for foreign export. One would expect that this concentration on external markets would change the central place structure. Eastern Guatemala has a higher proportion of ladinos than the highlands around Quetzaltenango. Ladinos dominate the government and commerce of Guatemala. This suggests that the provision of public services may be more abundant and perhaps more efficient in the east. The Petén is a near-wilderness of rain forests (although subject to severe deforestation in recent years). It was the object of a development effort, directed by the national government. The central place structure of such an area should be quite different from the core of Quetzaltenango, although perhaps similar to the the Far North subregion. The effect of the government development effort on the school and health facilities would also be interesting to examine.

Going further afield, comparisons of the current study region to central place systems in other developing countries might also be of interest. Are the patterns of central place development similar, or are these mainly the result of local conditions? How have other governments dealt with the problems of poverty, illiteracy, and ill health?

7.3.2. Other Facilities

The survey which generated the main dataset for this study also contained questions about police agencies, co-operatives, recreational facilities, and agricultural development offices of various kinds. The distribution of these could be investigated in the same manner as the health and school facilities were in the current study. Police agencies might be particularly interesting, since the study region was the site of guerilla activity during the 1970s. Security agencies, including the various types of police, would be deployed in an attempt to control the population as well as to protect it. Thus, we would see the adaptation of a system of central places to the attainment of quasi-military objectives.

7.3.3. Effects of Migratory Work Patterns

Rather than being true subsistence farming, the agriculture in the western highlands of Guatemala is only one part of most families' survival strategy. More than 80 percent of the families in the country own less than 4 hectares (10 acres) of land (World Bank 1978). The population density on arable land is particularly high in the study region. As a result, most families are forced to supplement their produce with cash labor. This generally means seasonal migration to the plantations of the coastal plain. What effect does this have on the provision of health and (particularly) educational services? If the children are migrating with the family, where (if anywhere) do they attend school? The survey dataset did not include the departamentos on the Pacific coast. It would be interesting to examine how such significant seasonal mobility affects the (necessarily static) system of central places.

7.4. The Limits of Central Place Theory

Given the time lapse between the collection and analysis of the survey data, this study should best be seen as an exploration of the techniques and problems of studying the provision of public goods in the context of central place theory. New techniques for identifying and exploring central place systems have been developed, and some progress has been made in the understanding the place of public finance in a regional system. However, the difficulties encountered also lead one to question the usefulness of the central place approach.

7.4.1. Data Requirements

The data used in this study were based on one of the most comprehensive surveys attempted in regional science. Yet, the data were still found to be inadequate for many purposes. This inadequacy stems from two sources: inaccuracy and incompleteness. The previous chapters recounted many circumstances in which the data were judged to be unreliable, missing, or inconsistent. In other words, the survey did attempt to gather information which would have been useful in this study, but failed to produce this information. The survey was also incomplete in that questions which might have been useful were not even asked. These problems are certainly not unique to this study or even to central place studies. It has long been recognized that regional and locational analysis requires a great deal of detailed information which is difficult to acquire. Consequently, the extent to which we can analyze the efficiency of local public goods will always be limited.

7.4.2. Equilibrium Approach

Central place theory is essentially about static equilibrium. It describes the conditions which will result in a stable system of cities and market areas. The theory is weak on the dynamical or even comparative static aspects of regional development. One can consider the forces which bring about the central place hierarchy and infer the kind of changes to that hierarchy from an alteration of those forces (as, for example, by the construction of a hospital or secondary school).

However, the mechanism which brings about these changes and the path which they take are not well specified or understood. Students of central place theory have often recognized that any particular study of any region will necessarily catch the central place structure in a transitional state, since the underlying forces are always changing (however slowly). Unfortunately, though, there is no agreed-upon description of what such a transitional state should look like, other than that it will not look like the classic equilibrium structures. Before central place theory can be usefully applied to the problem of where to place public facilities, the ways in which central place systems adapt to such changes must be more fully understood.

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IX. APPENDIX A

SURVEY QUESTIONS

This is a listing of all the questions from the Guatemalan government/USAID survey which were used in this study. The "variable" column shows the variable names in the SPSS dataset, which correspond to the question numbers in the survey. Each variable is of the form "Pqqqsss," where "P" stands for "pregunta" (Spanish for "question"), "qqq" is the main question number, and "sss" is the subquestion number, if any. Thus, the area of the municipio (P006000) was question number 6, which had no subquestions. The total 1979 place population (P009001) is the first subquestion of main question number 9. All of the variable labels in the original SPSS dataset were in Spanish. The translations here were made by the author.

Variable	Variable Label
P006000	Area of municipio (square km)
P009001	Total 1979 population of place
P009002	Total 1979 male population of place
P009003	Total 1979 female population of place
P010001	Ladino population (1979)
P010002	Indian population (1979)
P011001	Literate population (1979)
P011002	Illiterate population (1979)
P012000	Economically active population (1979)
P013002	Population age < 7 (1979)
P013002	Population age 7 - 9 (1979)
P013004	Population age 13 - 17 (1979)
P013005	Population age ≥ 18 (1979)
P014000	Number of births
P015000	Number of deaths
P016000	Number of dwellings
P017000	Number of families
P020001	Most important nearby place accessible by road
P020002	2nd most important nearby place accessible by road
P020003	3rd most important nearby place accessible by road
P094001	Number of marketplace grocers (tiendas)
P094002	Number of marketplace meat sellers
P094003	Number of marketplace pig sellers (?)

Variable	Variable Label
P094008	Number of marketpl. sellers of various articles
P095004	Total plaza grain vendors
P095007	Total plaza fruit & veg. (verduras) vendors
P095010	Total plaza plastic vendors
P095019	Total plaza maize-cake (panela) vendors
P095022	Total plaza ceramic vendors
P095025	Total plaza rope (?-jarcia) vendors
P095028	Total plaza dry goods (?-mercería)
P095031	Total plaza souvenirs (tipicas) vendors
P095034	Total plaza other vendors
P104001	Number of grocery stores
P104002	Number of general stores (pulpería)
P104003	Number of cantinas
P104004	Number of butcher shops
P104005	Number of corn mills (molino nixtamal)
P104006	Number of (low-class) restaurants (comedores)
P104007	Number of bakeries
P104008	Number of misc. food stores (almalenes misc.)
P104009	Number of tailor shops
P104010	Number of clothing shops
P104011	Number of carpentry workshops
P104012	Number of shoe workshops
P104013	Number of shoe stores
P104014	Number of boarding houses
P104015	Number of dry goods stores (mercería)
P104016	Number of cafeterias
P104017	Number of bars & restaurants
P104018	Number of hog butchers (marranerías)
P104019	Number of barber shops
P104020	Number of gasoline stations
P104021	Number of billiard shops
P104022	Number of construction materials stores
P104023	Number of seed stores
P104024	Number of electrical equipment stores
P104025	Number of hardware stores
P104026	Number of agrichemical stores (agroquimicos)
P104027	Number of fertilizer stores
P104028	Number of fireworks shops (coheterías)
P104029	Number of stationary & bookstores
P104030	Number of sawmills
P104031	Number of undertakers
P104032	Number of blacksmiths
P104033	Number of chandlers
P104034	Number of supermarkets (abarroterías)
P104035	Number of printing & editing
P104036	Number of palm article shops

Variable	Variable Label
P104037	Number of grain mills
P104038	Number of saddleries
P104039	Number of pita article shops
P104040	Number of dairies
P104041	Number of machine shops
P104042	Number of veterinarians
P104043	Number of hat shops
P104044	Number of non-alcoholic beverage shops
P104045	Number of new & used auto dealerships
P104046	Number of paints stores
P104047	Number of night clubs
P104048	Number of watchmaker's shops
P104049	Number of hotels
P104050	Number of propane sellers
P104051	Number of photography stores
P104052	Number of electricians
P104053	Number of alcoholic beverage stores
P104054	Number of coffee shops (beneficios de cafe)
P104055	Number of banks (or agencies)
P104056	Number of musical groups
P104057	Number of radio & TV stores
P104058	Number of ice cream stores
P104059	Number of photocopy stores
P104060	Number of locksmiths
P104061	Number of furniture stores
P104062	Number of chicken/egg stores
P104063	Number of fish/shellfish stores
P104064	Number of lumberyards
P105001	Nearest corn market (place to buy corn)
P105003	Nearest bean market (to buy)
P105005	Nearest rice market (to buy)
P105007	Nearest coffee market (to buy)
P105009	Nearest produce market (to buy)
P105011	Nearest egg market (to buy)
P105013	Nearest meat market (to buy)
P105015	Nearest poultry market (to buy)
P105017	Location of vegetable oil market
P105019	Location of clothing market
P105021	Location of dry gds (hats?) mkt (mercería)
P106000	Is there a slaughterhouse? (yes/no)
P118001	Primary meat source
P118003	Secondary meat source
P118005	Tertiary meat source
P128001	Number of post offices
P128002	Number of telegraph offices
P129001	DIGESA office (ag. services, extension, etc.)

