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Regional investment in road infrastructure in rural Colombia: an evaluation model

Claudia Stevenson
Iowa State University

Regional investment in road infrastructure in rural Colombia: An evaluation model

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Claudia Stevenson

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1. INTRODUCTION

Recently, Colombian policy has shifted towards political decentralization. Under the new Constitution of 1991, the responsibilities for infrastructure planning, construction and financing were redefined. The national government changed the definition of national roads and is only responsible for the main network that links the principal cities to themselves and to the ports. The remaining network is under regional responsibility.

The recent decentralization process and the new Constituency is giving the regions the autonomy for making their own decisions about investment. The national transportation policies have redefined the national and regional responsibilities. After 1992, the national government will only be responsible for the construction and maintenance of the high-volume roads that connect large cities within themselves and with the ports. The regions are now responsible for the management of the regional, low-volume road network. However, these new responsibilities have been given to the regional entities without taking into account the lack of technical planning capabilities and the need for a coordinated and integrated system for planning. Moreover, with decentralization of decision making, there is the risk or uncoordinated planning and duplication of efforts.

Two subregions of Colombia have identified road infrastructure as a key issue for their regional development, the Atlantic subregion and the Occident subregion. However, there is not enough information to enable them to make decisions regarding construction or improvement of regional roads. An efficient investment system should distribute investment resources where the greatest benefits to the communities should be produced. The benefits for the community and region will be measured in terms of reduction of transport costs, which is at the same time, a measure of the integration of the region.

The purpose of this research is to develop an easy to use methodology for evaluating investment in regional roads. This model should provide a simple way for evaluating the transportation needs within a region. For this, the first step will be to develop a model for generating traffic flows for secondary roads, and secondly, based on the predicted traffic flows, evaluate priorities for investment in road infrastructure. The model for generating traffic flows is going to be developed through a spatial interaction model, specifically a gravity model. The model for evaluating investment is going to be developed by maximizing a benefit function subject to budget constraints.

The gravity model has been widely applied under a varying range of settings with a wide range of results. It has been used for forecasting urban traffic flows (Wilson, 1990), freight movements (Pitfield, 1978), airline passenger flows (Fotheringham, 1983), international trade flows (Bikker, 1987, Hua, 1990) and migration flows (Fik, 1992), among others. The results and the theoretical application of the gravity model has also been widely discussed (Hua, 1979, Lo, 1992, Langlois, 1983). The empirical results show that the gravity model is very useful and may make accurate predictions for traffic flows without the need for collecting great quantities of data (Hua, 1990). Moreover, the gravity model is flexible enough to adapt to any particular set of needs.

However, there is little research about the applicability of gravity models in developing countries, where the availability of data is limited and the need for an efficient system of transportation planning is large. The first part of this research will adapt one type of gravity model to the conditions of agricultural flows in one department of one of the two subregions in Colombia. Non-agricultural flows will not be modelled, such as personal or commuting trips because of the lack of information about this types of trips.

As the accessibility benefits are very hard to measure, the decision of which rural roads should be considered for construction or upgrading is a very complex one. However, there are several guidelines and studies about the appropriate evaluation methodologies for low volume rural roads in developing countries.

The transportation model will be based on a methodology developed by Kumar (1991). This methodology for planning rural networks is based on the optimal use of a limited budget for road construction. The benefits for developing a rural road network will be conservatively measured as the reduction of transportation costs of agricultural commodities.

2. AGRICULTURE AND TRANSPORTATION IN COLOMBIA

2.1. Agricultural Production

Agriculture has played an important role in the Colombian economy. Although structural changes have been taking place in the last decades, agriculture continues to hold an important share of the nation's GDP. During the eighties', the participation of agriculture in GDP was 20% on average (World Bank, 1987). However, during the last three decades, the agricultural sector was the least dynamic sector with an annual rate of growth of only 1.16% compared to a 2.72% rate for industry and a 2.5% rate for services. Agriculture's share of total GDP declined from 34% in 1969 to 23% in 1980 to 17% in 1989 (World Bank, 1985, 1990).

Colombia traditionally has had a strong orientation towards agricultural exports, and coffee, as the main export product, was primarily responsible for the economic development of the seventies' and eighties' (Thomas, 1985). Colombia's agricultural product is roughly divided into equal proportions among coffee production, other agricultural production and animal production (García, 1991).

The tendency in agriculture has been to produce more cereals and export crops and less staple food crops. The area of cultivation of cash crops that are technology intensive has increased, while production of traditional crops that are grown by peasants has declined (Martinez, 1987). The small farmer rural economy has suffered from marginalization from the market and lack of access to technological innovation. The growth of agricultural output in

Colombia has been caused mainly by capital intensive, high-investment technologies. However, small peasant production, although dispersed, isolated and faced with unorganized markets, has maintained its importance as a food supplier (Pombo, 1992). Even with this lack of government support, small farmers producing traditional crops have experienced substantial increases in productivity, as they have been forced by the market to become efficient.

Some agricultural products have remained stagnant during the 1969-1990 period, such as rice, corn, soybeans and cotton, while some have shown dynamic growth such as sorghum, potatoes, African palm, bananas and cacao. Livestock production has remained stable while the poultry sector increased strongly during the period (Pombo, 1992).

There is a strong potential for improvement in the agricultural sector and one of the areas for improvement is to promote a better transportation system as transportation costs are a source of cost increases for inputs and lower farm prices of final products.

2.2. Demand Characteristics

Colombia's food imports have risen in recent years because the agricultural sector has been unable to keep up with the rise in domestic demand (Bolling, 1987). Agricultural production in Colombia has been burdened by the cost and short supply of many basic inputs like fertilizers and mixed feeds. Colombia's use of fertilizer is low compared with that of neighboring countries (Bolling, 1987). The use of fertilizer declined during the seventies' and eighties' as a consequence of rising prices of agricultural inputs and declining market prices (Thomas, 1985). In 1990, the total consumption of fertilizers was 603,000 tons, of which 80 percent were imported. Table 2.1 shows the use of the three principal fertilizers and the use of fertilizer on the main export crop, coffee.

Table 2.1. Use of fertilizer in Colombia

Fertilizer Use	Total 1,000 Tons 1991	Use Kilos/Ha 1979-1981	Coffee (%)
Total	603	537	
Nitrogen	312	269	31
Phosphate	32	135	14
Potash	73	134	22

The increase in the price of inputs of agricultural commodities is considered to be one of the main sources of stagnation of agriculture during the seventies' and eighties' because it caused a sub-optimal utilization of fertilizer (García, 1988).

As shown in Table 2.2, cereals are a main source of calories for Colombians. The consumption of cereals and roots is high. The average per capita food consumption in Colombia is about 2,300 calories per year. About 30 percent of the calories are from cereals, 10 percent from roots and tubers, while animal products provide only 16 percent of the calories (Bolling, 1987).

Table 2.2. Per capita food consumption, 1984-1986 average for selected products

Product	Per Person Average Kilogram/year
Wheat	25.6
Rice	57.0
Corn	26.8
Cassava	37.8
Potatoes	64.2
Plantain	64.0
Sugar	56.9
Bananas	6.5
Palm Oil	3.4
Beef and Veal	20.8
Poultry	2.9
Coffee	3.7

2.3. Market Characteristics of Principal Agricultural Products

This section will describe the marketing characteristics of the principal agricultural products in the subregions and will be the basis for the assumptions about flows taken in the model.

2.3.1. Coffee

Coffee has been traditionally Colombia's principal export product, although exports of oil and coal have become increasingly important tin the last decade. Other important sources of agricultural exports have been banana, flowers, raw sugar and cotton (International Trade Statistics, 1990). During the 1960-1990 period there have been wide variations in coffee prices. However, production and exports have grown at stable rates (Thomas, 1985). The expiration of the International Coffee Agreement in 1989 has created changes in coffee policies since international coffee prices have fallen to record lows. The recent tendency has been for coffee prices to fall, because international demand has fallen as a consequence of changes in taste. Also, coffee stocks have increased. The price elasticity of coffee production is low and diversification is difficult. However, several efforts for diversification to fruit exports and for developing a market niche based on quality lead to the expectation that the coffee growing region will continue to play an important role in the economy of the country.

Farmers sell their coffee at one of the 500 buying points of the Federation of Coffee growers or directly to the traders. The exporters and the Federation store the coffee and have it milled in any of the 100 factories before export. Not all the produced coffee is exported. Excess production stored in about 150 warehouses that have a capacity of 11 million bags. At least 90 percent of transport from the warehouses to the ports is shipped by road (Graaf, 1986). In the past two decades, about 18% of the national production has been used for national consumption. The recent tendency has been for coffee prices to fall, demand has fallen and coffee stocks have increased. Even though the price elasticity of coffee production is low and diversification is difficult, coffee production will be still be an important part of the Colombian economy in the next years.

2.3.2. Sugarcane

Colombia is the fourth largest producer of sugarcane in Latin America and sugarcane production has increased at an average rate of 3 percent per annum (Economic Survey of Latin America, 1988). Colombia exports raw and refined sugar, mainly to the United States. In Colombia, there are about 15 sugar refineries, most of them in the Occident region.

Sugar exports face many protectionist measures for entry and sugar importers in developed countries have replaced it by high fructose corn syrup. Latin American sugar producers face quota restrictions in the United States and in 1986, the sugar quota for Colombia was reduced almost in half, as well as for other Latin American sugar producers (Lord, 1987). Thus, sugar production is expected to remain stable in the next few years..

2.3.3. Cotton

Cotton production in Colombia started as a response from demand of local textile factories. Most of this factories are located in the second industrial city, Medellin. Cotton production and exports peaked during the seventy's and declined during the eighty's (Helmsing, 1986). The Atlantic region is the largest cotton production area, specially the departments of Cesar and Cordoba.

Cotton production stagnated during the late eighty's as a consequence of decline in the demand for cotton exports and the stagnation of the Colombian textile industry. The prospects for cotton production are improving as the Colombian textile industry is recovering and Colombian textile imports in 1990 doubled those of 1980 (Tackling United States Protectionism, 1992). For cotton exports, Colombia faces an export quota for cotton with the United States, but there are prospects for an increase in the international price (Lord, 1987).

2.3.4. Bananas

Colombia is the world's second largest producer of bananas and banana exports have increased rapidly since the 1970s. About 92% of the banana production is done in the Chigorodo-Uraba region of the Department of Antioquia. Most of the production is solely for export. The banana growers of the region market their products through UNIBAN, the private association of producers. The production is marketed through their own private port at the Atlantic Ocean. However, banana exports are facing the threat of more protectionist measures in the European Community market and it is likely that the export demand will be depressed (FAO, 1986, Bananas: A Signs of a Deal..., 1992).

2.3.5. Corn and Rice

Corn and rice are the nation's main staple foods. Per capita rice consumption has more than doubled in the last decades. Most rice production is for domestic consumption as local rice prices are higher than the international prices (FAO, 1991).

Corn is produced throughout Colombia, and about 80% comes from small farms. Corn and corn flour are a traditional part of the Colombian food diet. Corn consumption has declined in the last two decades (Bolling, 1987). However, the supply for staple foods such as rice, corn and vegetables is not satisfied by internal production and some staple foods have to be imported (FAO, 1991).

2.4. Characteristics of the Flow

The majority of flows that go into the agricultural production zones are composed of fertilizers and pesticides. Agricultural production may be either staple foods or export crops and it is subject to great variability depending on the conditions of the external and internal markets.

With continuous changes in the market conditions for locally consumed produce and export crops, the regions need a transportation system that enables the producer to get cheaper fertilizers and access to either internal or external markets. Most crops in Colombia are harvested on a biannual basis, mostly by the end of the rainy seasons, in May and September. For example, the major harvesting season for coffee is in September and usually lasts about four months (Graaf 1986).

The transportation system is burdened by the inflow of agricultural inputs and the outflow of agricultural products. It also carries the movements of people such as additional labor that is required during harvest time. Harvest labor is continuously moving from one region to the other, but there is no information about these type of movements. Also, there is lack of information abut the movements of people from the rural areas to the towns and cities related to work, amenities, health services or shopping. Thus, movements of people are not considered in the model. Also, the model is not able to take into account the traffic flows that are generated by the presence of industry in the region because there is not information about the nature and location of industries as well as of industrial flows.

2.5. Transportation

Transportation has had a significant role in Colombia's economy. The Colombian topography, with three mountain ranges crossing the country lengthwise has encouraged high construction costs, difficult roadway engineering and lack of integration among routes. Transportation facilities in Colombia have limited the distribution of goods. It is often less expensive to import foodstuffs and transport them to large consumption centers than to transport them from marginal producing areas (Bolling, 1987).

Roads and highways are the most important overland means of transportation, carrying about 87 percent of the cargo traffic. The road system has doubled in the past two decades, from 27,963 miles in 1969 to about 72,037 miles in 1991 (Colombia Information Service, 1991). Of those, about eight percent correspond to paved roads, 50 percent to gravel roads and the remaining to dirt roads.

The Colombian road network is estimated to be about 31,000 miles and most goods are commonly hauled by road. Complementary transport modes such as rail and river have decreased abruptly in importance.

The railway system played an important role in Colombia's transportation until the seventy's. The railway network consists of two main corridors. One corridor connects the capital of Bogotá with the port of Santa Marta in the Atlantic. The other corridor connects the coffee growing zone of the Departments of Antioquia and Valle with the port of Buenaventura in the Pacific. The length of the entire network is about 800 miles. This mode has not been able to compete with highways and privately owned trucks, and has been losing cargo since the 1970s. The railroads were the property of the government until in 1990 the government reorganized the system and encouraged the operation of equipment by private firms. However, the rail line serving the Occident region does not carry an important amount of cargo and needs a heavy investment to become competitive with the highway mode. Since the results of the process of privatization are still uncertain, this mode is not considered as an option in the model.

On the other hand, for many municipalities, the main access is by river. However, by the topographical nature of the region, the seasonal conditions and the lack of investment, the movement by river is very limited, unreliable and costly. Some municipalities have only access by river, but this access is not considered in the model.

3. LITERATURE REVIEW

3.1. The Spatial Interaction Model

Spatial interaction can be broadly defined as movement or communication over space that results from a decision process (Fotheringham, 1990). The simplest form of spatial interaction models is the unconstrained gravity model, that is based on Newton's physics law of attraction between two masses. The level of interaction between zones i and j is taken proportional to each of a mass at i, a mass at j, and inversely proportional to some function of distance (travel cost) (Wilson, 1974):

$$T_{ij} = \frac{KO_iD_j}{d_{ij}^2}$$

T_{ij} = Number of trips

O_i = Total Number of Origin Trips

D_j = Total Number of Destination Trips

K= Constant

d_{ij} = Function of distance or travel costs.

Since the unconstrained gravity model presented several theoretical and practical problems, Wilson (1967) developed a statistical theory based on entropy maximizing methods, by finding a maximum likelihood estimator.[1]. For Wilson (1967) the probability of the

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[1]The notion of maximum entropy implies that the most probable macro-state of a system is formed by that arrangement that gives rise to the maximum number of micro states. The use of entropy models in spatial

distribution $\{T_{ij}\}$ is proportional to the number of states of the system which gives rise to the distribution and satisfies the constraints:

$$\sum_i T_{ij} = O_i \qquad \text{and} \qquad \sum_j T_{ij} = D_{ij}$$

The number of distinct arrangements of individuals that give rise to the distribution $\{T_{ij}\}$ is:

$$\rho(T_{ij}) = \frac{(\bar{T}!)}{\left(\prod_{i,j} T_{ij}!\right)}$$

The maximum value of $p(T_{ij})$ will result in the most probable distribution of $\{T_{ij}\}$. The most probable distribution that satisfies the constraints found by Wilson is:

$$T_{ij} = A_i B_j O_i D_j \exp(-\beta C_{ij})$$

$$A_i = \left[\sum_j B_j D_j \exp(-\beta C_{ij})\right]^{-1}$$

$$B_i = \left[\sum_i A_i O_i \exp(-\beta C_{ij})\right]^{-1}$$

Ninjkamp (1975) specified a more general gravity model where A_i, B_j are the balancing factors that guarantee the fulfillment of the conditions:

$$A_i = \left[\sum_j B_j D_j f(-\beta, C_{ij})\right]^{-1}$$

$$B_i = \left[\sum_i A_i O_i f(-\beta C_{ij})\right]^{-1}$$

Since the pioneering work of Wilson (1967), several other types of models have been generated, depending of the distribution of the function, and the type of problem to be

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interaction analysis is based on the assumption that physical regularities can be transposed to social phenomena and they can be used to derive the most probable configuration of a system.

addressed. The model can be unconstrained, when neither the total origin trips or the total destination trips are known, production or attraction constrained, when only one set of the trips is known, and doubly constrained, when the total origin and destination trips are known. A production-constrained model is more widely used when there is only information about the number of flows originating in each zone, as in the case of allocation of retail flows from residential zones to retail establishments (Fotherinngham, 1987). The attraction constrained model is used when there is information only about the number of flows attracted at each zone, such as the case of residential land use or destinations for health care (Bikker, 1992). The doubly constrained model is the more generally applied to trips distribution and transportation models (Fortheringham, 1989).

On the other hand, several other types of models have been formulated, depending of the distribution of the impedance between the origin i and the destination j. Choukroun, (1975) developed a series of spatial interaction models:

Exponential Model:

$$T_{ij} = Kp_iq_j \exp(-c_{ij})$$

Inverse Distance Model:

$$T_{ij} = \frac{Kp_iq_j}{(d+C_{ij})^n}$$

Mixed Exponential Inverse Distance Model

$$T_{ij} = \frac{Kp_iq_j \exp(-f(C_{ij}))}{(d + C_{ij})^n}$$

where

p_i = P_i/PT, proportion of trip generations in i.

q_j = Q_j/QT, proportion of trip attractions in j.

Other common spatial interaction models identified by Pitfield (1978) are:

The negative exponential function:

$$f(C_{ij}) = \exp(-\beta C_{ij})$$

The negative power function:

$$f(C_{ij}) = C_{ij}^{-\beta}$$

And the Tanner function:

$$f(C_{ij}) = \exp(-\beta_1 C_{ij}) C_{ij}^{-\beta 2}$$

Based on empirical evidence, Pitfield suggests that the negative exponential function is more appropriate for shorter distance flows, while the negative power function is more appropriate for longer distance flows.

Fotheringham (1983) introduces the concept of competing destinations. Competition between two localities exists when the probability of making a particular trip realization decreases as that destination is located in close proximity with other destinations. The application of the competing destinations constraint in the gravity model reduces the possibility of under-predicting volumes for destinations with high levels of interaction and over-predicting volumes for destinations that are highly inaccessible. Fik (1992) noted the need to incorporate into the model the hierarchical nature of competing and intervening origins and destinations.

A double-constrained gravity model that includes competing and intervening origins and destination takes the form:

$$T_{ij} = A_i B_j O_i D_j G_{ij}{}^{w} f(-\beta, C_{ij})$$

$$A_i = \left[\sum_j B_j D_j f(C_{ij}{}^{-\beta}) \right]^{-1}$$

$$B_j = \left[\sum_i A_i O_i f(C_{ij}{}^{-\beta}) \right]^{-1}$$

$$G_{ij} = \sum_{k \neq i,j} D_k C_{jk}{}^{-\beta}$$

G_{ij} is the potential accessibility variable and measures the relative location of a destination with respect to all other destinations

3.2. The Transportation Model

Several types of transportation models have been used to evaluate the distribution, capacity for agricultural products for a region at the national and international levels (Koo, 1985). These studies have focused on finding the optimal location of processing facilities, finding the best combination of transportation modes for grain distribution and analyzing capacity constraints of networks and ports. A typical linear programming model used in transportation research is expressed as:

Minimize Z

$$Z = \sum_{i} \sum_{j} C_{ij} X_{ij}$$

subject to

$$\sum_{i=1}^{n} X_{ij} \leq D_i$$

$$\sum_{i=1}^{n} X_{ij} \leq S_i$$

C_{ij} = is the unit transportation cost of shipping one unit of commodity from producing region i to consuming region j.

X_{ij} = is the total quantity of a commodity shipped from producing region j to consuming region i.

D_i = Demand of the commodity in the consuming region

S_i = Supply of the commodity in the producing region.

This linear programming model has been applied for low volume roads in developing countries (Cook, 1991). However, there are several limitations due to the characteristics of low-volume rural roads in developing areas. Important drawbacks are the difficulty for evaluating the benefits of upgrading or building a rural road, the financial constraints, and the high proportion of the population that does not have adequate accessibility to an all weather road.

The lack of accessibility for rural communities means limited household income for farmers because of limitations for marketing products and high transportation costs. Farmers are not able to sell their products at a competitive price, they do not have access to improved seeds and latest technology and are not able to get fertilizer and pesticides at a good price and when its needed. On the other hand, marginal rural communities have lack of access to health and education services, amenities and employment opportunities. The lack of accessibility affects the poorest groups more, specially the small farmers that live in the marginal regions (Huddleston, 1990).

Some studies claim that the best way to measure the net benefit of increased mobility and accessibility is to measure the consumer surplus and the producer surplus (Cook, 1990). The consumer surplus approach stresses the quantification of road user savings and it is recommended for cases where the existing normal traffic or its projected growth is substantial and the estimated transport cost savings are a reliable measure of project benefits. The produce surplus approach stresses the assessment of economic activity, particularly agricultural production in the road's zone of influence. This model is recommended to be used for situations where there is enough information about the zone of influence of a road, the prices and yields of the agricultural products (Beenhakker, 1983). Among the recognized impacts of transportation improvements in low volume roads for developing countries are the increased agricultural production, the reduced costs of agricultural inputs, the availability of agricultural inputs at the right time, greater access to health, education, transport, increased trade, economies of scale, increases in productivity and access to technological change.

The variables usually considered in the evaluation process are producer surplus effects such as agricultural value added, increased agricultural production, increased land brought under cultivation; measures of consumer surplus such as vehicle operating costs savings for passenger and freight and investment and maintenance costs (Cook, 1990). Other effects that have been recognized as part of the impacts of transportation investment include increase in property values, population growth and distribution, increase in local revenues and increase in commercial and industrial activity (Huddleston, 1990). However, these studies have recognized the difficulty and the controversial nature of the measurement of these benefits. There are two problems in the quantification of these effects: first the problem of attribution that relates to the difficulty of defining the impacts only to changes in the transportation system, and second, the problem of double counting the benefits as the key variables are tied together in a regional economy. Some approaches (Forkenbrock, 1990) assert that all road benefits are derived from lower transportation costs, and they can also be represented as increases in the real incomes of individuals in their roles as consumers and producers. In this matter, all the benefits from a road investment are passed on to consumers and producers even when they do not directly use the road.

Empirical results of studies of accessibility to rural roads in developing countries (Mazlumolhosseini, 1990) have shown that transportation and agriculture are two economically important sectors that are strongly associated with changes in accessibility. The relationship between agriculture and transportation shows that rural dwellers can gain by transportation improvements by selling their crops at higher prices and buying inputs at cheaper prices as a consequence of cheaper transportation costs. The other socioeconomic effects would be simultaneous to increases in welfare in rural households measured by a reduction in transportation costs and increased agricultural production. Other studies have shown that in some cases rural roads do not generate increased agricultural production but increases in transport flows of non-agricultural commodities (Cook, 1990). However, these studies recognize a lot of uncertainty in measuring the potential increases in non-agricultural traffic.

These measurement problems has resulted in great uncertainty regarding investment in new links, upgrading and timing of new investment for rural roads at the regional level. Kumar (1991) developed a methodology for planning rural road networks based on optimum use of the a limited budget. The benefits of developing a rural road network include increased agricultural production, better access to hospitals, schools, administrative and employment areas and reduced sense of isolation. In this study, the benefits will be conservatively measured as the reduction of transportation costs of agricultural commodities.

The costs of developing a road network are the costs of construction, the cost of maintenance and the vehicle operating costs. The environmental costs of potential damage by a road construction are not computed into the analysis.

The methodology developed by Kumar (1991) for planning optimal rural networks in based on the optimal use of expenditure. The benefits of an optimal rural road network are achieved at the least cost by solving the function:

Minimize F

$$F = \sum_{i=1}^{n} \left[mZ(X_i, C_i) + I(C_i) \right]$$

where

C_i =	Construction specification of the rural link i
X_i =	Traffic flow in the link i
$I(C_i)$=	Construction Costs

$Z(X_i,C_i)$= Travel costs as a function of traffic flow and characteristics of the rural road

m= Factor of additivity of travel costs and construction costs.

3.3. The Benefit-Cost Analysis and Maximization of Benefits

The benefit-cost analysis is based on the changes in the consumer surplus that are caused by the project. The economic appraisal of the project requires the valuation of the opportunity cost for the nation in which the project will be situated. Derived from this concept, is the cost-saving benefit of investing on a project (Mishan, 1988). On the case of transportation projects, consumer surplus can be measured in two ways:

1. The cost-saving component which is calculated as the savings per trip times the number of trips.
2. The consumer surplus resulting from the additional trips generated by the project.

The economic appraisal of the project requires the valuation of the opportunity cost for the nation in which the project will be situated. The project appraisal is made in both financial and economic terms. The analysis in economic prices is made in terms of shadow prices. A shadow price is the price attributed to a good instead of the existing price when it's more appropriate for the purpose of economic calculation (Mishan, 1988). Shadow prices may be also defined as the value of the contribution to the country's basic socioeconomic objectives made by any marginal change in the availability of commodities (Squire, 1975).

There are several criteria for deciding whether or not to invest in a project. Both costs and benefits need to be discounted to reflect the incidence of time (Overseas Development Administration, 1988). Some basic criteria are the average rate of return, which is simply the sum of the net benefits divided by the number of years, expressed as a percentage. The most commonly used are the Net Present Value criteria (NPV) and the Internal Rate of Return (IRR). The NPV is the algebraic sum of the net benefits discounted to it's present value.

$$NPV = \sum_{i=1}^{n} \frac{B_t}{(1+r)}$$

where B_t are the net benefits in time t and r is the rate of discount.

The value of NPV depends upon the rate of discount used. The correct rate of discount is the rate that reflects society's rate of time preference. The formula above assumes that the time value of benefits falls at a constant rate. However, the rate of discount may vary over time. The investment decision rule is to accept the project if:

$NPV > 0$

The calculation may also be done by discounting the costs and benefits individually and the rule becomes that the discounted benefits should not exceed the costs (Irvin, 1978) :

$B > C$ or $B/C > 1$

The Internal Rate of Return is the rate which makes the present value of the benefits equal to the present value of the costs:

$$\sum_{i=1}^{n} \frac{B_t}{(1+IRR)} = 0$$

Where IRR is the discount rate that reduces the present value of net benefits to zero. The decision rule corresponding to the IRR is to accept the project if IRR is greater than the cost of capital (Irving, 1978).

For the purpose of determining whether a single project should or should not be implemented, the NPV and the IRR give the same results. However, empirical results show that in ranking projects, NPV and IRR will not always show the same results.

On the other hand, the benefits may be weighted. The weighting consists on the assignment of different values to marginal benefits. Benefits may be given different weights according to the region or income group. The weight d_i is calculated by the formula:

$$d_i = \left(\frac{CB}{C_i}\right)^n$$

where CB is the average consumption level, C_i is the level of consumption of group i and n is the rate at which utility increases relative to an increase in consumption.

For the projects in this study, the benefit-cost ratio (B/C) was used for ranking, in combination with a linear programing algorithm that maximizes the economic benefit function, but no weighting of the benefits of the project was done. The maximization of benefits was done by maximizing the objective function that represents the economic benefits of the projects in question.

4. SOURCE OF DATA AND METHODOLOGY

4.1. Sources of Data

The Colombian political division is composed of departments, intendencies, and comisariates, depending on the population and the level of economic activity. A department has the higher level of economic activity. Each department is subdivided into municipalities and the municipality is the lowest level of political authority. The region of study consists of two groupings of departments, the CORPES (Regional Council of Economic and Social Planning) of the Occident Region and the CORPES of the Atlantic Region. Together, the two CORPES comprise 30% of the land in Colombia, 18% in the Occident Regional and 12% in the Atlantic Region.

For each department there is information on the proportion of the area that is used in agriculture, the three principal crops and their yield for the 1990 year. The 15 Departments are grouped into a CORPES, the Regional Council of the Occident Region and the Regional Council of the Atlantic Region. Each one of these Councils groups a number of departments with similar geographic and economic characteristics. The Departments of the Council of the Occident Region are mainly coffee growing departments which are located over the Andean region, are densely populated and have two important urban centers, Cali and Medellin. The region is crossed by the Western Trunk Highway that runs from the Ecuadorean border to the Caribbean coast and is connected also to the port of Buenaventura in the Pacific. Buenaventura moves about half the country's dry cargo and is the main outlet for coffee exports. Besides coffee, sugar cane and bananas are important export products for this region. Staple food production consists of plantains, beans, corn and fruits.

The Departments of the Council of the Atlantic Region are less intensely dedicated to export agriculture, but mainly to cattle and staple food production. The only important export product has traditionally been cotton. The main staple products are plantain, corn, rice and African palm. Population densities are lower and the main geographical characterization is coastal plains and valleys with a sparse road network. This region is connected to the Occident Region by the Western Trunk Highway and to the country's capital by the Central Trunk Highway.

Each Department is divided into municipalities. For each municipality there is information about the population, area, the fiscal income, the three principal agricultural products and its principal market center. There is also information available on cattle production (kgs.), the value of industrial production (if any) and industrial employment. The municipal information and it's sources is shown on Table 4.1 and the Departamental information and it's sources is shown on Table 4.2.

Table 4. 1. Municipal information and its sources

Variable	Description	Source
Municipality	Name of Municipality, may be an origin or a destination	Municipal Statistics 1990
Population	Population of the Municipality	1985 Census
Area	Area in m2	Municipal Statistics 1990
Principal Products	Three most important agricultural products of the municipalities	Municipal Statistics 1990
Cattle Production	Kilograms of beef produced	Municipal Statistics 1990
Market Center	Center where the principal market transactions are done	Municipal Statistics 1990
Industry	Industrial production in thousand of pesos	1990 Industry Census

Table 4.2. Departmental information

Variable	Description	Source
Name	Department Name	
Agricultural Area	Proportion of the total area that is dedicated to agriculture	First National Agricultural Census 1990
Crops	Six principal crops in the department	First National Agricultural Census 1990
Yields	Average yield for each crop (kgs/Ha)	First National Agricultural Census 1990
Truck	Average size for truck in the region (Tons)	Traffic Volumes 1991

The information of the road network for the regions is codified for each road that connects a municipality. The network is classified into national, departmental and other roads. For each link, there is information on origin, destination, traffic volume, type of road and type of pavement (paved or unpaved). There is also the longitude of the link and the volume of traffic. The road and traffic information is shown on Table 4.3. The traffic counts are only available for the national roads, and the traffic on municipal and other roads is not systematically counted

Table 4.3. Road information

Variable	Description	Source
Initial Code, Final Code	Codification of the link	Own codification
Description	Description of the road	National Road Network 1990
Origin	Municipality of Origin	National Road Inventory
Destiny	Municipality of Destiny	National Road Inventory
Distance	Distance between origin and destination	National Road Network 1990
Paved	Indicates if the road is paved or not	National Road Network
Observed Traffic	Average Daily Traffic	Traffic Volumes 1991

Additional information was used on how much was exported during 1990 for domestic consumer demand and about the pesticides and fertilizer average consumption for each one of the principal export and staple crops. On the other hand, the model will use the operational transport costs that are developed on a yearly basis by the Ministry of Transportation through the HDM III model [2].

The construction and upgrading costs will be estimated based on World Bank data for developing countries, as well as cost estimates published by the Ministry of Public Works.

The model will focus on one department of the Occident region, the department of Antioquia, which is part of the CORPES of the Occident region. This department was chosen because it contains 25 percent of the road network, has a wide variety of subregions and provides a typical case of study for the application of the methodology in any other department. It is mainly a coffee growing region, but it is also the main banana growing and export department as well as an important grower of staple foods. It is also a link between the Occident region, the Atlantic Region and the capital of the country. On the other hand, this department also has marginal zones in the east and the west, consisting mainly of tropical rain forest. The location of this department is shown in Figure 4.1.

