Aspects of
Multi-National Transportation Investment Planning

by

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SUBMITTED TO THE DEPARTMENT OF
CIVIL ENGINEERING
IN PARTIAL FULFILLMENT OF THE
DEGREE OF

CIVIL ENGINEER

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

September 16, 1981

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July , 1981

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Submitted to the Department of Civil Engineering on July , 1981 in partial fulfillment of the requirements for the Degree of Civil Engineer in Civil Engineering

ABSTRACT

Until recently, investments for improving transportation infrastructure have been undertaken solely on a national level. Nowadays, however, since international traffic is increasing significantly, there is a growing tendency, especially among European countries, to undertake transportation investments as a group rather than alone. Such multi-national transportation investments are beneficial to all participating countries; in addition to furthering economic cooperation, they bring in many valuable economies of scale.

The thesis discusses the possibility of overcoming conflicts between national goals, socio-economic and political systems, and national institutional structures, and it suggests guidelines for forecasting international road traffic, financing and evaluating investments, allocating costs, and coordinating the timing of construction in each country. These guidelines are presented in a general scheme of recommendations. More technical aspects are discussed in the appendices.

Furthermore, because the present study is only a preliminary attempt to identify and solve several crucial problems related to multi-national transportation investment planning, it uses as an example the case of the Trans-European North-South Motorway, a joint investment undertaken by ten European countries for improving their road infrastructure.

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ACKNOWLEDGMENTS

I would like to express my gratitude and appreciation to Professor Fred Moavenzadeh for supervising the present thesis. His interest and encouragement at various points in this work, and throughout my studies at the Massachusetts Institute of Technology, was most helpful. In addition, I wish to express my appreciation to Professor Ann Friedlaender for her interest and support.

Furthermore, I am grateful to the Greek Ministry of Coordination for its financial support and educational leave without which my present studies would have been impossible. Also, I should like to thank my colleagues and superiors at the Ministry of Coordination for their encouragement. I am grateful to Neil and Marilyn Shimmield for editing the manuscript, and to Peter Baldwin for typing it in a hurry.

Finally, I dedicate this thesis to my family and friends.

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CHAPTER ONE

INTRODUCTION

1. Description of the case

We are living in an era of economic interdependence. Despite vast differences in production, the economies of the world are nowadays so interconnected that the strength of any one depends to a greater or lesser extent on the strength of all of the rest. Realizing their mutual interdependence, different countries are cooperating more closely than ever before. Trading agreements, cultural exchanges, and defense alliances are some of the many areas in which cooperation is becoming manifest.

One consequence is that international trade and tourism are expected rapidly to increase. For instance, a study sponsored by the European Economic Community and the European Conference of Ministers of Transport has predicted that, on present trends, the number of international passengers within Europe will reach 23% of the total number of passengers in all European countries by the year 2000, while the tonnage of goods transported outside each European country will reach 13% of the total tonnage of goods transported within Europe by the same date (8). These increases are not unique to Europe, but in Europe they are best documented.

To cope with such projected increases in international traffic, many countries have begun to undertake multi-national investment programs for improving their respective transportation infrastructures. Until recently, investments in transportation infrastructure were carried out at the level of national government, and then according to the demands set by domestic traffic alone. Conflicting goals, socio-economic and political tensions, and even difficulties in agreeing on prices and apportioning costs led most countries to emphasize their own national priorities and thus to ignore the increases in international traffic, depriving internationally significant transportation projects of cohesion, and preventing these countries from receiving many economically valuable benefits of scale. Nowadays, however, joint investment projects in transportation infrastructure are becoming increasingly common. Countries are cooperating in the construction and administration of international transportation links. They are jointly financing the feasability studies necessary for construction, changing their national transportation plans to accommodate international trends, and even jointly seeking loans from international banking organizations in the hope of negotiating better terms as a group.

Although the first modern multi-national transportation investment project was the Pan-American Highway, which involved the United States, Mexico, Nicaragua, El Salvador, Honduras, Costa Rica, Guatemala, and Panama, Western Europe is currently the place where such projects are best developed and enjoying their greatest success. Under the auspices of the United Nations Economic Commission for Europe, an agreement was reached in 1975 to make the construction and maintenance of European E-roads* the responsibility of all member countries. Road tunnels have been constructed between Italy and France, Italy and Switzerland, and Austria and Yugoslavia. Preliminary studies have been jointly financed by France and Great Britain for the construction of a cross-Channel tunnel,and a navigable waterway between the Danube and Aegean is being planned by Yugoslavia, Greece and the United Nations Development Programme. Of most importance for this thesis is the Trans-European North-South Motorway. Ten European countries have decided jointly to finance and coordinate the construction of this road network, which will form a system of high-capacity roadways linking Austria, Bulgaria, Czechoslovakia, Greece, Hungary, Italy, Poland, Romania, Turkey and Yugoslavia.

Despite budget constraints and increasing costs of motor fuel, countries have recently invested, at the expense of their railroads and waterways, in improving their road networks. In most countries, the existing road infrastructure is insufficient to handle even current domestic traffic. Increasing motorization has resulted in an upward trend for

*The European E-road system, linking all European countries, is similar to the interstate highway system in the USA.

international road useage, especially when the distances between main cities located in different countries are short and there is freedom of movement between countries enjoying good political and trading relations. Thus, although multi-national transportation investment plans may be designed to improve all modes of transportation infrastructure, they tend to concentrate on road networks because road networks are most heavily over-utilized. Indeed, Europe is in the vanguard of multi-national transportation investment planning precisely because it has a high density of population, one of the highest levels of motorization, and because its major cities are so easily accessible to each other by road (cf. Table 1, page 17)

2. Purpose and Scope of the Study

This thesis focuses on European road networks in an attempt to identify and solve some of the many problems that all multi-national transportation investment policies must face. At its most general, the problem is to recommend the best course of action for countries to pursue if they intend to undertake multi-national investment programs; but this general problem clearly involves more specific problems, such as

a) how to reconcile conflicting national priorities so as to ensure that adequate infrastructure is provided for present and future international and domestic traffic;

b) how to reduce traffic accidents, lower transport costs, save energy, promote tourism, facilitate the movement of goods and services, gain better access to trading partners, and speed the mobilization of capital; and

c) how to safeguard and improve the quality of life and the environment in participating countries, by reducing air pollution and noise, and by maintaining the beauty of the natural landscape.