Variable	Variable Label
P129002	ICTA office (ag. research)
P129003	INDECA office (marketing of crops)
P129004	INAFOR office (forestry)
P129005	INACOP office (co-operatives?)
P129006	Internal Revenue office
P129007	GUATEL office (communications)
P129008	INDE office (electricity)
P129009	Statistics office
P129010	Educational supervision office
P129011	Public Ministry office
P129012	Electoral register office
P129013	Community development office
P129014	INTECAP office (human resources?)
P129015	INTA office
P129017	other office
P130001	Most important outside gov't location
P130003	2nd most important gov't location
P130005	3rd most important gov't location
P132007	Number of public primary schools
P132008	Number of private primary schools
P132013	Number of public basic schools
P132014	Number of private basic schools
P132019	Number of public vocational schools (diversified)
P132020	Number of private vocational schools
P135001	1st destination of primary students
P135004	2nd destination of primary students
P135007	3rd destination of primary students
P135010	1st destination of basic students
P135013	2nd destination of basic students
P135016	3rd destination of basic students
P135019	1st destination of vocational students
P135022	2nd destination of vocational students
P135025	3rd destination of vocational students
P135028	1st destination of university students
P135031	2nd destination of university students
P135034	3rd destination of university students
P137001	Number of hospitals
P137011	Health center "A" establishments
P137016	Health center "B" establishments
P137021	Health center "C" establishments
P137026	Health place (station?) establishments
P137031	Private hospital establishments
P137036	Other health establishments
P140001	Number of medical clinics
P140002	Number of dental clinics
P140003	Is there a clinical laboratory? (yes/no)

Variable	Variable Label
P140004	Number of opticians
P140005	Number of pharmacies
P142001	1st location of outside medical assistance
P142003	2nd location of outside medical assistance
P142005	3rd location of outside medical assistance
P144002	Number of justices of the peace
P144004	Number of primary court of claims judges
P144006	Number of family judges
P144008	Number of traffic judges
P144009	Is there a national police station? (yes/no)
P144011	Are there ambulatory military police?
P144013	Are there municipal police?
P144014	Number of municipal police
P144015	Are there revenue agents?
P144019	Are there military commissioners?
P144027	Are there auxiliary police? (alcaldes)
P144029	Are there constables (bailiff?)?
P144031	Are there other security/justice officials?
P145000	Number of lawyers and notaries
P149002	Location of most important financial instit.
P149006	Location of 2nd most important financ. inst.
P153000	Are there agricult. storage installations?
P158001	Location of saving & credit cooperative
P158003	Location of agricultural cooperative
P158005	Location of consumer cooperative
P158007	Location of housing cooperative
P158009	Location of commercial cooperative
P158011	Location of transport cooperative
P158013	Location of artisans' cooperative
P158015	Location of other cooperative
P161001	Number of parks
P163001	Number of stadiums (playing fields?)
P163003	Number of gymnasiums
P163009	Number of open soccer fields
P163011	Number of open basketball courts
P163013	Number of other sports installations
P165001	Number of private movie theaters
P165004	Number of public (municipal) movie theaters
P165007	Number of other movie theaters
P166000	Is there a (legitimate) theater locally?
P167001	Number of live theaters
P168000	Is there a library or a lecture hall?
P168000	Is there a library or a lecture hall?
P170000	Are periodicals or weeklies published?
P171001	Number of daily periodicals
P171003	Number or weekly periodicals

Variable	Variable Label
P171005	Number of monthly periodicals
P171007	Number of wall periodicals (murales)
P172000	Are there museums or exhibit halls?
P174001	Is there a common (town?) hall?
P176001	Number of public nature spots
P176002	Number of private nature spots
P176004	Number of public religious centers
P176005	Number of private religious centers
P176007	Number of public recreation centers
P176008	Number of private recreation centers
P176010	Number of public archeological centers
P176011	Number of private archeological centers
P176013	Number of public swimming pools & beaches
P176014	Number of private swimming pools & beaches
P176016	Number of other public facilities
P176017	Number of other private facilities

X. APPENDIX B

CLUSTER ANALYSIS RESULTS

Table B.1. Quetzaltenango Subsystem

Merge No.	Clusters Merged		Diameter	Within Dists	Total Dists	Ratio
1	701003	711003	0.00000	1	315	0.00317
2	701004	708009	0.00000	2	315	0.00635
3	701009	706045	0.00000	3	315	0.00952
4	701013	717005	0.00000	4	315	0.01270
5	701016	906006	0.00000	5	315	0.01587
6	701021	702005	0.00000	6	315	0.01905
7	CLST6	801046	0.00000	8	315	0.02540
8	703002	719013	0.00000	9	315	0.02857
9	703003	705026	0.00000	10	315	0.03175
10	704004	717004	0.00000	11	315	0.03492
11	CLST9	707002	0.00000	13	315	0.04127
12	705033	707006	0.00000	14	315	0.04444
13	CLST3	713017	0.00000	16	315	0.05079
14	CLST11	714004	0.00000	19	315	0.06032
15	CLST12	806062	0.00000	21	315	0.06667
16	CLST2	716001	0.00000	23	315	0.07302
17	CLST1	712009	0.00000	25	315	0.07937
18	CLST17	805186	0.00000	28	315	0.08889
19	712013	902004	0.00000	29	315	0.09206
20	712018	719012	0.00000	30	315	0.09524
21	713004	912030	0.00000	31	315	0.09841
22	CLST13	806010	0.00000	34	315	0.10794
23	714002	808007	0.00000	35	315	0.11111
24	CLST14	801052	0.00000	39	315	0.12381
25	714008	802002	0.00000	40	315	0.12698
26	CLST16	915002	0.00000	43	315	0.13651
27	CLST20	805113	0.00000	45	315	0.14286
28	CLST8	801013	0.00000	47	315	0.14921
29	CLST28	804005	0.00000	50	315	0.15873
30	801017	904016	0.00000	51	315	0.16190
31	801020	801047	0.00000	52	315	0.16508
32	801044	903004	0.00000	53	315	0.16825
33	CLST7	804007	0.00000	56	315	0.17778
34	801048	906005	0.00000	57	315	0.18095
35	CLST24	802016	0.00000	62	315	0.19683

Table B.1 continued

Merge No.	Clusters Merged		Diameter	Within Dists	Total Dists	Ratio
36	801067	805274	0.00000	63	315	0.20000
37	CLST25	1203007	0.00000	65	315	0.20635
38	CLST35	808026	0.00000	71	315	0.22540
39	802017	1202038	0.00000	72	315	0.22857
40	803013	909005	0.00000	73	315	0.23175
41	CLST29	806019	0.00000	77	315	0.24444
42	CLST33	805204	0.00000	81	315	0.25714
43	805016	806004	0.00000	82	315	0.26032
44	805111	805185	0.00000	83	315	0.26349
45	CLST27	807023	0.00000	86	315	0.27302
46	CLST18	905009	0.00000	90	315	0.28571
47	CLST42	806040	0.00000	95	315	0.30159
48	CLST22	806047	0.00000	99	315	0.31429
49	CLST41	808037	0.00000	104	315	0.33016
50	CLST47	806052	0.00000	110	315	0.34921
51	CLST48	902005	0.00000	115	315	0.36508
52	CLST50	901013	0.00000	122	315	0.38730
53	CLST15	903008	0.00000	125	315	0.39683
54	CLST23	905014	0.00000	127	315	0.40317
55	CLST38	906007	0.00000	134	315	0.42540
56	CLST49	902002	0.00000	140	315	0.44444
57	CLST52	904002	0.00000	148	315	0.46984
58	CLST56	913004	0.00000	155	315	0.49206
59	CLST51	905008	0.00000	161	315	0.51111
60	CLST32	905007	0.00000	163	315	0.51746
61	CLST53	907003	0.00000	167	315	0.53016
62	CLST57	904014	0.00000	176	315	0.55873
63	CLST62	912024	0.00000	186	315	0.59048
64	CLST60	907004	0.00000	189	315	0.60000
65	CLST46	913005	0.00000	194	315	0.61587
66	CLST55	908002	0.00000	202	315	0.64127
67	CLST61	923003	0.00000	207	315	0.65714
68	CLST64	911003	0.00000	211	315	0.66984
69	CLST66	910002	0.00000	220	315	0.69841
70	CLST69	914010	0.00000	230	315	0.73016
71	CLST68	911006	0.00000	235	315	0.74603
72	CLST71	1202016	0.00000	241	315	0.76508
73	CLST63	916012	0.00000	252	315	0.80000
74	CLST21	912032	0.00000	254	315	0.80635
75	CLST65	924010	0.00000	260	315	0.82540