As shown on Figure 4.1, this department is located on the north-west corner of the country and is linked to the main ports in the Atlantic Ocean (Santa Marta, Barranquilla and Cartagena) by a national road and to the main port on the Pacific Ocean (Buenaventura) as well. It's capital, Medellín, is the second largest city in the country, and it is directly linked to the capital, Bogotá, and the third largest city, Cali. These connections consist mainly of paved two-lane roads that go across mountainous regions.

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[2] This model was developed by the World Bank and is traditionally used for estimating transportation costs for various types of roads (paved, unpaved, flat, mountainous or rolling hills terrain and several types of vehicles). It also considers travel time cost for freight and passengers.

Figure 4.1. Geographic characteristics of the zone of study

The department of Antioquia consists of 142 municipalities, as shown on Figure 4.2. These municipalities include Medellin, the capital, as well as coffee growing zones and some isolated regions near the Chocó department where agriculture is less intense. There is also a wide variety of climates because the Department is crossed by the Occident and Central Andean mountain ranges and by the Cauca River valley. These topographical characteristics also make construction of roads difficult and expensive.

4.2. Description of the Model

The model that this project used for forecasting traffic was a double-constrained, negative power function that incorporates the concept of competing destinations:

$$T_{ij} = A_i B_j O_i D_j G_{ij}{}^{w} f(-\beta, C_{ij})$$

$$A_i = \left[\sum_j B_j D_j f\left(C_{ij}{}^{-\beta} \right) \right]^{-1}$$

$$B_j = \left[\sum_i A_i O_i f\left(C_{ij}{}^{-\beta} \right) \right]^{-1}$$

$$G_{ij} = \sum_{k \neq i,j} D_k C_{jk}{}^{-\beta}$$

The model only simulates flows for agricultural commodities and is divided in two sub-models: 1) a gravity model for simulating export crops and 2) a gravity model for simulating the flows of staple foods.

The model for agricultural export flows simulates flows among the municipalities and the principal cities and the ports for each region. Since there are few large cities and ports, this sub-model does not have the constraint of competing or intervening destinations:

Figure 4.2. Codification and links of the municipalities of Antioquia

$$T_{ij} = A_i B_j O_i D_j G_{ij}^{w} (C_{ij}^{-\beta})$$

$$A_i = \left[\sum_j B_j D_j (C_{ij}^{-\beta}) \right]^{-1}$$

$$B_j = \left[\sum_i A_i O_i (C_{ij}^{-\beta}) \right]^{-1}$$

O_i = Number of trips of agricultural exports at the origin i.

D_j = Number of trips of agricultural exports at the destination (constrained by the demand for exports).

C_{ij} = Cost of the trip between i and j as a function of the characteristics of the road.

A_i and B_j are the balancing factors of the equation.

The second sub-model simulates the movement of staple foods among the municipalities and their market centers. Since staple foods can be marketed also in other municipalities that may be closer than the nearest market center, this model will be constrained with the competing destination condition:

$$T_{ij} = A_i B_j O_i D_j G_{ij}^{w} (C_{ij}^{-\beta})$$

$$A_i = \left[\sum_j B_j D_j (C_{ij}^{-\beta}) \right]^{-1}$$

$$B_j = \left[\sum_i A_i O_i (C_{ij}^{-\beta}) \right]^{-1}$$

$$G_{ij} = \sum_{k \neq i,j} D_k C_{jk}^{-\beta}$$

O_i = Number of trips of agricultural products at i

D_j = Population at market center j

C_{ij} = Cost of the trip between i and j

$G_{ij}{}^{W}$= Sum of the alternative population centers at which the products can be marketed.

Since the flows modelled are unidirectional, but the observed values are flows in both directions, the model will also contemplate back-haul flows. The back-haul flows are mainly going to be in the form of pesticides and fertilizers as a proportion of the total agricultural yield at production site i.

In the case of the transportation model, the traffic flows of the rural network are unknown and will be estimated through the gravity model described in the last section. The travel costs are based on a combination of the consumer surplus and the producer surplus approach, mainly by calculating the decrease in operation costs of moving agricultural goods and agricultural inputs and the travel time costs.

The transportation model will be based on the following assumptions:

1) The production patterns and the size of the farms does not influence the potential for traffic flows.
2) The on farm consumption is negligible
3) The prices of the products at the local market will not be affected by the road improvement.
4) The vehicle-operating costs of non-agricultural flow are negligible.
5) The increase in agricultural production is not a certain outcome of the road improvement.

The transportation model will be based on a methodology developed by Kumar (1991). This methodology for planning rural networks is based on the optimal use of the expenditure. The benefits for developing a rural road network will be conservatively measured in the reduction of transportation costs of agricultural commodities. The optimal rural network is achieved at the least investment cost by solving the function:

maximize $Z = \sum_i B_i(X_i, C_i)$

subject to:

$$\sum_i I(C_i) \leq M$$

where

C_i =	Construction specification of the rural link i
X_i=	Traffic flow in the link i
$I(C_i)$=	Construction or upgrading costs
$\mathbf{Z}(X_i,C_i)$ =	Benefits as a function of traffic flow and characteristics of the rural road.
M=	Budget constraint.

In this model, only the upgrading of earth roads or the construction of new roads will be considered.

4.3. Application of the Gravity Model

4.3.1. Generation of Potential Agricultural Trips

The generation of agricultural trips is based on the three principal agricultural products for each municipality and their yield. The model assumes that for each municipality, the proportion of area that can be used for agriculture is the same as the proportion of cultivable land of the department, and the yields of the products for each municipality are the same as the yields for the department at which they belong. The yields vary widely across departments.

The agricultural potential is divided into export and staple potential trips, and according to the distribution of the products and the model assigns a proportion of land to be used for export crops and a proportion for staple crops. The model calculates potential trips in the following way:

$$EX_j = \sum_i \frac{\left(\frac{(\mathrm{Re}ndi_k)}{(100 AE_j A_j)}\right)}{Ton_k}$$

$$ST_j = \sum_i \frac{\frac{\mathrm{Re}\,ndi_k}{(100 AS_j A_j)}}{Ton_k}$$

where:

EX_j = The potential for agricultural export trips in municipality j.

ST_j = The potential for staple food trips in municipality j.

$Rendi_k$=Yield of export crop i in kgs/Ha for department k.

AE_j= Proportion of cultivable land of municipality j that is dedicated to export crops.

ASj= Proportion of cultivable land of municipality j that is dedicated to staple crops.

Aj= Area in Km^2 of municipality j

Tonk= The average truck size for department k.

The potential for staple and export trips correspond to the potential for trips for a year, and they were seasonally adjusted to take into account the variation in flows through the year. The potential for trip attraction is calculated based on the consumption of fertilizer for each zone and on the demand for food of the population of the zone and for ports and strategic locations, the demand for exports. The potential for trip attraction is calculated as follows:

$$FET_j = \frac{(FE_j 100 AE_j A_j)}{Ton_k}$$

if the area is dedicated to export cropping

$$FST_j = \frac{(FS_j 100 AS_j A_j)}{Ton_k}$$

if the area is dedicated to staple crops

FEj= Fertilizer requirement for the average export crop

FS= Fertilizer requirement for the average staple crop

$$P_j = \frac{(Pop_j Dem_j)}{Ton_k}$$

where

Popj =Population in zone j

Demj =Average food consumption for the Colombian

The total potential for trip attraction was found by adding all the relevant potentials for the zone.

4.3.2. The Cost Function

For each link between origin i and destination j, the model looks at the distance between the two points and the type of road. The type of road may be paved, unpaved or an earth road. For each type of road, the model uses the economic cost per km for a middle-sized truck, based on the data on transportation costs provided by the Ministry of Transportation in Colombia, which is based on the model HDM-III of the World Bank. These data include the time costs for passenger and freight.

The cost per vehicle is a function of the distance and the type of terrain. The cost function used in the model has the following form:

Cost Function $= f(C_{ij,\, dij,\, terrain}) = C_{ij}^{-\beta}$

4.3.3. Calibration of the Model

The objective of the calibration process is to have a known generation matrix. This matrix is generated based on the network that has the information about traffic flows. This matrix is used to forecast the traffic volumes of the existing links for which there is no information and for forecasting the traffic flows of the network with added or improved links.

In this model, there are three variables that have to be estimated: the balancing factors Ai and Bj and the parameter β . For this type of calibration, Fotheringham (1989) estimates two basic methodologies. The first methodology is by linearizing the equation:

$$T_{ij} = A_i B_j O_i D_j G_{ij}{}^{w} C_{ij}{}^{-\beta}$$

The best methodology for linearizing the doubly-constrained gravity model is by the relationship:

$$\ln(T_{ij}) = \left[\frac{\sum_i \ln(T_{ij})}{n} - \frac{\sum_j \ln(T_{ij})}{m} + \frac{\sum_i \sum_j \ln(T_{ij})}{nm}\right] +$$

$$-\beta\left[\ln(C_{ij}) - \frac{\sum_i \ln(C_{ij})}{n} - \frac{\sum_j \ln(C_{ij})}{m} - \frac{\sum_i \sum_j \ln(C_{ij})}{nm}\right]$$

where:

$\frac{\sum_i \ln(T_{ij})}{n}$ the row of the $\ln T_{ij}$

$\frac{\sum_j \ln(T_{ij})}{m}$ the column mean of the $\ln T_{ij}$

$\frac{\sum_i \sum_j \ln(T_{ij})}{nm}$ The mean over all the range of the $\ln T_{ij}$

This transformation presents problems in the estimation of the constant term because it tends to have a downward bias. The goodness of fit statistics are not very useful to predict the interactions, and since the transformation includes logarithms, the interaction that involves zero flows between two points cannot be defined in this model.

These problems arise because the equations of the doubly-constrained gravity model are intrinsically non-linear and therefore, the application of linear methods will lead to biased estimates of the parameters (Batty, 1972). Furthermore, it can be shown that no consistent estimate can be obtained from ordinary least squares estimation (Anselin, 1988). Thus, Wilson (1970), Batty (1972) and Fotheringham (1989) recommend the use of the maximum likelihood estimation as a more efficient methodology for estimating the parameters. Maximum likelihood estimators are consistent, asymptotically efficient and asymptotically normally distributed.

The theory of maximum likelihood estimation is based on identifying a theoretical distribution for the interaction, and according to the maximum likelihood principle, the values of the parameters that maximize the distribution are the best estimators (Batty, 1972).

For a doubly constrained model, the best estimates of the model's parameters can be found by solving:

$$\sum_i \sum_j T_{ij}' \ln(C_{ij}) = \sum_i \sum_j T_{ij} \ln(C_{ij})$$

$$\sum_i \sum_j T_{ij}' = \sum_i \sum_j T_{ij}$$

where T_{ij}' are the estimated traffic flows.

The model was calibrated with a starting value of $\beta = 1.0$. The initial values of A_i where calculated according to the double constrained interaction formula and used as inputs to calculate the B_js. This iteration calculation was done until the values of A_i and B_j do not change over further calculations.

The stable values of A_i and B_j were put into the doubly constrained model and the model generated a set of predicted traffic flows. These traffic flows were compared to the real traffic flows and the constraint equation was checked. If the constraint was not met, the value of β was changed and the cycle was repeated..

4.4. Loading of the Road Network

The origin-destination matrix contains 480 origin-destination pairs, consisting of multiple combinations of 104 origins and 86 destinations. These combinations include all the competing set of destinations for each origin. The origin -destination matrix is shown in Appendix B.

The calibration of the A_is and B_js was done over this matrix, as well as the cumulative distance decay function $C_{ij}^{-\beta}$. The traffic for each origin-destination pair was then calculated based on the parameters. The results for the A_is, B_js and the cumulative distance decay function are shown on Appendix C, as well as the individual traffic counts for each link. The estimated traffic flows were then loaded in a road network matrix, adding each traffic flow that went over the links of the network. The aggregated level of traffic was then compared to the real traffic counts, and statistical tests were done on the road network matrix as well as on the origin-destination matrix. These tests are going to be discussed in the next section..

5. STATISTICAL ANALYSIS

5.1. Goodness of Fit Statistics

Williams (1984), Fotheringham (1989), Pitfield (1978) and Batty (1972) identified a set of statistics to measure the goodness of fit of the calibration. Fotheringham (1989), states that a reasonable strategy for evaluating spatial interaction models should include a combination of R^2 and the SRMSE, the Standardized Root Mean Square Error. The most commonly statistic identified by these authors is the R^2. The R^2 is based on regressing the set of predictions in the model:

$$T_{ij} = \alpha + \gamma T_{ij}'$$

The R^2 calculated in this form:

$$R^2 = \frac{\left[\sum_i \sum_j (T_{ij} - \overline{T}_{ij}) - (T_{ij}' - \overline{T}_{ij})\right]}{\sum_i \sum_j (T_{ij} - \overline{T}_{ij})^2 - \sum_i \sum_j (T_{ij}' - \overline{T}_{ij})^2}$$

where TIJ is the mean value of T_{ij}.

The parameter γ can be estimated in this form:

$$\gamma = \frac{\sum_i \sum_j T_{ij} \sum_i \sum_j T_{ij} / N - \sum_i \sum_j T_{ij} - T_{ij}^{'}}{\left[\left(\sum_i \sum_j T_{ij}^{'} \right)^2 / N - \left(\sum_i \sum_j T_{ij}^{'} \right)^2 / N \right]^{\frac{1}{2}}}$$

The standard error of γ' is defined as:

$$SE\gamma = \frac{\left(\sum_i \sum_j \left(T_{ij} - T_{ij}^{'} \right) / (N-2) \right)}{\left[\sum_i \sum_j T_{ij}^{'2} - \left(\sum_i \sum_j T_{ij}^{'} \right)^2 / N \right]^{\frac{1}{2}}}$$

A t statistic can be done on γ, with the purpose of testing the significance of γ being different than zero. The estimated value of γ yields further information about the model's predictions. If $\gamma > 1$, large interaction tend to be under-predicted and small interactions tend to be under-predicted.

The SRMSE is calculated as:

$$\text{SRMSE=} \quad \frac{1}{T} \sum_i \sum_j \left(T_{ij} - T_{ij}^{'} \right)^2 / N$$

where T is the average traffic over all the range of T_{ij}.

The SRMSE has a value of zero when the observed flows are replicated perfectly and increasing values indicate loss of accuracy.

5.2. Analysis of Spatial Autocorrelation

Another approach for statistical testing involves the measure of spatial autocorrelation. Spatial autocorrelation occurs when the independent variables display interdependence over space (Cliff, 1981). Spatial autocorrelation or spatial dependence is a source of measurement problems because of spatial aggregation and spatial interaction effects. Spatial autocorrelation or network autocorrelation will have two effects on a specified model. The first effect is mainly on the error terms. This case will correspond to a poor match between the phenomenon to be explained and the clustering of available data. The second effect will cause the independent variable to be determined by dependent values that are a function of location (Anselin, 1991). In this case, there is a two-dimensional, two-directional dependence in space. The latter is the type of measure that is relevant to the analysis by Maximum Likelihood Estimator parameter. In this case the parameter is β, calculated by the gravity model algorithm. Spatial organization generates at the same time interactions that are used in modelling spatial flows (Anselin, 1988). There are several ways of measuring spatial autocorrelation. One method is by representing the effect of spatial dependence on a dependent variable by using the spatial autoregressive model:

$$X_i = \rho \sum_j W_{ij} X_j + \varepsilon_i$$

Where εi is the independent error term, the constant ρ is the measure for spatial autocorrelation among (X_i, X_j) and W_{ij} are the weights that specify which areas j are spatially related with area i. In defining the elements of the weight matrix, it is stated that the value of the W_{ij} element is assigned a value if the locations i and j are connected and zero otherwise. W_{ij} can also represent a function of the distance between i and j such as:

$$W_{ij} = (C + d_{ij})^{-\beta}$$

Models such as the Geary model measure spatial autocorrelation between two places X_i and X_j by the expression:

$$C = \frac{(n-1)\sum_i \sum_j (X_i - \overline{X}_i)(X_j - \overline{X}_j)}{2\overline{W}(X_i - \overline{X}_i)^2}$$

where $\overline{X}_i$ is the mean value of all the X_i and $\overline{W}_{ij}$ is the overall average of W_{ij}.

The value of 1 for C implies that there is no spatial autocorrelation between the is and js related but the weight matrix (Getis, 1992). A similar, but most commonly used measure for spatial autocorrelation corresponds to Moran's I statistic (Black, 1992). Calculation of the index I is done as follows:

$$I = \frac{n\sum_i \sum_j W_{ij}(X_i - \overline{X}_i)(X_j - \overline{X}_j)}{\sum_i \sum_j W_{ij} \sum_i (X_i - \overline{X}_i)^2}$$

The expected value of I is

$$E(I) = \frac{-1}{(n-1)}$$

and

$$\frac{\left[n^2 S_1 - nS_2 + 3\left(\sum_i \sum_j W_{ij}^2\right)\right]}{\sum_i \sum_j W_{ij}^2 (n^2 - 1)} - E(I)^2$$

where:

$$S_1 = \frac{1}{2}\left[\sum_i \sum_j (W_{ij} + W_{ji})^2\right]$$

$$S_2 = \sum_i \left(\sum_j \left(W_{ij} + \sum_i W_{ji} \right) \right)$$

The I statistic can be qualitatively interpreted as described by Cliff (1981), with values near $\pm$ 1, when there is strong autocorrelation. Also, a Z test can be done on this statistic, where high values of Z(I) imply that the positive covariance is high.

A specific approach for relating spatial autocorrelation and spatial interaction was developed by Getis (1990), based on the assumption that the spatial interaction model is a special case of a general model of spatial autocorrelation. The purpose of this test is to check that the correlation between origin and destination has statistical significance. The G statistic for the gravity model takes the form:

$$G_j = \frac{\sum_j X_j X_i C_{ij}^{-\beta}}{\sum_j X_j X_i}$$

and

$$E(G_j) = \sum_{i,j} C_{ij}^{-\beta}$$

where $C_{ij}^{-\beta}$ is the distance decay function and X_i, X_j are the parameters of association between zones i and j. Specifically for this model:

$$X_i = A_i D_i$$

$$X_j = B_j O_j .$$

where A_i and B_j are the balancing factors of the gravity model equation and D_i and O_j are the number of trips generated at origin i or destination j.

The test for positive or negative spatial autocorrelation is done in the form of

$$Z = \frac{G_{ij} - E(G_{ij})}{\left(E(Var(G_{ij}))\right)^{\frac{1}{2}}}$$

where

$$Var(G_{ij}) = \sum_{j} \frac{C_{ij}^{-\beta}\left(N - 1 - C_{ij}^{-\beta}\right)Y_2^{\,2}}{(N-1)^2(N-2)Y_1^{\,2}}$$

$$Y_1 = \frac{\left(\sum_{i} X_i\right)}{(N-1)}$$

$$Y_2 = \frac{\left(\sum_{j} X_j^2\right)}{(N-1) - Y_1^{\,2}}$$

A large positive Z implies that large values are spatially associated. A large negative Z means that small X_j are spatially associated with one another. A test is done to assess the significance of Z being smaller than zero or larger than zero. A null hypothesis, Z=0 implies that the interaction is no larger or smaller that should be expected (Getty, 1992). The rejection of the null hypothesis implies that the pattern of data points will not contribute to bias in the results.

Getis (1992), recommends that any test for spatial autocorrelation should use both G and I statistics. Both statistics measure dependent structure in spatial patterns but the I statistic is more sensitive to changes in Xs while the G statistic is more sensitive to changes in the distance function.

6. RESULTS FROM THE GRAVITY MODEL

6.1. Interpretation of Statistical Results

6.1.1. Statistical Significance of the Maximum Likelihood Estimator

The Maximum Likelihood parameter for β was found to be 2.18467. It was found through successive iterations by the maximum likelihood algorithm as shown in figure 6.1. Figure 6.2 shows how the minimization of the maximum likelihood functions was done simultaneously with a reduction of the squared sum of errors (SSE).

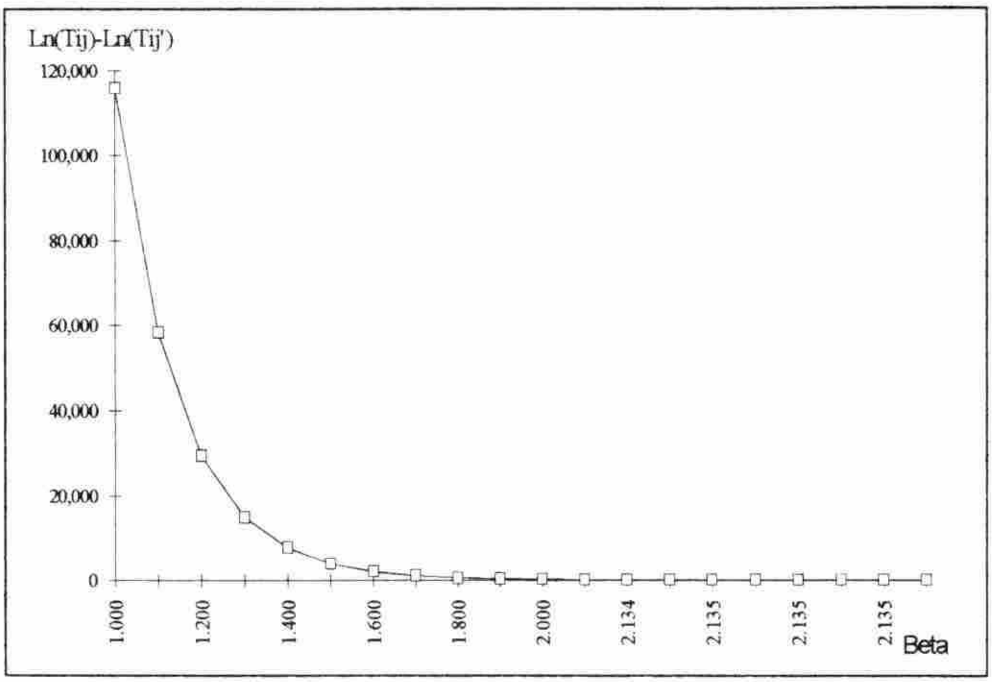

Figure 6.1. Convergence of Ln(Tij)

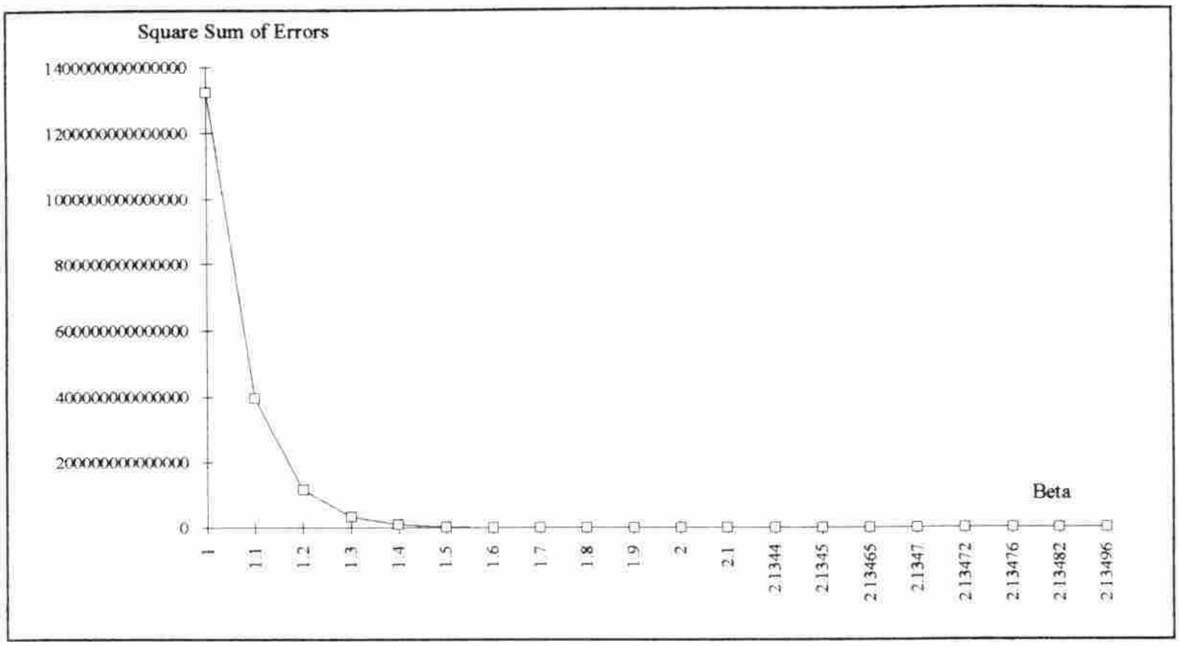

Figure 6.2. Minimization of the sum of standard errors.

With the estimated parameter β, the model calculates values of traffic for each origin-destination group. Each value of traffic was superimposed in the existing network and compared with the real traffic flows: The statistical results of the spatial interaction model and the statistical significance of the parameter γ are summarized in Table 6.1.

Table 6.2 shows the calculated values of traffic and the real level of traffic for the base network in the model. The origin and destination network is shown in Appendix B.

Table 6.1. Summary of statistical results for $T_{ij} = \alpha + \gamma T_{ij}'$

R^2	α	γ	F-Statistic	SRMSE	t-statistic	Confidence Interval for γ'
0.5431	1916.2	0.5435	49.927	0.343	7.065	0.388,0.699

Table 6.2. Values of calculated Traffic

ORIGIN	DESTINATION	DISTANCE	COST	Tij	Tij'	Residual
PUERTO BERRIO	MACEO	60	27768	704	1595	-891
MACEO	CISNEROS	47	21752	1410	3310	-1900
CISNEROS	SANTO DOMINGO	20	9256	2025	1349	676
SANTO DOMINGO	BARBOSA	20	9256	2031	1184	847
BARBOSA	GIRARDOTA	18	7258	4475	1230	3245
SAN JERONIMO	ANTIOQUIA	20	8065	302	381	-79
ANTIOQUIA	GIRALDO	35	16198	302	239	63
GIRALDO	CANASGORDAS	21	9719	302	376	-74
CANASGORDAS	URAMITA	28	65375	302	184	118
URAMITA	DABEIBA	45	98062	1507	135	1372
DABEIBA	MUTATA	85	49031	230	112	118
MUTATA	CHIGORODO	70	98062	226	223	3
CHIGORODO	CAREPA	10	16344	1537	3251	-1714
SUPIA	JARDIN	36	16661	635	44	591
JARDIN	ANDES	15	9256	635	2209	-1574
ANDES	HISPANIA	10	9256	635	640	-5
SANTA BARBARA	CALDAS	30	12097	12000	11730	270
CALDAS	ITAGUI	10	4032	12000	11847	153
GIRARDOTA	DON MATIAS	23	9274	7250	8361	-1111
DON MATIAS	SANTA ROSA DE	27	10887	7250	8390	-1140
SANTA ROSA DE	YARUMAL	43	17339	7531	8971	-1440
YARUMAL	VALDIVIA	42	16936	7531	8437	-906
VALDIVIA	TARAZA	75	25000	7532	11664	-4132
TARAZA	CACERES	63	25403	7531	9155	-1624
CACERES	CAUCASIA	63	25403	7531	9787	-2256
CAUCASIA	MONTELIBANO	20	8065	7650	8279	-629
RETIRO	LA CEJA	14	5645	1442	380	1062
LA CEJA	LA UNION	15	6048	1492	640	852
LA UNION	SONSON	55	25454	1304	1624	-320
EL CARMEN	BOLIVAR	31	14347	605	453	152
BOLIVAR	AMAGA	57	26380	2398	2168	230
AMAGA	CALDAS	29	11694	4307	53	4254
GUARNE	MARINILLA	22	8871	9907	73	9834
MARINILLA	SANTUARIO	10	4032	7604	12851	-5247
SANTUARIO	COCORNA	32	12903	4683	3215	1468
COCORNA	SAN LUIS	38	15323	6008	6267	-259
SAN LUIS	PUERTO TRIUNF	68	27420	2663	781	4861
RIONEGRO	SANTUARIO	20	8065	8279	2598	5003
SUPIA	SANTA BARBARA	93	37500	7742	11708	-3966
MEDELLIN	RETIRO	25	11570	6274	63	6211
MEDELLIN	GUARNE	20	8065	6273	16537	-10264
MEDELLIN	RIONEGRO	32	12903	2422	847	1575
MEDELLIN	SAN JERONIMO	45	18145	3243	2663	580
MEDELLIN	GIRARDOTA	37	12556	4474	8279	-3805

Even though the obtained value or R^2 is below the average obtained in gravity models, it is a good result considering the several sources of error that were involved in the principal assumptions and in the real traffic flows. These sources of error will be discussed in the next section. The γ parameter is 0.5435, when it should be around an unity and the α parameter is 1916, when it should be around zero. These results suggest that small traffic flows are going to be underpredicted. The value of the F-Statistic, however, shows a strong linear relationship between the real and the estimated values. The SRMSE also shows a relatively high level of accuracy in the model. The t-test on γ' shows that γ' is significantly different from zero. However, γ is significantly less than 1. It means that small level of interactions are going to be under-predicted and large interactions are going to be over-predicted. Figure 6.3 shows the relationship between the real values of traffic and the estimated traffic and how small real interactions are going to be underpredicted.

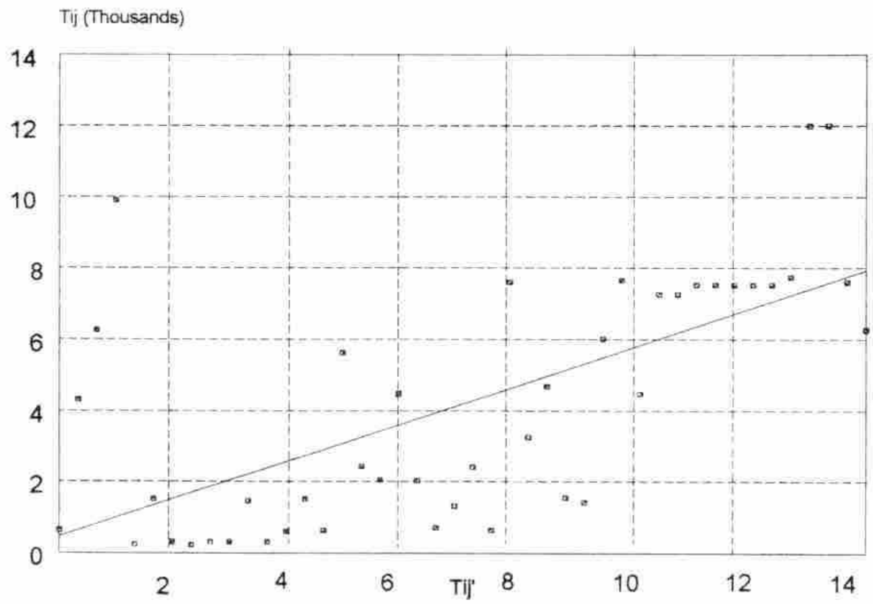

Figure 6.3. Relationship between estimated and real levels of traffic

Since the model is going to be applied to low volume roads, it may constitute a source of error by systematically underpredicting the types of flows that are of special interest. The distribution of the residuals does not show any sign of heteroscedasticity. The size of the error does not seem to be related to the size of the traffic flows.

The results from the model were studied in the context of the socioeconomic situation of the municipalities and its links, looking for discrepancies between the real traffic flows, the expected traffic flows and the type of economic activity of the region.

There are three points in which the model predicted low levels of traffic while high volumes occurred. These three points were assumed to have some external influence, such as the presence of the international airport in the case of the links Medellin-Retiro and Guarne-Marinilla. For the link Amaga-Caldas, the presence on industries in both municipalities is probably responsible for the discrepancy. These three points not considered in the model because they were considered to be a source of distortion, and the statistical results without these point improved considerably. The new statistical results with the modified database are shown on Table 6.3.