Only the first of these specific problems is unique to multi-national transportation investment planning; the others are important, but they lack the multi-national character of the first. As a result, the first problem is the main concern of this thesis.

To help solve this problem and the issues to which it gives rise, a general scheme is required. This general scheme is not an abstract mathematical model; neither is it a rigid set of principles to be unquestioningly followed by participating countries. Instead, the general scheme consists of guidelines whose purpose is to facilitate the implementation of multi-national transportation investment planning with the cooperation of all participating countries. These guidelines recommend institutional structures, methods of forecasting international traffic, uniform standards of design, construction and maintenance, financial policies and procedures for evaluating multi-national transportation investments.

In elaborating this general scheme, it is assumed that no major changes will occur in economic and political conditions, that international trade will continue to expand, that soaring energy costs will lead no country to suffer a severe economic setback, and that technological revolutions will not alter current transportation options while investments are in operation. Because the validity of these assumptions is open to question, the conclusions and recommendations of this study must necessarily be regarded as provisional. It should also be remembered that, because countries have only recently become involved in multi-national transportation projects, the study is based on a limited supply of empirical data.

3. Outline of the Study

In Chapter Two, issues arising from the fundamental problem of how to reconcile conflicting national priorities during the implementation of multi-national transportation investment planning are analyzed in greater detail. The general scheme is then applied to the formulation of workable institutional structures without which multi-national transportation investment planning is shown to be impossible. Chapters Three, Four and Five apply the general scheme respectively to forecasting, financing and evaluation. Conclusions and recommendations are given in Chapter Six. Finally, several technical models are included as appendices.

TABLE 1

DISTANCES BETWEEN MAJOR EUROPEAN CITIES

CITY PAIR	DISTANCE in kms.	in miles	AVERAGE TRAVEL TIME*
Amsterdam (Netherlands Brussels (Belgium)	205	127	1:30'
Amsterdam (Netherlands) Cologne (W.Germany)	254	158	3:10'
Athens (Greece) Belgrade (Yugoslavia)	1179	733	14:45'
Athens (Greece) Sofia (Bulgaria)	847	526	10:35'
Belgrade (Yugoslavia) Vienna (Austria)	651	405	8:10'
Belgrade (Yugoslavia) Munich (W.Germany)	993	617	12:25'
Belgrade (Yugoslavia) Budapest (Hungary)	401	249	5:00'
Brussels (Belgium) Paris (France)	301	187	3:45'
Brussels (Belgium) Frankfurt (W.Germany)	393	244	4:55'
Geneva (Switzerland) Marseille (France)	425	264	5:20'
Geneva (Switzerland) Milan (Italy)	330	205	4:10'
Hamburg (W. Germany) Copenhagen (Denmark)	323	201	4:00'
London (U.K.) Paris (France)	449	279	5:35'

TABLE 1, continued

London (U.K.) Brussels (Belgium)	371	230	4:40'
Madrid (Spain) Paris (France)	1269	789	15:50'
Zurich (Switzerland) Munich (W.Germany)	308	191	3:50'
Zurich (Switzerland) Vienna (Austria)	758	471	9:30'
Zurich (Switzerland) Amsterdam (Netherlands)	839	521	10:30'

*expressed in hours and minutes, based on average travelling speed of 80 kms/hr (50 mph), under free-flow traffic conditions.

CHAPTER TWO

GENERAL SCHEME AND INSTITUTIONAL STRUCTURE

1. Introduction

The fundamental problem of reconciling conflicting national priorities in multi-national transportation investment planning has two aspects. The first of these, the national planning aspect of multi-national investment planning, involves issues that might arise within participating countries. The second, the multi-national aspect of multi-national investment planning, involves issues that arise when these countries cooperate with one another.

This chapter begins by analyzing these aspects and then shows how they are exacerbated when combined. On the basis of this analysis, it is argued that the general scheme must provide for institutional structures if multi-national transportation investment planning is to succeed.

2. Problems in National Transportation Planning

National Transportation planning consists of several activities. Objectives are defined by the government as part of a proposed development plan for the country. Alternative plans are generated by a transport planner who considers alternatives that might fulfill the set objectives, having as variables options related to transportation itself and activity systems. Transportation options are the decision variables, controlled directly by the analyst or the agency involved in the planning process. They range from such broad items as alternative technologies and modes to specific items such as vehicle types, links to be improved, and type of investment. Activity system options are the social, political and economic variables that determine the demand for transport. They include variables such as spatial patterns of population, economic activity, agricultural and industrial policy and the like, all of which may influence the demand for transport services.

An alternative plan is feasible if all the constraints introduced by the analyst can be verified. Analysis of the resulting transport network is carried out for each alternative, employing simulation techniques or using direct mathematical procedures. With this analysis, the impacts of each alternative plan on different groups (the users of transport networks, producers, consumers and government) will be assessed.

The optimal alternative plan is then selected for implementation according to a proposed time schedule. This plan is that which best satisfies the set objectives and has the lowest proportion of costs to benefits.

Problems in national transportation planning are encountered at every stage of the process. They range from epistemic difficulties in estimating costs and drawing up timetables, through moral difficulties of low standards in public life, to institutional difficulties brought about by the multiplicity of government agencies. The latter are by far the most important. When the roles and responsibilities of government agencies overlap, coordination and communication are obstructed, the multiplicity of agencies encourages institutional jealousies, and thus the implementation of policies is delayed. Problems such as these are common to all countries throughout the world. They must be faced by all participant countries in multi-national transportation investment planning.

3, Problems in Multi-national Transportation Planning

Since multi-national transportation planning depends on the national transportation plans of each participating country, it faces all the problems presented above, which are compounded, emphasized and multiplied by the number of countries involved. Hence, multi-national transportation encompasses national transportation problems on an ultra-national scale, in addition to the problems that are unique to itself.

The most important of these is that of coordinating the schedules of activities that each participating country undertakes. Such coordination should require only minor changes in national plans, because major changes involve lengthy bureaucratic procedures and could upset the delicate balance of sectional and regional interests within a country. In any case, a compromise on schedules could easily be achieved if, for example, (a) the adjustments in national plans do not lead to budgetary revisions, (b) the changes guarantee that the resulting infrastructure will be able to accommodate domestic and international traffic, and (c) the need for investment loans from international banks will oblige governments to comply with the time constraints entailed by the loan agreements. The general scheme must therefore contain guidelines on the drawing up of schedules of activities.