Table B.1 continued

Merge No.	Clusters Merged		Diameter	Within Dists	Total Dists	Ratio
76	CLST70	915006	0.00000	271	315	0.86032
77	CLST76	916020	0.00000	283	315	0.89841
78	CLST73	916021	0.00000	295	315	0.93651
79	CLST78	924012	0.00000	308	315	0.97778
80	CLST72	1203010	0.00000	315	315	1.00000
81	CLST79	CLST74	0.03670	357	720	0.49583
82	CLST67	CLST5	0.03670	369	720	0.51250
83	CLST59	CLST58	0.03670	425	720	0.59028
84	CLST45	CLST44	0.03670	433	720	0.60139
85	CLST40	CLST4	0.03670	437	720	0.60695
86	CLST39	705021	0.03670	439	720	0.60972
87	CLST36	CLST26	0.03670	447	720	0.62083
88	701011	901005	0.03670	448	720	0.62222
89	704011	801011	0.03670	449	720	0.62361
90	713007	CLST19	0.03670	451	720	0.62639
91	801018	905005	0.03670	452	720	0.62778
92	801043	802015	0.03670	453	720	0.62917
93	CLST31	CLST43	0.03670	457	720	0.63472
94	802012	CLST37	0.03670	460	720	0.63889
95	804003	903003	0.03670	461	720	0.64028
96	805106	805182	0.03670	462	720	0.64167
97	906017	915005	0.03670	463	720	0.64306
98	909003	911007	0.03670	464	720	0.64444
99	CLST54	CLST75	0.05845	485	861	0.56330
100	706047	904004	0.05845	486	861	0.56446
101	805201	914008	0.05845	487	861	0.56562
102	904027	908001	0.05845	488	861	0.56678
103	CLST95	705044	0.06902	490	1042	0.47025
104	CLST93	CLST77	0.06902	542	1042	0.52015
105	CLST90	CLST84	0.06902	560	1042	0.53743
106	903005	CLST34	0.06902	562	1042	0.53935
107	909018	CLST97	0.06902	564	1042	0.54127
108	CLST30	805093	0.07341	566	1539	0.36777
109	CLST83	CLST80	0.07341	686	1539	0.44574
110	CLST89	909023	0.07391	688	1550	0.44387
111	CLST88	904030	0.07391	690	1550	0.44516
112	804004	911008	0.07391	691	1550	0.44581
113	CLST87	924005	0.09384	697	1704	0.40904
114	CLST104	CLST81	0.09384	986	1704	0.57864
115	CLST96	909024	0.09384	988	1704	0.57981

Table B.1 continued

Merge No.	Clusters Merged		Diameter	Within Dists	Total Dists	Ratio
116	708001	801079	0.09384	989	1704	0.58040
117	906011	911004	0.09384	990	1704	0.58099
118	CLST94	CLST82	0.11011	1022	2066	0.49468
119	CLST85	CLST86	0.11011	1034	2066	0.50048
120	918002	CLST110	0.11011	1037	2066	0.50194
121	806046	909027	0.11011	1038	2066	0.50242
122	808023	924003	0.12145	1039	2283	0.45510
123	CLST105	CLST113	0.12253	1102	2484	0.44364
124	CLST101	801069	0.12253	1104	2484	0.44444
125	CLST103	719004	0.12744	1107	2609	0.42430
126	CLST114	CLST99	0.13804	1447	2850	0.50772
127	CLST108	CLST106	0.13804	1456	2850	0.51088
128	801095	803014	0.13969	1457	2856	0.51015
129	701020	706008	0.14099	1458	2859	0.50997
130	CLST120	903007	0.14217	1462	2928	0.49932
131	712016	715001	0.14927	1463	3206	0.45633
132	904024	914009	0.15348	1464	3216	0.45522
133	CLST124	805198	0.16060	1467	3405	0.43084
134	CLST121	CLST117	0.16393	1471	3453	0.42601
135	CLST119	CLST111	0.16907	1492	3473	0.42960
136	CLST91	707007	0.17401	1494	3530	0.42323
137	CLST127	CLST107	0.19260	1512	4343	0.34815
138	CLST128	802010	0.19427	1514	4345	0.34845
139	CLST118	912006	0.19924	1526	4373	0.34896
140	CLST138	CLST116	0.20640	1532	4441	0.34497
141	CLST100	CLST115	0.20707	1538	4501	0.34170
142	801004	914007	0.20998	1539	4507	0.34147
143	710008	801040	0.21615	1540	4518	0.34086
144	CLST109	CLST126	0.21759	2552	4611	0.55346
145	CLST142	801009	0.22971	2554	4975	0.51337
146	901020	712001	0.23512	2555	5052	0.50574
147	CLST130	CLST134	0.24005	2575	5232	0.49216
148	901008	914002	0.25251	2576	5512	0.46734
149	CLST123	CLST131	0.25281	2608	5514	0.47298
150	CLST92	CLST125	0.25693	2616	5753	0.45472
151	CLST122	916007	0.25895	2618	5838	0.44844
152	CLST135	CLST102	0.27609	2638	6120	0.43105
153	801076	808006	0.29267	2639	6541	0.40346
154	CLST147	CLST112	0.29817	2657	6824	0.38936
155	CLST143	905003	0.30408	2659	6997	0.38002

Table B.1 continued

Merge No.	Clusters Merged		Diameter	Within Dists	Total Dists	Ratio
156	CLST154	CLST136	0.30659	2692	7040	0.38239
157	CLST152	CLST139	0.30719	2848	7065	0.40311
158	CLST149	CLST144	0.30767	4054	7097	0.57123
159	CLST133	CLST141	0.33034	4074	7601	0.53598
160	CLST146	801078	0.34453	4076	7805	0.52223
161	801016	806015	0.34511	4077	7845	0.51969
162	CLST129	CLST150	0.34587	4089	7850	0.52089
163	704010	717006	0.36140	4090	8211	0.49811
164	904013	914011	0.37239	4091	8510	0.48073
165	CLST159	CLST137	0.37400	4172	8579	0.48630
166	CLST132	901025	0.37623	4174	8612	0.48467
167	702001	702002	0.39914	4175	9051	0.46128
168	CLST98	701007	0.40374	4177	9152	0.45640
169	CLST10	CLST155	0.42422	4183	9620	0.43482
170	CLST145	910001	0.42545	4186	9664	0.43315
171	CLST162	906003	0.43447	4194	9926	0.42253
172	CLST158	705034	0.43912	4279	10022	0.42696
173	CLST140	904011	0.44900	4284	10276	0.41689
174	CLST148	902006	0.46442	4286	10440	0.41054
175	CLST156	CLST157	0.46794	4636	10498	0.44161
176	801055	CLST153	0.47931	4638	10748	0.43152
177	CLST170	CLST160	0.48124	4650	10827	0.42948
178	801056	803022	0.48232	4651	10853	0.42855
179	801038	805197	0.48711	4652	10911	0.42636
180	CLST174	705016	0.50425	4655	11195	0.41581
181	CLST175	CLST172	0.50919	8009	11260	0.71128
182	909037	923011	0.56226	8010	12239	0.65447
183	703001	805196	0.58666	8011	12707	0.63044
184	904007	908003	0.59285	8012	12908	0.62070
185	CLST181	903002	0.63502	8137	13862	0.58700
186	CLST171	CLST166	0.65135	8164	14185	0.57554
187	CLST167	CLST173	0.65634	8176	14260	0.57335
188	CLST169	CLST163	0.65977	8186	14299	0.57249
189	CLST178	803003	0.66809	8188	14435	0.56723
190	914003	924004	0.66958	8189	14457	0.56644
191	CLST187	CLST165	0.67597	8333	14607	0.57048
192	CLST182	923006	0.70255	8335	15086	0.55250
193	CLST185	CLST168	0.70338	8713	15095	0.57721
194	CLST190	717001	0.71482	8715	15316	0.56901
195	801054	710004	0.72877	8716	15514	0.56182

Table B.1 continued

Merge No.	Clusters Merged		Diameter	Within Dists	Total Dists	Ratio
196	CLST151	907002	0.72961	8719	15527	0.56154
197	709007	CLST176	0.74715	8722	15789	0.55241
198	CLST179	CLST177	0.76585	8736	16001	0.54597
199	711001	923001	0.78535	8737	16312	0.53562
200	709006	904008	0.79708	8738	16494	0.52977
201	CLST197	CLST180	0.84020	8754	17048	0.51349
202	CLST164	CLST191	0.84246	8806	17088	0.51533
203	CLST202	805251	0.91955	8834	17892	0.49374
204	803019	CLST161	0.92811	8836	17948	0.49231
205	CLST193	CLST186	0.94957	10384	18265	0.56852
206	CLST198	909017	0.96061	10393	18392	0.56508
207	905001	CLST194	1.01490	10396	19140	0.54316
208	CLST196	CLST205	1.06710	10960	19664	0.55736
209	801005	CLST188	1.07570	10967	19717	0.55622
210	CLST201	804002	1.13630	10975	20303	0.54056
211	CLST200	CLST183	1.14590	10979	20424	0.53755
212	CLST206	CLST203	1.18300	11269	20836	0.54084
213	CLST184	CLST195	1.19080	11273	20926	0.53871
214	CLST199	918001	1.20040	11275	21020	0.53639
215	CLST209	CLST207	1.20260	11307	21026	0.53776
216	CLST208	CLST192	1.27480	11742	21420	0.54818
217	CLST189	704003	1.27700	11745	21432	0.54801
218	CLST216	CLST212	1.45890	17517	22898	0.76500
219	CLST211	701008	1.48000	17521	23131	0.75747
220	CLST218	CLST210	1.67440	19204	24012	0.79977
221	CLST215	CLST213	1.68180	19252	24024	0.80137
222	806007	803021	1.71710	19253	24173	0.79647
223	CLST220	912001	1.76200	19449	24355	0.79856
224	CLST214	916001	1.90120	19452	24947	0.77973
225	CLST223	CLST217	2.14000	20240	25387	0.79726
226	CLST221	914012	2.24470	20256	25426	0.79667
227	CLST204	CLST219	2.26100	20271	25431	0.79710
228	CLST227	CLST225	2.37860	21879	25474	0.85888
229	CLST228	CLST226	2.66670	25432	26173	0.97169
230	804001	803004	2.90490	25433	26323	0.96619
231	CLST229	914006	3.10240	25659	26370	0.97304
232	CLST231	901019	3.34620	25886	26480	0.97757
233	913001	924001	3.54950	25887	27240	0.95033
234	CLST224	911001	3.55740	25891	27255	0.94995
235	CLST222	801003	3.58870	25893	27317	0.94787