Table 6.3. Summary of statistical results for $Tij = \alpha + \gamma Tij'$

R^2	α	γ	F-Statistic	SRMSE	t-statistic	Confidence Interval for γ
0.84453	1228.6	0.6172	96.9978	0.216	9.848	0.490,0.744

As a result of ignoring these particular destinations, the R^2 improves to 0.84, which is about the average that has been obtained for gravity models. The results from the F-Statistic and the t-statiscs show improved values and the α and γ parameters are closer to the expected values. Although the confidence interval for γ' continues to be biased downward, the bias is reduced with the modifications. As a result of this experiment, it can be concluded that the characteristics of certain locations may introduce sources of error and when the model is going to be applied, other types of economic activities besides agriculture should be studied.

6.1.2. Spatial Autocorrelation

Firstly, the Geary test was done on the overall network and the resulting value, 0.2869 does not indicate the existence of spatial autocorrelation. Then, both the I and the G statistics were calculated on the overall network and, under the assumption of normality, the statistical significance of spatial autocorrelation was tested by testing the null hypothesis $Z<1$ or $Z>1$. A Z statistic greater than 1.96 in absolute value will indicate that there is positive or negative spatial autocorrelation. As shown on Table 6.4, there is no significant proof of spatial autocorrelation by the use of the I or G statistic.

Morgan's I statistic has a higher value, which suggest the existence of a degree of spatial autocorrelation. This means that the value of Xs, or the weighted parameters are more significant in determining spatial autocorrelation that the distance among the points. Overall, it can be concluded that spatial autocorrelation is not a source of biased results. This means that the size of the error terms is not a function of the distance between the points.

Table 6.4. Tests for spatial autocorrelation

Statistic	Calculated value	Expected value	Variance	Z
I	0.575163	-0.002127	3.0002	-1.40005
C	0.001433	0.013172	13.4046	-0.00320

G tests were done individually for each individual origin-destination subnetwork, and no evidence of spatial autocorrelation was found for any particular link included in the model. The results of these tests are shown in Appendix D. An example of how the G statistics is calculated is shown for the municipality of Abejorral in Table 6.5.

Table 6.5. Calculation of the G statistic for the Abejorral municipality.

MARKET	LA CEJA	LA UNION	MEDELLIN	RETIRO	SONSON	AGGREGATE
C_{ij}^{-B}	4.49477E-07	1.078E-06	7.70728E-08	2.2998E-07	6.46E-08	1.89874E-06
A_I	18.01	18.01	18.01	18.01	18.01	90.06
B_I	0.5541	5.1358	0.0026	0.0549	1.0048	6.7522
T_{II}	2.59	371.55	0.88	2.04	5.45	382.51
D_I	1306	1306	3816	1306	1306	9040
P_I	442	2854	63435	6868	3568	77167
$\Sigma X_i X_i C_{ij}^{-B}$	2.589	371.555	0.878	2.039	5.448	382.510
$\Sigma X_i X_i$	5760964	344796075	11391933	8867994	84332916	455149883
$C_{ij}^{-B} * (n-1-C_{ij}^{-B})$	2.24739E-06	5.388E-06	3.85364E-07	1.1499E-06	3.23E-07	9.49372E-06
G_i						8.40405E-07
X_i	23523.32344	23523.323	68732.77354	23523.3234	23523.32	162826.0673
X_i^2	59978.14346	214845997	27470.53595	142119.422	12852774	227928339.4
Y_1						56982084.84
Y_2						-2.6455E+10
$VAR(G_{ij})$						0.042632964
$Z(G)$						-0.00000513

On the other hand, the I statistic was calculated for the whole combination of origin and destinations. However, this statistic may be calculated for each origin and all its possible destinations and a Z test may be done as well to test spatial dependence. An example of how the I statistic may be used on an individual set of relationships is shown on Table 6.6. Also, the individual results indicate that there is no spatial autocorrelation in the origin-destinations groups in the network. For both statistics, a t test on the 95 percent level of significance shows no evidence of spatial autocorrelation between the municipality of Abejorral and its four destinations.

Table 6.6. Calculation of the I statistic for the Abejorral municipality

MARKET	LA CEJA	LA UNION	MEDELLIN	RETIRO	SONSON	AGGREGATE
C_{ij}^{-B}	4.49477E-07	1.078E-06	7.70728E-08	2.2998E-07	6.46E-08	1.89874E-06
A_I	18.01	18.01	18.01	18.01	18.01	
B_I	0.5541	5.1358	0.0026	0.0549	1.0048	
T_{IJ}	2.59	371.55	0.88	2.04	5.45	
D_{IJ}	1306	1306	3816	1306	1306	
P_{IJ}	442	2854	63435	6868	3568	
X_i	23523.32344	23523.323	68732.77354	23523.3234	23523.32	32565.21346
X_j	244.9043557	14657.626	165.7423782	376.987297	3585.077	3806.067303
X_j^2	59978.14346	214845997	27470.53595	142119.422	12852774	
X_I-XB_i-	-9041.89002	-9041.89	36167.56008	-9041.89	-9041.89	
X_I_XB_j	-3561.16295	10851.559	-3640.32492	-3429.08	-220.991	
W_{IJ}*()	14.47301041	-105.7333	-10.1475378	7.13064286	0.129095	-94.1480911
X_I_XB_i^2	81755775.14	81755775	1308092402	81755775.1	81755775	
$W_{ij}(X_i$-$XB_j^2)$	36.74736885	88.100606	100.8183858	18.8022701	5.281961	249.7505916
W_{ij}^2	2.0203E-13	1.161E-12	5.94022E-15	5.2891E-14	4.17E-15	1.42627E-12
I						-1.5079
E(I)						-0.3333
Var(I)						41.428
S_1						7.13136E-13
S_2						1.42627E-12
Z(I)						-0.0284

6.2. Other Sources of Error

Other sources that may contribute to error in the model are the variables on which the model is based, and the accuracy of the observed traffic. One of the main variables that determines the number of trips in the model is the average size of the truck. This variable is calculated as the weighted average of the number of trucks for each weight category. The standard weights for each category vary from 10 to more than 35 tons, and these categories account for the maximum loaded capacity for each truck. The average weighted load for a truck in the region of Antioquia is 18.7247 tons with a standard error of ± 2.7506 tons. Although this variation is not very large, the average value represents a composition of different truck sizes as shown in Table 6.7. On the other hand, the observed traffic values correspond to counts taken during one week of the year, and there may be many factors such as seasonality and external factors that may introduce additional sources of error to the estimated values of traffic

Table 6.7. Composition and variability of the average truck

Average	18.7247
Standard Deviation	2.7506
Proportion of 10 ton Trucks	23.79%
Proportion of 15 ton Trucks	52.95%
Proportion of 20 ton Trucks	9.48%
Proportion of 35 ton Trucks	9.95%
Proportion of truck > 35 ton	3.83%

The average value of traffic for the zone of study was 6159 vehicles per day, but the average standard error, calculated according to the instructions in the traffic count report, amounts to ± 275 vehicles per day, which is the sign of a high level of error in the measuring of traffic flows. On the other hand, there is a high degree of uncertainty involving the estimation of the agricultural yields and the degrees of food consumption in the population. More detailed surveys of these relevant variables will certainly yield more accurate forecasts.

7. PREDICTIONS WITH THE GRAVITY MODEL

7.1. Generation of Traffic

After calibration, the results of the model were used first to calculate the traffic flows for the links where there was no traffic information available. The estimated levels of traffic between the codified origin and destinations in the network for which there are no traffic counts are shown on Table 7.1. These correspond to low volume traffic links.

Table 7.1. Calculated traffic flows for existing links in the network

ORIGIN	DESTINATION	DISTANCE	Initial Code	Final Code	Calculated Traffic
SAN PEDRO	DON MATIAS	22	045	054	8
YARUMAL	ANGOSTURA	15	035	034	326
AMALFI	VEGACHI	63	143	022	303
REMEDIOS	PUERTO BERRIO	102	023	024	366
SAN ROQUE	SANTO DOMINGO	22	104	073	32
REMEDIOS	SEGOVIA	18	023	106	187
PUERTO BERRIO	LA MAGDALENA	38	024	089	401
CAUCASIA	NECHI	68	070	094	118
FRONTINO	ABRIAQUI	27	079	007	683
BETULIA	URRAO	42	047	113	1629
JERICO	PUEBLO RICO	11	059	060	1894
MACEO	YALI	19	025	122	2042
YALI	YOLOMBO	47	122	123	2383
CARAMANTA	VALPARAISO	17	062	057	170
VALPARAISO	TAMESIS	25	057	058	3063
SAN PEDRO	BELMIRA	20	045	044	1486
ENTRERRIOS	SANTA ROSA DE	35	076	053	252
YARUMAL	CAMPAMENTO	20	035	052	501
DON MATIAS	ENTRERRIOS	21	054	076	8
GOMEZ PLATA	CAROLINA	15	080	090	42
CAROLINA	ANGOSTURA	28	090	034	23
SAN ANDRES	TOLEDO	20	088	087	592
GRANADA	SAN CARLOS	39	081	082	3245

Table 7.1. (Continued)

ORIGIN	DESTINATION	DISTANCE	Initial Code	Final Code	Calculated Traffic
PENOL	GUATAPE	15	084	083	25
MARINILLA	PENOL	17	074	084	673
RETIRO	MONTEBELLO	26	004	093	19
GUATAPE	SAN RAFAEL	26	083	103	33
SAN VICENTE	CONCEPCION	23	105	013	481
ARMENIA	TITIRIBI	31	043	048	72
HELICONIA	EBEJICO	36	136	133	809
LIBORINA	SAN JOSE DE L	50	131	117	161
ALEJANDRIA	SANTO DOMINGO	6	012	073	529
CONCEPCION	ALEJANDRIA	17	013	012	323
PUEBLO RICO	TARSO	13	060	061	279
ZARAGOZA	EL BAGRE	20	137	135	4673
VEGACHI	REMEDIOS	22	022	023	558
TURBO	SAN PEDRO	30	037	118	27
ITUANGO	TOLEDO	20	086	087	1096
OLAYA	LIBORINA	17	092	131	1327
BETANIA	ANDES	15	046	027	198
TAMESIS	JERICO	27	058	059	2888
SONSON	ARGELIA	35	006	042	1817
LA UNION	ABEJORRAL	52	002	001	361
APARTADO	TURBO	35	036	037	5331
PENOL	GUARNE	20	084	075	19
SAN ANDRES	SANTA ROSA DE	35	088	053	117
NECOCLI	TURBO	23	095	037	118
ENTRERRIOS	SAN PEDRO	20	046	045	229
SAN ANDRES	LIBORINA	70	088	131	46
SABANALARGA	LIBORINA	20	116	131	41
CONCEPCION	BARBOSA	23	013	014	8
MACEO	CARACOLI	30	025	056	391
SONSON	ARGELIA	35	006	042	1817
LA UNION	ABEJORRAL	52	002	001	361
CAICEDO	URRAO	45	112	113	319
ANTIOQUIA	OLAYA	17	009	092	36
VENECIA	CALDAS	32	120	020	9
BETULIA	SALGAR	40	047	101	769
SAN ANDRES	YARUMAL	30	088	035	2200
BARBOSA	DON MATIAS	20	014	054	4
URAMITA	PEQUE	68	068	107	858
CAUCASIA	ZARAGOZA	35	070	137	1272
ITAGUI	HELICONIA	20	021	136	3
SANTA BARBARA	FREDONIA	35	078	132	301

All the links in this table represent unpaved roads on secondary links. However, according to the results of the model, some of them have high levels of traffic, between 1500 and 2200 vehicles per day. This should be an important consideration for paving secondary roads. However, the focus of this paper is to consider upgrading from earth to all-weather, unpaved roads.

7.2. Transformation of the Existing Network

Some transformations were made on the existing network. These transformations included the upgrading of existing earth roads and the connection of municipalities to the rest of the network by an all weather road. Thus, an objective network is defined, where all the municipalities are integrated to the rest of the network by an all weather road, according to the methodology suggested by Kumar (1991). On this transformed network additional runs of the gravity model were done. The addition of a link affected mostly the particular link and the effect on the rest of the network was fairly small. Thus, the traffic flows of the additional network were considered to be independent of the existence of the other proposed links.

The resulting network links all the municipalities to a main road by an all-weather road either by upgrading an existing link or adding a new link to the network. With this new network, additional forecasts for traffic were made. The upgraded links correspond to links in the coffee-growing zone of the region, where the terrain is mountainous and construction costs are high. The added links to the network correspond to new links among mountainous zones in the coffee growing region. The links to be upgraded are shown on Figure 7.1. The forecasted traffic is shown on Table 7.2.

Figure 7.1. Proposed Investment Projects

Table 7.2. Traffic forecasts for the upgraded and extended traffic network.

ORIGIN	DESTINATION	DISTANCE	Type of Ro: (1)	Initial Code	Final Code	Calculated Traffic	Generated Traffic	Difference
DABEIBA	MUTATA	85	E	066	065	112	112.15	0
TITIRIBI	CALDAS	31	E	048	020	47	68.07	21
TARSO	VENECIA	25	E	061	120	43	255.37	212
GRANADA	SANTUARIO	15	E	081	134	3484	4239.18	755
ABRIAQUI	GIRALDO	15	E	007	008	85	226.43	141
BETULIA	ARMENIA	40	E	047	043	100	265.42	165
ANGELOPOLIS	LA ESTRELLA	20	E	138	139	0	56.36	56
ANORI	CAMPAMENTO	45	A	127	052	0	0.01	0
GUADALUPE	ANGOSTURA	25	A	140	034	0	56.60	57
MURINDO	ARGELIA	20	A	114	042	0	0.19	0
BRICENO	YARUMAL	27	A	111	035	0	209.38	209
CONCORDIA	TITIRIBI	20	A	129	048	0	10.70	11
ANZA	EBEJICO	20	A	143	133	0	51.68	52
SOPETRAN	SAN JERONIMO	15	A	119	010	0	0.09	0
BURITICA	GIRALDO	15	A	128	008	0	0.00	0
MURINDO	DABEIBA	60	A	114	066	0	0.00	0
VIGIA DEL FUE	URRAO	75	A	121	113	0	0.08	0
YONDO	PUERTO BERRIO	75	A	124	024	0	0.00	0

(1) 'E' stands for an upgraded earth road and 'A' stands for an added link to the network

These types of links will incorporate the municipalities of Anori, Guadalupe, Narino, Briceno, Concordia, Titiribi, Anza, Sopetran and Buritica. Since the main economic activity of these municipalities is coffee growing, there are possibly some links with the main network but mostly by penetration roads. The other municipalities, Murindo, Vigia del Fuerte and Yondo are marginal zones of the region. The main form of communication is made by river, but it is assumed that the conditions of these municipalities do not allow for export crop growing. Thus, the assumption is made that the incorporation of these zones will generate trips related to staple-food growing crops.

7.3. Cost Benefit Analysis of the Transformations in the Network

A cost-benefit analysis of the upgrading and adding of links was made as shown in table 7.3. For the links that were upgraded from earth to all-weather roads, the benefits were calculated as a reduction in operating costs for both the normal traffic that would exist without the upgrade and for the traffic that was generated by the upgrading. For each type of road, the model uses the economic cost per km for a middle-sized truck, based on the data on transportation costs provided by the Ministry of Transportation in Colombia, which is based on the model HDM-III of the World Bank. This model was developed by the World Bank and is traditionally used for estimating transportation costs for various types of roads (paved, unpaved, flat, mountainous or rolling hills terrain and several types of vehicles). It also considers travel time cost for freight and passengers and the costs are considered in both financial and economic terms.

The benefits for the new transport links, reductions of transport cost, are not an adequate measure of the economic benefits of the project. The benefits of the new link were calculated according to the methodologies proposed by Adler (1987) and Cook (1990) for new transport facilities. Under the assumption that the new link incorporates economic activity that would not have taken place without the improvement. Then, the value of the additional output is the measure of the economic benefit. These methodologies were discussed in detail in Chapter 3.

In the case of coffee growing zones that were incorporated, the net benefit is the value of the coffee that would be transported through the road, and in the case of marginal zones, the net benefit is the value of the staple food that would be taken to the market. These benefits were calculated according to the on farm prices of agricultural commodities. However, there are other types of benefits such as the effects of increased agricultural production, increased land brought into cultivation and benefits from non-agricultural sources such as decreased costs of passenger traffic that are not taken into account in this analysis. Also, there are some benefits such as increased trade, increased availability of education and health service that cannot be measured in economic or financial terms.

The costs that were considered included investment and maintenance cost over a 15 year period, which is considered to be the life span of the road. The investment cost differed whether it was an upgrade, or new construction in a coffee growing zone or a marginal zone.

Construction costs for marginal zones are higher, mostly because the transportation costs of construction material are much higher. The Colombian Ministry of Public Works publishes the approximate investment and maintenance costs for these categories. The costs are published in both financial and economic terms and the economic costs include the shadow prices of the activities.

Both costs and benefits were discounted over a 15 year period at a selected discount rate of 12%, which is the conventionally used for investment projects by the Colombian government. Then, the benefit-cost ratio was calculated. Of the eighteen projects that were evaluated, eight had a benefit/cost ratios greater than one, in economic terms. All the economically feasible projects are located in the coffee growing zone. Four of the upgraded links and four of the additional links resulted in a benefit cost ratio greater than one in economic and financial costs. Of the ten non-viable projects, six corresponded to coffee growing zones and four to marginal zones. However, none of the projects of the marginal zones had benefit-cost ratios greater than one.

The most viable projects, the projects with greater benefit-cost ratios, ranked under the highest benefit-cost ratios were:

1. Briceno-Yarumal
2. Anza Ebejico
3. Guadalupe-Angostura
4. Concordia-Titiribi

The other viable projects, Dabeiba-Mutata, Granada Santuario, Abriaqui-Giraldo and Betulia-Armenia had benefit cost ratios very close to one. All of these viable projects are located in the coffee growing zone and are shown on Figure 7.1. The non-viable projects on the marginal zones and on the coffee growing zones are also shown on this figure. The non-viable projects of the coffee growing region correspond to Murindo-Dabeiba, Vigia del Fuerte-Urrao and Yondo-Puerto Berrio. One of the reasons for the low feasibility of these projects is the high construction costs of marginal zones and the length of the road which is required.

This economic analysis underestimates the benefits, specially in the marginal zones where the benefits from integration with the economy of the country and the social costs of marginalization are very hard to measure. This type of evaluation is sensitive to the volume of traffic generated, as well as on-farm prices. Since during the 1970s and the 1980s the Colombian government was following a policy of intervention in agricultural prices, and on farm-prices are by affected government policies (Berry 1992). Thus, the type of governmental policy influencing agricultural prices will have an effect on the viability of the project.

On the other hand, the benefits are calculated on a node to node basis. However, there might be some benefits of incorporating a node into the network that may affect the whole system, but the model does not quantify these benefits. Also, it is possible that the traffic that goes through a new link may consist of both generated traffic and traffic that is diverted.

The traffic may be diverted as new alternative routes with lower operating costs are created, but the model does not differentiate between diverted and generated traffic. This is likely to happen when the incorporated node was not serviced directly but through an indirect link.

On the other hand, some congestion may be created in other links by incorporating a new node and generating additional traffic. This additional burden on the traffic network may cause increased congestion in some links of the network, and increased congestion has a cost. However, the model is not able to quantify these additional costs.

Table 7.3. Cost benefit analysis of the upgraded links
Economic costs (Colombian pesos)

ORIGIN	DESTINATION	DIST	TYPE OF ROAD (1)	UPGRADED TRAFFIC	REDUCTION IN TRAVEL COSTS (000)	INVESTMENT (2) (000)	MAINT. COST (000)	TOTAL COST	NET S BENEFIT	BENEFIT /COST
1. DABEIBA	MUTATA	85	E	112.1595	525,863	5,304,000	3,612,482	8,916,482	15,856,027	1.78
2. TITIRIBI	CALDAS	31	E	68.0770	80,799	1,934,400	1,317,493	3,251,893	2,436,299	0.75
3. TARSO	VENECIA	25	E	255.3706	59,840	1,560,000	1,062,494	2,622,494	1,804,331	0.69
4. GRANADA	SANTUARIO	15	E	4239.1844	288,244	936,000	637,496	1,573,496	1,963,196	1.25
5. ABRIAQUI	GIRALDO	15	E	226.4364	70,689	936,000	637,496	1,573,496	2,131,441	1.35
6. BETULIA	ARMENIA	40	E	265.4201	220,873	2,496,000	1,699,991	4,195,991	6,659,856	1.59
7. ANGELOPOLIS	LA ESTRELLA	20	E	56.3692	62,185	4,000,000	2,724,345	6,724,345	423,537	0.06
8. ANORI	CAMPAMENTO	45	A	0.0182	0	9,000,000	6,129,778	15,129,778	138,346	0.01
9. GUADALUPE	ANGOSTURA	25	A	56.6068	0	5,000,000	3,405,432	8,405,432	429,241,629	51.07
10.NARINO	ARGELIA	20	A	0.1954	0	4,000,000	2,724,345	6,724,345	1,481,331	0.22
11.BRICENO	YARUMAL	27	A	209.3806	0	8,100,000	5,516,800	13,616,800	1,587,705,027	116.60
12.CONCORDIA	TITIRIBI	20	A	10.7078	0	4,000,000	2,724,345	6,724,345	81,196,054	12.07
13.ANZA	EBEJICO	20	A	51.6856	0	6,000,000	4,086,518	10,086,518	391,925,175	38.86
14.SOPETRAN	SAN JERONIMO	15	A	0.0918	0	3,000,000	2,043,259	5,043,259	696,159	0.14
15.BURITICA	GIRALDO	15	A	0.0006	0	3,000,000	2,043,259	5,043,259	4,469	0.00
16.MURINDO	DABEIBA	60	A	0.0017	0	18,000,000	12,259,556	30,259,556	2,186	0.00
17.VIGIA DEL FUE	URRAO	75	A	0.0800	0	22,500,000	15,324,445	37,824,445	103,013	0.00
18.YONDO	PUERTO BERRIO	75	A	0.0002	0	22,500,000	15,324,445	37,824,445	247	0.00

(1) 'E' stands for an upgraded earth road and 'A' stands for and added link to the network.

(2) 62.4 Million Pesos per km for an upgraded link, 200 Million pesos per km for an added link in mountainous terrain and 300 million pesos per km for and added link in rain-forest terrain.

Table 7.3. (Continued)
Financial costs

ORIGIN	DESTINATION	DIST	TYPE OF ROAD (1)	UPGRADED TRAFFIC	REDUCTION IN TRAVEL COSTS (000)	INVESTMENT (2) (000)	MAINT. COST (000)	TOTAL COST (000)	NET S BENEFIT (000)	BENEFIT /COST (000)
1. DABEIBA	MUTATA	85	E	112.1595	502,388	7,182,500	4,891,903	12,074,403	15,856,027	1.31
2. TITIRIBI	CALDAS	31	E	68.0770	77,192	2,619,500	1,784,105	4,403,605	2,436,299	0.55
3. TARSO	VENECIA	25	E	255.3706	57,169	2,112,500	1,438,795	3,551,295	1,804,331	0.51
4. GRANADA	SANTUARIO	15	E	4239.1844	2,753,771	1,267,500	863,277	2,130,777	1,963,196	0.92
5. ABRIAQUI	GIRALDO	15	E	226.4364	67,533	1,267,500	863,277	2,130,777	2,131,441	1.00
6. BETULIA	ARMENIA	40	E	265.4201	211,013	3,380,000	2,302,072	5,682,072	6,659,856	1.17
7. ANGELOPOLIS	LA ESTRELLA	20	E	56.3692	59,409	1,690,000	1,151,036	2,841,036	423,537	0.15
8. ANORI	CAMPAMENTO	45	A	0.0182	0	12,187,500	8,300,741	20,488,241	138,346	0.01
9. GUADALUPE	ANGOSTURA	25	A	56.6068	0	6,770,833	4,611,522	11,382,356	429,241,629	37.71
10.NARINO	ARGELIA	20	A	0.1954	0	5,416,666	3,689,218	9,105,884	1,481,331	0.16
11.BRICENO	YARUMAL	27	A	209.3806	0	7,312,500	4,980,444	12,292,944	1,587,705	129.16
12.CONCORDIA	TITIRIBI	20	A	10.7078	0	5,416,666	3,689,218	9,105,884	81,196,054	8.92
13.ANZA	EBEJICO	20	A	51.6856	0	5,416,666	3,689,218	9,105,884	391,925,175	43.04
14.SOPETRAN	SAN JERONIMO	15	A	0.0918	0	4,062,500	2,766,913	6,829,413	696,159	0.10
15.BURITICA	GIRALDO	15	A	0.0006	0	4,062,500	2,766,913	6,829,413	4,469	0.00
16.MURINDO	DABEIBA	60	A	0.0017	0	24,375,000	16,601,482	40,976,482	2,186	0.00
17.VIGIA DEL FUE	URRAO	75	A	0.0800	0	30,468,750	20,751,852	51,220,602	99,147,986	1.94
18.YONDO	PUERTO BERRIO	75	A	0.0002	0	30,468,750	20,751,852	51,220,602	7,385,204	0.14

7.4. Prioritization of the Projects

After the benefit-cost analysis, the question is how to invest scarce resources in transportation projects. To answer this question, the GAMS program for linear optimization was used. The mathematical problem is based on the methodology proposed by Kumar (1991), which is explained in Chapter 4 and it was modified to fit the constraints and specifications of this particular problem. The mathematical form of the problem to be solved is:

Maximize $\sum_i X_i B_i$

Subject to

$$\sum_i X_i C_i \leq I$$

Where X_i is a binary decision variable, the decision to invest or not invest in the construction or upgrading of the road link. B_i is the economic benefit of project i and C_i is the cost of constructing of upgrading link i. I is the budget constraint for investment.

Since there is not enough information about the public finances of the region and the municipalities, a sensitivity analysis was made to determine, under different budget constraints, which would be the optimal investment solution. The projects that were used in the model were only the ones that had a benefit-cost ratio greater than one. The results of the different optimization scenarios are shown on Table 7.4.

For each budget constraint, a yes indicates that the investment project should be included to maximize benefits. The projects that maximize benefits are not necessarily the projects with the greater benefit-cost ratios.

Table 7.4. Investment decisions by maximization of benefits.

Budget Constraint	15,000	25,000	35,000	45,000	55,000	65,000	Marginal Benefit	Benefit/ Cost
Briceno-Yarumal	Yes	Yes	Yes	Yes	Yes	Yes	1,587,700	116.60
Guadalupe-Angostura			Yes	Yes	Yes	Yes	429,240	51.07
Anza-Ebejico		Yes	Yes	Yes	Yes	Yes	319,920	38.86
Concordia-Titiribi				Yes	Yes	Yes	81,196	12.07
Betulia-Armenia						Yes	6,659	1.59
Abriaqui-Giraldo						Yes	2,131	1.35
Dabeiba-Mutata					Yes	Yes	15,856	1.31
Granada-Santuario						Yes	1,963	1.25

The amount of funds needed to invest in all the projects that have a benefit-cost ratio above one corresponds to 65,000 Million pesos. However, the maximizing of benefits does not necessarily rank the projects by the magnitude of the benefit/cost ratio. The marginal benefit of including a project will lead to the decision if a project will be included or not. Under tight budget constraints, the model may choose projects that will not necessarily give the highest returns but have smaller investment costs.

If all the projects were contemplated, including the ones that had benefit-cost ratios smaller than one, the amount needed would be 205,000 Million pesos. The Gams program was also run with all the investment projects and the results are shown on Table 7.5.

By including all the projects in the evaluation the prioritization of project changes and some that have benefit-cost rations below one are included before projects that have benefit-cost ratios above one. There are three variables that have a role in the maximizing of benefits: the profitability of each project, the size of the project and the marginal benefit. The combination of these variables leads to a solution that maximizes the benefits but that does not necessarily corresponds to the ranking of the projects by their profitability.

Table 7.5. Investment decisions by maximization of benefits for all projects

Budget Constraint (000)	Rank	13	35	45	95	120	140	200	220	Marginal Benefit	Benefit/Cost
11.Briceno-Yarumal	1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	1,587,700	116.60
9.Guadalupe-Angostura	2		Yes	Yes	Yes	Yes	Yes	Yes	Yes	429,240	51.07
13.Anza-Ebejico	3		Yes	Yes	Yes	Yes	Yes	Yes	Yes	319,920	38.86
12.Concordia-Titiribi	4			Yes	Yes	Yes	Yes	Yes	Yes	81,196	12.07
6.Betulia-Armenia	6					Yes	Yes	Yes	Yes	6,659	1.59
5.Abriaqui-Giraldo	7					Yes	Yes	Yes	Yes	2,131	1.35
1.Dabeiba-Mutata	8					Yes	Yes	Yes	Yes	15,856	1.31
4.Granada-Santuario	9					Yes	Yes	Yes	Yes	1,963	1.25
2.Titiribi-Caldas	10					Yes	Yes	Yes	Yes	2,436	0.75
3.Tarso-Venecia	11						Yes	Yes	Yes	1,804	0.69
10.Narino-Argelia	12						Yes	Yes	Yes	1,481	0.22
14.Sopetran San Jeronimo	14							Yes	Yes	696	0.14
7.Angelopolis- La Estrella	14						Yes	Yes	Yes	423	0.06
8.Anori-Campamento	16								Yes	138	0.01
15.Buritica-Giraldo										4	0.009
16.Murindo-Dabeiba										2	0.002
17.Vigia del Fuerte-Urrao	5				Yes	Yes	Yes	Yes	Yes	99,147	0.001
18.Yondo-Puerto Berrio	15							Yes	Yes	7,385	0.000

On the other hand, as shown on Table 7.6, if the projects are ranked by the benefit-cost ratio, then the returns of the network will be maximized by maximizing the rate of return of the project selected. In this case, the benefit-cost ratio is the first criteria for selecting a project. However, since the returns of a road can only be obtained by investing on the totality of the road, the cost constraints are a binding criteria. With budget constraints, there may not be enough funds to invests in the projects with higher rates of return. Thus, the question of the selection of investment projects is closely related to the budget constraint. If investment funds are scarce, then project with lesser cost requirements and smaller rates of return would have to be chosen.

Table 7.6. Investment projects ranked by benefit-cost ratios

ORIGIN	DESTINATION	DISTANCE (km)	TYPE OF ROAD	INITIAL CODE	FINAL CODE	PROJECT COST (Financial terms)	BENEFIT-COST RATIO	ACCUMULATED COST
BRICENO	YARUMAL	27	A	111	035	5,682,072	116.5990	5,682,072
GUADALUPE	ANGOSTURA	25	A	140	034	12,292,945	51.0672	17,975,017
ANZA	EBEJICO	20	A	143	133	2,130,777	38.8563	20,105,794
CONCORDIA	TITIRIBI	20	A	129	048	20,488,241	12.0749	40,594,035
DABEIBA	MUTATA	85	E	066	065	11,382,356	1.7783	51,976,391
BETULIA	ARMENIA	40	E	047	043	2,130,777	1.5872	54,107,168
ABRIAQUI	GIRALDO	15	E	007	008	12,074,403	1.3546	66,181,572
GRANADA	SANTUARIO	15	E	081	134	9,105,885	1.2477	75,287,457
TITIRIBI	CALDAS	31	E	048	020	40,976,482	0.7492	116,263,939
TARSO	VENECIA	25	E	061	120	6,829,414	0.6880	123,093,353
NARINO	ARGELIA	20	A	114	042	9,105,885	0.2203	132,199,237
SOPETRAN	SAN JERONIMO	15	A	119	010	6,829,414	0.1380	139,028,651
ANGELOPOL	LA ESTRELLA	20	E	138	139	4,403,606	0.0630	143,432,257
ANORI	CAMPAMENT	45	A	127	052	3,551,295	0.0091	146,983,552
VIGIA DEL F	URRAO	75	A	121	113	51,220,603	0.0027	198,204,155
BURITICA	GIRALDO	15	A	128	008	2,841,036	0.0009	201,045,191
MURINDO	DABEIBA	60	A	114	066	9,105,885	0.0001	210,151,076
YONDO	PUERTO BERR	75	A	124	024	51,220,603	0.0000	261,371,679

The first criteria for the optimization of benefits through optimizing a linear objective function is the cost constraint, while the return on the investment is a secondary criteria. Under a limited budget, projects with small rates of return but with modest costs will be ranked higher than projects with higher rates of return but larger costs. Also, projects with cost-benfit ratios below one may be included early into the selection.