Another problem concerns the technical and engineering design standards. To preserve the multi-national character of the investment planning, the most significant of these standards should be uniform and compulsory, and the less significant should be recommended but not required. The former could cover such technical aspects as (a) level of service, (b) alignment design parameters, (c) cross-section design parameters, (d) traffic regulations and safety facilities, and (e) maintenance. The latter could cover such issues as design and allocation of facilities, environmental considerations, and tunnel design. Guidelines on these issues should moreover be included in the general scheme.

Although problems associated with international traffic forecasting, transportation investment financing, international road traffic pricing and evaluating multi-national investments are no more important than the above, they are highly technical and complex and thus require mathematical techniques of considerable sophistication if they are to be solved. Hence, since they must be incorporated in the general scheme, they will be presented at greater length in the following chapters.

The problems discussed so far can be solved only by the formation of appropriate institutions. This is because these problems persist throughout the time horizon of the investments and it is futile to plan ahead without taking adequate steps to ensure that these plans can be brought to completion. Only institutions have the authority, ability and permanence to guide a plan through its various stages of execution. Hence, multi-national transportation investment planning without the appropriate institutional structure is bound to fail.

4. Institutional Structure

The most important aspect of the general scheme for multi-national transportation investment planning is the institutional structure. If this is carefully planned, it will guarantee that investments are successful. It will establish the inter-governmental agencies where decisions are made and it will enable differences between participating countries to be discussed and reconciled. Only highly technical problems cannot be solved by institutional means and require specific studies to be undertaken by the participating countries.

The institutional structure should include the following inter-governmental bodies:

a) A Steering Committee, which will be composed of representatives of all participating countries and, if necessary, of officials from international organizations. This committee is responsible for taking decisions that concern activities of common interest to all countries.

b) A Working Group on Technical Coordination, which will coordinate the activities in various technical fields, as directed by the Steering Committee.* The members of this group will be National Coordinators, nominated by each country to coordinate domestic and multi-national activities.

c) Several Groups of Experts, which will be set up on an ad hoc basis to produce working papers and discuss technical issues. Experts nominated by the competent authorities of the participating countries will partici-

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*The Working Group is not responsible for solving technical problems. Its task is rather to initiate technical studies and supervise their elaboration.

pate in these groups.

d) Finally, a Project Central Office, headed by a Project Manager, which will coordinate the several administrative activities related to multi-national transportation investment planning.

5. Existing Practices

Throughout the multi-national transportation investment projects undertaken in Europe, the above problems have inevitable occurred. They were ultimately overcome, however, and multi-national cooperation was established through the formation and acceptance of the appropriate inter-governmental institutions.

Since the necessary inter-governmental agencies already exist within the European Economic Communities* and the Council for Mutual Economic Assistance**, it is easy to set up the instiutional structure when multi-national ventures are undertaken by countries that are members of either of these economic alliances. Also, no major problems

*The European Economic Communities (E.E.C.) consist of ten Western European Countries: Belgium, Denmark, Eire (Ireland), Federal REpublic of Germany, France, Greece, Italy, Luxembourg, the Netherlands and the United Kingdom.

**The Council for Mutual Economic Assistance (known as COMECON) consists of seven Eastern European countries: Democratic Republic of Germany, Hungary, Romania, Poland and the U.S.S.R. Yugoslavia is an associate member.

are encountered if the participating countries are in Western Europe since their political and economic systems are similar and their diplomatic relations are excellent. The institutional structure becomes rather more difficult to form, however, when the participating countries come from both Western and Eastern Europe. The procedure followed in such cases, as for instance the Trans-European North-South Motorway, was to request the assistance of the United Nations Economic Commission for Europe and the United Nations Development Programme (31). Owing to this mediation in the case of the Trans-European North-South Motorway, an agreement was signed by all ten governments and an institutional structure was formulated comprising a Steering Committee, a Working Group for Technical Coordination, Ad-hoc Groups of Experts and a Project Central Office headed by a Project Manager.

6. Conclusions

The previous sections have shown that it is no easy task to formulate the general scheme for multi-national transportation investment planning. Complex procedures are involved which must assign due weight to existing national plans and administrative systems. In order to overcome the problems of coordinating multi-national investment activities in each country, a workable institutional structure is needed. In addition, several technical issues must be included in the general scheme. It is to these technical issues, notably the forecasting of international road traffic, the financing of transportation invesments, the pricing of international road traffic and the evaluation of multi-national transportation investments, that we turn in the following chapters.

CHAPTER THREE

INTERNATIONAL ROAD TRAFFIC FORECASTING

1. Introduction

In the context of the general scheme, the participating countries must elaborate a common methodology for forecasting the international traffic in their respective transport networks. The methodology should meet the available data, be easily applicable to any country, and be capable of estimating the international traffic during the planning time horizon. The latter, if carried out independently by each country for the traffic in its own network, would result in an unncessary duplication of effort. Therefore, it would be better if a joint study forecasting international traffic were undertaken by all the participating countries. Each participating country would still forecast its national (domestic) traffic.

The forecast of both domestic and international traffic is very important since it determines the time schedule for constructing the transport infrastructure sections in the participating countries. Thus, the multi-national investment planning will be coordinated on the basis of the findings of the traffic forecast. In the following sections, the most well-known methodologies and models for forecasting passenger and goods traffic at the national level will be presented. Based on them, a model for forecasting the international traffic will be proposed. Finally, as an example, the model developed for forecasting the international traffic on the Trans-European North-South Motorway will be outlined.

2. Passenger Domestic Traffic Forecasting Models

Numerous models have been developed for forecasting domestic passenger traffic. According to their different theories, they may be grouped into four categories: trip generation-distribution models, direct traffic estimation models, econometric models and behavioral models. In Appendix A, these models are presented in detail.

2.1. Trip Generation-distribution models

Trip generation is the first phase in travel forecasting; it involves estimating the total number of trips entering or leaving an area (zone) as a function of the socio-economic, locational and land-use characteristics of the zone. It takes as input the predicated distributions of zonal population, employment, activities and land uses for the design years, and, by extrapolating base-year relationships between these distributions and zonal tripmaking, generates as output estimates of design year trip productions and attractions.