Table B.1 continued

Merge No.	Clusters Merged		Diameter	Within Dists	Total Dists	Ratio
236	CLST232	704009	3.60770	26121	27414	0.95283
237	707001	806082	3.66020	26122	27516	0.94934
238	701002	801015	3.80650	26123	27913	0.93587
239	CLST237	CLST236	4.24290	26581	28455	0.93414
240	CLST235	CLST230	4.37000	26587	28528	0.93196
241	CLST234	805184	4.92780	26592	29537	0.90029
242	706001	904001	5.29200	26593	29809	0.89211
243	CLST240	CLST239	5.35450	27748	30034	0.92389
244	CLST243	CLST233	5.96780	28220	30621	0.92159
245	CLST244	712002	6.75290	28458	31087	0.91543
246	CLST245	916019	7.35090	28697	31584	0.90859
247	CLST246	CLST242	7.72510	29177	31618	0.92280
248	CLST238	915001	7.95580	29179	31629	0.92254
249	CLST248	CLST247	8.18740	29905	31646	0.94499
250	713001	714001	8.26720	29906	31648	0.94496
251	CLST249	907001	8.96760	30151	31918	0.94464
252	CLST241	914001	9.04400	30157	32068	0.94041
253	CLST252	CLST251	10.46900	31879	32397	0.98401
254	704001	902001	10.63100	31880	32411	0.98362
255	806001	718001	10.66000	31881	32415	0.98353
256	CLST253	801019	11.93200	32134	33130	0.96994
257	CLST254	803001	12.52800	32136	33625	0.95572
258	CLST256	CLST255	14.19700	32644	34183	0.95498
259	CLST258	CLST257	15.78100	33412	34435	0.97029
260	CLST259	705001	16.99100	33671	34695	0.97049
261	CLST260	909001	17.82800	33931	34715	0.97742
262	CLST261	CLST250	19.02800	34453	35475	0.97119
263	719001	906001	19.63400	34454	35495	0.97067
264	CLST262	701001	21.98200	34717	36276	0.95702
265	CLST264	808001	22.31700	34981	36285	0.96406
266	802001	805001	24.53300	34982	36564	0.95673
267	CLST263	CLST265	25.41100	35512	36571	0.97104
268	903001	CLST266	26.11600	35514	36577	0.97094
269	CLST268	CLST267	27.09100	36315	36583	0.99267
270	CLST269	1201001	28.96500	36585	36637	0.99858
271	801001	1401001	33.25900	36586	37391	0.97847
272	710001	CLST270	34.47900	36857	37397	0.98556
273	CLST272	CLST271	36.32800	37401	37412	0.99971
274	1301001	CLST273	40.24500	37675	37675	1.00000
275	901001	CLST274	85.92600	37950	37950	1.00000

Table B.2. San Marcos Subsystem

Merge No.	Clusters Merged		Cluster Diameter	Within Dists	Total Dists	Ratio
1	1201005	1207024	0.00000	1	598	0.00167
2	1201013	1201124	0.00000	2	598	0.00334
3	CLST2	1202037	0.00000	4	598	0.00669
4	CLST3	1203006	0.00000	7	598	0.01171
5	CLST4	1223008	0.00000	11	598	0.01839
6	1204019	1204039	0.00000	12	598	0.02007
7	1204038	1205027	0.00000	13	598	0.02174
8	CLST6	1229008	0.00000	15	598	0.02508
9	CLST7	1207027	0.00000	17	598	0.02843
10	1205064	1206020	0.00000	18	598	0.03010
11	1206006	1206019	0.00000	19	598	0.03177
12	1206008	1207057	0.00000	20	598	0.03344
13	1206016	1206018	0.00000	21	598	0.03512
14	CLST13	1206038	0.00000	23	598	0.03846
15	CLST11	1207059	0.00000	25	598	0.04181
16	CLST10	1207020	0.00000	27	598	0.04515
17	1206031	1206043	0.00000	28	598	0.04682
18	CLST14	1206045	0.00000	31	598	0.05184
19	CLST17	1206052	0.00000	33	598	0.05518
20	CLST18	1206047	0.00000	37	598	0.06187
21	CLST20	1207046	0.00000	42	598	0.07023
22	CLST19	1207088	0.00000	45	598	0.07525
23	CLST16	1207022	0.00000	48	598	0.08027
24	CLST23	1207062	0.00000	52	598	0.08696
25	CLST1	1209055	0.00000	54	598	0.09030
26	CLST9	1207092	0.00000	57	598	0.09532
27	1207028	1321011	0.00000	58	598	0.09699
28	CLST21	1207068	0.00000	64	598	0.10702
29	CLST15	1207067	0.00000	67	598	0.11204
30	CLST24	1227007	0.00000	72	598	0.12040
31	CLST29	1207121	0.00000	76	598	0.12709
32	CLST28	1207082	0.00000	83	598	0.13880
33	CLST32	1207083	0.00000	91	598	0.15217
34	CLST33	1207086	0.00000	100	598	0.16722
35	CLST34	1207089	0.00000	110	598	0.18395
36	CLST22	1209118	0.00000	114	598	0.19064
37	CLST35	1207091	0.00000	125	598	0.20903
38	CLST37	1208006	0.00000	137	598	0.22910
39	CLST26	1226023	0.00000	141	598	0.23579

Table B.2 continued

Merge No.	Clusters Merged		Cluster Diameter	Within Dists	Total Dists	Ratio
40	CLST38	1208007	0.00000	154	598	0.25753
41	CLST40	1208023	0.00000	168	598	0.28094
42	CLST41	1209116	0.00000	183	598	0.30602
43	1209002	1210045	0.00000	184	598	0.30769
44	1209059	1210002	0.00000	185	598	0.30936
45	CLST42	1210024	0.00000	201	598	0.33612
46	CLST36	1223037	0.00000	206	598	0.34448
47	1210003	1210008	0.00000	207	598	0.34615
48	CLST47	1223029	0.00000	209	598	0.34950
49	CLST45	1210049	0.00000	226	598	0.37793
50	CLST43	1228009	0.00000	228	598	0.38127
51	CLST49	1223031	0.00000	246	598	0.41137
52	CLST51	1223032	0.00000	265	598	0.44314
53	CLST52	1223033	0.00000	285	598	0.47659
54	CLST53	1223045	0.00000	306	598	0.51171
55	CLST46	1224002	0.00000	312	598	0.52174
56	CLST54	1223049	0.00000	334	598	0.55853
57	CLST56	1224032	0.00000	357	598	0.59699
58	CLST55	1226003	0.00000	364	598	0.60870
59	CLST57	1224034	0.00000	388	598	0.64883
60	CLST59	1224038	0.00000	413	598	0.69064
61	CLST60	1224043	0.00000	439	598	0.73411
62	CLST61	1226029	0.00000	466	598	0.77926
63	CLST58	1321002	0.00000	474	598	0.79264
64	CLST62	1304085	0.00000	502	598	0.83946
65	CLST30	1228004	0.00000	508	598	0.84950
66	CLST64	1321004	0.00000	537	598	0.89799
67	CLST66	1321015	0.00000	567	598	0.94816
68	CLST67	1321016	0.00000	598	598	1.00000
69	CLST65	CLST31	0.07998	633	995	0.63618
70	CLST50	1206041	0.07998	636	995	0.63920
71	1204016	CLST12	0.07998	638	995	0.64121
72	1228008	CLST8	0.07998	641	995	0.64422
73	CLST63	CLST68	0.07998	929	995	0.93367
74	CLST48	CLST5	0.15209	944	1108	0.85199
75	CLST25	CLST39	0.15209	959	1108	0.86552
76	CLST44	CLST73	0.17184	1041	1425	0.73053
77	CLST69	1204031	0.20010	1053	1450	0.72621
78	1227005	1229014	0.20010	1054	1450	0.72690
79	1211027	CLST72	0.22072	1058	1473	0.71826