The inclusion of projects that have benefit-cost ratios below one has several drawbacks. Firstly, the inclusion of a project with a benefit-cost ratio below one means than the benefits to society are smaller than the costs of the projects and the society, in this case the region of the country, will decrease it's net welfare by investing in these type of projects. Second, the resources invested in these projects could be better used in other type of investment projects. However, this model is not taking into account many of the benefits and it is probable that some of this projects would have a benefit-cost ratio above one if all the benefits could be quantified.

The two approaches have different results. as shown in Figures 7.2 and 7.3. Figure 7.2 shows which projects could be chosen and its ranking if the primary constraint is the budget constraint. The projects that connect to areas close to the large urban area of Medellín or close to the highway tend to be ranked high, while projects that tend to be in the marginal zones of the east and west of the borders to be ranked low. With a large enough budget, most of the projects could be contemplated. However, even with an unlimited budget, some of the projects of roads in marginal zones are excluded from the model because of their high construction costs and limited benefits.

For these type of projects, another methodology for evaluation that includes the benefits of integrating marginal areas could be used. However, these types of benefits are hard to quantify.

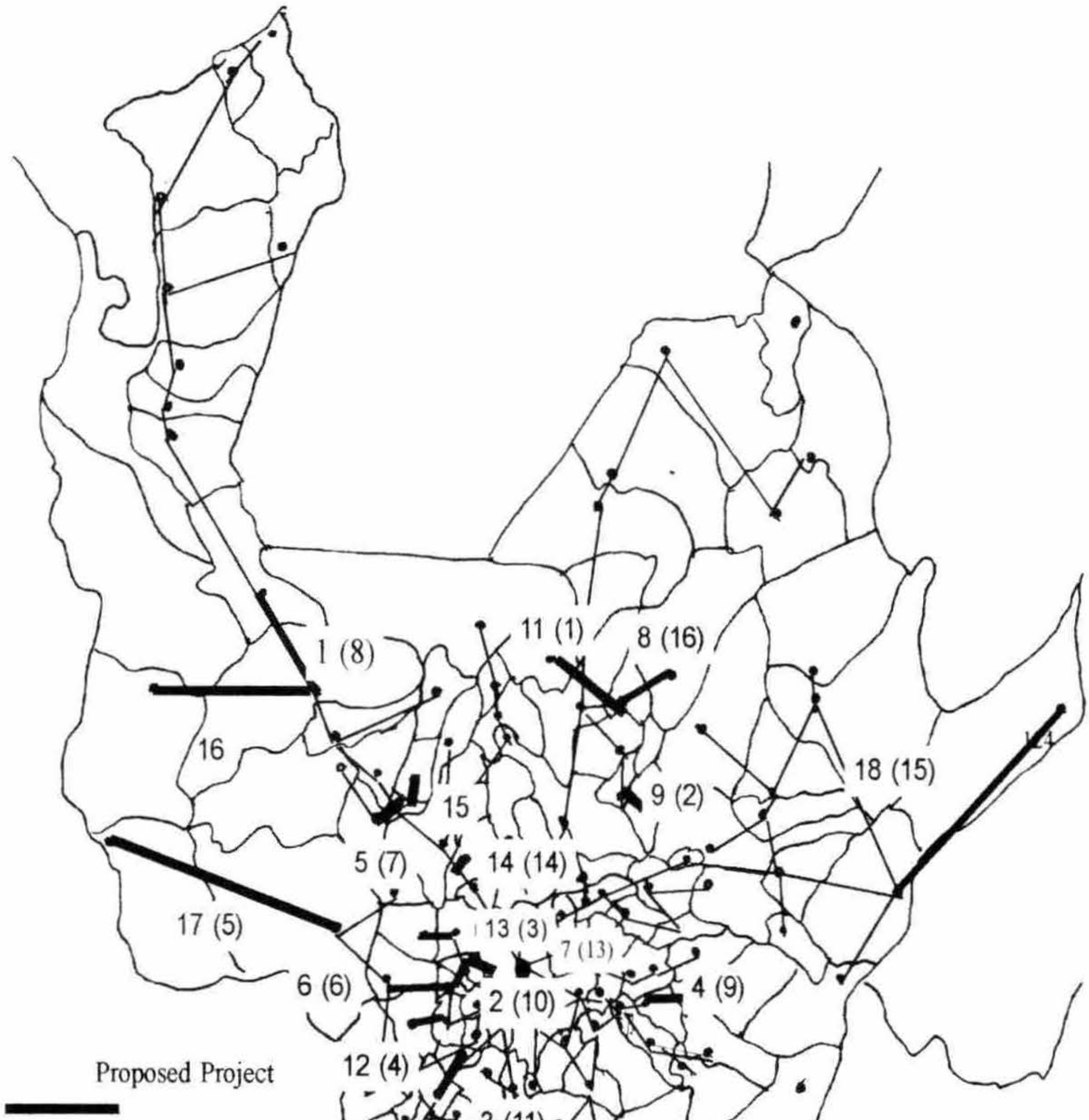

Figure 7.2. Ranking of the projects using cost as a constraint

Figure 7.3 shows how the geographical location of the selected ranked projects would change if the criteria for selection and ranking is the benefit-cost ratio. This methodology has a bias toward roads that are close to the larger urban centers and the main roads. The projects in the marginal zones are not included because of their low benefit-cost ratios.

On the other hand, projects that appeared to be important, such as the Dabeiba-Mutat link, did not rank very high with either of the two approaches. This link is important because it connects the banana growing region with the rest of the Department and the country. However, this type of agricultural activity does not seem to need much interaction with the rest of the country's economy.

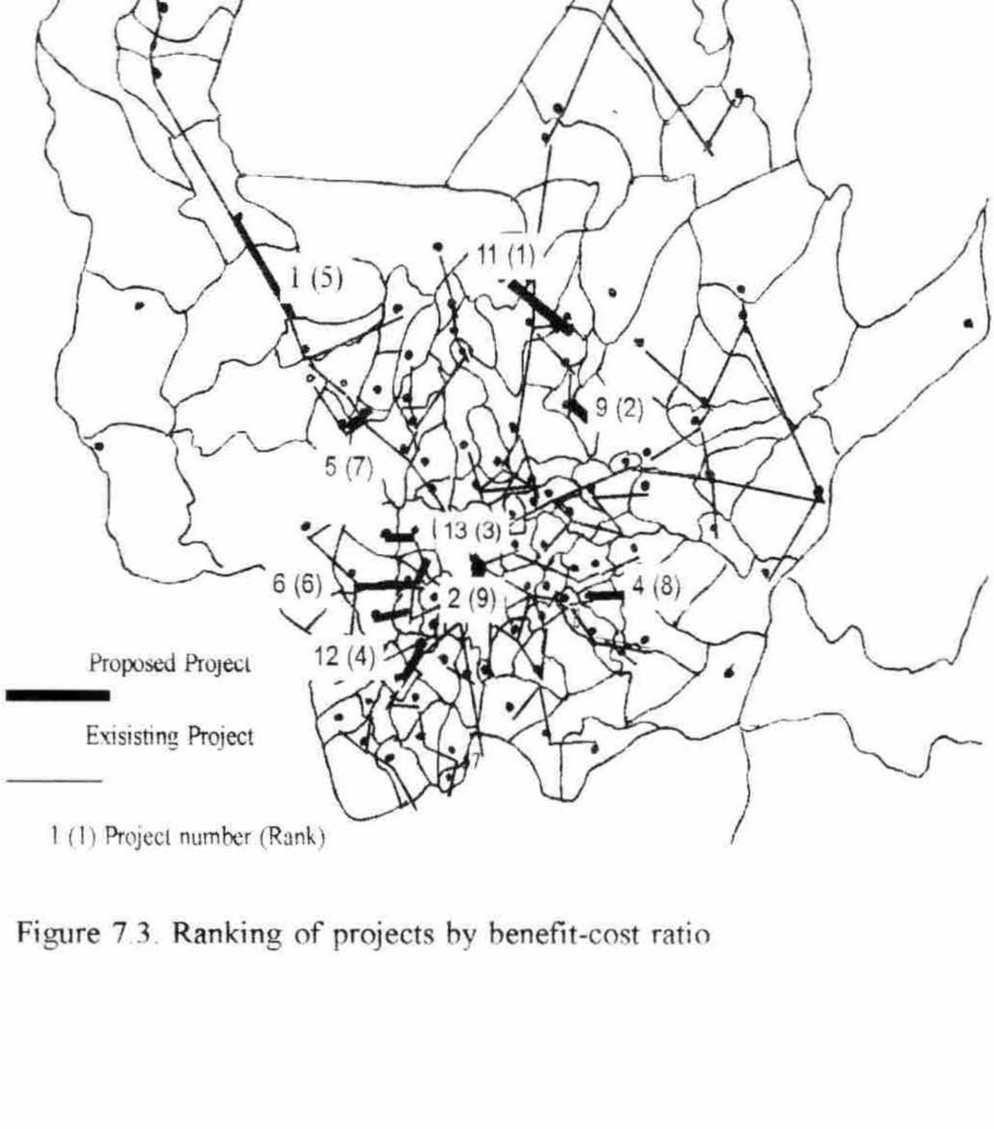

Figure 7.3. Ranking of projects by benefit-cost ratio

8. FURTHER APPLICATIONS AND LIMITATIONS

One of the most relevant limitations is the availability and quality of the Colombian data. The data available was scarce and the main variables used had great variability. This has to be taken in consideration when making investment decisions in the country.

The gravity model applied was intrinsically non-linear. Thus, it cannot be linearized without introducing bias in the estimators. The best model for the estimation of parameters was the gravity model based on a Maximum Likelihood Estimation methodology.

The results of the gravity model for predicting agricultural traffic flows may be affected by the presence of distortions in the area, such as the presence of a large industry or an airport. However, the statistical tests showed satisfactory results. The application of spatial correlation statistics corroborated the goodness of fit of the results.

In the application of models that are based on spatial interactions, the application of spatial analysis is essential to verity the spatial lack of bias of the results.

The cost benefit analysis has the limitation that the benefits were understated and not all of them were quantifiable. Also, some of the costs, such as the environmental costs were ignored in the analysis. This causes uncertainty on the viability of each project. The application of cost-benefit analysis at the same time that a social objective function is maximized will bring slightly different results in the ranking of the projects. The main problem with this is that projects that do not have a cost-benefit ratio above one may be included by maximizing benefits. However, the benefit-cost ratio analysis is biased toward links that are closer to the large urban areas while marginal roads are not likely to be feasible.

The same sequence of model may be applied for the rest of the department of the region of to regional groups of departments. However, the model has to be calibrated again for each new region, to capture the essential characteristics of each interaction.

The results will be likely to improve with more detailed and validated data. An on-site survey of the infrastructure of the region, as well as the socioeconomic conditions will improve the quality of the model.

9. CONCLUSION

A doubly-constrained with competing destinations gravity model was the best type of model which produced the best results for forecasting long-distance traffic flows. The results for forecasting agricultural traffic between rural municipalities in Colombia were satisfactory, even with the limitations of the quality and quantity of the data.

The goodness of fit statistics and the spatial correlation statistics were important in determining the lack of bias of the results. Moreover, the statistics showed satisfactory results in the forecast. Also, the use of several spatial autocorrelation statistics helped determine that the type of activity of the region was more important than the distance in the determination of the interaction.

The results from the application of the cost-benefit analysis varied widely for each of the projects considered. The main factors in this analysis were traffic flows for the calculation of benefits and the investment and maintenance costs. With this methodology, the benefit-cost ratio for investment in roads in marginal zones was much below one. Roads in the marginal zones have above average costs because construction and maintenance costs are higher and the distances longer than on the average project. Also, since these municipalities are not integrated with the rest of the economy, population is scarce and agricultural activity limited. These factor make the potential benefits to be small. Thus, it is very unlikely that this methodology will favor the investment of roads in marginal zones. Also, it is very difficult to predict that with the construction of a road, economic development will occur in a marginal zone.

The ranking of projects by maximizing a benefit function are different than by maximizing returns of each project. However, the budget constraint is a binding criteria for the selection of projects in both methodologies. The quantity of funds available for investment will determine which projects may be chosen and smaller projects may provide an alternative to large projects that need large amounts of capital.

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APPENDIX A: INFORMATION ON ROADS AND MUNICIPALITIES

Table A.1. Information on Municipalities

CODE	MUNICIPALITY	POPULATION	AREA (m2)	PRODUCT 1	PRODUCT 2	PRODUCT 3	CATTLE (KGS)	MARKET CENTER	INDUSTRY ($000)
001	ABEJORRAL	25355	491	COFFEE	POTATOES	CORN	1030	MEDELLIN	0
007	ABRIAQUI	2705	290				23815	MEDELLIN	0
033	AGUADAS	26455	471	COFFEE	PLANTAIN	SUGAR	1470	MEDELLIN	4
012	ALEJANDRIA	4640	149				129	MEDELLIN	0
018	AMAGA	20154	84				1940	MEDELLIN	92
144	AMALFI	1550	1210				1260	MEDELLIN	0
027	ANDES	37507	444	COFFEE	PLANTAIN	SUGAR	3651	MEDELLIN	0
138	ANGELOPOLIS	5711	86	COFFEE	SUGAR	PLANTAIN	360	MEDELLIN	0
034	ANGOSTURA	12636	387	COFFEE	SUGAR	PLANTAIN	637	YARUMAL	0
127	ANORI	11177	430				507		0
009	ANTIOQUIA	18555	493	BEANS	COFFEE	CORN	800	MEDELLIN	0
143	ANZA	6044	107	COFFEE	CORN	SUGAR	231	MEDELLIN	0
036	APARTADO	4661	600	PLANTAIN	BANANAS		5013	MEDELLIN	1983
029	ARANZAZU	13463	145	COFFEE			1273	MANIZALES	17
038	ARBOLETES	34962	727	PLANTAIN	COCONUT	CORN	671	MONTERIA	0
042	ARGELIA	11733	254	COFFEE	COCOA	SUGAR	459	SONSON	0
043	ARMENIA	1808	110				345	MEDELLIN	0
014	BARBOSA	28623	206	COFFEE	SUGAR	FRUITS	2472	MEDELLIN	18640
016	BELLO	212861	149				0	MEDELLIN	113462
044	BELMIRA	5415	276				110		0
046	BETANIA	12560	168	COFFEE	PLANTAIN	CASSAVA	630	MEDELLIN	0
047	BETULIA	14475	252	COFFEE	SUGAR	PLANTAIN	836	MEDELLIN	0
049	BOLIVAR	28142	282	COFFEE	PLANTAIN	CASSAVA	2577	MEDELLIN	0
111	BRICENO	8358	401	COFFEE	SUGAR	BEANS	208	YARUMAL	0
125	BUENAVISTA	14453	486	RICE	CORN	CASSAVA	247	PLANETA RICA	0
128	BURITICA	6575	364	BEANS	CORN	COFFEE	119	MEDELLIN	0
050	CACERES	18160	1973				802	TARAZA	0
112	CAICEDO	6469	221	COFFEE	CORN	BEANS	195	MEDELLIN	0
020	CALDAS	42158	150				4048	MEDELLIN	7804
052	CAMPAMENTO	10099	290	SUGAR	COFFEE	TOMATOES	552	YARUMAL	0
055	CANASGORDAS	10099	391	COFFEE	SUGAR	PLANTAIN	878	MEDELLIN	0
056	CARACOLI	6416	260				656	MEDELLIN	0
062	CARAMANTA	7751	86	COFFEE	PLANTAIN	SUGAR	626	MEDELLIN	0
063	CAREPA	12518	380	BANANAS	PLANTAIN	CORN	651	MEDELLIN	0
067	CARMEN DE VIB	29132	448	POTATOES	CORN	BEANS	1095	MEDELLIN	636
090	CAROLINA	4080	166				280	MEDELLIN	0
070	CAUCASIA	39190	1046				2637	MEDELLIN	814
064	CHIGORODO	23171	608				1846	MEDELLIN	0
026	CISNEROS	9183	1923	COFFEE	SUGAR	FRUITS	1142	MEDELLIN	0
072	COCORNA	27890	222	COFFEE	PLANTAIN	GUAVA	548	MEDELLIN	0
013	CONCEPCION	6077	167	CORN	BEANS	POTATOES	104	MEDELLIN	0
129	CONCORDIA	20367	231	COFFEE	SUGAR	PLANTAIN	1623	MEDELLIN	0
130	COPACABANA	40309	70	COFFEE	SUGAR	BEANS	6946	MEDELLIN	20877
066	DABEIBA	20939	1883	COFFEE	SUGAR	BEANS	866	MEDELLIN	0
054	DON MATIAS	11168	181				822	MEDELLIN	1202
133	EBEJICO	14802	235				1023	MEDELLIN	0
135	EL BAGRE	18962	1928				2524	MEDELLIN	0
127	EL CARMEN	5790	938				203	QUIBDO	0
076	ENTRERRIOS	5286	219				184	MEDELLIN	0
141	ENVIGADO	91391	50				27404	MEDELLIN	102158
132	FREDONIA	22777	247	COFFEE	PLANTAIN	COCOA	2089	MEDELLIN	0
079	FRONTINO	25997	1263				839	MEDELLIN	0
008	GIRALDO	3782	96	BEANS	ANIS	CORN	0	CANASGORDAS	17
015	GIRARDOTA	23684	78				3591	MEDELLIN	72941
080	GOMEZ PLATA	9034	360	COFFEE	PLANTAIN	SUGAR	474	MEDELLIN	0
081	GRANADA	18692	183	COFFEE	SUGAR	POTATOES	548	MEDELLIN	0
140	GUADALUPE	6278	87	COFFEE	PLANTAIN		444	MEDELLIN	0
075	GUARNE	23269	151	POTATOE	BEANS		1387	MEDELLIN	9099
083	GUATAPE	4189	69				272	MEDELLIN	0
074	HELICONIA	7710	117	COFFEE	PLANTAIN		259	MEDELLIN	0
085	HISPANIA	5022	58	COFFEE	SUGAR	CASSAVA	231	MEDELLIN	0

(R) Stands for access only by river, (ND) stands for indirect access.

Table A.1. (Continued)

CODE	MUNICIPALITY	POPULATION	AREA (m2)	PRODUCT 1	PRODUCT 2	PRODUCT 3	CATTLE (KGS)	MARKET CENTER	IND USTRY ($000)
021	ITAGUI	137623	17				15305	MEDELLIN	319308
086	ITUANGO	22501	2347	COFFEE	CORN	BEANS	396	MEDELLIN	0
028	JARDIN	12879	224	COFFEE	SUGAR	PLANTAIN	628	MEDELLIN	167
059	JERICO	15083	193	COFFEE	PLANTAIN	BEANS	1027	MEDELLIN	25
003	LA CEJA	2876	131				3300	MEDELLIN	1395
098	LA DORADA	54195	531				4889	BOGOTA	110
139	LA ESTRELLA	29918	35				0		4976
089	LA MAGDALENA	0	0				1375		9312
002	LA UNION	13313	198	POTATOES	BEANS	CORN	573	MEDELLIN	513
131	LIBORINA	10511	217	BEANS	COFFEE	CORN	450	MEDELLIN	0
025	MACEO	8921	431				818	MEDELLIN	0
074	MARINILLA	31310	115	BEANS	POTATOES	CORN	1916	MEDELLIN	4516
005	MEDELLIN	1468089	382				88130		766447
093	MONTEBELLO	8957	83	COFFEE	PLANTAIN	AVOCADO	342	MEDELLIN	0
126	MONTELIBANO	34115	1897				1735	MEDELLIN	70852
039	MONTERIA	224147	3040				25614		7512
114	MURINDO	1758	1349				3	TURBO (R)	0
065	MUTATA	9150	1106	PLANTAIN	RICE	FRUITS	455	MEDELLIN	0
115	NARINO	15346	313	COFFEE	COCOA	SUGAR	877	MEDELLIN	0
094	NECHI	11062	914				1068	MEDELLIN	0
095	NECOCLI	25987	1361	CORN	COTTON	RICE	611	MEDELLIN	0
092	OLAYA	3034	90	COFFEE	PLANTAIN	BEANS	1068	CAUCASIA (R)	0
032	PACORA	18140	262	COFFEE	PLANTAIN	SUGAR	1303	MANIZALES	0
084	PENOL	13791	143	TOMATOES	BEANS	POTATOES	982	MEDELLIN	0
107	PEQUE	6787	392	COFFEE	BEANS	SUGAR	117	MEDELLIN	0
146	PLANETA RICA	44267	1187				1762	MONTERIA	0
060	PUEBLO RICO	9042	85	COFFEE	PLANTAIN	SUGAR	817	MEDELLIN	0
024	PUERTO BERRIO	28470	1184				2489	MEDELLIN	0
097	PUERTO TRIUNF	8684	1361				501	LA DORADA	0
023	REMEDIOS	17736	1985				1599	MEDELLIN	0
004	RETIRO	11126	273				253	MEDELLIN	262
069	RIONEGRO	56195	196	BEANS	CORN	POTATOES	4813	MEDELLIN	43907
116	SABANALARGA	7133	265	COFFEE	CORN	BEANS	189	MEDELLIN	0
142	SABANETA	20491	15				0	MEDELLIN	42809
101	SALGAR	20865	418	COFFEE	PLANTAIN	CORN	1096	MEDELLIN	0
097	SAMANA	32870	944	COFFEE			1890	BOGOTA	0
088	SAN ANDRES	7930	177	COFFEE	COCOA	SUGAR	208	MEDELLIN	0
082	SAN CARLOS	26616	702	COFFEE	SUGAR	PLANTAIN	964	MEDELLIN	0
010	SAN JERONIMO	9833	155				484	MEDELLIN	0
117	SAN JOSE DE L	2696	171				67	MEDELLIN	0
100	SAN LUIS	13442	453	COFFEE	CORN	BEANS	407	MEDELLIN	0
045	SAN PEDRO	13430	229	CORN	RICE		596	MEDELLIN	588
118	SAN PEDRO DE	20602	476				937	MEDELLIN	0
103	SAN RAFAEL	18866	362	COFFEE	CORN	PLANTAIN	1258	MEDELLIN	0
104	SAN ROQUE	18551	441	COFFEE	SUGAR	CASSAVE	914	MEDELLIN	0
105	SAN VICENTE	19643	243	POTATOES	BEANS	CORN	84	MEDELLIN	0
144	SANTA BARBAR	25872	220	COFFEE	MANGOES	AVOCADO	2257	MEDELLIN	7779
017	SANTA ROSA DE	23537	812				753	MEDELLIN	345
073	SANTO DOMING	15233	271				345	MEDELLIN	0
134	SANTUARIO	22690	75	CARROTS	POTATOES	BEANS	1506	MEDELLIN	518
106	SEGOVIA	20862	1231				1924	MEDELLIN	0
006	SONSON	39017	1323	POTATOES	CORN	BEANS	2523	MEDELLIN	10444
119	SOPETRAN	12369	223	FRUIT	CORN	BEANS	794	MEDELLIN	173
030	SUPIA	21338	115	COFFEE	SUGAR	PLANTAIN	1928	MANIZALES	0
058	TAMESIS	20018	243	COFFEE	PLANTAIN	COCOA	1022	MEDELLIN	0
051	TARAZA	13756	1650				1837	TARAZA	0
061	TARSO	6711	119	COFFEE	PLANTAIN	CASSAVA	393	MEDELLIN	0
048	TITIRIBI	13387	142	COFFEE	CORN	PLANTAIN	761	MEDELLIN	0
087	TOLEDO	6070	139	COFFEE	CORN	BEANS	177	MEDELLIN	0

Table A.1 (Continued)

CODE	MUNICIPALITY	POPULATION	AREA (m2)	PRODUCT 1	PRODUCT 2	PRODUCT 3	CATTLE (KGS)	MARKET CENTER	IND USTRY ($000)
037	TURBO	70113	3055	PLANTAIN	BANANAS		1383	MEDELLIN	731
068	URAMITA	8369	236	BEANS	CORN	COFFEE	198	MEDELLIN	0
113	URRAO	25912	2330	COFFEE	PLANTAIN	CASSAVA	1202	MEDELLIN	260
071	VALDIVIA	12271	545				605	MEDELLIN	0
057	VALPARAISO	8290	150	COFFEE	PLANTAIN	CASSAVA	589	MEDELLIN	0
022	VEGACHI	11599	512	SUGAR	COFFEE	CASSAVA	876	MEDELLIN	0
120	VENECIA	12284	141	COFFEE	PLANTAIN	CASSAVA	1183	MEDELLIN	155
121	VIGIA DEL FUE	6317	1780	RICE	PLANTAIN	CORN	5	QUIBDO (R)	0
122	YALI	7409	477	COFFEE	SUGAR	CASSAVA	468	MEDELLIN	0
035	YARUMAL	33070	1724				1642	MEDELLIN	0
123	YOLOMBO	20369	941	COFFEE	SUGAR	COCOA	1642	MEDELLIN	0
124	YONDO	7388	1881	CASSAVA	CORN	PLANTAIN	315	B/BRMEJA (IN)	0
137	ZARAGOZA	11114	1064				920	MEDELLIN	0

Table A.2. Information on the existing road network

TYPE (1)	ORIGIN	DEPT OF ORIGIN	DESTINATION	DEPT OF DESTIN.	ORIGIN CODE	DESTIN. CODE	DISTANCE (Km)	PAVED (2)	REAL TRAFFIC
NAL	PUERTO BERRIO	ANT	MACEO	ANT	024	025	60	N	554
NAL	MACEO	ANT	CISNEROS	ANT	025	026	47	N	554
NAL	CISNEROS	ANT	SANTO DOMINGO	ANT	026	073	20	N	433
NAL	SANTO DOMINGO	ANT	BARBOSA	ANT	073	014	20	N	947
NAL	BARBOSA	ANT	GIRARDOTA	ANT	014	015	18	Y	5211
NAL	BELLO	ANT	MEDELLIN	ANT	016	005	20	Y	11885
NAL	MEDELLIN	ANT	SAN JERONIMO	ANT	005	010	48	Y	1104
NAL	SAN JERONIMO	ANT	ANTIOQUIA	ANT	010	009	20	Y	784
NAL	ANTIOQUIA	ANT	GIRALDO	ANT	009	008	35	N	435
NAL	GIRALDO	ANT	CANASGORDAS	ANT	008	055	21	N	435
NAL	CANASGORDAS	ANT	URAMITA	ANT	055	068	50	N	435
NAL	URAMITA	ANT	DABEIBA	ANT	068	066	60	N	229
NAL	DABEIBA	ANT	MUTATA	ANT	066	065	30	N	229
NAL	MUTATA	ANT	CHIGORODO	ANT	065	064	80	N	227
NAL	CHIGORODO	ANT	CAREPA	ANT	064	063	20	N	1557
NAL	CAREPA	ANT	APARTADO	ANT	063	036	15	N	2848
NAL	SUPIA	CAL	JARDIN	ANT	030	028	36	N	332
NAL	JARDIN	ANT	ANDES	ANT	028	027	20	N	332
NAL	ANDES	ANT	HISPANIA	ANT	027	085	20	N	332
NAL	SUPIA	CAL	SANTA BARBARA	ANT	029	078	93	Y	1922
NAL	SANTA BARBARA	ANT	CALDAS	ANT	144	020	30	Y	2602
NAL	CALDAS	ANT	ITAGUI	ANT	020	021	10	Y	8292
NAL	GIRARDOTA	ANT	DON MATIAS	ANT	015	054	23	Y	1932
NAL	DON MATIAS	ANT	SANTA ROSA DE	ANT	054	053	27	Y	1535
NAL	SANTA ROSA DE	ANT	YARUMAL	ANT	053	035	43	Y	1671
NAL	YARUMAL	ANT	VALDIVIA	ANT	035	071	42	Y	1671
NAL	VALDIVIA	ANT	TARAZA	ANT	071	051	62	Y	1671
NAL	TARAZA	ANT	CACERES	ANT	051	050	63	Y	1671
NAL	CACERES	ANT	CAUCASIA	ANT	050	070	63	Y	1671
NAL	CAUCASIA	ANT	MONTELIBANO	COR	070	126	20	Y	1671
NAL	MEDELLIN	ANT	RETIRO	ANT	005	004	25	N	6274
NAL	RETIRO	ANT	LA CEJA	ANT	004	003	14	Y	1699
NAL	LA CEJA	ANT	LA UNION	ANT	003	002	15	Y	907
NAL	LA UNION	ANT	SONSON	ANT	002	006	55	N	484
NAL	EL CARMEN	CHO	BOLIVAR	ANT	127	049	31	N	1096
NAL	BOLIVAR	ANT	AMAGA	ANT	049	018	57	N	1027
NAL	MEDELLIN	ANT	GUARNE	ANT	005	075	20	Y	6273
NAL	AMAGA	ANT	CALDAS	ANT	018	020	29	Y	582
NAL	GUARNE	ANT	MARINILLA	ANT	075	074	22	Y	8317

(1) NAL indicates that the road belongs to the Nation, DEP indicates that the road belongs to the Department and OTH indicates that the road belongs by links to the Nation and Department or some other agency, or that it is unknown to whom it belongs.

(2) 'E" stands for an earth road.