Trip distribution is frequently the second phase in the travel forecasting process. The primary objective of this phase is to distribute the total numbers of trips originating in each zone among all the possible destination zones available.

As input, this second phase uses a set of zone trip productions and attractions, and attempts to estimate the ways in which these productions and attractions will be linked. Thus, these models are developed in such a way as to reflect these two phases: generation and distribution.

2.2. Direct Traffic Estimation Models

The technique of direct traffic estimation attempts to obtain traffic volumes on a network link by a single estimating process after trip generation. This method is somewhat dis-associated from individual or aggregate behavior of trip makers (passengers). It concentrates on the links in a transportation network and estimates traffic volumes on these links as a function of the potential traffic generation of the region under consideration for each link, as well as the availability of parallel links to accommodate this traffic. The analysis of each link proceeds independently of the analysis of other links.

2.3. Econometric Models

These models were developed in such a manner as to apply the microeconomic theory of demand to travel. Thus, demand for travel by a transport mode is not dependent on the type of the mode, but on the characteristics that describe the level of service that each mode offers (travel time, travel costs, frequency, safety, comfort, etc.)

2.4. Behavioral travel demand models

These models are based on an approach described as being disaggregate, behavioral and probabilistic. The models developed from this approach are quite different from those described previously. The development of these models was based on the following: (i) the basic unit of observation for model calibration is the individual traveller and not a traffic zone; (ii) the approach is founded in two disciplines dealing with behavior: the economics of consumer behavior (utility functions), and the psychology of choice behavior; (iii) a probability is assigned to each possible outcome of a particular travel decision for an actual traveller, or a potential traveller.

3. Model for Forecasting the International Passenger Road Traffic

Data have shown that all international passenger travel by road is non-business, unlike urban and intercity passenger traffic. An exception may be made for traffic at a 50 km (31 mile) radius from borders, which could be considered as local regional traffic. On the other hand, the data available in some countries are quite limited, and sometimes data from different countries may not be comparable. Therefore, the model for forecasting international passenger traffic should be computationally simple and have few data requirements.

The analysis of models developed for domestic passenger road traffic implies that the most appropriate models for international passenger travel are the growth factor models and the Baumol-Quandt econometric model. In the following section, the proposed model for forecasting the international passenger road traffic (private cars and buses) is described.

As a first step, in developing this model, each country must be divided into zones according to the degree of urbanization, and social, cultural and administrative aspects (for trip generation) and attractiveness -- quality of tourist sites, type, quality and accommodation facilities -- (for trip attraction). Then, the total number of private car trips between zone i in country A and zone j in country B may be estimated with a model expressed with the following general function:

$$T_{ij}^{a} = D^{a}(C_{ij}^{a},\ C_{ij}^{(K)},\ t_{ij}^{a}, d_{ij}, I_{i}, P_{i}, A_{i}, R_{j}, P_{ij}, U_{ij}) \quad (3.1)$$

where:

T_{ij}^{a}: total number of auto trips from zone i to zone j

C_{ij}: cost of travel from zone i to zone j by auto, for every passenger of the car (assuming an auto occupancy) expressed in the currency of country A (where zone i is located)

$C_{ij}^{(K)}$: cost of travel from zone i to zone j by other mode K (K = bus, train, airplane)

t_{ij}^{a}: travel time by auto from zone i to zone j

$t_{ij}^{(K)}$: travel time by mode K from zone i to zone j

d_{ij}: total time for vacation at zone j of a tourist from zone i (an average figure could be taken)

I_{i}: average income in zone i (beyond its influence on car ownership)

P_{i}: population of zone i

A_{i}: car ownership in zone i

R_{j}: attractiveness of zone j

P_{ij}: relative prices in zone j (of country B) with respect to prices in zone i (of country A)

U_{ij}: this variable could be broken down into several others to capture such factors as : a) required formalities for the trip from zone i to zone j, b) political and economic situation in xones i and j, c) other relevant factors.

Furthermore, the number of bus trips (assuming the number of passengers per bus is fixed) may be estimated with a model, expressed by the following general function:

$$T_{ij}^{b} = D^{b}(C_{ij}^{b},\ C_{ij}^{(K)},\ t_{ij}^{b},\ t_{ij}^{(K)},\ d_{ij},\ I_{i},\ P_{i},\ A_{i},\ R_{j},\ P_{ij},\ U_{ij},\ F_{ij}) \qquad (3.2)$$

where:

C_{ij}^{b}: cost of travel from zone i to zone j by bus

t_{ij}^{b} : travel time from zone i to zone j by bus

F_{ij}: frequency of bus service between zones i and j; and all other variables are the same, with K = auto, train, airplane.

As a second step, the estimated traffic has to be assigned on the network. Since each passenger plans well in advance the route he would follow for his international trip, it is fair to apply the all or nothing assignment method. Therefore, the route chosen by private cars for trips from zone i to zone j can be found applying the following general expression:*

$$\min A_{ij}^{rs} = f(t_{ij}^{rs},\ \varepsilon_{ij}^{rs}) \qquad (3.3)$$

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* This is a general expression for a minimum cost route algorithm, which is solved with iteration techniques.

Where:

t_{ij}^{rs}; Total travel time from zone i to zone j, over route rs

ε_{ij}^{rs}: Correction variable, to reflect any road charges and additional border formalities on route rs

rs: Route chosen by private cars.

For bus trips ,the above described route assignment has to be modified to reflect the fact that buses must pass through pre-specified cities according to their schedule. Thus, equation (3. 3) has to be changed to:

$$\min B_{ij}^{rs} = F\,(t_{ij}^{i\alpha} + t_{ij}^{\alpha b} + \ldots + t_{ij}^{k\ell} + \ldots + t_{ij}^{qj},$$

$$\varepsilon_{ij}^{i\alpha} + \varepsilon_{ij}^{\alpha b} + \ldots + \varepsilon_{ij}^{k\ell} + \ldots + \varepsilon_{ij}^{qj}) \qquad (3.4)$$

Where:

$t_{ij}^{k\ell}$: Travel time from mandatory stop in zone k to the mandatory stop in zone l, along the route rs, to be chosen from zone i to zone j.

$\varepsilon_{ij}^{k\ell}$: Correction variable, to reflect any road charges and additional border formalities from mandatory stop in zone k to the mandatory stop in zone l, along the route rs, to be chosen from zone i to zone j.