Table B.2 continued

Merge No.	Clusters Merged		Cluster Diameter	Within Dists	Total Dists	Ratio
80	CLST71	1207072	0.22072	1061	1473	0.72030
81	CLST74	1208016	0.23828	1069	1479	0.72279
82	1201038	1223034	0.28408	1070	1723	0.62101
83	CLST77	CLST76	0.28699	1629	1726	0.94380
84	1206037	1207031	0.30201	1630	1729	0.94274
85	CLST75	1226024	0.30418	1638	1849	0.88588
86	1204014	1210027	0.30418	1639	1849	0.88643
87	1201024	1227008	0.30418	1640	1849	0.88697
88	CLST70	1204002	0.31452	1644	1889	0.87030
89	1204034	CLST27	0.32670	1646	1948	0.84497
90	1207087	1209075	0.33091	1647	1951	0.84418
91	1204042	1208024	0.36876	1648	2062	0.79922
92	CLST79	CLST88	0.38742	1673	2090	0.80048
93	CLST92	CLST78	0.45036	1693	2296	0.73737
94	CLST82	CLST90	0.48267	1697	2832	0.59922
95	1203011	1211018	0.49177	1698	3049	0.55690
96	CLST80	CLST83	0.50339	1922	3086	0.62281
97	CLST91	1229004	0.55606	1924	3459	0.55623
98	1227004	1201003	0.55794	1925	3500	0.55000
99	CLST94	CLST93	0.56706	1973	3669	0.53775
100	1204036	1207010	0.58318	1974	3748	0.52668
101	CLST81	CLST85	0.58339	2055	3785	0.54293
102	CLST86	CLST95	0.64989	2059	4377	0.47041
103	1204035	1204050	0.68075	2060	4624	0.44550
104	CLST89	CLST96	0.69430	2240	4700	0.47660
105	CLST97	1228010	0.72344	2243	4746	0.47261
106	CLST102	1211010	0.77455	2247	4898	0.45876
107	1202026	CLST87	0.78071	2249	4905	0.45851
108	CLST106	1209076	0.83616	2254	5064	0.44510
109	1210020	1211026	0.85376	2255	5095	0.44259
110	CLST100	CLST84	0.85573	2259	5099	0.44303
111	CLST99	CLST104	0.89405	3267	5192	0.62924
112	CLST101	CLST98	0.90758	3303	5248	0.62938
113	1202043	1228006	0.93965	3304	5335	0.61931
114	CLST105	1211006	0.97115	3308	5389	0.61384
115	1224005	1224008	1.01970	3309	5517	0.59978
116	CLST103	1207026	1.12160	3311	5922	0.55910
117	1209008	1203005	1.12990	3312	6016	0.55053
118	1206024	CLST111	1.18010	3391	6177	0.54897
119	CLST112	CLST108	1.24110	3511	6315	0.55598

Table B.2 continued

Merge No.	Clusters Merged		Cluster Diameter	Within Dists	Total Dists	Ratio
120	1227001	1204043	1.29180	3512	6381	0.55038
121	CLST107	1201037	1.35250	3515	6514	0.53961
122	CLST113	1202042	1.35960	3517	6558	0.53629
123	1210030	CLST114	1.39830	3522	6710	0.52489
124	CLST110	CLST118	1.47950	3842	6894	0.55730
125	CLST116	CLST124	1.56920	4094	6972	0.58721
126	CLST122	CLST109	1.68720	4100	7058	0.58090
127	CLST119	CLST123	1.79760	4256	7229	0.58874
128	1210029	1202039	1.84870	4257	7354	0.57887
129	1201012	CLST115	2.03670	4259	7818	0.54477
130	CLST117	1204011	2.06990	4261	7915	0.53835
131	CLST128	CLST120	2.08500	4265	7932	0.53770
132	CLST127	1226001	2.10570	4297	7952	0.54037
133	CLST126	CLST121	2.13510	4317	7984	0.54071
134	1206002	CLST125	2.22910	4404	8288	0.53137
135	1208017	CLST134	2.81500	4492	9244	0.48594
136	CLST133	1201023	2.84330	4501	9303	0.48382
137	CLST131	1229010	2.86570	4505	9330	0.48285
138	1201036	1228001	2.96750	4506	9571	0.47080
139	CLST132	1321001	3.07390	4539	9870	0.45988
140	CLST129	1204046	3.33960	4542	10622	0.42760
141	CLST139	CLST135	3.40640	7568	10737	0.70485
142	1209001	1227010	3.45220	7569	10763	0.70324
143	CLST137	1207069	3.57500	7574	10897	0.69505
144	1205063	CLST130	3.76620	7577	11024	0.68732
145	CLST136	CLST138	3.82340	7597	11100	0.68441
146	CLST142	CLST141	3.88710	7843	11128	0.70480
147	CLST140	CLST145	4.28270	7891	11206	0.70418
148	CLST144	CLST146	4.34910	8391	11249	0.74593
149	CLST147	CLST148	4.78160	10455	11448	0.91326
150	CLST143	1208001	5.01010	10461	11466	0.91235
151	CLST150	CLST149	5.43280	11476	11478	0.99983
152	1229015	1229001	6.46640	11477	11640	0.98600
153	1203001	1205001	7.10830	11478	11922	0.96276
154	CLST152	CLST151	7.73000	11782	12154	0.96939
155	CLST153	1202013	9.54020	11784	12701	0.92780
156	1204021	1202014	9.94640	11785	12860	0.91641
157	CLST156	CLST154	10.10500	12093	12867	0.93985
158	CLST155	CLST157	11.18200	12561	12903	0.97349
159	1205047	CLST158	12.06700	12720	13186	0.96466

Table B.2 continued

Merge No.	Clusters Merged		Cluster Diameter	Within Dists	Total Dists	Ratio
160	1223005	CLST159	13.00200	12880	13481	0.95542
161	1202051	1202044	13.23400	12881	13536	0.95161
162	1202045	CLST160	13.34900	13042	13586	0.95996
163	1223001	1226006	15.25800	13043	14101	0.92497
164	1211001	1207001	15.92400	13044	14307	0.91172
165	CLST161	CLST162	16.66700	13368	14331	0.93280
166	CLST164	CLST163	18.32000	13372	14353	0.93165
167	CLST166	1206048	18.93300	13376	14364	0.93122
168	1224001	CLST165	19.70800	13540	14386	0.94119
169	CLST167	CLST168	20.21700	14365	14527	0.98885
170	1210001	1204001	22.98500	14366	14698	0.97741
171	CLST170	CLST169	25.03400	14706	14706	1.00000
172	1206001	CLST171	34.41000	14878	14878	1.00000
173	1201001	CLST172	48.51600	15051	15051	1.00000
174	1202001	CLST173	64.60100	15225	15225	1.00000

Table B.3. Huehuetenango Subsystem

Merge No.	Clusters Merged		Cluster Diameter	Within Dists	Total Dists	Ratio
1	1205041	1306061	0.00000	1	1176	0.00085
2	1206025	1206039	0.00000	2	1176	0.00170
3	CLST2	1206040	0.00000	4	1176	0.00340
4	CLST3	1301023	0.00000	7	1176	0.00595
5	1301004	1301017	0.00000	8	1176	0.00680
6	1301009	1301035	0.00000	9	1176	0.00765
7	1301012	1303067	0.00000	10	1176	0.00850
8	CLST5	1308017	0.00000	12	1176	0.01020
9	1301022	1302028	0.00000	13	1176	0.01105
10	CLST4	1302009	0.00000	17	1176	0.01446
11	1301027	1306031	0.00000	18	1176	0.01531
12	1301028	1304099	0.00000	19	1176	0.01616
13	1301033	1307005	0.00000	20	1176	0.01701
14	CLST6	1303005	0.00000	22	1176	0.01871
15	CLST10	1302053	0.00000	27	1176	0.02296
16	1302012	1302054	0.00000	28	1176	0.02381
17	1302021	1302030	0.00000	29	1176	0.02466
18	1302027	1303034	0.00000	30	1176	0.02551

Table B.3 continued

Merge No.	Clusters Merged		Cluster Diameter	Within Dists	Total Dists	Ratio
19	CLST9	1303040	0.00000	32	1176	0.02721
20	CLST17	1308036	0.00000	34	1176	0.02891
21	CLST15	1302093	0.00000	40	1176	0.03401
22	CLST16	1302095	0.00000	42	1176	0.03571
23	1302092	1311019	0.00000	43	1176	0.03657
24	CLST21	1304005	0.00000	50	1176	0.04252
25	CLST22	1304009	0.00000	53	1176	0.04507
26	CLST14	1304023	0.00000	56	1176	0.04762
27	1303025	1308034	0.00000	57	1176	0.04847
28	CLST19	1303072	0.00000	60	1176	0.05102
29	CLST7	1304049	0.00000	62	1176	0.05272
30	CLST28	1304027	0.00000	66	1176	0.05612
31	1303073	1315007	0.00000	67	1176	0.05697
32	CLST24	1305051	0.00000	75	1176	0.06378
33	CLST25	1319006	0.00000	79	1176	0.06718
34	CLST26	1305064	0.00000	83	1176	0.07058
35	CLST30	1306012	0.00000	88	1176	0.07483
36	CLST29	1304053	0.00000	91	1176	0.07738
37	CLST36	1305052	0.00000	95	1176	0.08078
38	CLST12	1324036	0.00000	97	1176	0.08248
39	1304108	1307044	0.00000	98	1176	0.08333
40	1305005	1312002	0.00000	99	1176	0.08418
41	CLST32	1306010	0.00000	108	1176	0.09184
42	CLST37	1305061	0.00000	113	1176	0.09609
43	CLST42	1309012	0.00000	119	1176	0.10119
44	CLST34	1309010	0.00000	124	1176	0.10544
45	CLST41	1308004	0.00000	134	1176	0.11395
46	CLST35	1308021	0.00000	140	1176	0.11905
47	CLST11	1309045	0.00000	142	1176	0.12075
48	CLST1	1310021	0.00000	144	1176	0.12245
49	CLST13	1307008	0.00000	146	1176	0.12415
50	CLST49	1309029	0.00000	149	1176	0.12670
51	CLST39	1311058	0.00000	151	1176	0.12840
52	CLST45	1308016	0.00000	162	1176	0.13776
53	CLST52	1309037	0.00000	174	1176	0.14796
54	CLST8	1309039	0.00000	177	1176	0.15051
55	CLST46	1309052	0.00000	184	1176	0.15646
56	CLST27	1308053	0.00000	186	1176	0.15816
57	CLST20	1313010	0.00000	189	1176	0.16071
58	1308050	1312091	0.00000	190	1176	0.16157