Table A.2. (Continued)

TYPE (1)	ORIGIN	DEPT OF ORIGIN	DESTINATION	DEPT OF DESTIN.	ORIGIN CODE	DESTIN. CODE	DISTANCE (Km)	PAVED (2)	REAL TRAFFIC
NAL	MARINILLA	ANT	SANTUARIO	ANT	074	134	18	Y	2739
NAL	SANTUARIO	ANT	COCORNA	ANT	134	072	32	Y	1266
NAL	COCORNA	ANT	SAN LUIS	ANT	072	100	38	Y	1250
NAL	SAN LUIS	ANT	PUERTO TRIUNF	ANT	100	097	68	Y	1328
NAL	LA UNION	ANT	ABEJORRAL	ANT	002	001	52	N	82
NAL	SONSON	ANT	ARGELIA	ANT	006	042	35	N	75
NAL	MEDELLIN	ANT	RIONEGRO	ANT	005	069	32	Y	2422
NAL	PACORA	CAL	AGUADAS	CAL	032	033	15	Y	288
NAL	ARANZAZU	CAL	SANTA BARBARA	ANT	029	144	25	N	576
NAL	BUENAVISTA	COR	PLANETA RICA	COR	125	146	25	Y	2052
NAL	MONTELIBANO	COR	BUENAVISTA	COR	126	125	70	N	409
NAL	RIONEGRO	ANT	CARMEN DE VIB	ANT	069	067	11	Y	1085
NAL	SUPIA	CAL	SANTA BARBARA	ANT	030	078	93	Y	1922
NAL	MEDELLIN	ANT	GIRARDOTA	ANT	015	005	37	Y	4474
NAL	DABEIBA	ANT	MUTATA	ANT	066	065	85	E	230
DEP	SAN PEDRO	ANT	DON MATIAS	ANT	045	054	22	N	0
DEP	YARUMAL	ANT	ANGOSTURA	ANT	035	034	15	N	0
DEP	AMALFI	ANT	VEGACHI	ANT	143	022	63	N	0
DEP	REMEDIOS	ANT	PUERTO BERRIO	ANT	023	024	102	N	0
DEP	SAN ROQUE	ANT	SANTO DOMINGO	ANT	104	017	22	N	0
DEP	REMEDIOS	ANT	SEGOVIA	ANT	023	106	18	N	0
DEP	ARBOLETES	ANT	SAN JUAN DE U	ANT	038	102	17	N	0
DEP	SAN JUAN DE U	ANT	NECOCLI	ANT	102	095	45	N	0
DEP	PUERTO BERRIO	ANT	LA MAGDALENA	ANT	024	089	38	N	0
DEP	CAUCASIA	ANT	NECHI	ANT	070	094	68	N	0
DEP	BARBOSA	ANT	SANTO DOMINGO	ANT	014	073	64	N	0
DEP	FRONTINO	ANT	ABRIAQUI	ANT	079	007	27	N	0
DEP	BETULIA	ANT	URRAO	ANT	047	113	42	N	0
DEP	JERICO	ANT	PUEBLO RICO	ANT	059	060	11	N	0
DEP	MACEO	ANT	YALI	ANT	025	122	19	N	0
DEP	YALI	ANT	YOLOMBO	ANT	122	123	47	N	0
DEP	CARAMANTA	ANT	VALPARAISO	ANT	062	057	17	N	0
DEP	VALPARAISO	ANT	TAMESIS	ANT	057	058	25	N	0
DEP	SANTA BARBARA	ANT	FREDONIA	ANT	144	132	27	N	0
DEP	SAN PEDRO	ANT	BELMIRA	ANT	045	044	20	N	0
DEP	ENTRERRIOS	ANT	SANTA ROSA DE	ANT	076	053	35	N	0
DEP	YARUMAL	ANT	CAMPAMENTO	ANT	035	052	20	N	0
DEP	DON MATIAS	ANT	ENTRERRIOS	ANT	054	076	21	N	0
DEP	GOMEZ PLATA	ANT	CAROLINA	ANT	080	090	15	N	0
DEP	CAROLINA	ANT	ANGOSTURA	ANT	090	034	28	N	0
DEP	SAN ANDRES	ANT	TOLEDO	ANT	088	087	20	N	0
DEP	GRANADA	ANT	SAN CARLOS	ANT	081	082	39	N	0
DEP	PENOL	ANT	GUATAPE	ANT	084	083	15	N	0
DEP	CARMEN DE VIB	ANT	LA UNION	ANT	067	002	19	N	0
DEP	SANTUARIO	ANT	MARINILLA	ANT	073	074	10	N	0

Table A.2. (Continued)

TYPE (1)	ORIGIN	DEPT OF ORIGIN	DESTINATION	DEPT OF DESTIN.	ORIGIN CODE	DESTIN. CODE	DISTANCE (Km)	PAVED (2)	REAL TRAFFIC
DEP	MARINILLA	ANT	PENOL	ANT	074	084	17	N	0
DEP	RETIRO	ANT	MONTEBELLO	ANT	004	093	26	N	0
DEP	GUATAPE	ANT	SAN RAFAEL	ANT	083	103	26	N	0
DEP	SAN VICENTE	ANT	CONCEPCION	ANT	105	013	23	N	0
DEP	ARMENIA	ANT	TITIRIBI	ANT	043	048	31	N	0
DEP	HELICONIA	ANT	EBEJICO	ANT	136	133	36	N	0
DEP	LIBORINA	ANT	SAN JOSE DE L	ANT	131	117	50	N	0
DEP	ALEJANDRIA	ANT	SANTO DOMINGO	ANT	012	073	6	N	0
DEP	CONCEPCION	ANT	ALEJANDRIA	ANT	013	012	17	N	0
DEP	PUEBLO RICO	ANT	TARSO	ANT	060	061	13	N	0
OTH	ZARAGOZA	ANT	EL BAGRE	ANT	137	135	20	N	0
OTH	VEGACHI	ANT	REMEDIOS	ANT	022	023	22	N	0
OTH	TURBO	ANT	SAN PEDRO	ANT	037	118	30	N	0
OTH	ITUANGO	ANT	TOLEDO	ANT	086	087	20	N	0
OTH	OLAYA	ANT	LIBORINA	ANT	092	131	17	N	0
OTH	BETANIA	ANT	ANDES	ANT	046	027	15	N	0
OTH	TAMESIS	ANT	JERICO	ANT	058	059	27	N	0
OTH	ARBOLETES	ANT	MONTERIA	COR	038	039	90	N	0
OTH	TITIRIBI	ANT	CALDAS	ANT	048	020	31	E	0
OTH	GIRARDOTA	ANT	BELLO	ANT	015	016	20	Y	0
OTH	ANTIOQUIA	ANT	SAN JERONIMO	ANT	009	008	25	Y	0
OTH	TARSO	ANT	VENECIA	ANT	061	120	25	E	0
OTH	APARTADO	ANT	TURBO	ANT	036	037	35	N	0
OTH	GRANADA	ANT	SANTUARIO	ANT	081	134	15	E	0
OTH	SANTUARIO	ANT	RIONEGRO	ANT	073	069	20	Y	0
OTH	PENOL	ANT	GUARNE	ANT	084	075	20	N	0
OTH	SAN ANDRES	ANT	SANTA ROSA DE	ANT	088	053	35	Y	0
OTH	NECOCLI	ANT	TURBO	ANT	095	037	23	N	0
OTH	PUERTO TRIUNF	ANT	SAMANA	ANT	097	098	27	N	0
OTH	BETANIA	ANT	ANDES	ANT	045	027	27	N	0
OTH	ENTRERRIOS	ANT	SAN PEDRO	ANT	046	045	20	N	0
OTH	SAN ANDRES	ANT	LIBORINA	ANT	088	131	70	N	0
OTH	ENTRERRIOS	ANT	SAN PEDRO	ANT	046	047	20	N	0
OTH	ABRIAQUI	ANT	GIRALDO	ANT	007	008	15	E	0
OTH	VEGACHI	ANT	AMALFI	ANT	022	143	63	Y	0
OTH	VEGACHI	ANT	AMALFI	ANT	022	021	63	Y	0
OTH	ANGELOPOLIS	ANT	LA ESTRELLA	ANT	138	139	20	E	0
OTH	SABANALARGA	ANT	LIBORINA	ANT	116	131	20	N	0
OTH	BUENAVISTA	ANT	NECHI	ANT	125	094	63	Y	0
OTH	GIRALDO	ANT	URAMITA	ANT	008	049	49	Y	0
DEP	CONCEPCION	ANT	ALEJANDRIA	ANT	013	012	17	N	0
DEP	CONCEPCION	ANT	BARBOSA	ANT	013	014	23	N	0
DEP	BETULIA	ANT	URRAO	ANT	047	113	42	N	0
OTH	BETULIA	ANT	ARMENIA	ANT	047	043	40	E	0
OTH	MACEO	ANT	CARACOLI	ANT	025	056	30	N	0

Table A.2. (Continued)

TYPE (1)	ORIGIN	DEPT OF ORIGIN	DESTINATION	DEPT OF DESTIN.	ORIGIN CODE	DESTIN. CODE	DISTANCE (Km)	PAVED (2)	REAL TRAFFIC
OTH	CAICEDO	ANT	URRAO	ANT	112	113	45	N	0
OTH	ANTIOQUIA	ANT	OLAYA	ANT	009	092	17	N	0
OTH	VENECIA	ANT	CALDAS	ANT	120	020	32	Y	0
DEP	BETULIA	ANT	URRAO	ANT	047	113	42	N	0
OTH	BETULIA	ANT	SALGAR	ANT	047	101	40	N	0
OTH	BETULIA	ANT	ARMENIA	ANT	047	043	40	E	0
OTH	SAN ANDRES	ANT	YARUMAL	ANT	088	035	30	N	0
OTH	SAN ANDRES	ANT	YARUMAL	ANT	088	035	30	N	0
OTH	BARBOSA	ANT	DON MATIAS	ANT	014	054	20	Y	0
OTH	ENTRERRIOS	076	SAN PEDRO	045	076	045	20	N	0
DEP	URAMITA	ANT	PEQUE	ANT	068	107	68	N	0
OTH	CAUCASIA	ANT	ZARAGOZA	ANT	070	137	35	N	0
OTH	LOS CORDOBAS	COR	ARBOLETE	ANT	041	038	45	N	0
OTH	ITAGUI	ANT	HELICONIA	ANT	021	136	20	N	0
OTH	RIONEGRO	ANT	SANTUARIO	ANT	069	134	20	Y	7601
OTH	SANTO DOMINGO	ANT	SAN ROQUE	ANT	073	104	30	N	0
OTH	CANALETE	COR	ARBOLETE	ANT	040	038	50	N	0

APPENDIX B: ORIGIN AND DESTINATION NETWORK

Table B.1. Codification of links, origins and destinations for the network

ORIGIN	TYPE	DESTINATION	DISTANCE	LINK 1	LINK 2	LINK 3	LINK 4	LINK 5	LINK 6	LINK 7	LINK 8	LINK 9	LINK 10
ABEJORRAL	E	MEDELLIN	106	001	002	003	004	005	000	000	000	000	000
ABEJORRAL	S	LA UNION	50	001	002	000	000	000	000	000	000	000	000
ABEJORRAL	S	LA CEJA	66	001	002	003	000	000	000	000	000	000	000
ABEJORRAL	S	RETIRO	80	001	002	003	004	000	000	000	000	000	000
ABEJORRAL	S	SONSON	106	001	002	006	000	000	000	000	000	000	000
ABRIAQUI	S	MEDELLIN	133	007	008	009	010	005	000	000	000	000	000
ABRIAQUI	S	GIRALDO	10	007	008	000	000	000	000	000	000	000	000
ABRIAQUI	S	ANTIOQUIA	45	007	008	009	000	000	000	000	000	000	000
ABRIAQUI	S	SAN JERONIMO	65	007	008	009	010	000	000	000	000	000	000
ABRIAQUI	S	FRONTINO	27	007	079	000	000	000	000	000	000	000	000
ALEJANDRIA	S	MEDELLIN	90	012	013	014	015	016	005	000	000	000	000
ALEJANDRIA	S	CONCEPCION	17	012	013	000	000	000	000	000	000	000	000
ALEJANDRIA	S	BARBOSA	40	012	013	014	000	000	000	000	000	000	000
ALEJANDRIA	S	GIRARDOTA	58	012	013	014	015	000	000	000	000	000	000
ALEJANDRIA	S	BELLO	78	012	013	014	015	016	000	000	000	000	000
ALEJANDRIA	S	SANTO DOMIN	20	012	073	000	000	000	000	000	000	000	000
AMAGA	S	MEDELLIN	49	018	020	021	005	000	000	000	000	000	000
AMAGA	S	CALDAS	29	018	020	000	000	000	000	000	000	000	000
AMAGA	S	ITAGUI	39	018	020	021	000	000	000	000	000	000	000
AMALFI	S	MEDELLIN	392	143	022	023	024	025	026	073	014	015	016
AMALFI	S	MACEO	247	143	022	023	024	025	000	000	000	000	000
AMALFI	S	CISNEROS	294	143	022	023	024	025	026	000	000	000	000
AMALFI	S	BARBOSA	334	143	022	023	024	025	026	073	014	000	000
AMALFI	S	GIRARDOTA	352	143	022	023	024	025	026	073	014	015	000
AMALFI	S	BELLO	372	143	022	023	024	025	026	073	014	015	016
AMALFI	S	MEDELLIN	392	143	022	023	024	025	026	017	014	015	016
AMALFI	S	REMEDIOS	85	143	022	023	000	000	000	000	000	000	000
AMALFI	S	PUERTO BERRIO	187	143	022	023	024	000	000	000	000	000	000
AMALFI	S	SANTO DOMIN	314	143	022	023	024	025	026	073	000	000	000
ANDES	S	SUPIA	51	027	028	030	000	000	000	000	000	000	000
ANDES	S	SANTA BAR	144	027	028	029	078	000	000	000	000	000	000
ANDES	E	MEDELLIN	0	027	028	030	000	000	000	000	000	000	000
ANDES	S	JARDIN	36	027	028	000	000	000	000	000	000	000	000
ANDES	S	SUPIA	51	027	028	030	000	000	000	000	000	000	000
ANGELOPOLIS	E	LA ESTRELLA	25	138	139	000	000	000	000	000	000	000	000
ANGOSTURA	E	YARUMAL	15	034	035	000	000	000	000	000	000	000	000
ANORI	E	CAMPAMENTO	0	127	052	000	000	000	000	000	000	000	000
ANORI	E	MEDELLIN	0	127	052	035	053	054	015	016	005	000	000
ANTIOQUIA	S	MEDELLIN	45	009	010	005	000	000	000	000	000	000	000
ANTIOQUIA	S	SAN JERONIMO	20	009	010	000	000	000	000	000	000	000	000
ANTIOQUIA	S	SAN JERONIMO	20	009	010	000	000	000	000	000	000	000	000

Table B.1. (Continued)

ORIGIN	TYPE	DESTINATION	DISTANCE	LINK 1	LINK 2	LINK 3	LINK 4	LINK 5	LINK 6	LINK 7	LINK 8	LINK 9	LINK 10
ANZA	E	EBEJICO	0	143	133	000	000	000	000	000	000	000	000
ANZA	E	MEDELLIN	0	143	133	136	021	005	000	000	000	000	000
APARTADO	E	TURBO	25	036	037	000	000	000	000	000	000	000	000
ARBOLETES	S	MONTERIA	90	038	039	000	000	000	000	000	000	000	000
ARBOLETES	S	LOS CORDOBAS	30	038	040	000	000	000	000	000	000	000	000
ARGELIA	S	SONSON	20	042	006	000	000	000	000	000	000	000	000
ARGELIA	E	MEDELLIN	40	042	006	002	003	004	000	000	000	000	000
ARMENIA	S	MEDELLIN	82	043	048	020	021	005	000	000	000	000	000
ARMENIA	S	TITIRIBI	31	043	048	000	000	000	000	000	000	000	000
ARMENIA	S	CALDAS	62	043	048	020	000	000	000	000	000	000	000
ARMENIA	S	ITAGUI	72	043	048	020	021	000	000	000	000	000	000
BARBOSA	E	MEDELLIN	68	014	015	016	005	000	000	000	000	000	000
BARBOSA	S	GIRARDOTA	18	014	015	016	000	000	000	000	000	000	000
BARBOSA	S	BELLO	48	015	016	000	000	000	000	000	000	000	000
BARBOSA	S	DON MATIAS	25	014	054	000	000	000	000	000	000	000	000
BELLO	S	MEDELLIN	20	016	005	000	000	000	000	000	000	000	000
BELMIRA	S	SAN PEDRO	20	044	045	000	000	000	000	000	000	000	000
BETANIA	S	MEDELLIN	219	046	027	028	030	078	020	021	005	000	000
BETANIA	S	ANDES	15	046	027	000	000	000	000	000	000	000	000
BETANIA	S	SUPIA	66	046	027	028	000	000	000	000	000	000	000
BETANIA	S	CALDAS	199	045	027	028	030	078	020	000	000	000	000
BETANIA	S	ITAGUI	209	045	027	028	030	078	020	021	000	000	000
BETANIA	S	MEDELLIN	219	046	027	029	078	020	021	005	000	000	000
BETANIA	S	SANTA BARBARA	169	046	027	029	078	000	000	000	000	000	000
BETULIA	E	MEDELLIN	122	047	043	048	020	021	005	000	000	000	000
BETULIA	S	ARMENIA	40	047	043	000	000	000	000	000	000	000	000
BETULIA	S	TITIRIBI	71	047	043	048	000	000	000	000	000	000	000
BETULIA	S	CALDAS	102	047	043	048	020	000	000	000	000	000	000
BETULIA	S	ITAGUI	110	047	043	048	020	021	000	000	000	000	000
BETULIA	E	URRAO	25	047	113	000	000	000	000	000	000	000	000
BETULIA	E	ARMENIA	20	043	047	000	000	000	000	000	000	000	000
BOLIVAR	S	MEDELLIN	106	049	018	020	021	005	000	000	000	000	000
BOLIVAR	S	AMAGA	57	049	018	000	000	000	000	000	000	000	000
BOLIVAR	S	CALDAS	86	049	018	020	000	000	000	000	000	000	000
BOLIVAR	S	ITAGUI	96	049	018	020	021	000	000	000	000	000	000
BRICENO	E	YARUMAL	0	111	035	000	000	000	000	000	000	000	000
BRICENO	E	MEDELLIN	0	111	035	053	054	015	016	005	000	000	000
BURITICA	E	GIRALDO	0	008	128	000	000	000	000	000	000	000	000
BURITICA	E	MEDELLIN	0	128	008	009	010	005	000	000	000	000	000
CACERES	S	TARAZA	33	050	051	000	000	000	000	000	000	000	000
CAICEDO	E	MEDELLIN	206	112	113	047	043	048	020	021	005	000	000

Table B.1. (Continued)

ORIGIN	TYPE	DESTINATION	DISTANCE	LINK 1	LINK 2	LINK 3	LINK 4	LINK 5	LINK 6	LINK 7	LINK 8	LINK 9	LINK 10
CAICEDO	S	URRAO	42	112	113	000	000	000	000	000	000	000	000
CAICEDO	S	BETULIA	84	112	113	047	000	000	000	000	000	000	000
CAICEDO	S	ARMENIA	124	112	113	047	043	000	000	000	000	000	000
CAICEDO	S	TITIRIBI	155	112	113	047	043	048	000	000	000	000	000
CAICEDO	S	CALDAS	186	112	113	047	043	048	020	000	000	000	000
CAICEDO	S	ITAGUI	196	112	113	047	043	048	020	021	000	000	000
CAICEDO	S	BETULIA	84	112	113	047	000	000	000	000	000	000	000
CAICEDO	S	ARMENIA	124	112	113	047	043	000	000	000	000	000	000
CALDAS	S	MEDELLIN	20	020	021	005	000	000	000	000	000	000	000
CALDAS	S	ITAGUI	10	020	021	000	000	000	000	000	000	000	000
CAMPAMENTO	E	YARUMAL	20	052	035	000	000	000	000	000	000	000	000
CANASGORDAS	S	GIRALDO	21	055	008	000	000	000	000	000	000	000	000
CANASGORDAS	S	ANTIOQUIA	56	055	008	000	000	000	000	000	000	000	000
CANASGORDAS	S	SAN JERONIMO	76	055	008	009	010	000	000	000	000	000	000
CANASGORDAS	E	MEDELLIN	124	055	008	009	010	005	000	000	000	000	000
CARACOLI	S	MEDELLIN	175	056	025	026	073	014	015	016	005	000	000
CARACOLI	S	CISNEROS	77	056	025	026	000	000	000	000	000	000	000
CARACOLI	S	SANTO DOMIN	77	056	025	026	073	000	000	000	000	000	000
CARACOLI	S	BARBOSA	117	056	025	026	073	014	000	000	000	000	000
CARACOLI	S	GIRARDOTA	135	056	025	026	073	014	000	000	000	000	000
CARACOLI	S	BELLO	135	056	025	026	073	014	015	016	000	000	000
CARAMANTA	S	MEDELLIN	170	062	057	058	059	060	061	120	020	021	005
CARAMANTA	S	JERICO	69	062	057	058	059	000	000	000	000	000	000
CARAMANTA	S	CALDAS	150	062	057	058	059	060	061	120	020	000	000
CARAMANTA	S	ITAGUI	160	062	057	058	059	060	061	120	020	021	000
CARAMANTA	S	TAMESIS	42	062	057	058	000	000	000	000	000	000	000
CARAMANTA	S	PUEBLO RICO	80	062	057	058	059	060	000	000	000	000	000
CARAMANTA	S	TARSO	93	062	057	058	059	060	061	000	000	000	000
CAREPA	S	CHIGORODO	10	063	064	000	000	000	000	000	000	000	000
CAREPA	S	MUTATA	60	063	064	065	000	000	000	000	000	000	000
CAREPA	S	DABEIBA	115	063	064	065	066	000	000	000	000	000	000
CAREPA	S	URAMITA	149	063	064	065	066	068	000	000	000	000	000
CAREPA	E	TURBO	30	063	036	037	000	000	000	000	000	000	000
CAREPA	S	APARTADO	25	036	063	020	000	000	000	000	000	000	000
CARMEN DE	S	MEDELLIN	41	067	069	005	000	000	000	000	000	000	000
CARMEN DE	S	RIONEGRO	32	067	069	000	000	000	000	000	000	000	000
CAROLINA	S	MEDELLIN	176	090	034	035	053	054	015	016	005	000	000
CAROLINA	S	ANGOSTURAS	28	090	034	000	000	000	000	000	000	000	000
CAROLINA	S	YARUMAL	43	090	034	035	000	000	000	000	000	000	000

Table B.1. (Continued)

ORIGIN	TYPE	DESTINATION	DISTANCE	LINK 1	LINK 2	LINK 3	LINK 4	LINK 5	LINK 6	LINK 7	LINK 8	LINK 9	LINK 10
CAROLINA	S	DON MATIAS	113	090	034	035	053	054	000	000	000	000	000
CAROLINA	S	BELLO	156	090	034	035	053	054	015	016	000	000	000
CAROLINA	S	SANTA ROSA DE	86	090	034	035	053	000	000	000	000	000	000
CAROLINA	S	GIRADOTA	136	090	034	035	053	054	015	000	000	000	000
CAUCASIA	S	MEDELLIN	326	070	050	051	071	035	053	054	015	016	005
CAUCASIA	S	CACERES	63	070	050	000	000	000	000	000	000	000	000
CAUCASIA	S	TARAZA	99	070	050	051	000	000	000	000	000	000	000
CAUCASIA	S	VALDIVIA	161	070	050	051	071	000	000	000	000	000	000
CAUCASIA	S	YARUMAL	203	070	050	051	071	035	000	000	000	000	000
CAUCASIA	S	DON MATIAS	273	070	050	051	071	035	053	054	000	000	000
CAUCASIA	S	GIRARDOTA	296	070	050	051	071	035	053	054	015	000	000
CAUCASIA	S	BELLO	296	070	050	051	071	035	053	054	015	016	000
CAUCASIA	S	SANTA ROSA DE	246	070	050	051	071	035	053	000	000	000	000
CAUCASIA	E	MONTELIBANO	700	070	126	000	000	000	000	000	000	000	000
CHIGORODO	S	APARTADO	25	064	063	036	000	000	000	000	000	000	000
CHIGORODO	S	MUTATA	50	064	065	000	000	000	000	000	000	000	000
CHIGORODO	S	DABEIBA	105	064	065	066	000	000	000	000	000	000	000
CHIGORODO	S	MEDELLIN	191	064	065	066	067	055	008	009	010	005	000
CHIGORODO	E	TURBO	64	064	063	036	037	000	000	000	000	000	000
CISNEROS	S	BARBOSA	40	026	073	014	000	000	000	000	000	000	000
CISNEROS	S	GIRARDOTA	78	026	073	014	015	000	000	000	000	000	000
CISNEROS	E	MEDELLIN	128	026	017	014	015	016	005	000	000	000	000
CISNEROS	S	BELLO	108	026	017	014	015	016	000	000	000	000	000
CISNEROS	E	SANTO DOMINGO	20	026	073	000	000	000	000	000	000	000	000
COCORNA	S	SANTUARIO	32	072	134	000	000	000	000	000	000	000	000
COCORNA	S	MARINILLA	42	072	134	074	000	000	000	000	000	000	000
COCORNA	S	GUARNE	62	072	134	074	075	000	000	000	000	000	000
COCORNA	E	MEDELLIN	82	072	134	074	075	005	000	000	000	000	000
CONCEPCION	S	MEDELLIN	81	013	014	015	016	005	000	000	000	000	000
CONCEPCION	S	BARBOSA	23	013	014	000	000	000	000	000	000	000	000
CONCEPCION	S	GIRARDOTA	41	013	014	015	000	000	000	000	000	000	000
CONCEPCION	S	BELLO	61	013	014	015	016	000	000	000	000	000	000
CONCORDIA	E	TITIRIBI	0	129	048	000	000	000	000	000	000	000	000
CONCORDIA	E	MEDELLIN	129	048	020	210	005	000	000	000	000	000	000
DABEIBA	E	MEDELLIN	186	066	068	055	008	009	010	005	000	000	000
DABEIBA	S	URAMITA	34	066	068	000	000	000	000	000	000	000	000
DABEIBA	S	CANASGORDAS	62	066	068	055	000	000	000	000	000	000	000
DABEIBA	S	GIRALDO	83	066	068	055	008	000	000	000	000	000	000

Table B.1 (Continued)

ORIGIN	TYPE	DESTINATION	DISTANCE	LINK 1	LINK 2	LINK 3	LINK 4	LINK 5	LINK 6	LINK 7	LINK 8	LINK 9	LINK 10
DABEIBA	S	ANTIOQUIA	118	066	068	055	008	009	000	000	000	000	000
DABEIBA	S	SAN JERONIMO	138	066	068	055	008	009	010	000	000	000	000
DON MATIAS	S	MEDELLIN	63	054	015	016	005	000	000	000	000	000	000
DON MATIAS	S	GIRARDOTA	23	054	015	000	000	000	000	000	000	000	000
DON MATIAS	S	BELLO	43	054	015	016	000	000	000	000	000	000	000
EBEJICO	S	HELICONIA	36	133	136	000	000	000	000	000	000	000	000
EBEJICO	S	ITAGUI	66	133	136	021	000	000	000	000	000	000	000
EBEJICO	S	MEDELLIN	76	133	136	021	005	000	000	000	000	000	000
EL BAGRE	S	MEDELLIN	372	135	137	070	050	051	071	035	053	054	015
EL BAGRE	S	ZARAGOZA	20	135	137	000	000	000	000	000	000	000	000
EL BAGRE	S	CAUCASIA	55	135	137	070	000	000	000	000	000	000	000
EL BAGRE	S	CACERES	118	135	137	070	050	000	000	000	000	000	000
EL BAGRE	S	TARAZA	151	135	137	070	050	051	000	000	000	000	000
EL BAGRE	S	VALDIVIA	151	135	137	070	050	051	071	000	000	000	000
EL BAGRE	S	YARUMAL	255	135	137	070	050	051	071	035	000	000	000
EL BAGRE	S	SANTA ROSA DE	282	135	137	070	050	051	071	035	053	000	000
EL BAGRE	S	DON MATIAS	309	135	137	070	050	051	071	035	053	054	000
EL CARMEN	S	MEDELLIN	100	127	049	018	020	021	005	000	000	000	000
EL CARMEN	S	BOLIVAR	100	127	049	000	000	000	000	000	000	000	000
ENTRERRIOS	S	MEDELLIN	88	076	054	015	016	005	000	000	000	000	000
ENTRERRIOS	S	DON MATIAS	21	076	054	000	000	000	000	000	000	000	000
ENTRERRIOS	S	GIRARDOTA	48	076	054	015	000	000	000	000	000	000	000
ENTRERRIOS	S	BELLO	68	076	054	015	016	000	000	000	000	000	000
FREDONIA	S	CALDAS	57	132	144	020	000	000	000	000	000	000	000
FREDONIA	S	ITAGUI	67	132	078	020	021	000	000	000	000	000	000
FREDONIA	E	MEDELLIN	77	132	144	020	021	005	000	000	000	000	000
FREDONIA	S	SANTA BAR	27	132	144	000	000	000	000	000	000	000	000
FRONTINO	S	MEDELLIN	160	079	007	008	009	010	005	000	000	000	000
FRONTINO	S	ABRIAQUI	160	079	007	000	000	000	000	000	000	000	000
FRONTINO	S	GIRALDO	37	079	007	008	000	000	000	000	000	000	000
FRONTINO	S	ANTIOQUIA	72	079	007	008	009	000	000	000	000	000	000
FRONTINO	S	SAN JERONIMO	92	079	007	008	009	010	000	000	000	000	000
GIRALDO	S	CANASGORDAS	21	008	055	000	000	000	000	000	000	000	000
GIRALDO	S	ANTIOQUIA	35	008	009	000	000	000	000	000	000	000	000
GIRARDOTA	S	MEDELLIN	40	015	005	000	000	000	000	000	000	000	000
GIRARDOTA	S	BELLO	20	015	016	000	000	000	000	000	000	000	000
GOMEZ PLATA	E	MEDELLIN	201	080	090	034	035	053	054	015	016	005	000
GOMEZ PLATA	S	CAROLINA	15	080	090	000	000	000	000	000	000	000	000
GOMEZ PLATA	S	ANGOSTURAS	43	080	090	034	000	000	000	000	000	000	000

Table B.1 (Continued)

ORIGIN	TYPE	DESTINATION	DISTANCE	LINK 1	LINK 2	LINK 3	LINK 4	LINK 5	LINK 6	LINK 7	LINK 8	LINK 9	LINK 10
GOMEZ PLATA	S	YARUMAL	58	080	090	034	035	000	000	000	000	000	000
GOMEZ PLATA	S	DON MATIAS	128	080	090	034	035	053	054	000	000	000	000
GOMEZ PLATA	S	GIRARDOTA	151	080	090	034	035	053	054	015	000	000	000
GOMEZ PLATA	S	BELLO	181	080	090	034	035	053	054	015	016	005	000
GOMEZ PLATA	S	SANTA ROSA	101	080	090	034	035	053	000	000	000	000	000
GRANADA	E	MEDELLIN	52	081	134	069	005	000	000	000	000	000	000
GRANADA	S	SAN CARLOS	39	081	082	000	000	00	000	000	000	000	000
GRANADA	S	SANTUARIO	15	081	134	000	000	000	000	000	000	000	000
GRANADA	S	RIONEGRO	20	081	134	069	000	000	000	000	000	000	000
GUADALUPE	E	ANGOSTURA	25	140	034	000	000	000	000	000	000	000	000
GUADALUPE	E	MEDELLIN	23	140	034	035	053	054	015	016	005	000	000
GUARNE	S	MEDELLIN	20	075	005	000	000	000	000	000	000	000	000
GUATAPE	S	MEDELLIN	42	083	084	075	005	000	000	000	000	000	000
GUATAPE	S	EL PENOL	15	083	084	000	000	000	000	000	000	000	000
GUATAPE	S	GUARNE	22	083	084	075	000	000	000	000	000	000	000
HISPANIA	S	ANDES	10	085	027	000	000	000	000	000	000	000	000
HISPANIA	S	JARDIN	23	085	027	028	000	000	000	000	000	000	000
HISPANIA	S	SUPIA	61	085	027	028	030	000	000	000	000	000	000
HISPANIA	S	SANTA BARBAR	164	085	027	028	030	078	000	000	000	000	000
HISPANIA	S	CALDAS	194	085	027	028	030	078	020	000	000	000	000
HISPANIA	E	MEDELLIN	214	085	027	028	029	078	020	021	000	000	000
HISPANIA	S	ITAGUI	204	085	027	028	029	078	020	021	000	000	000
ITUANGO	E	MEDELLIN	153	086	087	088	053	054	015	016	005	000	000
ITUANGO	S	DON MATIAS	90	086	087	088	053	054	000	000	000	000	000
ITUANGO	S	GIRARDOTA	113	086	087	088	053	054	015	000	000	000	000
ITUANGO	S	BELLO	133	086	087	088	053	054	015	016	000	000	000
ITUANGO	S	BELLO	133	086	087	088	053	054	015	016	000	000	000
ITUANGO	S	MEDELLIN	153	086	087	088	053	054	015	016	005	000	000
ITUANGO	S	TOLEDO	20	086	087	000	000	000	000	000	000	000	000
ITUANGO	S	SAN ANDRES	40	086	087	088	000	000	000	000	000	000	000
ITUANGO	S	SANTA ROSA DE	63	086	087	088	053	000	000	000	000	000	000
JARDIN	E	SUPIA	28	028	030	000	000	000	000	000	000	000	000
LA MAGDALE	E	PUERTO BERRIO	243	089	024	025	026	073	014	015	016	005	000
LA MAGDALE	S	MACEO	38	089	024	000	000	000	000	000	000	000	000
LA MAGDALE	S	CISNEROS	98	089	024	025	000	000	000	000	000	000	000
LA MAGDALE	S	SANTO DOMING	229	089	024	025	026	073	000	000	000	000	000
LA MAGDALE	S	BARBOSA	249	089	024	025	026	073	014	000	000	000	000

Table B.1 (Continued)