In addition, the conservation rule for traffic has to be satisfied for both private car and bus trips. Thus:

$$\sum_i T_{ij}^{\alpha} = \sum_j T_{ij}^{\alpha} \qquad (3.5)$$

$$\sum_i T_{ij}^{b} = \sum_j T_{ij}^{b} \qquad (3.6)$$

Solving the system of equations (3.1)-(3.6) by the iteration method, the number of trips from zone i to zone j and the volume of traffic on each link of the network will be estimated.

The international passenger road traffic can be estimated for any future period if we: (a) change the variables in modes (3.1) and (3.2) according to the economic development plans of the countries and in models (3.1)-(3.4) according to the construction schedules established by the multi-national transportation investment planning, and (b) solve the system of equations (3.1)-(3.6).

The proposed models for forecasting international passenger road traffic (private cars and buses) require data at an aggregate as well as at a disaggregate level since they try to approximate the utility functions of individuals in zone i concerning their trips to zone j. However, if the necessary data at the disaggregate level are not available, it would be approprite to modify the models in order to comply with data availibility.

4. Domestic Freight Traffic Forecasting Models

4.1. Factors determining the demand for freight transportation*

The demand for freight transportation results from the demand for commodities in markets which are geographically removed from the locations where commodities are produced. Thus, the demand for freight transportation is linked with the functioning of the market system. However, at an

*This section was based on: a) McClain, J. and Thomas, J, Operations Management, Prentice-Hall, 1980; b) Chiang, Y., "A Policy Sensitive Model of Freight Demand, Ph.D. Thesis MIT, 1979; and c) Terziev, M., "Modeling the Demand for Freight Transportation," M.Sc. thesis, MIT, 1976.

aggregate level, the market system behaves in such a complex manner that the influence of any single factor is virtually unidentifiable. It is only at the level of the individual decision-maker that the interaction of transportation and other market factors can be studied in detail.

In freight transportation, the decision-maker is the manager of a manufacturing plant, or a wholesale or retail store. It is the manager's responsibility to determine or forecast the daily level of output and to guarantee that an adquate supply of required inputs is available. These inputs are usually stored according to an inventory control plan, which is designed to offer a desired degree of protection against stock-out.The orders for the various inputs are usually generated according to the operations plan. Each order for a particular commodity involves the choice of a supplier, the origin and size of the shipment and the mode of transport. Although a manager has some alternatives available each time an order is placed, long run decisions make the use of some modes, suppliers and shipment sizes economically unattractive.

Four types of variables affect the transport decisions of the manager:

a) Level of service offered by each mode for various commodities, shipment sizes, origins and destinations. The key parameters are:

-Waiting time: time spent waiting at the origin for a vehicle to become available;

- Travel time;
- Delivery time reliability;
- Loss and damage;
- Packaging cost;
- Handling cost;
- Tariff;
- Minimum shipment size requirements.

b) Nature of commodity to be transported. The key parameters are:

- Value. The price at the origin (the point of supply);
- Shelf life: this is determined by spoilage or obsolescence;
- Seasonality: commodity demand may be seasonal or non-seasonal;
- Density: the means by which maximum shipment size is determined (by volume or by weight);
- Perishability: this refers to the sensitivity of the commodity to environmental factors during transportation;

c) State of the market for the commodity being ordered: this will affect the choice of supplier and shipment origin.

The key parameters are:

- Price: the FOB factory price at each source of supply;
- Quality: although difficult to measure, it is often important;
- Supply availability: this depends on whether the orders are filled from stock or from production runs;
- Total volume of production of the supplier.

d) Characteristics of the decision-maker's firm. The key parameters are:

- Annual usage of the commodity being ordered;
- Variability in the usage rate;
- Results of a stockout: the consequences of a stockout to the plant operations are plant shutdown, or a move to a less efficient process, the loss of sales or the postponement of sales;
- Reorder cost;
- Storage cost, including the fixed costs of the warehouse and the variable costs of the personnel;
- Capital carrying costs.

It is clear that these variables interact in a complex manner.

4.2. Review of existing models

Relatively little work has been done in the area of freight demand modeling in comparison with the extensive work done on modeling the demand for passenger transportation. Nevertheless, a fairly large number of studies of freight demand have appeared in transportation and economics literature during the past ten years. The freight demand models developed in these studies generally address one of three types of commodity flows: intra-city, inter-city, or international shipping.

Demand models for freight transportation can be separated into two general groups: i) aggregate, and

ii) disaggregate, according to the types of data they use. In Appendix A, these models are described in detail.

5. Model for Forecasting International Freight Road Traffic

As in the case of forecasting international passenger road traffic, the data for forecasting international freight road traffic are quite limited. In addition, data from different countries may not be comparable because different countries classify freight road traffic according to dissimilar principles. For example, tomatoes might be classified as a fruit in one country and as a vegetable in another.

The task of forecasting international freight road traffic is further complicated by the requirement that trucks must have permits to cross international borders. Each country limits the issue of such permits according to its quota system. These permits specify the routes that trucks must take when within the country's territory. Furthermore, several countries charge a fee ("road charge") depending on the distance to be covered and the weight of goods to be transported. These fees are an important source of foreign exchange for countries with foreign exchange problems.

The analysis of models developed for domestic freight road traffic implies that the most appropriate model for international freight road traffic is an aggregate type model, modified to capture the prevailing economic conditions in each country and the existing "quota system."

As a first step in developing this model, each country must be divided into agricultural and industrial zones for purposes of trip generation and trip attraction. However, since data about exports and imports of goods might not be available for every zone, the proposed model will estimate the volume of freight traffic (number of truck trips) between countries. As a second step, the traffic between zones can be easily estimated.