Table B.3 continued

Merge No.	Clusters Merged		Cluster Diameter	Within Dists	Total Dists	Ratio
59	CLST56	1310025	0.00000	193	1176	0.16412
60	1309003	1314014	0.00000	194	1176	0.16497
61	CLST44	1311008	0.00000	200	1176	0.17007
62	CLST43	1310041	0.00000	207	1176	0.17602
63	1309021	1331010	0.00000	208	1176	0.17687
64	CLST50	1317043	0.00000	212	1176	0.18027
65	CLST53	1311012	0.00000	225	1176	0.19133
66	CLST54	1311007	0.00000	229	1176	0.19473
67	CLST47	1320005	0.00000	232	1176	0.19728
68	CLST55	1311039	0.00000	240	1176	0.20408
69	1310002	1320016	0.00000	241	1176	0.20493
70	1310006	1326196	0.00000	242	1176	0.20578
71	CLST48	1312006	0.00000	245	1176	0.20833
72	CLST59	1311004	0.00000	249	1176	0.21174
73	CLST62	1314013	0.00000	257	1176	0.21854
74	CLST72	1314021	0.00000	262	1176	0.22279
75	CLST66	1313033	0.00000	267	1176	0.22704
76	CLST61	1312046	0.00000	274	1176	0.23299
77	CLST65	1311018	0.00000	288	1176	0.24490
78	CLST77	1316005	0.00000	303	1176	0.25765
79	CLST23	1313012	0.00000	305	1176	0.25935
80	CLST68	1311057	0.00000	314	1176	0.26701
81	CLST80	1315008	0.00000	324	1176	0.27551
82	CLST51	1324033	0.00000	327	1176	0.27806
83	CLST71	1315064	0.00000	331	1176	0.28146
84	CLST76	1315016	0.00000	339	1176	0.28827
85	CLST58	1317054	0.00000	341	1176	0.28997
86	CLST57	1313011	0.00000	345	1176	0.29337
87	CLST86	1313053	0.00000	350	1176	0.29762
88	CLST75	1316009	0.00000	356	1176	0.30272
89	CLST87	1314011	0.00000	362	1176	0.30782
90	CLST89	1320009	0.00000	369	1176	0.31378
91	CLST73	1318063	0.00000	378	1176	0.32143
92	CLST74	1320015	0.00000	384	1176	0.32653
93	CLST31	1328004	0.00000	386	1176	0.32823
94	CLST81	1316024	0.00000	397	1176	0.33759
95	CLST84	1320004	0.00000	406	1176	0.34524
96	CLST83	1316022	0.00000	411	1176	0.34949
97	CLST78	1316027	0.00000	427	1176	0.36310
98	CLST88	1319016	0.00000	434	1176	0.36905

Table B.3 continued

Merge No.	Clusters Merged		Cluster Diameter	Within Dists	Total Dists	Ratio
99	CLST96	1320018	0.00000	440	1176	0.37415
100	CLST94	1319008	0.00000	452	1176	0.38435
101	CLST97	1320021	0.00000	469	1176	0.39881
102	CLST64	1319004	0.00000	474	1176	0.40306
103	CLST91	1319005	0.00000	484	1176	0.41157
104	CLST102	1324002	0.00000	490	1176	0.41667
105	CLST103	1319007	0.00000	501	1176	0.42602
106	CLST105	1319018	0.00000	513	1176	0.43622
107	CLST100	1319014	0.00000	526	1176	0.44728
108	CLST107	1320022	0.00000	540	1176	0.45918
109	CLST98	1320007	0.00000	548	1176	0.46599
110	CLST106	1327011	0.00000	561	1176	0.47704
111	CLST95	1323026	0.00000	571	1176	0.48554
112	CLST67	1326073	0.00000	575	1176	0.48895
113	CLST109	1327035	0.00000	584	1176	0.49660
114	CLST92	1323015	0.00000	591	1176	0.50255
115	1320017	1325014	0.00000	592	1176	0.50340
116	CLST99	1323005	0.00000	599	1176	0.50935
117	CLST101	1320027	0.00000	617	1176	0.52466
118	CLST108	1320025	0.00000	632	1176	0.53742
119	CLST118	1322004	0.00000	648	1176	0.55102
120	CLST117	1322016	0.00000	667	1176	0.56718
121	CLST119	1325003	0.00000	684	1176	0.58163
122	CLST120	1323012	0.00000	704	1176	0.59864
123	CLST122	1326128	0.00000	725	1176	0.61650
124	CLST114	1323040	0.00000	733	1176	0.62330
125	CLST111	1325024	0.00000	744	1176	0.63265
126	CLST104	1326003	0.00000	751	1176	0.63861
127	CLST82	1327027	0.00000	755	1176	0.64201
128	CLST38	1329012	0.00000	758	1176	0.64456
129	CLST121	1326202	0.00000	776	1176	0.65986
130	CLST125	1325038	0.00000	788	1176	0.67007
131	CLST130	1328009	0.00000	801	1176	0.68112
132	CLST126	1327016	0.00000	809	1176	0.68793
133	CLST123	1326151	0.00000	831	1176	0.70663
134	CLST133	1327007	0.00000	854	1176	0.72619
135	CLST129	1327010	0.00000	873	1176	0.74235
136	CLST134	1328003	0.00000	897	1176	0.76276
137	CLST135	1327019	0.00000	917	1176	0.77976
138	CLST110	1327040	0.00000	931	1176	0.79167

Table B.3 continued

Merge No.	Clusters Merged		Cluster Diameter	Within Dists	Total Dists	Ratio
139	CLST132	1327038	0.00000	940	1176	0.79932
140	CLST137	1327039	0.00000	961	1176	0.81718
141	CLST127	1328007	0.00000	966	1176	0.82143
142	CLST113	1327061	0.00000	976	1176	0.82993
143	CLST140	1329002	0.00000	998	1176	0.84864
144	CLST138	1327056	0.00000	1013	1176	0.86140
145	CLST144	1329011	0.00000	1029	1176	0.87500
146	CLST142	1328010	0.00000	1040	1176	0.88435
147	CLST136	1330009	0.00000	1065	1176	0.90561
148	CLST131	1329023	0.00000	1079	1176	0.91752
149	CLST146	1330008	0.00000	1091	1176	0.92772
150	CLST145	1330003	0.00000	1108	1176	0.94218
151	CLST148	1331002	0.00000	1123	1176	0.95493
152	CLST147	1330022	0.00000	1149	1176	0.97704
153	CLST152	1330024	0.00000	1176	1176	1.00000
154	CLST153	CLST116	0.09566	1400	1608	0.87065
155	CLST124	CLST90	0.09566	1472	1608	0.91542
156	CLST79	CLST93	0.09566	1481	1608	0.92102
157	CLST150	CLST143	0.12598	1895	3284	0.57704
158	CLST18	CLST40	0.12598	1899	3284	0.57826
159	1305002	1305004	0.12598	1900	3284	0.57856
160	CLST60	1318033	0.12598	1902	3284	0.57917
161	CLST112	CLST128	0.12598	1922	3284	0.58526
162	1326201	1327046	0.12598	1923	3284	0.58557
163	CLST139	CLST141	0.12598	1983	3284	0.60384
164	CLST151	CLST154	0.15819	2559	3412	0.75000
165	CLST33	CLST155	0.19132	2644	3823	0.69160
166	CLST115	CLST69	0.19132	2648	3823	0.69265
167	1303058	1312048	0.19132	2649	3823	0.69291
168	CLST163	CLST149	0.25197	2857	5536	0.51608
169	1306011	1317035	0.25197	2858	5536	0.51626
170	CLST158	1324007	0.26243	2862	5540	0.51661
171	CLST157	1329001	0.36463	2903	6459	0.44945
172	CLST168	1309031	0.37284	2932	6477	0.45268
173	CLST161	CLST70	0.37795	2950	7609	0.38770
174	CLST170	CLST160	0.37795	2965	7609	0.38967
175	CLST159	CLST85	0.37795	2971	7609	0.39046
176	1305065	1318002	0.37795	2972	7609	0.39059
177	1317019	1318087	0.37795	2973	7609	0.39072
178	CLST156	CLST165	0.38265	3105	8000	0.38813