ORIGIN	TYPE	DESTINATION	DISTANCE	LINK 1	LINK 2	LINK 3	LINK 4	LINK 5	LINK 6	LINK 7	LINK 8	LINK 9	LINK 10
LA MAGDALE	S	GIRARDOTA	267	089	024	025	026	073	014	015	000	000	000
LA MAGDALE	S	BELLO	287	089	024	025	026	073	014	015	016	000	000
LA MAGDALE	S	VEGACHI	25	023	022	000	000	000	000	000	000	000	000
LA UNION	S	MEDELLIN	95	002	003	004	005	000	000	000	000	000	000
LA UNION	S	LA CEJA	15	002	003	000	000	000	000	000	000	000	000
LA UNION	S	RETIRO	70	002	003	004	000	000	000	000	000	000	000
LIBORINA	S2	OLAYA	17	131	092	000	000	000	000	000	000	000	000
LIBORINA	E	ANTIOQUIA	34	131	092	009	000	000	000	000	000	000	000
LIBORINA	S	SAN JERONIMO	54	131	092	009	010	000	000	000	000	000	000
LIBORINA	E	MEDELLIN	102	131	092	009	010	005	000	000	000	000	000
MACEO	S	MEDELLIN	145	025	026	073	014	015	016	015	000	000	000
MACEO	S	CARACOLI	30	025	026	000	000	000	000	000	000	000	000
MACEO	S	CISNEROS	47	025	026	000	000	000	000	000	000	000	000
MACEO	S	YALI	19	025	122	000	000	000	000	000	000	000	000
MACEO	S	SANTO DOMIN	87	025	026	073	000	000	000	000	000	000	000
MACEO	S	BARBOSA	87	025	026	073	014	000	000	000	000	000	000
MACEO	S	GIRARDOTA	105	025	026	073	014	015	000	000	000	000	000
MACEO	S	BELLO	125	025	026	073	014	015	016	000	000	000	000
MARINILLA	S	MEDELLIN	42	074	075	005	000	000	000	000	000	000	000
MARINILLA	S	GUARNE	22	074	075	000	000	000	000	000	000	000	000
MONTEBELLO	E	MEDELLIN	51	093	004	005	000	000	000	000	000	000	000
MONTEBELLO	S	RETIRO	26	093	004	000	000	000	000	000	000	000	000
MONTELIBAN	E	MEDELLIN	100	126	070	050	051	071	035	053	054	015	005
MURINDO	E	ARGELIA	0	114	042	000	000	000	000	000	000	000	000
MURINDO	E	DABEIBA	0	114	066	000	000	000	000	000	000	000	000
MURINDO	E	MEDELLIN	0	114	042	006	002	003	004	000	000	000	000
MUTATA	S	DABEIBA	55	065	066	000	000	000	000	000	000	000	000
MUTATA	S	CHIGORODO	60	065	064	000	000	000	000	000	000	000	000
MUTATA	S	MEDELLIN	241	065	066	067	008	009	010	005	000	000	000
MUTATA	S	URAMITA	89	065	066	068	000	000	000	000	000	000	000
MUTATA	S	GIRALDO	188	065	066	068	055	008	000	000	000	000	000
MUTATA	S	ANTIOQUIA	173	065	066	068	055	008	009	000	000	000	000
NECHI	S	MEDELLIN	397	094	070	050	051	071	035	000	000	000	000
NECHI	S	CAUCASIA	68	094	070	050	051	071	035	053	054	015	016
NECHI	S	CACERES	131	094	070	050	000	000	000	000	000	000	000
NECHI	S	TARAZA	164	094	070	050	051	000	000	000	000	000	000
NECHI	S	VALDIVIA	226	094	070	050	051	071	000	000	000	000	000
NECHI	S	YARUMAL	268	094	070	050	051	071	035	000	000	000	000
NECHI	S	SANTA ROSA DE	311	094	070	050	051	071	035	053	000	000	000

Table B.1 (Continued)

ORIGIN	TYPE	DESTINATION	DISTANCE	LINK 1	LINK 2	LINK 3	LINK 4	LINK 5	LINK 6	LINK 7	LINK 8	LINK 9	LINK 10
NECHI	S	DON MATIAS	334	094	070	050	051	071	035	053	054	000	000
NECHI	S	GIRARDOTA	357	094	070	050	051	071	035	053	054	015	000
NECHI	S	BELLO	357	094	070	050	051	071	035	053	054	015	016
NECHI	S	CAUCASIA	68	094	070	050	051	071	035	053	054	015	016
NECOCLI	S	TURBO	25	095	037	000	000	000	000	000	000	000	000
NECOCLI	S	APARTADO	50	095	037	036	000	000	000	000	000	000	000
NECOCLI	S	CAREPA	65	095	037	036	063	000	000	000	000	000	000
NECOCLI	S	CHIGORODO	75	095	037	036	063	064	000	000	000	000	000
NECOCLI	S	MUTATA	125	095	037	036	063	064	065	000	000	000	000
NECOCLI	S	SAN JERONIMO	353	095	037	036	063	064	065	066	068	055	008
PENOL	S	MEDELLIN	40	084	075	005	000	000	000	000	000	000	000
PENOL	S	GUARNE	20	084	075	000	000	000	000	000	000	000	000
PENOL	S	MARINILLA	17	084	074	000	000	000	000	000	000	000	000
PEQUE	E	MEDELLIN	220	107	068	055	008	009	010	005	000	000	000
PEQUE	S	URAMITA	68	107	068	000	000	000	000	000	000	000	000
PEQUE	S	GIRALDO	117	107	068	055	000	000	000	000	000	000	000
PEQUE	S	ANTIOQUIA	152	107	068	055	008	000	000	000	000	000	000
PEQUE	S	SAN JERONIMO	172	107	068	055	008	009	010	000	000	000	000
PEQUE	S	GIRALDO	117	107	068	055	000	000	000	000	000	000	000
PUEBLO RICO	E	MEDELLIN	90	060	061	120	020	021	005	000	000	000	000
PUEBLO RICO	S	TARSO	13	060	061	000	000	000	000	000	000	000	000
PUEBLO RICO	S	VENECIA	38	060	061	120	000	000	000	000	000	000	000
PUEBLO RICO	S	CALDAS	70	060	061	120	020	000	000	000	000	000	000
PUEBLO RICO	S	ITAGUI	70	060	061	120	020	021	000	000	000	000	000
PUERTO BERRI	E	MEDELLIN	205	024	025	026	073	014	015	016	005	000	000
PUERTO BERRI	S	MACEO	60	024	025	000	000	000	000	000	000	000	000
PUERTO BERRI	S	CISNEROS	104	024	025	026	000	000	000	000	000	000	000
PUERTO BERRI	S	SANTO DOMING	127	024	025	026	073	000	000	000	000	000	000
PUERTO BERRI	S	BARBOSA	147	024	025	026	073	014	000	000	000	000	000
PUERTO BERRI	S	GIRARDOTA	165	024	025	026	073	014	015	000	000	000	000
PUERTO BERRI	S	BELLO	185	024	025	026	073	014	015	016	000	000	000
PUERTO TRIU	S	COCORNA	93	097	100	134	074	075	005	0	000	000	000
PUERTO TRIU	E	MEDELLIN	100	097	100	072	134	069	005	000	000	000	000
RETIRO	S	MEDELLIN	25	004	005	000	000	000	000	000	000	000	000
RIONEGRO	S	MEDELLIN	20	069	005	000	000	000	000	000	000	000	000
SABANALARGA	E	MEDELLIN	122	116	131	092	009	000	000	000	000	000	000
SABANALARGA	S	LIBORINA	20	116	131	000	000	000	000	000	000	000	000
SABANALARGA	S	OLAYA	37	116	131	092	000	000	000	000	000	000	000

Table B.1 (Continued)

ORIGIN	TYPE	DESTINATION	DISTANCE	LINK 1	LINK 2	LINK 3	LINK 4	LINK 5	LINK 6	LINK 7	LINK 8	LINK 9	LINK 10
SABANALARGA	S	ANTIOQUIA	74	116	131	092	009	000	000	000	000	000	000
SABANALARGA	S	SAN JERONIMO	74	116	131	092	009	010	000	000	000	000	000
SALGAR	E	BETULIA	40	101	047	000	000	000	000	000	000	000	000
SALGAR	S	ARMENIA	80	101	047	043	000	000	000	000	000	000	000
SALGAR	S	TITIRIBI	111	101	047	043	048	000	000	000	000	000	000
SALGAR	S	CALDAS	142	101	047	043	048	020	000	000	000	000	000
SALGAR	S	ITAGUI	152	101	047	043	048	020	021	000	000	000	000
SALGAR	E	MEDELLIN	162	101	047	043	048	020	021	005	000	000	000
SAN ANDRES	E	MEDELLIN	125	088	053	054	015	016	005	000	000	000	000
SAN ANDRES	S	SANTA ROSA DE	35	088	053	000	000	000	000	000	000	000	000
SAN ANDRES	S	DON MATIAS	62	088	053	054	000	000	000	000	000	000	000
SAN ANDRES	S	GIRARDOTA	85	088	053	054	015	000	000	000	000	000	000
SAN ANDRES	S	BELLO	105	088	053	054	015	016	000	000	000	000	000
SAN ANDRES	S	YARUMAL	20	088	035	000	000	000	000	000	000	000	000
SAN ANDRES	S	VALDIVIA	62	088	035	071	000	000	000	000	000	000	000
SAN ANDRES	S	TOLEDO	20	088	087	000	000	000	000	000	000	000	000
SAN ANDRES	E	LIBORINA	70	088	131	000	000	000	000	000	000	000	000
SAN CARLOS	E	MEDELLIN	94	082	081	134	069	005	000	000	000	000	000
SAN CARLOS	S	GRANADA	944	082	081	000	000	000	000	000	000	000	000
SAN CARLOS	S	SANTUARIO	54	082	081	134	000	000	000	000	000	000	000
SAN CARLOS	S	RIONEGRO	74	082	081	134	069	000	000	000	000	000	000
SAN JERONIMO	S	MEDELLIN	48	010	005	000	000	000	000	000	000	000	000
SAN JOSE DE L	S	MEDELLIN	138	117	131	092	009	010	005	000	000	000	000
SAN JOSE DE L	S	LIBORINA	50	117	131	000	000	000	000	000	000	000	000
SAN JOSE DE L	S	OLAYA	67	117	131	092	000	000	000	000	000	000	000
SAN JOSE DE L	S	ANTIOQUIA	84	117	131	092	009	000	000	000	000	000	000
SAN JOSE DE L	S	SAN JERONIMO	108	117	131	092	009	010	000	000	000	000	000
SAN JUAN DE U	E	TURBO	45	102	095	037	000	000	000	000	000	000	000
SAN LUIS	E	MEDELLIN	122	100	072	134	069	005	000	000	000	000	000
SAN LUIS	S	COCORNA	38	100	072	000	000	000	000	000	000	000	000
SAN LUIS	S	SANTUARIO	70	100	072	134	000	000	000	000	000	000	000
SAN LUIS	S	MEDELLIN	122	100	072	073	069	005	000	000	000	000	000
SAN LUIS	S	RIONEGRO	90	100	072	073	069	000	000	000	000	000	000
SAN PEDRO	S	MEDELLIN	85	045	054	015	016	005	000	000	000	000	000
SAN PEDRO	S	DON MATIAS	22	045	054	000	000	000	000	000	000	000	000
SAN PEDRO	S	GIRARDOTA	45	045	054	015	000	000	000	000	000	000	000
SAN PEDRO	S	BELLO	65	045	054	015	016	000	000	000	000	000	000
SAN PEDRO	S	ENTRERRIOS	20	045	046	000	000	000	000	000	000	000	000
SAN PEDRO	S	BELMIRA	30	045	044	000	000	000	000	000	000	000	000

Table B.1 (Continued)

ORIGIN	TYPE	DESTINATION	DISTANCE	LINK 1	LINK 2	LINK 3	LINK 4	LINK 5	LINK 6	LINK 7	LINK 8	LINK 9	LINK 10
SAN PEDRO	S	BELLO	65	045	054	015	016	000	000	000	000	000	000
SAN PEDRO	S	BELMIRA	30	045	044	000	000	000	000	000	000	000	000
SAN PEDRO DE	S	TURBO	37	118	037	000	000	000	000	000	000	000	000
SAN PEDRO DE	S	APARTADO	62	118	037	036	000	000	000	000	000	000	000
SAN PEDRO DE	S	CAREPA	77	118	037	036	063	000	000	000	000	000	000
SAN PEDRO DE	S	CHIGORODO	87	118	037	036	063	064	000	000	000	000	000
SAN PEDRO DE	S	MUTATA	147	118	037	036	063	064	065	000	000	000	000
SAN PEDRO DE	S	DABEIBA	202	118	037	036	063	064	065	066	000	000	000
SAN PEDRO DE	S	URAMITA	236	118	037	036	063	064	065	066	068	000	000
SAN PEDRO DE	S	GIRALDO	285	118	037	036	063	064	065	066	068	055	008
SAN PEDRO DE	S	ANTIOQUIA	320	118	037	036	063	064	065	066	068	055	008
SAN PEDRO DE	S	SAN JERONIMO	340	118	037	036	063	064	065	066	068	055	008
SAN RAFAEL	E	MEDELLIN	83	103	083	084	075	005	000	000	000	000	000
SAN RAFAEL	S	GUATAPE	26	103	083	000	000	000	000	000	000	000	000
SAN RAFAEL	S	PENOL	41	103	083	084	000	000	000	000	000	000	000
SAN RAFAEL	S	GUARNE	63	103	083	084	075	000	000	000	000	000	000
SAN ROQUE	E	MEDELLIN	100	104	073	014	015	016	005	000	000	000	000
SAN ROQUE	S	SANTO DOMING	22	104	073	000	000	000	000	000	000	000	000
SAN ROQUE	S	BARBOSA	42	104	073	014	000	000	000	000	000	000	000
SAN ROQUE	S	GIRARDOTA	60	104	073	014	015	000	000	000	000	000	000
SAN ROQUE	S	BELLO	80	104	073	014	015	016	000	000	000	000	000
SAN ROQUE	S	MEDELLIN	100	104	017	014	015	016	005	000	000	000	000
SAN VICENTE	S	MEDELLIN	105	105	013	014	015	016	005	000	000	000	000
SAN VICENTE	S	CONCEPCION	23	105	013	000	000	000	000	000	000	000	000
SAN VICENTE	S	BARBOSA	46	105	013	014	000	000	000	000	000	000	000
SAN VICENTE	S	BELLO	84	105	013	014	015	016	000	000	000	000	000
SAN VICENTE	S	GIRADOTA	64	105	013	014	015	000	000	000	000	000	000
SANTA BARB	S	CALDAS	30	144	020	000	000	000	000	000	000	000	000
SANTA BARB	E	SUPIA	27	078	030	000	000	000	000	000	000	000	000
SANTA BARBA	S	MEDELLIN	50	144	020	021	005	016	000	000	000	000	000
SANTA BARBA	S	ITAGUI	40	144	020	021	000	000	000	000	000	000	000
SANTA BARBA	E	FREDONIA	25	078	132	000	000	000	000	000	000	000	000
SANTA ROSA D	S	MEDELLIN	90	053	054	015	016	005	000	000	000	000	000
SANTA ROSA D	S	DON MATIAS	27	053	054	000	000	000	000	000	000	000	000
SANTA ROSA D	S	GIRARDOTA	50	053	054	015	000	000	000	000	000	000	000
SANTA ROSA D	S	BELLO	70	053	054	015	016	000	000	000	000	000	000
SANTA ROSA D	S	ENTRERRIOS	35	053	076	000	000	000	000	000	000	000	000
SANTA ROSA D	S	YARUMAL	43	053	035	000	000	000	000	000	000	000	000

Table B.1. (Continued)

ORIGIN	TYPE	DESTINATION	DISTANCE	LINK 1	LINK 2	LINK 3	LINK 4	LINK 5	LINK 6	LINK 7	LINK 8	LINK 9	LINK 10
SANTO DOMIN	S	MEDELLIN	78	073	014	015	016	005	000	000	000	000	000
SANTO DOMIN	S	BARBOSA	22	073	014	000	000	000	000	000	000	000	000
SANTO DOMIN	S	GIRARDOTA	38	073	014	015	000	000	000	000	000	000	000
SANTO DOMIN	S	BELLO	58	073	014	015	016	000	000	000	000	000	000
SANTUARIO	S	MEDELLIN	60	134	074	075	005	000	000	000	000	000	000
SANTUARIO	S	MARINILLA	20	134	074	000	000	000	000	000	000	000	000
SANTUARIO	S	GUARNE	40	134	074	075	000	000	000	000	000	000	000
SEGOVIA	S	MEDELLIN	345	106	023	024	025	026	073	014	015	016	005
SEGOVIA	S	REMEDIOS	18	106	023	000	000	000	000	000	000	000	000
SEGOVIA	S	PUERTO BERRIO	120	106	023	024	000	000	000	000	000	000	000
SEGOVIA	S	MACEO	180	106	023	024	025	000	000	000	000	000	000
SEGOVIA	S	CISNEROS	227	106	023	024	025	026	000	000	000	000	000
SEGOVIA	S	SANTO DOMINGO	267	106	023	024	025	026	073	000	000	000	000
SEGOVIA	S	BARBOSA	287	106	023	024	025	026	073	014	000	000	000
SEGOVIA	S	GIRARDOTA	305	106	023	024	025	026	073	014	015	000	000
SEGOVIA	S	BELLO	325	106	023	024	025	026	073	014	015	016	000
SEGOVIA	S	VEGACHI	63	106	023	022	000	000	000	000	000	000	000
SEGOVIA	S	AMALFI	126	106	023	022	143	000	000	000	000	000	000
SONSON	S	MEDELLIN	109	006	002	003	004	005	000	000	000	000	000
SONSON	S	LA UNION	55	006	002	000	000	000	000	000	000	000	000
SONSON	S	LA CEJA	70	006	002	003	000	000	000	000	000	000	000
SONSON	S	RETIRO	84	006	002	003	004	000	000	000	000	000	000
SONSON	S	ARGELIA	35	006	042	000	000	000	000	000	000	000	000
SOPETRAN	E	SAN JERONIMO	0	119	010	000	000	000	000	000	000	000	000
SOPETRAN	E	MEDELLIN	0	119	010	005	000	000	000	000	000	000	000
SUPIA	E	MEDELLIN	120	005	021	020	078	030	000	000	000	000	000
TAMESIS	E	MEDELLIN	128	058	059	060	061	120	020	021	005	000	000
TAMESIS	S	JERICO	27	058	059	000	000	000	000	000	000	000	000
TAMESIS	S	CALDAS	108	058	059	060	061	120	020	000	000	000	000
TAMESIS	S	ITAGUI	118	058	059	060	061	120	020	021	000	000	000
TAMESIS	S	MEDELLIN	128	058	059	060	061	062	020	021	050	000	000
TAMESIS	S	JERICO	27	058	059	000	000	000	000	000	000	000	000
TAMESIS	S	TARSO	51	058	059	060	061	000	000	000	000	000	000
TAMESIS	S	VENECIA	76	058	059	060	061	120	000	000	000	000	000
TARAZA	S	YARUMAL	104	051	071	035	000	000	000	000	000	000	000
TARAZA	S	VALDIVIA	62	051	071	000	000	000	000	000	000	000	000
TARAZA	S	CACERES	63	051	050	000	000	000	000	000	000	000	000
TARSO	E	MEDELLIN	77	061	120	020	021	005	000	000	000	000	000
TARSO	S	VENECIA	25	061	120	000	000	000	000	000	000	000	000

Table B.1. (Continued)

ORIGIN	TYPE	DESTINATION	DISTANCE	LINK 1	LINK 2	LINK 3	LINK 4	LINK 5	LINK 6	LINK 7	LINK 8	LINK 9	LINK 10
TARSO	S	CALDAS	57	061	120	020	000	000	000	000	000	000	000
TARSO	S	ITAGUI	67	061	120	020	021	000	000	000	000	000	000
TITIRIBI	E	CALDAS	34	048	020	000	000	000	000	000	000	000	000
TITIRIBI	E	MEDELLIN	51	048	020	021	005	000	000	000	000	000	000
TOLEDO	E	MEDELLIN	51	087	088	053	054	015	016	005	000	000	000
TOLEDO	S	SAN ANDRES	20	087	088	000	000	000	000	000	000	000	000
TOLEDO	S	SANTA ROSA DE	55	087	088	053	000	000	000	000	000	000	000
TOLEDO	S	DON MATIAS	82	087	088	053	054	000	000	000	000	000	000
TOLEDO	S	GIRARDOTA	105	087	088	053	054	015	000	000	000	000	000
TOLEDO	S	BELLO	105	087	088	053	054	015	016	000	000	000	000
TOLEDO	S	ITAGUI	41	048	020	021	000	000	000	000	000	000	000
TURBO	S	APARTADO	25	037	036	000	000	000	000	000	000	000	000
TURBO	S	CAREPA	40	037	036	063	000	000	000	000	000	000	000
TURBO	S	CHIGORODO	50	037	036	063	064	000	000	000	000	000	000
TURBO	S	MUTATA	100	037	036	063	064	065	000	000	000	000	000
URAMITA	S	MEDELLIN	138	068	055	008	009	010	005	000	000	000	000
URAMITA	S	CANASGORDAS	28	068	055	000	000	000	000	000	000	000	000
URAMITA	S	GIRALDO	49	068	055	008	000	000	000	000	000	000	000
URAMITA	S	ANTIOQUIA	84	068	055	008	009	000	000	000	000	000	000
URAMITA	S	SAN JERONIMO	104	068	055	008	009	010	000	000	000	000	000
URAMITA	S	PEQUE	68	068	107	000	000	000	000	000	000	000	000
URAMITA	S	GIRALDO	49	068	055	008	000	000	000	000	000	000	000
URRAO	S	MEDELLIN	164	113	047	043	048	020	021	005	000	000	000
URRAO	S	BETULIA	42	113	047	000	000	000	000	000	000	000	000
URRAO	E	ARMENIA	82	113	047	043	000	000	000	000	000	000	000
URRAO	S	CALDAS	144	113	047	043	048	020	000	000	000	000	000
URRAO	S	ITAGUI	154	113	047	043	048	020	021	000	000	000	000
URRAO	S	CAICEDO	42	113	112	000	000	000	000	000	000	000	000
URRAO	S	MEDELLIN	164	113	047	043	048	020	021	005	000	000	000
URRAO	S	TITIRIBI	115	113	047	043	048	000	000	000	000	000	000
VALDIVIA	S	YARUMIAL	42	071	035	000	000	000	000	000	000	000	000
VALDIVIA	S	MEDELLIN	175	071	035	053	054	015	016	005	000	000	000
VALDIVIA	S	SANTA ROSA DE	71	071	035	053	000	000	000	000	000	000	000
VALDIVIA	S	DON MATIAS	112	071	035	053	054	000	000	000	000	000	000
VALDIVIA	S	GIRARDOTA	135	071	035	053	054	015	000	000	000	000	000
VALDIVIA	S	BELLO	155	071	035	053	054	015	016	000	000	000	000
VALPARAISO	E	MEDELLIN	153	057	058	059	060	061	120	020	021	005	000
VALPARAISO	S	TAMESIS	25	057	058	000	000	000	000	000	000	000	000
VALPARAISO	S	JERICO	52	057	058	059	000	000	000	000	000	000	000

Table B.1. (Continued)

ORIGIN	TYPE	DESTINATION	DISTANCE	LINK 1	LINK 2	LINK 3	LINK 4	LINK 5	LINK 6	LINK 7	LINK 8	LINK 9	LINK 10
VALPARAISO	S	TARSO	76	057	058	059	060	061	000	000	000	000	000
VALPARAISO	S	VENECIA	101	057	058	059	060	061	120	000	000	000	000
VALPARAISO	S	CALDAS	133	057	058	059	060	061	120	020	000	000	000
VALPARAISO	S	ITAGUI	143	057	058	059	060	061	120	020	021	000	000
VALPARAISO	S	MEDELLIN	153	057	058	059	060	061	120	021	005	000	000
VALPARAISO	S	PUEBLO RICO	63	057	058	059	060	000	000	000	000	000	000
VEGACHI	S2	MEDELLIN	329	022	023	024	025	026	073	014	015	016	005
VEGACHI	S2	REMEDIOS	22	022	023	000	000	000	000	000	000	000	000
VEGACHI	S2	MACEO	237	022	023	024	025	000	000	000	000	000	000
VEGACHI	S2	SANTO DOMIN	251	022	023	024	025	026	073	000	000	000	000
VEGACHI	S2	BARBOSA	271	022	023	024	025	026	073	014	000	000	000
VEGACHI	S2	BELLO	309	022	023	024	025	026	073	014	015	016	000
VEGACHI	S2	MEDELLIN	329	022	023	024	025	026	017	014	015	016	005
VEGACHI	S2	PUERTO BERRIO	124	022	023	024	000	000	000	000	000	000	000
VEGACHI	S2	GIRADOTA	288	022	023	024	025	026	073	014	015	000	000
VIGIA DEL FUE	E	URRAO	0	121	113	000	000	000	000	000	000	000	000
YALI	E	MEDELLIN	154	122	025	026	073	014	015	016	005	000	000
YALI	S	MACEO	19	122	025	000	000	000	000	000	000	000	000
YALI	S	CISNEROS	72	122	025	026	000	000	000	000	000	000	000
YALI	S	SANTO DOMING	86	122	025	026	073	000	000	000	000	000	000
YALI	S	BARBOSA	106	122	025	026	073	014	000	000	000	000	000
YALI	S	GIRARDOTA	123	122	025	026	073	014	015	000	000	000	000
YALI	S	BELLO	144	122	025	026	073	014	015	016	000	000	000
YALI	S	YOLOMBO	47	122	123	000	000	000	000	000	000	000	000
YARUMAL	S	MEDELLIN	13	035	053	054	015	016	005	000	000	000	000
YARUMAL	S	SANTA ROSA DE	43	035	053	000	000	000	000	000	000	000	000
YARUMAL	S	DON MATIAS	70	035	053	054	000	000	000	000	000	000	000
YARUMAL	S	GIRARDOTA	93	035	053	054	015	000	000	000	000	000	000
YARUMAL	S	BELLO	113	035	053	054	015	016	000	000	000	000	000
YARUMAL	S	CAMPAMENTO	20	035	052	000	000	000	000	000	000	000	000
YARUMAL	S	ANGOSTURAS	15	035	034	000	000	000	000	000	000	000	000
YARUMAL	S	SAN ANDRES	20	035	088	000	000	000	000	000	000	000	000
YOLOMBO	S	MEDELLIN	201	123	122	025	026	073	014	015	016	005	000
YOLOMBO	S	YALI	47	123	122	000	000	000	000	000	000	000	000
YOLOMBO	S	MACEO	66	123	122	025	000	000	000	000	000	000	000
YOLOMBO	S	CISNEROS	119	123	122	025	026	000	000	000	000	000	000
YOLOMBO	S	SANTO DOMIN	133	123	122	025	026	073	000	000	000	000	000
YOLOMBO	S	BARBOSA	133	123	122	025	026	073	014	000	000	000	000
YOLOMBO	S	GIRARDOTA	170	123	122	025	026	073	014	015	000	000	000

Table B.1. (Continued)

ORIGIN	TYPE	DESTINATION	DISTANCE	LINK 1	LINK 2	LINK 3	LINK 4	LINK 5	LINK 6	LINK 7	LINK 8	LINK 9	LINK 10
YOLOMBO	S	BELLO	191	123	122	025	026	073	014	015	016	000	000
YONDO	E	MEDELLIN	124	024	025	026	073	014	015	016	005	000	000
ZARAGOZA	S	MEDELLIN	355	137	070	050	051	071	035	053	054	015	016
ZARAGOZA	S	CAUCASIA	35	137	070	000	000	000	000	000	000	000	000
ZARAGOZA	S	CACERES	98	137	070	050	000	000	000	000	000	000	000
ZARAGOZA	S	TARAZA	131	137	070	050	051	000	000	000	000	000	000
ZARAGOZA	S	VALDIVIA	192	137	070	050	051	071	000	000	000	000	000
ZARAGOZA	S	YARUMAL	235	137	070	050	051	071	035	000	000	000	000
ZARAGOZA	S	SANTA ROSA DE	278	137	070	050	051	071	035	053	000	000	000
ZARAGOZA	S	DON MATIAS	302	137	070	050	051	071	035	053	054	000	000
ZARAGOZA	S	GIRARDOTA	325	137	070	050	051	071	035	053	054	015	000
ZARAGOZA	S	BELLO	345	137	070	050	051	071	035	053	054	015	016
ZARAGOZA	S	EL BAGRE	20	137	135	000	000	000	000	000	000	000	000

APPENDIX C: RESULTS FROM CALIBRATION

Table C.1. Results from calibration by using the gravity model

ORIGYN	TYPE (1)	MARKET	DISTANCE (Km)	COST	AI	BJ	TIJ	DI	PJ
ABEJORRAL	E	MEDELLIN	106	7.707E-08	18.0117	0.0026	0.878	3816	63435
ABEJORRAL	S	LA UNION	50	1.078E-06	18.0117	5.1358	371.555	1306	2854
ABEJORRAL	S	LA CEJA	66	4.495E-07	18.0117	0.5541	2.589	1306	442
ABEJORRAL	S	RETIRO	80	2.3E-07	18.0117	0.0549	2.039	1306	6868
ABEJORRAL	S	SONSON	106	6.461E-08	18.0117	1.0048	5.448	1306	3568
ABRIAQUI	S	MEDELLIN	133	4.034E-08	12.8104	0.0026	0.077	904	63435
ABRIAQUI	S	GIRALDO	10	1.497E-05	12.8104	0.3032	15.763	904	300
ABRIAQUI	S	ANTIOQUIA	45	5.606E-07	12.8104	0.0098	0.096	904	1502
ABRIAQUI	S	SAN JERONIMO	65	2.118E-07	12.8104	0.1047	0.936	904	3643
ABRIAQUI	S	FRONTINO	27	1.389E-05	12.8104	1.0000	470.338	904	2925
ALEJANDRIA	S	MEDELLIN	90	1.24E-07	0.1908	0.0026	0.002	464	63435
ALEJANDRIA	S	CONCEPCION	17	8.436E-05	0.1908	102.1465	381.343	464	500
ALEJANDRIA	S	BARBOSA	40	2.998E-06	0.1908	0.0345	0.019	464	2067
ALEJANDRIA	S	GIRARDOTA	58	8.252E-07	0.1908	0.0308	0.000	464	126
ALEJANDRIA	S	BELLO	78	2.854E-07	0.1908	0.0076	0.002	464	9332
ALEJANDRIA	S	SANTO DOMI	20	0.0048987	0.1908	2.1530	971.794	464	1041
AMAGA	S	MEDELLIN	49	5.664E-06	0.2736	0.0026	1.608	6262	63435
AMAGA	S	CALDAS	29	1.798E-05	0.2736	0.2163	4.806	6262	721
AMAGA	S	ITAGUI	39	5.664E-06	0.2736	0.0117	0.218	6262	1920
AMALFI	S	MEDELLIN	392	5.274E-10	14.9077	0.0026	0.005	3772	63435
AMALFI	S	MACEO	247	2.474E-09	14.9077	0.0601	0.004	3772	500
AMALFI	S	CISNEROS	294	1.254E-09	14.9077	1.7743	1.031	3772	8241
AMALFI	S	BARBOSA	334	7.625E-10	14.9077	0.0345	0.003	3772	2067
AMALFI	S	GIRARDOTA	352	6.376E-10	14.9077	0.0308	0.000	3772	126
AMALFI	S	BELLO	372	5.274E-10	14.9077	0.0076	0.002	3772	9332
AMALFI	S	MEDELLIN	392	5.274E-10	14.9077	0.0026	0.005	3772	63435
AMALFI	S	REMEDIOS	85	1.585E-07	14.9077	0.6854	22.036	3772	3606
AMALFI	S	SANTO DOMI	314	9.702E-10	14.9077	2.1530	0.122	3772	1041
ANDES	S	SUPIA	51	8.071E-07	0.9462	5.0687	6.918	1047	1707
ANDES	S	SANTA BARB	144	8.082E-08	0.9462	8.2746	1.329	1047	2006
ANDES	E	MEDELLIN	0	8.071E-07	0.9462	0.0026	0.437	3451	63435
ANDES	S	JARDIN	36	4.476E-05	0.9462	13.6221	885.421	1047	1466
ANDES	S	SUPIA	51	8.071E-07	0.9462	5.0687	6.918	1047	1707
ANGOSTURA	E	YARUMAL	15	0.0001374	1.0000	0.5157	829.093	3008	3889
ANTIOQUIA	S	MEDELLIN	45	6.478E-07	0.9878	0.0026	0.228	2152	63435
ANTIOQUIA	S	SAN JERONIMO	20	7.66E-05	0.9878	0.1047	62.100	2152	3643
APARTADO	E	TURBO	25	5.047E-06	1.0000	0.4211	1270.756	80985	7384
ARBOLETES	S	MONTERIA	90	1.269E-07	31.1202	17.9262	8164.422	14129	8165
ARBOLETES	S	LOS CORDOBAS	30	8.98E-06	31.1202	0.0000	0.000	14129	0

(1) E stands for export trip and S stands for a trip of staple crops.