The proposed model for estimating the total number of truck trips from country A to country B could be expressed by the following general formulation:

$$x^{AB} = f^{A} \left(C^{A}_{AB},\ C^{K,A}_{AB},\ F^{rs}_{AB},\ E^{AB}_{A},\ \ell_{A}\right)$$

$$y^{AB} = f^{I} \left(C^{I}_{AB},\ C^{K,I}_{AB},\ F^{rs}_{AB},\ E^{AB}_{I},\ \ell_{I}\right) \qquad (3.7)$$

subject to:

$$\sum_{\substack{\text{all countries B} \\ \text{(destinations)}}} \left(x^{AB} + y^{AB}\right) \leq N^{rs}_{A}$$

where:

x^{AB} : total number of truck trips from A to B, with trucks transporting exports of agricultural products from A (imports to B);

y^{AB}: total number of truck trips from A to B, with trucks transporting exports of industrial products from A (imports to B);

E_A^{AB}: total exports (in tons) of agricultural products from A to B (imports for B);

E_I^{AB}: total exports (in tons) of industrial products from A to B (imports for B);

ℓ_A: average total weight (in tons) of agricultural products per truck;

ℓ_I: average total weight (in tons) of industrial products per truck;

C_{AB}^{A}: total travel costs per ton (travel time costs and any road charges are included), for agricultural products transported by truck from A to B;

$C_{AB}^{K,A}$: total travel costs per ton for agricultural products transported by mode K (K = ship, railroad, airplane), from A to B;

N_A^{rs}: existing "quota system" on route rs with respect to trucks registered in country A (i.e., maximum number of trucks registered in A allowed to use route rs for their trips from A to any other country).

F_{AB}^{rs}: formalities along the route rs;

rs: route chosen by a truck for the trip from A to B;

C_{AB}^{I}, $C_{AB}^{K,I}$: same as C_{AB}^{A} and $C_{AB}^{K,A}$, but for industrial products.

The total number of truck trips between pairs of countries cannot be estimated by simply applying equation (3.7) for each pair: a system of equations (3.7), (3.9) and (3.10) must be solved and the constraints imposed by the "quota system" must be met. (Equations (3.9) and (3.10) are described later). This system could be solved after several iterations. Thus, the total number of truck trips (x^{AB}, y^{AB}) from A to B can be estimated.

The next step is to estimate the total number of truck trips from zone i in A to zone j in B. For this estimation, it is assumed that truck trips originating in A are distributed in the several zones of the country, adcording to each zone's proportion of total national employment in agriculture or industry, as the case may be. Furthermore, it is assumed that truck trips from A to B are distributed in the zones of country B according to each zone's proportion of total national population (if agricultural products are transported) and of total national employment in industry (if industrial products are transported). Thus, the total number of truck trips from zone i to zone j could be estimated by applying the following expression:

$$T_{ij} = x^{AB} \cdot P_{Ai} \cdot M_{Aj} + y^{AB} \cdot P_{Ij} \cdot M_{Ij} \quad (3.8)$$

where:

T_{ij}: total number of truck trips from i to j;

P_{Ai}: i's proportion of total national employment in agriculture;

P_{Ii}: i's proportion of total national employment in industry;

M_{Aj}: j's proportion of total national population;

M_{Ij}: j's proportion of total national employment in industry;

x^{AB}, y^{AB}: as defined previously.

Another step, necessary for solving equation (3.7), deals with the traffic assignment on the network. Since other considerations besides link congestion are more important to the shipper (e.g., border formalities, existing quota systems, etc.), and since the route that a truck has to follow is specified on its permit, the all or nothing assignment is most appropriate. Thus, the route chosen by a truck can be found by applying the following general expression:*

$$\min Z_{ij}^{rs} = f(t_{ij}^{rs}, \varepsilon_{ij}^{rs}) \qquad (3.9)$$

where:

t_{ij}^{rs}: total travel time from i to j over route rs;

ε_{ij}^{rs}: correction variable to include any road charges and border formalities on rs.

Furthermore, the conservation rule for traffic has to be satisfied. Thus:

$$\sum_i TT_{ij} = \sum_j TT_{ij} \qquad (3.10)$$

Solving the system of equations (3.7), (3.9) and (3.10) with the iteration method, the number of truck trips from i to j, as well as the volume of truck traffic on each link of the network can be estimated.

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* This is a general expression for a minimum cost route algorithm, which is solved with iteration techniques.

International freight road traffic can be estimated for any future period by (a) changing the variables in models (3.7) and (3.8) according to the economic development plans of the countries, (b) changing the variables in models (3.7) and (3.9) according to the construction schedules, as established by the multi-national transportation investment planning, and (c) solving the system of equations (3.7) - (3.10).

The proposed models for forecasting international freight road traffic require data at a relatively aggregate level. However, if the necessary data are not available, it would be appropriate to modify the models accordingly.

6. Example of Existing Practices (31, 44)

Excellent examples of models for forecasting international road traffic were developed for the Trans-European North-South Motorway. In the following section, they are described briefly, and a detailed discussion of them is to be found in Appendix B.

These models are average growth forecast models, which use the traffic pattern that existed in 1978 as base year data.* Countries were divided into zones, and traffic was expressed in terms of trips between these zones.

To find the future traffic of private cars generated by each zone, the 1978 traffic figure is multiplied by a growth

*These figures were established by the O-D survey and by the traffic counts that were carried out in 1978.

factor, which depends on the evolution of the private car fleet and the income per capita in each zone. To find the future traffic of private cars attracted by each zone, the 1978 traffic figure is multiplied by a growth factor, which expresses the expected growth in arrivals of foreign tourists by private cars, modified in such a way that the total number of attracted trips corresponds to the total number of generated trips.

To find the future generated and attracted truck trips for each zone, the number of 1978 trips is multiplied by a growth factor, which reflects the development of exports and imports respectively. Individual consideration is given to agricultural and industrial products. Initially, the generated and attracted truck trips are calculated for each country, and, applying a zonal distributional factor, they are calculated for each zone. The zonal distributional factor reflects the zone's proportion to total national employment in agriculture and industry for the generated truck trips and the zone's proportion to total national population and emplyment in industry for the attracted truck trips.

Finally, the traffic assignment to the network is carried out in accordance with the all or nothing rule.

CHAPTER FOUR

ROAD INFRASTRUCTURE PRICING AND FINANCING

1. Introduction

In various countries, financing the construction and maintenance of the road infrastructure has been undertaken according to different approaches, although there are several methods common to all. Different approaches in financing improvements in road infrastructure are the result of each country's political, economic, and administrative systems.