Table B.3 continued

Merge No.	Clusters Merged		Cluster Diameter	Within Dists	Total Dists	Ratio
179	1313032	1331003	0.40113	3106	8146	0.38129
180	1322017	1307022	0.44412	3107	8620	0.36044
181	CLST162	1327028	0.47540	3109	9357	0.33227
182	1310028	1323032	0.47831	3110	9492	0.32764
183	CLST167	CLST164	0.49048	3214	9542	0.33683
184	1313013	CLST63	0.55243	3216	11381	0.28258
185	CLST171	1331024	0.56305	3258	11391	0.28602
186	CLST179	1312009	0.56661	3260	11405	0.28584
187	CLST174	CLST175	0.57527	3300	11705	0.28193
188	1322003	1326198	0.57788	3301	11722	0.28161
189	CLST172	1307033	0.59089	3331	11967	0.27835
190	1304050	1307004	0.61639	3332	12155	0.27413
191	1302121	1307032	0.64566	3333	12958	0.25722
192	CLST189	CLST185	0.65264	4666	12970	0.35975
193	1318088	CLST166	0.66963	4670	13301	0.35110
194	CLST181	1309004	0.67950	4673	13324	0.35072
195	CLST184	1315072	0.69156	4676	13477	0.34696
196	CLST183	CLST178	0.71940	6188	13793	0.44863
197	CLST180	1307039	0.80647	6190	15102	0.40988
198	1322025	CLST177	0.82292	6192	15313	0.40436
199	1331004	CLST176	0.83783	6194	15378	0.40278
200	CLST173	1301007	0.88920	6205	16268	0.38142
201	CLST196	CLST169	0.90837	6369	16664	0.38220
202	CLST187	1317041	0.97193	6382	17350	0.36784
203	1306036	1314015	0.99682	6383	17576	0.36317
204	CLST201	CLST192	1.03880	12599	18320	0.68772
205	CLST202	CLST186	1.04060	12641	18371	0.68810
206	1302020	1301002	1.06070	12642	18546	0.68166
207	CLST194	1317073	1.07370	12646	18644	0.67829
208	1301013	1302005	1.19190	12647	19512	0.64817
209	CLST188	CLST190	1.21580	12651	19701	0.64215
210	1302002	CLST204	1.21790	12809	19709	0.64991
211	CLST207	CLST200	1.22930	12869	19763	0.65117
212	CLST203	1303065	1.25550	12871	19933	0.64571
213	CLST197	CLST193	1.25730	12886	19951	0.64588
214	CLST206	1301019	1.30320	12888	20389	0.63211
215	CLST195	CLST205	1.42640	12956	21250	0.60969
216	CLST215	CLST210	1.53830	16295	21929	0.74308
217	CLST213	CLST191	1.72490	16311	23030	0.70825
218	CLST214	CLST211	1.74340	16362	23123	0.70761

Table B.3 continued

Merge No.	Clusters Merged		Cluster Diameter	Within Dists	Total Dists	Ratio
219	1326139	1325001	1.76960	16363	23315	0.70182
220	CLST209	CLST216	1.83630	17083	23645	0.72248
221	CLST212	CLST220	2.13540	17635	24800	0.71109
222	CLST218	CLST219	2.19640	17675	24882	0.71035
223	CLST217	CLST182	2.33810	17695	25099	0.70501
224	CLST198	1317042	2.36370	17698	25269	0.70038
225	CLST199	CLST221	2.37220	18259	25294	0.72187
226	1301015	1301037	2.41190	18260	25474	0.71681
227	1310001	1331001	2.41920	18261	25517	0.71564
228	1301038	1301006	2.43520	18262	25611	0.71305
229	1315001	1323001	2.46620	18263	25732	0.70974
230	CLST222	CLST225	2.72470	22443	26249	0.85500
231	1304003	1306056	2.82730	22444	26367	0.85122
232	1326136	1330001	3.05910	22445	26640	0.84253
233	1319001	1328001	3.14540	22446	26697	0.84077
234	1325006	CLST230	3.25050	22658	26791	0.84573
235	CLST208	CLST226	3.34110	22662	26823	0.84487
236	CLST227	1304109	3.35070	22664	26828	0.84479
237	CLST223	CLST234	3.44840	25220	27035	0.93287
238	CLST228	CLST237	3.75930	25670	27274	0.94119
239	CLST233	1206022	3.93730	25672	27671	0.92776
240	CLST235	CLST232	4.16670	25680	28268	0.90845
241	CLST236	CLST229	4.32310	25686	28949	0.88728
242	CLST240	1312010	4.63940	25692	29581	0.86853
243	1326152	1324006	4.78360	25693	29816	0.86172
244	CLST224	1318001	4.81440	25697	29869	0.86032
245	CLST242	CLST238	5.27630	27286	30129	0.90564
246	1313005	1320001	5.75710	27287	30352	0.89902
247	1301016	1312047	6.41400	27288	30680	0.88944
248	CLST241	CLST245	6.48950	28458	30931	0.92005
249	CLST239	1322001	6.65090	28461	31243	0.91096
250	CLST244	CLST248	6.88810	29656	31325	0.94672
251	CLST249	CLST250	8.54090	30632	31643	0.96805
252	CLST231	CLST251	9.20140	31128	32103	0.96963
253	1313001	1314001	11.52700	31129	33117	0.93997
254	CLST243	CLST252	11.58700	31629	33121	0.95495
255	CLST247	CLST254	12.92800	32133	33706	0.95333
256	CLST246	1326118	13.15100	32135	34106	0.94221
257	CLST256	1315038	13.93300	32138	34415	0.93384
258	1312001	1304001	13.97800	32139	34417	0.93381

Table B.3 continued

Merge No.	Clusters Merged		Cluster Diameter	Within Dists	Total Dists	Ratio
259	1306001	1308001	14.18000	32140	34431	0.93346
260	CLST257	CLST255	14.67000	33156	34688	0.95584
261	1309001	CLST260	15.94200	33414	35714	0.93560
262	1305001	CLST261	16.53500	33673	35810	0.94032
263	CLST258	1327001	16.77200	33675	35977	0.93602
264	1301003	CLST262	17.70600	33935	36256	0.93598
265	1303061	CLST264	18.54600	34196	36281	0.94253
266	1311001	CLST263	19.14800	34199	36538	0.93598
267	1316001	CLST265	20.14100	34461	36806	0.93629
268	CLST266	CLST259	20.46600	34469	36813	0.93633
269	CLST268	CLST253	22.10400	34481	36846	0.93581
270	CLST269	CLST267	24.00200	36585	37366	0.97910
271	1303001	CLST270	26.52800	36856	37650	0.97891
272	1302001	CLST271	29.24300	37128	37929	0.97888
273	1317001	CLST272	31.08100	37401	37940	0.98579
274	1307001	CLST273	33.49200	37675	37948	0.99281
275	1324001	CLST274	35.67100	37950	37950	1.00000
276	1326001	CLST275	47.55300	38226	38226	1.00000
277	1301001	CLST276	87.27500	38503	38503	1.00000

Table B.4. El Quiché Subsystem

Merge No.	Clusters Merged		Cluster Diameter	Within Dists	Total Dists	Ratio
1	807025	807027	0.00000	1	221	0.00452
2	CLST1	1401013	0.00000	3	221	0.01357
3	1401002	1402021	0.00000	4	221	0.01810
4	1401003	1401040	0.00000	5	221	0.02262
5	CLST2	1401041	0.00000	8	221	0.03620
6	CLST4	1402012	0.00000	10	221	0.04525
7	CLST5	1403005	0.00000	14	221	0.06335
8	1401043	1404019	0.00000	15	221	0.06787
9	1402002	1409043	0.00000	16	221	0.07240
10	1402010	1409042	0.00000	17	221	0.07692
11	CLST6	1412012	0.00000	20	221	0.09050
12	CLST3	1404018	0.00000	22	221	0.09955
13	1402029	1403007	0.00000	23	221	0.10407
14	CLST7	1403012	0.00000	28	221	0.12670

Table B.4 continued

Merge No.	Clusters Merged		Cluster Diameter	Within Dists	Total Dists	Ratio
15	CLST14	1403016	0.00000	34	221	0.15385
16	CLST15	1404017	0.00000	41	221	0.18552
17	1403017	1416036	0.00000	42	221	0.19005
18	1404006	1411002	0.00000	43	221	0.19457
19	1404009	1410033	0.00000	44	221	0.19910
20	1404010	1404020	0.00000	45	221	0.20362
21	CLST16	1405062	0.00000	53	221	0.23982
22	CLST12	1407004	0.00000	56	221	0.25339
23	CLST8	1407014	0.00000	58	221	0.26244
24	CLST20	1406045	0.00000	60	221	0.27149
25	CLST21	1407005	0.00000	69	221	0.31222
26	CLST24	1417012	0.00000	72	221	0.32579
27	1406058	1407009	0.00000	73	221	0.33032
28	CLST22	1417016	0.00000	77	221	0.34842
29	CLST25	1408002	0.00000	87	221	0.39367
30	CLST23	1412083	0.00000	90	221	0.40724
31	CLST29	1408008	0.00000	101	221	0.45701
32	CLST31	1408024	0.00000	113	221	0.51131
33	1408021	1409044	0.00000	114	221	0.51584
34	CLST32	1412040	0.00000	127	221	0.57466
35	1409028	1412020	0.00000	128	221	0.57919
36	CLST9	1412101	0.00000	130	221	0.58824
37	CLST33	1412039	0.00000	132	221	0.59729
38	CLST19	1412056	0.00000	134	221	0.60633
39	CLST18	1413041	0.00000	136	221	0.61538
40	1412013	1412074	0.00000	137	221	0.61991
41	CLST37	1416025	0.00000	140	221	0.63348
42	CLST34	1414005	0.00000	154	221	0.69683
43	CLST36	1414009	0.00000	157	221	0.71041
44	1413007	1413062	0.00000	158	221	0.71493
45	CLST39	1413050	0.00000	161	221	0.72851
46	CLST42	1417002	0.00000	176	221	0.79638
47	1414007	1416023	0.00000	177	221	0.80090
48	1414023	1417011	0.00000	178	221	0.80543
49	CLST47	1416041	0.00000	180	221	0.81448
50	CLST49	1418008	0.00000	183	221	0.82805
51	CLST46	1418016	0.00000	199	221	0.90045
52	CLST48	1417028	0.00000	201	221	0.90950
53	CLST52	1418028	0.00000	204	221	0.92308
54	CLST51	1505033	0.00000	221	221	1.00000