Table C.1. (Continued)

ORIGIN	TYPE (1)	MARKET	DISTANCE (Km)	COST	AI	BJ	TIJ	DI	PJ
ARBOLETES	S	CANALETE	45	1.354E-05	31.1202	0.0000	0.000	14129	0
ARGELIA	S	SONSON	20	5.047E-06	55.5195	1.0048	1585.108	1578	3568
ARGELIA	E	MEDELLIN	40	4.833E-08	55.5195	0.0026	0.878	1975	63435
ARMENIA	S	MEDELLIN	82	1.051E-07	1.2623	0.0026	0.008	343	63435
ARMENIA	S	TITIRIBI	31	8.101E-06	1.2623	0.0252	0.102	343	1153
ARMENIA	S	CALDAS	62	1.533E-07	1.2623	0.2163	0.010	343	721
ARMENIA	S	ITAGUI	72	1.051E-07	1.2623	0.0117	0.001	343	1920
BARBOSA	E	MEDELLIN	68	1.205E-06	0.0200	0.0026	0.035	8702	63435
BARBOSA	S	GIRARDOTA	18	6.268E-06	0.0200	0.0308	0.004	7496	126
BARBOSA	S	BELLO	48	7.66E-05	0.0200	0.0076	0.811	7496	9332
BARBOSA	S	DON MATIAS	25	7.66E-05	0.0200	0.0292	0.247	7496	738
BELLO	S	MEDELLIN	20	7.66E-05	1.0000	0.0026	5.891	464	63435
BELMIRA	S	SAN PEDRO	20	4.476E-05	24.6885	1.0000	859.050	860	904
BETANIA	S	MEDELLIN	219	1.321E-08	1.8779	0.0026	0.001	161	63435
BETANIA	S	ANDES	15	0.0001374	1.8779	1.7596	249.989	161	3419
BETANIA	S	SUPIA	66	5.047E-06	1.8779	5.0687	13.202	161	1707
BETANIA	S	CALDAS	199	1.221E-08	1.8779	0.2163	0.001	161	721
BETANIA	S	ITAGUI	209	9.977E-09	1.8779	0.0117	0.000	161	1920
BETANIA	S	MEDELLIN	219	1.321E-08	1.8779	0.0026	0.001	161	63435
BETANIA	S	SANTA BARB	169	9.851E-08	1.8779	8.2746	0.494	161	2006
BETULIA	E	MEDELLIN	122	1.191E-08	86.6443	0.0026	0.335	1960	63435
BETULIA	S	ARMENIA	40	3.265E-07	86.6443	0.2872	1.134	594	235
BETULIA	S	TITIRIBI	71	7.898E-08	86.6443	0.0252	0.118	594	1153
BETULIA	S	CALDAS	102	1.471E-08	86.6443	0.2163	0.118	594	721
BETULIA	S	ITAGUI	110	1.191E-08	86.6443	0.0117	0.014	594	1920
BOLIVAR	S	MEDELLIN	106	1.216E-07	12.3162	0.0026	0.410	1651	63435
BOLIVAR	S	AMAGA	57	7.533E-07	12.3162	28.0473	2141.188	1651	4984
BOLIVAR	S	CALDAS	86	1.801E-07	12.3162	0.2163	0.571	1651	721
BOLIVAR	S	ITAGUI	96	1.216E-07	12.3162	0.0117	0.056	1651	1920
CACERES	S	TARAZA	33	8.726E-07	1.0000	100.3901	1592.014	6150	2955
CAICEDO	E	MEDELLIN	206	2.285E-09	0.4507	0.0026	0.000	1719	63435
CAICEDO	S	URRAO	42	1.894E-06	0.4507	1.0000	1.251	138	10619
CAICEDO	S	BETULIA	84	1.448E-07	0.4507	25.9172	0.385	138	1649
CAICEDO	S	ARMENIA	124	1.426E-08	0.4507	0.2872	0.000	138	235
CAICEDO	S	TITIRIBI	155	7.079E-09	0.4507	0.0252	0.000	138	1153
CAICEDO	S	CALDAS	186	2.621E-09	0.4507	0.2163	0.000	138	721
CAICEDO	S	ITAGUI	196	2.285E-09	0.4507	0.0117	0.000	138	1920
CAICEDO	S	BETULIA	84	1.448E-07	0.4507	25.9172	0.385	138	1649
CAICEDO	S	ARMENIA	124	1.426E-08	0.4507	0.2872	0.000	138	235

Table C.1. (Continued)

ORIGIN	TYPE (1)	MARKET	DISTANCE (Km)	COST	AI	BJ	TIJ	DI	PJ
CALDAS	S	MEDELLIN	20	0.0011435	0.0014	0.0026	0.095	368	63435
CALDAS	S	ITAGUI	10	0.0011435	0.0014	0.0117	0.013	368	1920
CAMPAMENTO	E	YARUMAL	20	4.476E-05	5.7437	0.5157	3467.490	6726	3889
CANASGORDAS	S	GIRALDO	21	3.7E-05	10.1062	0.3032	111.655	3283	300
CANASGORDAS	S	ANTIOQUIA	56	3.7E-05	10.1062	0.0098	18.088	3283	1502
CANASGORDAS	S	SAN JERONIMO	76	2.806E-07	10.1062	0.1047	3.550	3283	3643
CANASGORDAS	E	MEDELLIN	124	4.836E-08	10.1062	0.0026	0.246	3040	63435
CARACOLI	S	MEDELLIN	175	1.124E-08	106.0522	0.0026	0.160	810	63435
CARACOLI	S	CISNEROS	77	2.331E-07	106.0522	1.7743	292.796	810	8241
CARACOLI	S	SANTO DOMI	77	9.472E-08	106.0522	2.1530	18.237	810	1041
CARACOLI	S	BARBOSA	117	4.56E-08	106.0522	0.0345	0.279	810	2067
CARACOLI	S	GIRARDOTA	135	4.56E-08	106.0522	0.0308	0.015	810	126
CARACOLI	S	BELLO	135	1.725E-08	106.0522	0.0076	0.105	810	9332
CARAMANTA	S	MEDELLIN	170	9.756E-09	0.0956	0.0026	0.000	624	63435
CARAMANTA	S	JERICO	69	3.576E-07	0.0956	172.1823	5.264	624	1434
CARAMANTA	S	CALDAS	150	1.192E-08	0.0956	0.2163	0.000	624	721
CARAMANTA	S	ITAGUI	160	9.756E-09	0.0956	0.0117	0.000	624	1920
CARAMANTA	S	TAMESIS	42	2.479E-06	0.0956	1.8975	0.518	624	1849
CARAMANTA	S	PUEBLO RICO	80	2.008E-07	0.0956	11167.6182	98.154	624	734
CARAMANTA	S	TARSO	93	1.116E-07	0.0956	0.7545	0.004	624	773
CAREPA	S	CHIGORODO	10	4.476E-05	0.3931	1.2552	40.013	2097	864
CAREPA	S	MUTATA	60	8.412E-08	0.3931	0.8069	0.111	2097	1978
CAREPA	S	URAMITA	149	6.882E-09	0.3931	0.6736	0.006	2097	1697
CAREPA	E	TURBO	30	1.256E-06	0.3931	0.4211	8.244	5371	7384
CAREPA	S	APARTADO	25	0.0001374	0.3931	0.0929	11.157	2097	1060
CARMEN DE VIB	S	MEDELLIN	41	3.87E-06	0.4716	0.0026	0.423	1397	63435
CAROLINA	S	MEDELLIN	176	1.383E-08	54.3877	0.0026	0.064	517	63435
CAROLINA	S	ANGOSTURAS	28	1.205E-05	54.3877	0.0000	0.000	517	0
CAROLINA	S	YARUMAL	43	2.261E-06	54.3877	0.5157	127.510	517	3889
CAROLINA	S	DON MATIAS	113	7.221E-08	54.3877	0.0292	0.044	517	738
CAROLINA	S	BELLO	156	2.175E-08	54.3877	0.0076	0.043	517	9332
CAROLINA	S	SANTA ROSA DE	86	1.963E-07	54.3877	0.4199	5.038	517	2173
CAROLINA	S	GIRADOTA	136	3.632E-08	54.3877	0.0000	0.000	517	0
CAUCASIA	S	MEDELLIN	326	9.432E-10	2.0699	0.0026	0.001	3261	63435
CAUCASIA	S	CACERES	63	8.726E-07	2.0699	10.8876	231.313	3261	3607
CAUCASIA	S	TARAZA	99	5.845E-08	2.0699	100.3901	117.045	3261	2955
CAUCASIA	S	VALDIVIA	161	1.228E-08	2.0699	0.7788	0.084	3261	1307
CAUCASIA	S	YARUMAL	203	5.591E-09	2.0699	0.5157	0.076	3261	3889
CAUCASIA	S	DON MATIAS	273	1.984E-09	2.0699	0.0292	0.000	3261	738

Table C.1. (Continued)

ORIGIN	TYPE (1)	MARKET	DISTANCE (Km)	COST	AI	BJ	TIJ	DI	PJ
CAUCASIA	S	GIRARDOTA	296	1.487E-09	2.0699	0.0308	0.000	3261	126
CAUCASIA	S	BELLO	296	1.177E-09	2.0699	0.0076	0.001	3261	9332
CAUCASIA	S	SANTA ROSA DE	246	2.866E-09	2.0699	0.4199	0.018	3261	2173
CAUCASIA	E	MONTELIBANO	700	7.66E-05	2.0699	1.0000	0.394	2	1243
CHIGORODO	S	APARTADO	25	5.047E-06	45.4240	0.0929	20.204	895	1060
CHIGORODO	E	TURBO	64	3.381E-07	45.4240	0.4211	226.836	4751	7384
CISNEROS	S	BARBOSA	40	2.998E-06	1.1351	0.0345	1.828	7534	2067
CISNEROS	S	GIRARDOTA	78	8.252E-07	1.1351	0.0308	0.027	7534	126
CISNEROS	E	MEDELLIN	128	1.205E-06	1.1351	0.0026	3.388	14947	63435
CISNEROS	S	BELLO	108	6.268E-06	1.1351	0.0076	3.795	7534	9332
COCORNA	S	MARINILLA	42	2.149E-06	5.0410	29.3857	587.326	1225	1506
COCORNA	S	GUARNE	62	5.184E-07	5.0410	0.1357	0.527	1225	1213
COCORNA	E	MEDELLIN	82	1.993E-07	5.0410	0.0026	0.454	2726	63435
CONCEPCION	S	MEDELLIN	81	2.79E-07	5.3354	0.0026	0.129	521	63435
CONCEPCION	S	BARBOSA	23	2.595E-05	5.3354	0.0345	5.144	521	2067
CONCEPCION	S	GIRARDOTA	41	3.416E-06	5.3354	0.0308	0.037	521	126
CONCEPCION	S	BELLO	61	8.01E-07	5.3354	0.0076	0.158	521	9332
DABEIBA	E	MEDELLIN	186	3.544E-09	8.5696	0.0026	0.082	16385	63435
DABEIBA	S	URAMITA	34	6.167E-07	8.5696	0.6736	26.825	4440	1697
DABEIBA	S	CANASGORDAS	62	5.8E-08	8.5696	0.1379	0.617	4440	2028
DABEIBA	S	GIRALDO	83	2.934E-08	8.5696	0.3032	0.102	4440	300
DABEIBA	S	ANTIOQUIA	118	1.165E-08	8.5696	0.0098	0.007	4440	1502
DABEIBA	S	SAN JERONIMO	138	7.895E-09	8.5696	0.1047	0.115	4440	3643
DON MATIAS	S	MEDELLIN	63	8.726E-07	1.7520	0.0026	0.143	564	63435
DON MATIAS	S	GIRARDOTA	23	4.441E-05	1.7520	0.0308	0.170	564	126
DON MATIAS	S	BELLO	43	3.87E-06	1.7520	0.0076	0.271	564	9332
EBEJICO	S	HELICONIA	36	4.522E-06	1.9190	157.0091	806.899	733	808
EBEJICO	S	ITAGUI	66	8.071E-07	1.9190	0.0117	0.026	733	1920
EBEJICO	S	MEDELLIN	76	8.071E-07	1.9190	0.0026	0.188	733	63435
EL BAGRE	S	MEDELLIN	372	6.088E-10	8.9333	0.0026	0.005	6010	63435
EL BAGRE	S	ZARAGOZA	20	4.476E-05	8.9333	0.4161	2001.667	6010	2002
EL BAGRE	S	CAUCASIA	55	8.659E-07	8.9333	0.0955	14.111	6010	3179
EL BAGRE	S	CACERES	118	5.823E-08	8.9333	10.8876	122.769	6010	3607
EL BAGRE	S	TARAZA	151	1.199E-08	8.9333	100.3901	191.014	6010	2955
EL BAGRE	S	VALDIVIA	151	3.969E-09	8.9333	0.7788	0.217	6010	1307
EL BAGRE	S	YARUMAL	255	2.171E-09	8.9333	0.5157	0.234	6010	3889
EL BAGRE	S	SANTA ROSA DE	282	1.273E-09	8.9333	0.4199	0.062	6010	2173
EL BAGRE	S	DON MATIAS	309	9.42E-10	8.9333	0.0292	0.001	6010	738
EL CARMEN	S	MEDELLIN	100	3.876E-08	40.1004	0.0026	1.635	6348	63435

Table C.1. (Continued)

ORIGIN	TYPE (1)	MARKET	DISTANCE (Km)	COST	AI	BJ	TIJ	DI	PJ
EL CARMEN	S	BOLIVAR	100	8.101E-06	40.1004	1.0000	4858.737	6348	2356
ENTRERRIOS	S	MEDELLIN	88	2.467E-07	5.1681	0.0026	0.144	683	63435
ENTRERRIOS	S	DON MATIAS	21	3.7E-05	5.1681	0.0292	2.813	683	738
ENTRERRIOS	S	GIRARDOTA	48	2.713E-06	5.1681	0.0308	0.037	683	126
ENTRERRIOS	S	BELLO	68	6.823E-07	5.1681	0.0076	0.171	683	9332
FREDONIA	S	CALDAS	57	9.903E-07	0.3869	0.2163	0.080	1343	721
FREDONIA	S	ITAGUI	67	0.0011435	0.3869	0.0117	13.350	1343	1920
FREDONIA	E	MEDELLIN	77	5.478E-07	0.3869	0.0026	0.067	1921	63435
FREDONIA	S	SANTA BARB	27	1.389E-05	0.3869	8.2746	119.768	1343	2006
FRONTINO	S	MEDELLIN	160	1.836E-08	49.6679	0.0026	0.595	3937	63435
FRONTINO	S	ABRIAQUI	160	1.389E-05	49.6679	0.3682	531.865	3937	532
FRONTINO	S	GIRALDO	37	9.655E-07	49.6679	0.3032	17.170	3937	300
FRONTINO	S	ANTIOQUIA	72	1.355E-07	49.6679	0.0098	0.390	3937	1502
FRONTINO	S	SAN JERONIMO	92	6.723E-08	49.6679	0.1047	5.014	3937	3643
GIRALDO	S	CANASGORDAS	21	3.7E-05	13.3199	0.1379	41.208	299	2028
GIRALDO	S	ANTIOQUIA	35	5.047E-06	13.3199	0.0098	0.296	299	1502
GIRARDOTA	S	MEDELLIN	40	1.66E-05	0.0877	0.0026	0.059	243	63435
GIRARDOTA	S	BELLO	20	7.66E-05	0.0877	0.0076	0.116	243	9332
GOMEZ PLATA	E	MEDELLIN	201	9.725E-09	3.8007	0.0026	0.017	2799	63435
GOMEZ PLATA	S	CAROLINA	15	0.0001374	3.8007	1.0000	563.296	2611	413
GOMEZ PLATA	S	ANGOSTURAS	43	2.261E-06	3.8007	0.0000	0.000	2611	0
GOMEZ PLATA	S	YARUMAL	58	7.039E-07	3.8007	0.5157	14.008	2611	3889
GOMEZ PLATA	S	DON MATIAS	128	4.27E-08	3.8007	0.0292	0.009	2611	738
GOMEZ PLATA	S	GIRARDOTA	151	2.327E-08	3.8007	0.0308	0.001	2611	126
GOMEZ PLATA	S	BELLO	181	9.725E-09	3.8007	0.0076	0.007	2611	9332
GOMEZ PLATA	S	SANTA ROSA	101	1.008E-07	3.8007	0.0000	0.000	2611	0
GRANADA	E	MEDELLIN	52	3.063E-07	0.0203	0.0026	0.001	1423	63435
GRANADA	S	SAN CARLOS	39	3.309E-06	0.0203	1.0000	0.116	431	4005
GRANADA	S	SANTUARIO	15	1.497E-05	0.0203	1588.6213	224.376	431	1080
GRANADA	S	RIONEGRO	20	2.084E-06	0.0203	1948.3332	95.352	431	2688
GUARNE	S	MEDELLIN	20	7.66E-05	1.0000	0.0026	18.663	1470	63435
GUATAPE	S	MEDELLIN	42	1.044E-06	1.2036	0.0026	0.045	215	63435
GUATAPE	S	EL PENOL	15	0.0001374	1.2036	0.0000	0.000	215	0
GUATAPE	S	GUARNE	22	5.047E-06	1.2036	0.1357	0.215	215	1213
HISPANIA	S	ANDES	10	4.476E-05	40.3391	1.7596	1694.391	156	3419
HISPANIA	S	JARDIN	23	2.998E-06	40.3391	13.6221	376.764	156	1466
HISPANIA	S	SUPIA	61	2.453E-07	40.3391	5.0687	13.356	156	1707
HISPANIA	S	SANTA BARB	164	1.447E-08	40.3391	8.2746	1.512	156	2006
HISPANIA	S	CALDAS	194	1.447E-08	40.3391	0.2163	0.014	156	721

Table C.1. (Continued)

ORIGIN	TYPE (1)	MARKET	DISTANCE (Km)	COST	AI	BJ	TIJ	DI	PJ
HISPANIA	E	MEDELLIN	214	3.047E-08	40.3391	0.0026	0.092	452	63435
HISPANIA	S	ITAGUI	204	3.047E-08	40.3391	0.0117	0.004	156	1920
ITUANGO	E	MEDELLIN	153	1.78E-08	13.8990	0.0026	0.748	18243	63435
ITUANGO	S	DON MATIAS	90	1.07E-07	13.8990	0.0292	0.047	1463	738
ITUANGO	S	GIRARDOTA	113	5.036E-08	13.8990	0.0308	0.004	1463	126
ITUANGO	S	BELLO	133	2.892E-08	13.8990	0.0076	0.042	1463	9332
ITUANGO	S	BELLO	133	2.892E-08	13.8990	0.0076	0.042	1463	9332
ITUANGO	S	MEDELLIN	153	1.78E-08	13.8990	0.0026	0.060	1463	63435
ITUANGO	S	TOLEDO	20	4.476E-05	13.8990	1.7218	1295.874	1463	827
ITUANGO	S	SAN ANDRES	40	2.998E-06	13.8990	6.4476	417.440	1463	1062
ITUANGO	S	SANTA ROSA DE	63	3.289E-07	13.8990	0.4199	6.103	1463	2173
LA MAGDALENA	E	PUERTO BERRIO	243	2.978E-09	5.3555	315083.0692	79.557	2	7917
LA MAGDALENA	S	MACEO	38	3.662E-06	5.3555	0.0601	10.000	2	500
LA MAGDALENA	S	CISNEROS	98	9.101E-08	5.3555	1.7743	0.230	2	8241
LA MAGDALENA	S	SANTO DOMIN	229	1.193E-08	5.3555	2.1530	0.0200	2	1041
LA MAGDALENA	S	BARBOSA	249	7.637E-09	5.3555	0.0345	0.002	2	2067
LA MAGDALENA	S	GIRARDOTA	267	5.56E-09	5.3555	0.0308	0.001	2	126
LA MAGDALENA	S	BELLO	287	4.018E-09	5.3555	0.0076	0.019	2	9332
LA MAGDALENA	S	VEGACHI	25	3.086E-05	5.3555	22.5940	0.000	2	2586
LA UNION	S	MEDELLIN	95	1.23E-06	1.0830	0.0026	0.798	3617	63435
LA UNION	S	LA CEJA	15	0.0002352	1.0830	0.5541	225.665	3617	442
LA UNION	S	RETIRO	70	1.798E-05	1.0830	0.0549	26.558	3617	6868
LIBORINA	S2	OLAYA	17	8.436E-05	8.5108	28.8958	9764.130	947	497
LIBORINA	E	ANTIOQUIA	34	5.651E-06	8.5108	0.0098	0.845	1192	1502
LIBORINA	S	SAN JERONIMO	54	1.125E-06	8.5108	0.1047	3.459	947	3643
LIBORINA	E	MEDELLIN	102	1.105E-07	8.5108	0.0026	0.186	1192	63435
MACEO	S	MEDELLIN	145	2.427E-08	4.5748	0.0026	0.025	1344	63435
MACEO	S	CARACOLI	30	1.598E-06	4.5748	1.0000	6.369	1344	648
MACEO	S	YALI	19	5.467E-05	4.5748	0.5131	390.507	1344	2264
MACEO	S	SANTO DOMIN	87	4.01E-07	4.5748	2.1530	5.526	1344	1041
MACEO	S	BARBOSA	87	1.448E-07	4.5748	0.0345	0.063	1344	2067
MACEO	S	GIRARDOTA	105	7.586E-08	4.5748	0.0308	0.002	1344	126
MACEO	S	BELLO	125	4.117E-08	4.5748	0.0076	0.018	1344	9332
MARINILLA	S	MEDELLIN	42	4.242E-06	0.3664	0.0026	1.123	4358	63435
MARINILLA	S	GUARNE	22	5.282E-05	0.3664	0.1357	13.886	4358	1213
MONTEBELLO	E	MEDELLIN	51	1.162E-06	1.1642	0.0026	0.145	646	63435
MONTEBELLO	S	RETIRO	26	1.609E-05	1.1642	0.0549	3.234	458	6868
MONTELIBANO	E	MEDELLIN	100	8.519E-10	1.0000	0.0026	0.054	380001	63435
MUTATA	S	MEDELLIN	241	3.607E-08	7.4296	0.0026	0.955	21495	63435

Table C.1.(Continued)

ORIGIN	TYPE (1)	MARKET	DISTANCE (Km)	COST	AI	BJ	TIJ	DI	PJ
MUTATA	S	URAMITA	89	1.269E-07	7.4296	0.6736	23.160	21495	1697
MUTATA	S	GIRALDO	188	1.313E-08	7.4296	0.3032	0.191	21495	300
MUTATA	E	CHIGORODO	40	2.008E-07	7.4296	1.2552	161.810	100000	864
NECHI	S	MEDELLIN	397	1.789E-09	18.2255	0.0026	0.015	2849	63435
NECHI	S	CAUCASIA	68	4.413E-10	18.2255	0.0955	0.007	2849	3179
NECHI	S	CACERES	131	3.765E-08	18.2255	10.8876	76.771	2849	3607
NECHI	S	TARAZA	164	8.919E-09	18.2255	100.3901	137.383	2849	2955
NECHI	S	VALDIVIA	226	3.169E-09	18.2255	0.7788	0.167	2849	1307
NECHI	S	YARUMAL	268	1.789E-09	18.2255	0.5157	0.186	2849	3889
NECHI	S	SANTA ROSA DE	311	1.075E-09	18.2255	0.4199	0.051	2849	2173
NECHI	S	DON MATIAS	334	8.051E-10	18.2255	0.0292	0.001	2849	738
NECHI	S	GIRARDOTA	357	6.394E-10	18.2255	0.0308	0.000	2849	126
NECHI	S	BELLO	357	5.289E-10	18.2255	0.0076	0.002	2849	9332
NECHI	S	CAUCASIA	68	4.413E-10	18.2255	0.0955	0.007	2849	3179
NECOCLI	S	TURBO	25	2.595E-05	4.0455	0.4211	1384.940	4243	7384
NECOCLI	S	APARTADO	50	7.039E-07	4.0455	0.0929	1.190	4243	1060
NECOCLI	S	CAREPA	65	2.87E-07	4.0455	0.1402	1.442	4243	2087
NECOCLI	S	CHIGORODO	75	1.116E-07	4.0455	1.2552	2.078	4243	864
NECOCLI	S	MUTATA	125	9.92E-09	4.0455	0.8069	0.272	4243	1978
NECOCLI	S	SAN JERONIMO	353	5.17E-10	4.0455	0.1047	0.003	4243	3643
PENOL	S	MEDELLIN	40	3.886E-06	0.3806	0.0026	0.109	446	63435
PENOL	S	GUARNE	20	4.476E-05	0.3806	0.1357	1.251	446	1213
PENOL	S	MARINILLA	17	8.436E-05	0.3806	29.3857	633.663	446	1506
PEQUE	E	MEDELLIN	220	3.093E-09	19.9550	0.0026	0.031	3048	63435
PEQUE	S	URAMITA	68	3.785E-07	19.9550	0.6736	7.979	924	1697
PEQUE	S	GIRALDO	117	4.411E-08	19.9550	0.3032	0.074	924	300
PEQUE	S	ANTIOQUIA	152	2.329E-08	19.9550	0.0098	0.006	924	1502
PEQUE	S	SAN JERONIMO	172	6.685E-09	19.9550	0.1047	0.047	924	3643
PEQUE	S	GIRALDO	117	4.411E-08	19.9550	0.3032	0.074	924	300
PUEBLO RICO	E	MEDELLIN	90	1.082E-07	3.8971	0.0026	0.046	662	63435
PUEBLO RICO	S	TARSO	13	0.0002402	3.8971	0.7545	336.791	617	773
PUEBLO RICO	S	VENECIA	38	7.459E-07	3.8971	0.8974	1.774	617	1102
PUEBLO RICO	S	CALDAS	70	1.584E-07	3.8971	0.2163	0.059	617	721
PUEBLO RICO	S	ITAGUI	70	1.082E-07	3.8971	0.0117	0.006	617	1920
PUERTO BERRIO	E	MEDELLIN	205	5.914E-09	202.7428	0.0026	50.674	255001	63435
PUERTO BERRIO	S	MACEO	60	6.167E-07	202.7428	0.0601	24.285	6465	500
PUERTO BERRIO	S	SANTO DOMIN	127	3.312E-08	202.7428	2.1530	97.285	6465	1041
PUERTO BERRIO	S	BARBOSA	147	1.872E-08	202.7428	0.0345	1.750	6465	2067
PUERTO BERRIO	S	GIRARDOTA	165	1.261E-08	202.7428	0.0308	0.064	6465	126

Table C.1. (Continued)

ORIGEN	TYPE (1)	MARKET	DISTANCE (Km)	COST	AI	BJ	TIJ	DI	PJ
PUERTO BERRIO	S	BELLO	185	8.478E-09	202.7428	0.0076	0.787	6465	9332
PUERTO TRIUNF	E	MEDELLIN	100	1.178E-08	131.9419	0.0026	64.398	250001	63435
RETIRO	S	MEDELLIN	25	1.875E-05	0.0829	0.0026	1.765	6851	63435
RIONEGRO	S	MEDELLIN	20	1.225E-05	0.1269	0.0026	0.157	611	63435
SABANALARGA	E	MEDELLIN	122	9.301E-07	1.5695	0.0026	0.499	2061	63435
SABANALARGA	S	LIBORINA	20	4.476E-05	1.5695	3.8414	33.882	165	761
SABANALARGA	S	OLAYA	37	4.063E-06	1.5695	28.8958	15.112	165	497
SABANALARGA	S	ANTIOQUIA	74	9.301E-07	1.5695	0.0098	0.004	165	1502
SABANALARGA	S	SAN JERONIMO	74	3.125E-07	1.5695	0.1047	0.031	165	3643
SALGAR	S	ARMENIA	80	5.673E-08	106.5609	0.2872	0.941	2307	235
SALGAR	S	TITIRIBI	111	2.165E-08	106.5609	0.0252	0.155	2307	1153
SALGAR	S	CALDAS	142	6.052E-09	106.5609	0.2163	0.232	2307	721
SALGAR	S	ITAGUI	152	5.109E-09	106.5609	0.0117	0.028	2307	1920
SALGAR	E	MEDELLIN	162	5.109E-09	106.5609	0.0026	0.293	3250	63435
SAN ANDRES	E	MEDELLIN	125	6.03E-08	7.2945	0.0026	0.100	1377	63435
SAN ANDRES	S	SANTA ROSA DE	35	8.637E-06	7.2945	0.4199	23.169	403	2173
SAN ANDRES	S	DON MATIAS	62	9.288E-07	7.2945	0.0292	0.059	403	738
SAN ANDRES	S	GIRARDOTA	85	2.713E-07	7.2945	0.0308	0.003	403	126
SAN ANDRES	S	BELLO	105	1.19E-07	7.2945	0.0076	0.025	403	9332
SAN ANDRES	S	YARUMAL	20	9.207E-06	7.2945	0.5157	54.276	403	3889
SAN ANDRES	S	VALDIVIA	62	4.107E-07	7.2945	0.7788	1.229	403	1307
SAN ANDRES	S	TOLEDO	20	4.476E-05	7.2945	1.7218	187.342	403	827
SAN ANDRES	E	LIBORINA	70	3.381E-07	7.2945	3.8414	9.926	1377	761
SAN CARLOS	E	MEDELLIN	94	5.64E-08	0.6029	0.0026	0.031	5457	63435
SAN CARLOS	S	GRANADA	944	3.309E-06	0.6029	1.0000	15.726	5092	1548
SAN CARLOS	S	SANTUARIO	54	4.384E-07	0.6029	1588.6213	2309.133	5092	1080
SAN CARLOS	S	RIONEGRO	74	1.747E-07	0.6029	1948.3332	2808.510	5092	2688
SAN JERONIMO	S	MEDELLIN	48	2.52E-06	1.0000	0.0026	0.619	1483	63435
SAN JOSE DE L	S	MEDELLIN	138	2.071E-08	29.0174	0.0026	0.053	533	63435
SAN JOSE DE L	S	LIBORINA	50	1.256E-06	29.0174	3.8414	56.774	533	761
SAN JOSE DE L	S	OLAYA	67	4.01E-07	29.0174	28.8958	89.076	533	497
SAN JOSE DE L	S	ANTIOQUIA	84	1.66E-07	29.0174	0.0098	0.038	533	1502
SAN JOSE DE L	S	SAN JERONIMO	108	7.96E-08	29.0174	0.1047	0.470	533	3643
SAN LUIS	E	MEDELLIN	122	6.629E-08	5.2034	0.0026	0.201	3522	63435
SAN LUIS	S	COCORNA	38	6.268E-06	5.2034	6.3842	827.708	1282	3101
SAN LUIS	S	SANTUARIO	70	5.786E-07	5.2034	1588.6213	6621.955	1282	1080
SAN LUIS	S	MEDELLIN	122	6.629E-08	5.2034	0.0026	0.073	1282	63435
SAN PEDRO	S	MEDELLIN	85	2.344E-07	3.8399	0.0026	0.107	714	63435
SAN PEDRO	S	DON MATIAS	22	3.086E-05	3.8399	0.0292	1.822	714	738

Table C.1. (Continued)