Another important factor in such differences is the state of the road network in each country. In several developed countries (e.g., the U.S.A., West Germany, Belgium, the Netherlands, Italy, Japan), an extensive road and freeway network is almost finished. Other developed countries (e.g., France, the United Kingdom, Switzerland, Sweden) are undertaking active construction programs that will provide them with larger networks within a few years. By contrast, in developing countries the road networks are of poor quality, and few or no freeways exist. In addition, capital is scarce in these countries, government budgets are dramatically limited, the supply of labor is high but unskilled, vehicle ownership is low, and unemployment is severe.

Finance for the construction and maintenance of road infrastructure comes from each country's revenues from taxes and other sources. In any case, the most important source of revenue for financing investments for road infrastructure comes from road user taxes and tolls, which may or may not be part of general state revenues. Road user taxes may include only fuel taxes, although they may also include a tax on vehicles, according to their size and value.

The different approaches used for financing the investments in road infrastructure may be classified into the following categories:*

a) Budget allocations with no earmarking

In this case, road user taxes and tolls, if any, are part of the general state revenue, and therefore are not related to road investment, which can be higher, equal to, or lower than road revenue. Tolls may or may not exist on freeways.

b) Earmarking and budget allocation

In this case, part of the road revenues are used for road financing, but other budget funds can be added; that is, highway expenditures are higher or equal to road taxation revenues. Tolls may or may not exist on freeways.

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*In Appendix C, the approaches followed in several countries will be presented.

c) Earmarking as the only source of funds

In this case, all highway expenditures necessarily equal road user revenues; that is, there is a breakdown constraint. The whole system has to be self-financing.

d) Breakdown constraint for expressways

In this case, toll recepts must equal expressway expenditures, but other roads may be non-self-financing.

e) Breakeven for each kind of highway

In this case, there are two breakeven constraints: freeways are financed out of toll revenues, and the other class of roads is financed by gas taxes.

f) Rate of return regulation for turnpikes

In this case, while roads may be self-financing, turnpikes must provide a given rate of return on fixed invested capital (in addition to capital costs).

From the above analysis, it seems impossible to develop a unique approach to financing, which can be applied to all countries participating in multi-national investment to improve their road infrastructure.

However, the most important issue is the pricing schemes upon which each financing approach is based. A model could found which predicts the optimal values of road user pricing (e.g., tolls, fuel taxes) and of level of investment, independent of the financing approach followed. This model could be applied to each country, but the results obtained would depend on the approach followed in each country. This model would be quite useful to all participating countries if they were to decide to apply uniform tolls and/or user taxes to the international traffic on their respective road networks.

Another issue is governmental charges imposed on foreign trucks. As mentioned earlier, these charges are related to the permit that each truck must have in order to enter a foreign country. The revenues from these charges to international traffic are the subject of discussion among European countries. In the following sections, several methodologies will be developed for the computation of the optimal value of these charges to foreign trucks. This could enable partcipating countries to adopt a common method for foreign truck pricing.

Finally, as examples of existing practice, the approaches for financing the construction and maintenance of the road infrastructure and the methods for road user pricing in several countries will be presented in Appendix C.

2. Model for Financing the Investments in Road Infrastructure and for Road User Pricing

2.1. In developing a model that could be applied to any country regardless of its financing approach, the following guidelines should be followed.

a) the model should be based on a flexible and comprehensive methodology;

b) the model should be capable of producing an indicator that could simplify comparison between pricing schemes while suggesting the optimum alternative;

c) the indicator should reflect: i) the users' desire to maximize their utility from the use of the road infrastrucuture, ii) the need of the government to minimize the losses incurred by the construction and maintenance of the infrastructure, and iii), if the operation of the road infrastructure is done by a private firm, the objective of this firm (usually profit maximization);

d) the model should include all possible pricing schemes and all investment options available to the government(s).

2.2. There are numerous models developed in this area. However, the model proposed by Graells-Ferrandez (10) seems most appropriate for application to multi-national investment planning for improving the road infrastructure.

The model was formulated as a welfare function. The welfare function is composed of the sum of consumers' surplus plus revenues for the road authority minus public costs (i.e., construction and maintenance costs, toll collection expenses, cost of capital, land acquisition costs).

The objective of the model is to find both the optimal values of tolls and fuel taxes and the optimal level of investment (expressed in lane-miles of road construction), in order to maximize the welfare function. According to the financing schemes in each country, constraints could be added this maximization problem to reflect the country's policies. Therefore, the model could be adapted to any situation without changing its basic structure. The model as developed by Graells-Ferrandez is presented in its unconstrainted form in Appendix D.

3. Revenues from the Road Charges Imposed on Foreign Trucks

3.1. Background Information

Another potential revenue for government is the road charges collected from foreign trucks using its road network. Each country wishes to achieve the lowest charges for its own trucks travelling in other countries and, at the same time, to impose the highest possible charges for foreign trucks travelling within its own territory. Because these objectives are contradictory, a common methodology for computing the charges to foreign trucks should be adopted by the participating countries.

3.2. Introduction to the Variables and Issues Involved

The value of the charges imposed on foreign trucks will be considered on a network link basis. The link might be fictitious (e.g., from a point "a" at the border with country A to a point "b" at the border with country B), or real. The link might be located in only one country, or it might cover the territories of two or more countries. The costs incurred by the trucks using the link are:

(1) capital costs, (2) fuel costs, (3) maintenance costs, (4) insurance costs, (5) crew costs, (6) travel time costs, (7) tolls (if any), and (8) road charges. From the above costs, the financial costs are those from (1) to (4). Travel time costs are based on i) the average travel time on the link, and ii) the value time according to the kind of commodity transported. Tolls (if any) depend on the truck type. All the costs are computed per km (or mile).

Trucks registered in the country where the link (or link section) is located do not pay road charges in the country of their registration. (Eventually they pay road charges indirectly through their country's taxation system.)

The following symbols are employed:

i : country of truck's registration;

j : type of truck according to its tonnage capacity;

Q_{ij} : annual number of foreign trucks on the link, according to the country of registration and type;

P_j : road charges to foreign trucks according to their tonnage capacity (It is assumed that these costs are the same for all countries.);

C_{ij} : all costs relevant to commodity transportation along the link (except road charges), according to the country of truck registration and truck type;

$h(\ldots)$: generalized function representing the costs of alternative modes, alternative routes, the total tonnage of commodities to be transported within the year in question, etc.;

Using these symbols, the number of foreign trucks during the year in question on the link considered, according to the country of registration and type, could be expressed in a general form by the following expression:

$$Q_{ij} = f(C_{ij} + P_j, h(\ldots)) \qquad (4.1)$$

3.3. Economic and Financial Costs of the Trucking Firms*

It is quite difficult to compute the economic and financial costs of trucking firms incurred in the operation of their trucks outside their country of registration. As a first step, the costs must be divided into financial costs, which may differ from one country to another, and economic costs, which are considered uniform, except for a minor correction factor to establish a difference among countries. The financial costs will be used in the demand function, and the economic costs will be used in determining on a link basis, the benefits (and costs) to the economy.