Table B.4 continued

Merge No.	Clusters Merged		Cluster Diameter	Within Dists	Total Dists	Ratio
55	CLST45	CLST10	0.11175	229	344	0.66570
56	807018	1402013	0.11175	230	344	0.66860
57	807035	1416062	0.11175	231	344	0.67151
58	1406009	1406074	0.11175	232	344	0.67442
59	CLST38	CLST44	0.11175	238	344	0.69186
60	CLST41	CLST50	0.11175	254	344	0.73837
61	1401052	1409032	0.12430	255	510	0.50000
62	1406020	CLST27	0.12430	257	510	0.50392
63	1406040	1407010	0.12430	258	510	0.50588
64	1406069	CLST30	0.12430	262	510	0.51373
65	1409087	CLST26	0.12430	266	510	0.52157
66	CLST11	1417017	0.12430	270	510	0.52941
67	CLST43	CLST28	0.12430	290	510	0.56863
68	CLST55	1406035	0.16715	296	535	0.55327
69	1406043	1406065	0.16715	297	535	0.55514
70	CLST60	CLST54	0.22350	441	645	0.68372
71	CLST40	CLST59	0.22350	451	645	0.69922
72	CLST56	1407008	0.22350	453	645	0.70233
73	1406060	1409040	0.22350	454	645	0.70388
74	CLST67	CLST53	0.24860	490	768	0.63802
75	CLST62	CLST35	0.24860	496	768	0.64583
76	1416045	CLST17	0.27660	498	847	0.58796
77	1406064	CLST57	0.29832	500	868	0.57604
78	CLST74	1402018	0.30325	513	890	0.57640
79	1407007	CLST66	0.30325	518	890	0.58202
80	1401011	1409050	0.30325	519	890	0.58315
81	CLST63	1401051	0.30325	521	890	0.58539
82	CLST68	CLST72	0.35561	542	1047	0.51767
83	1410025	CLST70	0.35561	568	1047	0.54250
84	CLST80	1406067	0.37291	570	1204	0.47342
85	CLST79	CLST64	0.37291	600	1204	0.49834
86	CLST65	CLST13	0.37291	610	1204	0.50664
87	CLST71	1408005	0.40898	617	1257	0.49085
88	CLST82	CLST76	0.43462	647	1298	0.49846
89	CLST81	1406048	0.44025	650	1428	0.45518
90	1412069	1401019	0.45053	651	1478	0.44046
91	CLST58	CLST75	0.45205	661	1577	0.41915
92	CLST77	1412102	0.45421	664	1578	0.42079
93	1406031	1406055	0.45521	665	1704	0.39026
94	1406032	1406003	0.46350	666	1707	0.39016

Table B.4 continued

Merge No.	Clusters Merged		Cluster Diameter	Within Dists	Total Dists	Ratio
95	CLST73	1401010	0.46737	668	1738	0.38435
96	1401055	1406002	0.50070	669	1931	0.34645
97	CLST69	CLST84	0.50145	675	1947	0.34669
98	CLST61	CLST86	0.50355	689	2085	0.33046
99	CLST78	CLST83	0.51529	1067	2175	0.49057
100	1412005	1410022	0.55150	1068	2419	0.44150
101	1416027	1416044	0.55594	1069	2424	0.44101
102	CLST90	CLST87	0.58574	1085	2463	0.44052
103	CLST94	CLST91	0.56897	1099	2546	0.43166
104	1401042	1409012	0.57517	1100	2716	0.40501
105	1416036	1416033	0.59945	1101	2828	0.38932
106	1401020	1408019	0.62575	1102	3119	0.35332
107	1416028	CLST92	0.65537	1106	3270	0.33823
108	1406022	1406068	0.66087	1107	3303	0.33515
109	CLST88	1418020	0.69197	1120	3520	0.31818
110	CLST95	CLST97	0.69353	1135	3522	0.32226
111	1402020	1406017	0.74242	1136	3727	0.30480
112	1406049	1412011	0.74581	1137	3765	0.30199
113	CLST89	CST98	0.74806	1173	3780	0.31032
114	CLST85	CLST99	0.75196	1624	3791	0.42838
115	801075	CLST101	0.75217	1626	3801	0.42778
116	1405063	1406025	0.76718	1627	3854	0.42216
117	CLST110	CLST103	0.77168	1699	3887	0.43710
118	1412006	1413077	0.78820	1700	3963	0.42897
119	CLST105	1416048	0.83712	1702	4151	0.41002
120	1406070	1406075	0.84827	1703	4183	0.40712
121	CLST109	CLST114	0.85623	2431	4193	0.57978
122	CLST107	CLST100	0.89999	2441	4533	0.53850
123	CLST116	1410016	0.96660	2443	5049	0.48386
124	CLST93	1406057	0.97064	2445	5108	0.47866
125	CLST96	801007	0.98302	2447	5232	0.46770
126	1402009	1412022	1.02520	2448	5610	0.43636
127	CLST104	1406016	1.02690	2450	5640	0.43440
128	CLST115	CLST106	1.03180	2456	5687	0.43186
129	CLST108	CLST112	1.03680	2460	5710	0.43082
130	CLST117	1406026	1.08770	2477	6011	0.41208
131	CLST102	CLST121	1.11270	3137	6136	0.51125
132	1406044	1406061	1.13320	3138	6263	0.50104
133	CLST122	CLST119	1.16090	3159	6362	0.49654
134	CLST130	CLST111	1.25330	3195	6715	0.47580

Table B.4 continued

Merge No.	Clusters Merged		Cluster Diameter	Within Dists	Total Dists	Ratio
135	CLST113	CLST131	1.36130	4183	7185	0.58219
136	CLST127	1401026	1.36320	4186	7190	0.58220
137	1406019	CLST125	1.38770	4189	7382	0.56746
138	1406015	1414048	1.43540	4190	7635	0.54879
139	14060100	1406021	1.49190	4191	7880	0.53185
140	CLST132	1406014	1.50970	4193	7973	0.52590
141	CLST123	1406041	1.50980	4196	7974	0.52621
142	CLST120	1413073	1.56800	4198	8295	0.50609
143	CLST137	CLST136	1.68040	4214	8786	0.47963
144	CLST128	CLST133	1.68390	4264	8795	0.48482
145	1406012	CLST139	1.69550	4266	8837	0.48274
146	CLST142	CLST126	1.89220	4272	9537	0.44794
147	CLST134	CLST144	1.89730	4572	9551	0.47869
148	CLST124	CLST135	1.95120	4839	9773	0.49514
149	CLST129	CLST141	2.06180	4855	10222	0.47496
150	CLST147	CLST148	2.18390	8075	10450	0.77273
151	CLST146	CLST138	2.20810	8085	10566	0.76519
152	CLST143	CLST145	2.41660	8109	11279	0.71895
153	1410008	CLST140	2.53320	8112	11569	0.70118
154	CLST149	1405022	2.55240	8120	11606	0.69964
155	1401012	1403001	2.72290	8121	12081	0.67221
156	CLST151	CLST150	2.83140	9010	12271	0.73425
157	CLST152	CLST118	2.84840	9032	12291	0.73485
158	1418006	1416055	3.00290	9033	12547	0.71993
159	CLST157	CLST156	3.27440	10775	12701	0.84836
160	CLST154	CLST159	3.56200	12098	12954	0.93392
161	1402028	CLST160	3.98240	12254	13155	0.93151
162	1401008	1410001	4.23010	12255	13228	0.92644
163	CLST153	CLST161	4.44970	12883	13313	0.96770
164	CLST155	CLST163	5.31330	13205	13715	0.96281
165	CLST158	CLST164	5.71620	13531	13901	0.97338
166	1407001	CLST162	6.30620	13533	14028	0.96471
167	CLST166	CLST165	7.09640	14028	14217	0.98671
168	1417001	CLST167	7.93730	14196	14413	0.98494
169	1418001	CLST168	8.07820	14365	14421	0.99612
170	807001	CLST169	1.00870	14535	14913	0.97465
171	1401062	CLST170	1.09540	14706	15485	0.94969
172	1409006	1401059	1.20770	14707	15703	0.93657
173	1416001	1413001	1.21110	14708	15775	0.93236
174	1406024	CLST171	1.28110	14880	15909	0.93532

Table B.4 continued

Merge No.	Clusters Merged		Cluster Diameter	Within Dists	Total Dists	Ratio
175	CLST172	CLST174	1.35810	15226	15925	0.95611
176	1408001	CLST173	1.48180	15228	16433	0.92667
177	1414001	CLST175	1.49430	15403	16437	0.93709
178	CLST176	CLST177	1.57320	15931	16446	0.96869
179	1404001	CLST178	1.74320	16110	16462	0.97862
180	1409001	CLST179	1.77410	16290	16467	0.98925
181	1408013	CLST180	1.98320	16471	16504	0.99800
182	1411001	CLST181	2.38950	16653	16834	0.98925
183	1415001	CLST182	2.53200	16836	16836	1.00000
184	1406001	CLST183	3.36230	17020	17334	0.98189
185	1412001	CLST184	3.39450	17205	17383	0.98976
186	1402001	CLST185	4.17290	17391	17391	1.00000
187	1401001	CLST186	7.17630	17578	17578	1.00000