ORIGIN	TYPE (1)	MARKET	DISTANCE (Km)	COST	AI	BJ	TIJ	DI	PJ
SAN PEDRO	S	GIRARDOTA	45	2.469E-06	3.8399	0.0308	0.026	714	126
SAN PEDRO	S	BELLO	65	6.386E-07	3.8399	0.0076	0.124	714	9332
SAN PEDRO	S	ENTRERRIOS	20	4.476E-05	3.8399	4.6952	311.120	714	540
SAN PEDRO	S	BELMIRA	30	4.476E-05	3.8399	8.1379	627.122	714	628
SAN PEDRO	S	BELLO	65	6.386E-07	3.8399	0.0076	0.124	714	9332
SAN PEDRO	S	BELMIRA	30	4.476E-05	3.8399	8.1379	627.122	714	628
SAN PEDRO DE	S	TURBO	37	9.207E-06	9.5944	0.4211	407.568	1484	7384
SAN PEDRO DE	S	APARTADO	62	4.513E-07	9.5944	0.0929	0.633	1484	1060
SAN PEDRO DE	S	CAREPA	77	2.008E-07	9.5944	0.1402	0.837	1484	2087
SAN PEDRO DE	S	CHIGORODO	87	8.412E-08	9.5944	1.2552	1.299	1484	864
SAN PEDRO DE	S	MUTATA	147	8.498E-09	9.5944	0.8069	0.193	1484	1978
SAN PEDRO DE	S	DABEIBA	202	4.658E-09	9.5944	0.0163	0.009	1484	8582
SAN PEDRO DE	S	URAMITA	236	1.748E-09	9.5944	0.6736	0.028	1484	1697
SAN PEDRO DE	S	GIRALDO	285	7.033E-10	9.5944	0.3032	0.001	1484	300
SAN PEDRO DE	S	ANTIOQUIA	320	7.033E-10	9.5944	0.0098	0.000	1484	1502
SAN PEDRO DE	S	SAN JERONIMO	340	4.804E-10	9.5944	0.1047	0.003	1484	3643
SAN RAFAEL	E	MEDELLIN	83	2.17E-07	6.7164	0.0026	0.680	2815	63435
SAN RAFAEL	S	GUATAPE	26	1.609E-05	6.7164	1.0000	60.014	1998	278
SAN RAFAEL	S	PENOL	41	2.723E-06	6.7164	1.0000	29.085	1998	796
SAN RAFAEL	S	GUARNE	63	5.782E-07	6.7164	0.1357	1.278	1998	1213
SAN ROQUE	E	MEDELLIN	100	8.238E-08	3.8878	0.0026	0.182	3429	63435
SAN ROQUE	S	SANTO DOMIN	22	9.207E-06	3.8878	2.1530	95.225	1187	1041
SAN ROQUE	S	BARBOSA	42	1.256E-06	3.8878	0.0345	0.413	1187	2067
SAN ROQUE	S	GIRARDOTA	60	4.333E-07	3.8878	0.0308	0.008	1187	126
SAN ROQUE	S	BELLO	80	1.731E-07	3.8878	0.0076	0.057	1187	9332
SAN ROQUE	S	MEDELLIN	100	8.238E-08	3.8878	0.0026	0.063	1187	63435
SAN VICENTE	S	MEDELLIN	105	9.652E-08	11.3072	0.0026	0.137	757	63435
SAN VICENTE	S	BARBOSA	46	1.738E-06	11.3072	0.0345	1.061	757	2067
SAN VICENTE	S	BELLO	84	2.098E-07	11.3072	0.0076	0.127	757	9332
SAN VICENTE	S	GIRADOTA	64	5.536E-07	11.3072	0.0000	0.000	757	0
SANTA BARB	S	CALDAS	30	1.576E-05	1.4394	0.2163	0.485	137	721
SANTA BARB	E	SUPIA	0	1.911E-07	1.4394	5.0687	1.692	711	1707
SANTA BARB	S	MEDELLIN	50	1.056E-06	1.4394	0.0026	0.034	137	63435
SANTA BARB	S	ITAGUI	40	5.131E-06	1.4394	0.0117	0.023	137	1920
SANTA ROSA DE	S	MEDELLIN	90	2.171E-07	3.7330	0.0026	0.340	2531	63435
SANTA ROSA DE	S	DON MATIAS	27	2.376E-05	3.7330	0.0292	4.836	2531	738
SANTA ROSA DE	S	GIRARDOTA	50	2.149E-06	3.7330	0.0308	0.079	2531	126
SANTA ROSA DE	S	BELLO	70	5.786E-07	3.7330	0.0076	0.387	2531	9332
SANTA ROSA DE	S	ENTRERRIOS	35	5.047E-06	3.7330	4.6952	120.895	2531	540

Table C.1. (Continued)

ORIGIN	TYPE (1)	MARKET	DISTANCE (Km)	COST	AI	BJ	TIJ	DI	PJ
SANTA ROSA DE	S	YARUMAL	43	3.87E-06	3.7330	0.5157	73.330	2531	3889
SANTO DOMIN	S	MEDELLIN	78	3.282E-07	4.4005	0.0026	0.442	1845	63435
SANTO DOMIN	S	BARBOSA	22	4.476E-05	4.4005	0.0345	25.914	1845	2067
SANTO DOMIN	S	GIRARDOTA	38	4.68E-06	4.4005	0.0308	0.147	1845	126
SANTO DOMIN	S	BELLO	58	9.925E-07	4.4005	0.0076	0.571	1845	9332
SANTUARIO	S	MEDELLIN	60	1.056E-06	1.1717	0.0026	0.663	3234	63435
SANTUARIO	S	MARINILLA	20	0.0001155	1.1717	29.3857	19373.920	3234	1506
SANTUARIO	S	GUARNE	40	5.131E-06	1.1717	0.1357	3.202	3234	1213
SEGOVIA	S	MEDELLIN	345	9.287E-10	3.8465	0.0026	0.002	3837	63435
SEGOVIA	S	REMEDIOS	18	6.75E-05	3.8465	0.6854	2462.435	3837	3606
SEGOVIA	S	MACEO	180	8.498E-09	3.8465	0.0601	0.004	3837	500
SEGOVIA	S	CISNEROS	227	3.439E-09	3.8465	1.7743	0.742	3837	8241
SEGOVIA	S	SANTO DOMIN	267	2.474E-09	3.8465	2.1530	0.082	3837	1041
SEGOVIA	S	BARBOSA	287	1.826E-09	3.8465	0.0345	0.002	3837	2067
SEGOVIA	S	GIRARDOTA	305	1.462E-09	3.8465	0.0308	0.000	3837	126
SEGOVIA	S	BELLO	325	1.157E-09	3.8465	0.0076	0.001	3837	9332
SEGOVIA	S	VEGACHI	63	2.998E-06	3.8465	22.5940	2585.326	3837	2586
SEGOVIA	S	AMALFI	126	1.032E-07	3.8465	656.3489	1800.531	3837	1801
SONSON	S	MEDELLIN	109	6.885E-08	7.6424	0.0026	1.232	14124	63435
SONSON	S	LA UNION	55	8.659E-07	7.6424	5.1358	1369.967	14124	2854
SONSON	S	LA CEJA	70	3.77E-07	7.6424	0.5541	9.967	14124	442
SONSON	S	RETIRO	84	1.982E-07	7.6424	0.0549	8.067	14124	6868
SONSON	S	ARGELIA	35	5.047E-06	7.6424	1.0000	838.367	14124	1539
SUPIA	E	MEDELLIN	120	1.283E-07	1.0000	0.0026	0.734	34501	63435
TAMESIS	E	MEDELLIN	128	2.871E-08	2.1419	0.0026	0.019	1890	63435
TAMESIS	S2	JERICO	27	1.389E-05	2.1419	172.1823	9707.848	1322	1434
TAMESIS	S2	CALDAS	108	3.749E-08	2.1419	0.2163	0.017	1322	721
TAMESIS	S2	ITAGUI	118	2.871E-08	2.1419	0.0117	0.002	1322	1920
TAMESIS	S2	MEDELLIN	128	2.871E-08	2.1419	0.0026	0.013	1322	63435
TAMESIS	S2	JERICO	27	1.389E-05	2.1419	172.1823	9707.848	1322	1434
TAMESIS	S2	TARSO	51	1.162E-06	2.1419	0.7545	1.920	1322	773
TAMESIS	S2	VENECIA	76	1.021E-07	2.1419	0.8974	0.286	1322	1102
TARAZA	S	YARUMAL	104	1.235E-07	522.5063	0.5157	665.920	5144	3889
TARAZA	S	VALDIVIA	62	9.288E-07	522.5063	0.7788	2541.072	5144	1307
TARSO	E	MEDELLIN	77	1.938E-07	7.8163	0.0026	0.232	926	63435
TARSO	S	VENECIA	25	2.041E-06	7.8163	0.8974	10.998	697	1102
TARSO	S	CALDAS	57	3.025E-07	7.8163	0.2163	0.257	697	721
TARSO	S	ITAGUI	67	1.938E-07	7.8163	0.0117	0.024	697	1920
TITIRIBI	E	CALDAS	34	8.822E-07	3.1342	0.2163	0.477	1105	721

Table C.1. (Continued)

ORIGIN	TYPE (1)	MARKET	DISTANCE (Km)	COST	AI	BJ	TIJ	DI	PJ
TITIRIBI	E	MEDELLIN	51	4.959E-07	3.1342	0.0026	0.285	1105	63435
TOLEDO	E	MEDELLIN	51	3.124E-08	2.1938	0.0026	0.012	1081	63435
TOLEDO	S	SAN ANDRES	20	4.476E-05	2.1938	6.4476	58.491	87	1062
TOLEDO	S	SANTA ROSA DE	55	1.208E-06	2.1938	0.4199	0.210	87	2173
TOLEDO	S	DON MATIAS	82	2.719E-07	2.1938	0.0292	0.001	87	738
TOLEDO	S	GIRARDOTA	105	1.068E-07	2.1938	0.0308	0.000	87	126
TOLEDO	S	BELLO	105	5.505E-08	2.1938	0.0076	0.001	87	9332
TOLEDO	S	ITAGUI	41	4.959E-07	2.1938	0.0117	0.002	87	1920
TURBO	S	APARTADO	25	5.047E-06	255.4686	0.0929	8747.090	68898	1060
TURBO	S	CHIGORODO	50	3.381E-07	255.4686	1.2552	6452.847	68898	864
URAMITA	S	MEDELLIN	138	1.186E-08	88.9980	0.0026	0.705	4030	63435
URAMITA	S	CANASGORDAS	28	1.256E-06	88.9980	0.1379	125.941	4030	2028
URAMITA	S	ANTIOQUIA	84	6.702E-08	88.9980	0.0098	0.354	4030	1502
URAMITA	S	SAN JERONIMO	104	3.702E-08	88.9980	0.1047	5.063	4030	3643
URAMITA	S	PEQUE	68	3.785E-07	88.9980	3.2873	843.935	4030	1891
URAMITA	S	GIRALDO	49	3.199E-07	88.9980	0.3032	10.434	4030	300
URRAO	S	MEDELLIN	164	4.92E-09	77.3049	0.0026	0.860	13637	63435
URRAO	E	ARMENIA	82	5.29E-08	77.3049	0.2872	4.998	18111	235
URRAO	S	CALDAS	144	5.818E-09	77.3049	0.2163	0.957	13637	721
URRAO	S	ITAGUI	154	4.92E-09	77.3049	0.0117	0.117	13637	1920
URRAO	S	CAICEDO	42	1.894E-06	77.3049	1.0000	2353.880	13637	1179
URRAO	S	MEDELLIN	164	4.92E-09	77.3049	0.0026	0.860	13637	63435
URRAO	S	TITIRIBI	115	2.049E-08	77.3049	0.0252	0.628	13637	1153
VALDIVIA	S	YARUMIAL	42	4.242E-06	89.9111	0.0000	0.000	1699	0
VALDIVIA	S	MEDELLIN	175	1.623E-08	89.9111	0.0026	0.411	1699	63435
VALDIVIA	S	SANTA ROSA DE	71	2.713E-07	89.9111	0.4199	37.822	1699	2173
VALDIVIA	S	DON MATIAS	112	9.253E-08	89.9111	0.0292	0.304	1699	738
VALDIVIA	S	GIRARDOTA	135	4.466E-08	89.9111	0.0308	0.026	1699	126
VALDIVIA	S	BELLO	155	2.606E-08	89.9111	0.0076	0.282	1699	9332
VALPARAISO	E	MEDELLIN	153	1.458E-08	13.7542	0.0026	0.039	1167	63435
VALPARAISO	S	TAMESIS	25	1.875E-05	13.7542	1.8975	794.238	878	1849
VALPARAISO	S	JERICO	52	1.078E-06	13.7542	172.1823	3213.117	878	1434
VALPARAISO	S	TARSO	76	2.453E-07	13.7542	0.7545	1.728	878	773
VALPARAISO	S	VENECIA	101	4.112E-08	13.7542	0.8974	0.491	878	1102
VALPARAISO	S	CALDAS	133	1.822E-08	13.7542	0.2163	0.034	878	721
VALPARAISO	S	ITAGUI	143	1.458E-08	13.7542	0.0117	0.004	878	1920
VALPARAISO	S	MEDELLIN	153	1.458E-08	13.7542	0.0026	0.029	878	63435
VALPARAISO	S	PUEBLO RICO	63	5.099E-07	13.7542	11167.6182	50469.658	878	734
VEGACHI	S2	MEDELLIN	329	8.845E-10	8.8273	0.0026	0.001	682	63435

Table C.1. (Continued)

ORIGIN	TYPE (1)	MARKET	DISTANCE (Km)	COST	AI	BJ	TIJ	DI	PJ
VEGACHI	S2	REMEDIOS	22	3.086E-05	8.8273	0.6854	459.239	682	3606
VEGACHI	S2	MACEO	237	7.8E-09	8.8273	0.0601	0.001	682	500
VEGACHI	S2	SANTO DOMIN	251	2.324E-09	8.8273	0.0000	0.000	682	0
VEGACHI	S2	BARBOSA	271	1.723E-09	8.8273	0.0345	0.001	682	2067
VEGACHI	S2	BELLO	309	1.099E-09	8.8273	0.0076	0.000	682	9332
VEGACHI	S2	MEDELLIN	329	8.845E-10	8.8273	0.0026	0.001	682	63435
VEGACHI	S2	GIRADOTA	288	1.384E-09	8.8273	0.0000	0.000	682	0
YALI	E	MEDELLIN	154	1.465E-08	20.7315	0.0026	0.187	3708	63435
YALI	S	MACEO	19	5.467E-05	20.7315	0.0601	43.719	1284	500
YALI	S	CISNEROS	72	4.253E-07	20.7315	1.7743	165.520	1284	8241
YALI	S	SANTO DOMIN	86	1.515E-07	20.7315	2.1530	9.037	1284	1041
YALI	S	BARBOSA	106	6.702E-08	20.7315	0.0345	0.127	1284	2067
YALI	S	GIRARDOTA	123	3.913E-08	20.7315	0.0308	0.004	1284	126
YALI	S	BELLO	144	2.322E-08	20.7315	0.0076	0.044	1284	9332
YALI	S	YOLOMBO	47	1.598E-06	20.7315	6.0463	1212.481	1284	4713
YARUMAL	S	MEDELLIN	13	4.734E-08	8.1732	0.0026	0.345	5374	63435
YARUMAL	S	SANTA ROSA DE	43	3.87E-06	8.1732	0.4199	155.109	5374	2173
YARUMAL	S	DON MATIAS	70	5.786E-07	8.1732	0.0292	0.547	5374	738
YARUMAL	S	GIRARDOTA	93	1.911E-07	8.1732	0.0308	0.033	5374	126
YARUMAL	S	BELLO	113	8.938E-08	8.1732	0.0076	0.278	5374	9332
YARUMAL	S	CAMPAMENTO	20	4.476E-05	8.1732	1.0000	3176.783	5374	1616
YARUMAL	S	ANGOSTURAS	15	0.0001374	8.1732	0.0000	0.000	5374	0
YARUMAL	S	SAN ANDRES	20	9.207E-06	8.1732	6.4476	2768.952	5374	1062
YOLOMBO	S	MEDELLIN	201	5.262E-09	128.9173	0.0026	0.241	2143	63435
YOLOMBO	S	YALI	47	1.598E-06	128.9173	0.5131	513.033	2143	2264
YOLOMBO	S	MACEO	66	4.253E-07	128.9173	0.0601	3.530	2143	500
YOLOMBO	S	CISNEROS	119	5.222E-08	128.9173	1.7743	210.961	2143	8241
YOLOMBO	S	SANTO DOMIN	133	2.766E-08	128.9173	2.1530	17.127	2143	1041
YOLOMBO	S	BARBOSA	133	1.602E-08	128.9173	0.0345	0.316	2143	2067
YOLOMBO	S	GIRARDOTA	170	1.095E-08	128.9173	0.0308	0.012	2143	126
YOLOMBO	S	BELLO	191	7.461E-09	128.9173	0.0076	0.146	2143	9332
ZARAGOZA	S	MEDELLIN	355	6.264E-10	5.6455	0.0026	0.002	3317	63435
ZARAGOZA	S	CAUCASIA	35	5.047E-06	5.6455	0.0955	28.686	3317	3179
ZARAGOZA	S	CACERES	98	1.275E-07	5.6455	10.8876	93.736	3317	3607
ZARAGOZA	S	TARAZA	131	1.987E-08	5.6455	100.3901	110.353	3317	2955
ZARAGOZA	S	VALDIVIA	192	5.768E-09	5.6455	0.7788	0.110	3317	1307
ZARAGOZA	S	YARUMAL	235	2.984E-09	5.6455	0.5157	0.112	3317	3889
ZARAGOZA	S	SANTA ROSA DE	278	1.678E-09	5.6455	0.4199	0.029	3317	2173
ZARAGOZA	S	DON MATIAS	302	1.215E-09	5.6455	0.0292	0.000	3317	738

Table C.1. (Continued)

ORIGIN	TYPE (1)	MARKET	DISTANCE (Km)	COST	AI	BJ	TIJ	DI	PJ
ZARAGOZA	S	GIRARDOTA	325	9.415E-10	5.6455	0.0308	0.000	3317	126
ZARAGOZA	S	BELLO	345	7.639E-10	5.6455	0.0076	0.001	3317	9332
ZARAGOZA	S	EL BAGRE	20	4.476E-05	5.6455	1.0000	2997.931	3317	3577

APPENDIX D: G TESTS FOR INDIVIDUAL DESTINATIONS

Table D.1. G tests for individual destinations

ORIGIN	Number of Destinations	C_{ij}^{-B}	$\Sigma X_i X_j C_{ij}^{-B}$	$\Sigma X_i X_j$	$\Sigma C_{ij}^{-B}(n-1-C_{ij}^{-B})$	Gj	$Var(G_j)$	Z
ABEJORRAL	5	0.0000019	382.51	455149882.7	0.000008	8.40E-07	3.41E-02	-5.73E-06
ABRIAQUI	5	0.0000297	487.21	41433040.7	0.000119	1.18E-05	5.82E+00	-7.42E-06
ALEJANDRIA	6	0.0049873	1353.16	4746540.7	0.019925	2.85E-04	1.99E-04	-3.33E-01
AMAGA	3	0.0000293	6.63	589646.5	0.000117	1.12E-05	1.02E-06	-1.78E-02
AMALFI	10	0.0000002	23.21	1115772020.0	0.000001	2.08E-08	1.21E-01	-4.18E-07
ANDES	5	0.0000473	901.02	53910310.9	0.000189	1.67E-05	2.19E-06	-2.06E-02
ANGOSTURA	1	0.0001374	829.09	6032338.8	0.000550	1.44E-06	8.59E-04	-4.69E-03
ANTIOQUIA	2	0.0000772	62.33	1163014.9	0.000309	5.36E-05	1.67E+00	-1.83E-05
APARTADO	1	0.0000050	1270.76	251799030.3	0.000020	1.27E-05	9.26E+00	-1.66E-06
ARBOLETES	1	0.0000227	8164.42	64357289556.2	0.000091	1.27E-07	2.32E-01	-4.68E-05
ARGELIA	2	0.0000277	9750.41	64689550944.3	0.000111	1.51E-07	5.06E+02	-1.23E-06
ARMENIA	4	0.0000085	0.12	161610.3	0.000034	7.48E-07	4.81E-01	-1.11E-05
BARBOSA	4	0.0001607	1.10	43167.5	0.000643	2.54E-05	3.82E-01	-2.19E-04
BELLO	1	0.0000766	5.89	76904.5	0.000306	1.27E-06	1.43E-02	-6.40E-04
BETANIA	10	0.0002640	1128.63	28878274.9	0.001056	3.91E-05	3.31E-02	-1.24E-03
BETULIA	5	0.0000004	1.72	42300482.0	0.000002	4.06E-08	8.50E+07	-4.37E-11
BOLIVAR	4	0.0000012	2142.22	2849450625.3	0.000005	7.52E-07	1.66E-07	-1.04E-03
CACERES	1	0.0000009	1592.01	1824414830.9	0.000003	4.27E-05	3.49E-06	-4.67E-04
CAICEDO	6	0.0000022	2.02	6126275.0	0.000009	3.30E-07	3.49E-06	-1.01E-03
CALDAS	1	0.0022871	0.11	94.1	0.009146	1.14E-03	2.29E-03	-2.39E-02
CAMPAMENTO	1	0.0000448	3467.49	77474475.4	0.000179	8.76E-07	2.45E+01	-9.04E-06
CANASGORDAS	4	0.0000743	133.54	21252352.5	0.000297	6.28E-06	1.17E+07	-1.99E-08
CARACOLI	6	0.0000004	311.59	1475355741.9	0.000002	2.11E-07	3.30E+01	-4.12E-08
CARAMANTA	9	0.0000032	103.94	503724545.9	0.000013	2.06E-07	5.01E-06	-1.33E-03
CAREPA	5	0.0001835	59.53	9798381.2	0.000734	6.08E-06	1.88E-02	-1.29E-03
CARMEN DE V	2	0.0007924	2720809.75	3450577800.7	0.003169	7.89E-04	7.04E-04	-1.47E-04
CAROLINA	5	0.0000026	132.70	89303983.3	0.000010	1.49E-06	1.34E+03	-2.95E-08
CAUCASIA	10	0.0000776	348.93	2295797044.3	0.000310	1.52E-07	4.34E-05	-1.17E-02
CHIGORODO	2	0.0000054	247.04	674999661.2	0.000022	3.66E-07	1.99E+03	-1.13E-07
CISNEROS	4	0.0000113	9.0381554	4060437.1	0.000033	2.23E-06	3.49E+05	-1.54E-08
COCORNA	3	0.0000029	588.30739	276576389.4	0.000011	2.13E-06	4.67E-09	-1.08E-02
CONCEPCION	4	0.0000304	5.4672099	866564.4	0.000018	6.31E-06	8.76E+02	-8.16E-07
DABEIBA	6	0.0000007	27.747191	95941257.4	0.000003	2.89E-07	1.77E+05	-1.04E-09
DON MATIAS	3	0.0000492	0.5840249	237576.5	0.000197	2.46E-06	2.87E+01	-8.72E-06
EBEJICO	3	0.0000061	807.11286	178718435.9	0.000025	4.52E-06	5.42E-06	-6.96E-04
EL BAGRE	9	0.0000457	2330.0811	18317949506.8	0.000183	1.27E-07	3.64E-02	-2.39E-04
EL CARMEN	2	0.0000081	4860.3717	641927370.3	0.000033	7.57E-06	1.41E+05	-1.52E-09
ENTRERRIOS	4	0.0000406	3.1647842	924687.5	0.000163	3.42E-06	2.68E+04	-2.28E-07
FREDONIA	5	0.0011590	133.26547	8841432.6	0.004635	1.51E-05	1.11E-03	-3.43E-02
FRONTINO	5	0.0000151	555.0348	165956007.6	0.000060	3.34E-06	9.12E+09	-1.23E-10
GIRALDO	2	0.0000420	41.503954	1172361.3	0.000168	3.54E-05	5.50E+01	-8.96E-07
GIRARDOTA	2	0.0000932	0.1742939	5042.8	0.000373	3.46E-05	3.67E-05	-9.67E-03
GOMEZ PLATA	8	0.0001406	577.33857	26717612.3	0.000562	3.54E-05	2.24E+03	-2.22E-06
GRANADA	4	0.0000207	319.84479	60796050.3	0.000083	5.26E-06	2.32E-05	-3.19E-03
GUARNE	1	0.0000766	18.66317	243641.3	0.000306	3.49E-05	1.85E+00	-5.63E-05
GUATAPE	3	0.0001435	0.2598163	85501.5	0.000574	3.04E-06	1.32E-01	-3.87E-04
HISPANIA	7	0.0000481	2086.1342	326576030.6	0.000192	6.39E-06	5.13E-02	-1.84E-04
ITUANGO	7	0.0000483	1719.5687	192072289.2	0.000193	8.95E-06	1.02E+03	-1.23E-06
LA MAGDA	8	0.0000346	79.557334	26718924916.9	0.000139	2.98E-09	5.31E-05	-4.76E-03
LA UNION	3	0.0002544	253.02188	3085296.9	0.001018	8.20E-05	7.36E+02	-6.36E-06
LIBORINA	4	0.0000912	9768.6197	120652030.6	0.000365	8.10E-05	6.26E-02	-4.11E-05
MACEO	7	0.0000570	402.51048	26824819.4	0.000228	1.50E-05	3.01E+02	-2.42E-06
MARINILLA	2	0.0000571	15.009074	527528.1	0.000228	2.85E-05	1.59E+01	-7.18E-06
MONTEBELLO	2	0.0000172	3.3785326	325657.5	0.000069	1.04E-05	2.95E-03	-1.27E-04
MONTELIBAN	1	0.0000000	0.0536565	62982269.5	0.000000	5.24E-07	9.42E+04	-2.78E-12
MUTATA	4	0.0000004	186.11517	1029272249.8	0.000002	1.81E-07	2.39E+06	-1.27E-10
NECHI	8	0.0000001	214.59152	17692186997.7	0.000000	1.21E-08	1.44E-04	-3.75E-06
NECOCLI	6	0.0000271	1389.925	112641677.3	0.000108	1.23E-05	8.19E+02	-5.14E-07
PENOL	3	0.0001330	635.02343	7567739.1	0.000532	8.39E-05	1.18E-04	-4.52E-03
PEQUE	5	0.0000005	8.2109807	41816829.8	0.000002	1.96E-07	3.91E+03	-4.85E-09
PUEBLO RICO	5	0.0002418	346.88753	46453886.8	0.000967	7.47E-06	7.01E+05	-2.80E-07
PUERTO BERRI	6	0.0000007	174.84467	11737246029.0	0.000003	1.49E-08	1.00E+13	-2.15E-13

Table 14.1. G tests for individual destinations

ORIGIN	Number of Destinations	C_{ij}^{-B}	$\sum X_i X_j C_{ij}^{-B}$	$\sum X_i X_j$	$\sum C_{ij}^{-B}(n-1-C_{ij}^{-B})$	Gj	$Var(G_j)$	Z
PUERTO TRIU	1	0.0000000	64.397741	5467114563.0	0.000000	1.56E-06	7.39E+13	-1.37E-15
RETIRO	1	0.0000187	1.7647486	94140.3	0.000075	3.72E-06	8.66E-03	-2.01E-04
RIONEGRO	1	0.0000123	0.1573874	12847.1	0.000049	4.57E-05	2.99E-05	-2.24E-03
SABANALARGA	5	0.0000632	49.68457	5127674.0	0.000253	9.69E-06	2.54E-05	-1.06E-02
SALGAR	6	0.0000031	44375.658	14925940961.8	0.000012	2.97E-06	3.66E+02	-6.26E-09
SAN ANDRES	4	0.0000001	0.0247729	208143.7	0.000000	3.35E-05	0.00E+00	
SAN ANDRES	9	0.0000647	276.12942	47066442.2	0.000259	5.87E-06	8.31E+01	-6.46E-06
SAN CARLOS	4	0.0000040	5133.3993	21349260285.4	0.000016	2.40E-07	4.48E-06	-1.77E-03
SAN JERONIMO	1	0.0000025	0.6194202	245795.9	0.000010	7.49E-05	6.30E-02	-1.00E-05
SAN JOSE DE L	4	0.0000019	146.40983	276017207.6	0.000008	5.30E-07	4.69E-02	-6.43E-06
SAN LUIS	4	0.0000082	49536.916	46516616127.5	0.000033	1.06E-06	1.05E-05	-2.20E-03
SAN PEDRO	6	0.0001691	1567.5659	35887419.1	0.000676	4.37E-05	1.80E+00	-9.36E-05
SAN PEDRO DE	10	0.0000095	409.93845	111596174.1	0.000038	3.67E-06	1.16E+03	-1.71E-07
SAN RAFAEL	4	0.0000196	1630.2736	5936.0	6.000000	2.75E-01	1.64E+54	2.15E-28
SAN ROQUE	5	0.0000112	2445.4105	8904.0	4.000000	2.75E-01	2.77E+54	1.65E-28
SAN VICENTE	4	0.0000280	1630.2736	5936.0	6.000000	2.75E-01	2.98E+45	5.03E-24
SANTA BARBA	4	0.0000502	3668.1157	13356.0	6.000000	2.75E-01	1.12E+47	8.20E-25
SANTA ROSA	6	0.0000356	199.86649	45378064.0	0.000143	4.40E-06	1.67E+02	-2.41E-06
SANTO DOMIN	4	0.0000508	27.073312	2531007.6	0.000203	1.07E-05	7.19E+05	-4.72E-08
SANTUARIO	3	0.0001217	19377.785	168950360.5	0.000487	1.15E-04	6.96E-05	-8.41E-04
SEGOVIA	11	0.0000707	1527767.9	36834835532653.5	0.000283	4.15E-08	1.17E-04	-6.53E-03
SONSON	5	0.0000066	2227.5984	1833301760.2	0.000026	1.22E-06	3.76E+02	-2.75E-07
SUPIA	1	0.0000001	0.7335869	5718277.8	0.000001	7.42E-05	9.63E+02	-4.13E-09
TAMESIS	6	0.0000293	19418.687	1410108581.4	0.000117	1.38E-05	2.70E-05	-2.98E-03
TARAZA	2	0.0000011	3206.9915	8125999112.2	0.000004	3.95E-07	2.75E+08	-3.97E-11
TARSO	4	0.0000027	11.51126	7559682.9	0.000011	1.52E-06	1.43E+01	-3.20E-07
TITIRIBI	2	0.0000014	0.7611393	1114168.3	0.000006	6.83E-07	6.04E+04	-2.83E-09
TOLEDO	7	0.0000469	58.717795	1896725.5	0.000188	3.10E-05	4.55E-05	-2.37E-03
TURBO	3	0.0000066	21668.705	25972687133.6	0.000027	8.34E-07	2.55E+14	-3.63E-13
URAMITA	6	0.0000021	2702716.8	2563996325.7	0.000008	1.05E-03	1.47E+06	8.69E-07
URRAO	7	0.0000045	1.345E+09	46959674826.7	0.000018	2.86E-02	7.78E+05	3.25E-05
VALDIVIA	6	0.0000047	38.846047	179406937.7	0.000019	2.17E-07	2.21E+08	-3.01E-10
VALPARAISO	6	0.0000191	796.56279	68171406.4	0.000076	1.17E-05	7.98E+02	-2.62E-07
VEGACHI	6	0.0000309	546378.04	15017568376246.7	0.000124	3.64E-08	4.29E-05	-4.71E-03
YALI	7	0.0000554	218.63724	466309723.4	0.000222	4.69E-07	2.61E+02	-3.40E-06
YARUMAL	10	0.0001962	6102.0472	423320421.1	0.000785	1.44E-05	1.16E+05	-5.35E-07
YOLOMBO	10	0.0000021	745.36456	5074143518.6	0.000009	1.47E-07	1.03E+05	-6.21E-09
ZARAGOZA	11	0.0000500	3230.9614	6441812983.7	0.000200	5.02E-07	1.46E-03	-1.29E-03