Financial costs are defined as those incurred in transport operations by trucking firms; they are capital and operating costs (fuel, maintenance, insurance). No corrections are made in the elements for taxes, subsidies, etc. Capital costs include the depreciation cost (capital for replacement

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*This analysis was based on the study prepared by BROKONSULT for the navigable waterway between the Danube River and the Aegean Sea. (32,43) of equipment computed on a replacement plan at constant pricing) and the opportunity cost (the earnings that could be made on the money, spent to purchase the vehicle, according to the existing rate of return to capital in the economy). Usually there is no salvage value for the trucks.

There is a difference between tariffs and financial costs. Tariffs include depreciation costs, operating costs, interest on the capital of the shipper's firm, and a profit component. Therefore, tariffs could not be used instead of financial costs.

Financial costs are computed by examining the real factors (vehicles, fuel, maintenance, etc.) and applying the market prices. These market prices will contain the effects of various government interventions. In order to formulate the demand function for road transport, the financial costs of other modes should be collected as well. The financial costs should be prepared for each country involved. This involves collection of the local prices and costs as reported from actual transactions and typical transport enterprises. To obtain a coherent set of data, it is first necessary to establish all cost estimates in the same currency. Second, it is necessary to establish a cost on a road link by considering the country of truck registration, where the transport firm that owns the truck is operating. This raises a number of questions of some complexity. For adjusting all estimates to a common currency, some set of exchange rates is needed. As these transport cost estimates are proxys for decision prices and have no welfare connotation, the market exchange rates should be used. Owing to the great variability of exchange rates in recent years, it is necessary to establish a set of such rates that will hold throughout the analysis. To establish the costs accurately, we must develop a correction for the ownership of the transport firm. We could assume, for simplicity, that, on the average, each trading pair of countries transports goods through national enterprises. The only question then is the shares of the two countries. If, on a link, the transport costs for a specific mode owned by a firm in country m are $C_{\underline{m}n}$, and those of the same mode owned by a firm in country n are $C_{m\underline{n}}$, then the average cost for both firms is:

$$FC = \lambda C_{\underline{m}n} + (1-\lambda) C_{m\underline{n}} \qquad (4.2)$$

where λ is the percentage of transport firms in one country m and $(1-\lambda)$ the percentage in country n, if the total number of transport firms in both countries is considered to be 1. Of course, the costs $C_{\underline{m}n}$, $C_{m\underline{n}}$ will depend partly on prices in m and partly on prices in n, as the transport firm makes expenditures in both countries. The above defined average cost concept will be used in computing the capital, fuel, maintenance and insurance costs for the truck operation on the link in question.

To estimate the economic costs, we could proceed as follows. First, for each of the cost components, a standard price cost in the common currency will be established. This price or cost must exclude all taxes imposed on commodities or services. Then the costs associated with the link are computed from physical factors and standard prices. Second, a percentage based on the ratio of public consumption to GDP (less public consumption) is added on for each country. This ratio is designated t_m for the m^{th} country. For the link, we have an associated economic cost CE_m, excluding this taxation correction. On this link cost a fraction f_{mn} is value added. Then the economic cost associated with the link is given by

$$CE = \lambda(CE_m + f_{mn} \cdot t_m) + (1-\lambda)(CE_n + f_{mn} \cdot CE_n \cdot t_n) \quad (4.3)$$

where λ is the same ownership weighting factor previously defined.

The term $(CE_m + f_{mn}\ CE_m \cdot t_m)$ is the correct economic costs for a truck registered in country m. We could apply this formula in computing the economic cost for truck (ij) on the link under consideration. Thus, each economic cost CE_m should be corrected by adding the term $(f_{mn} \cdot CE_m \cdot y_m)$, if a comparison is desired with another country n.

The economic costs should be computed for the crew wages, travel time, road charges and tolls (if any).

Finally, by applying equations (4.2) and (4.3), we can compute the financial and economic costs on the link independently of the truck's registration country, using as a reference country the country where the link (or section of it) is located. This is very convenient, because the costs (C_{ij}) and road charges (P_j), after the adjustments resulting from the application of equations (4.2) and (4.3), are computed in the same currency and they are comparable. In the following, when we are referring to C_{ij} and P_j, we assume that equations (4.2) and (4.3) have been applied for their computation.

3.4. Construction and maintenance costs related to foreign trucks

The total construction costs (discounted to the present) for the link's new construction (or improvement) may be denoted as C, the years until the end of the time horizon as T, and the anticipated total traffic during the T years as V (expressed in Passenger Car Units: P.C.U.).

We could relate the construction costs to the anticipated total traffic. Thus

$$CV = \frac{C}{V} \qquad (4.4)$$

where: CV: construction cost/P.C.U.

So, if a truck of type j is a_j Passenger Car Units for the link in question, the construction costs related to a foreign truck of type j are:

$$CF_j = CV \cdot a_j \qquad (4.5)$$

Therefore, the construction costs related to a volume of Q_{ij} foreign trucks per year are

$$CF_{ij} = Q_{ij} \cdot CF_j \qquad (4.6)$$

where Q_{ij} is as previously defined.

On the other hand, it is known that the annual maintenance costs are a function of the volume and composition of traffic. Thus, the maintenance costs related to a volume of Q_{ij} foreign trucks per year: are

$$MF_{ij} = g(Q_{ij}) \qquad (4.7)$$

Finally, the total annual construction and maintenance costs related to an ancicipated annual volume of Q_{ij} foreign trucks are

$$TCF_{ij} = CF_{ij} + MF_{ij} = F(Q_{ij}) \qquad (4.8)$$

where $F(Q_{ij})$ is a function of Q_{ij}.

3.5. Road charges imposed on foreign trucks

The road charges imposed on foreign trucks for travel on the link in question can be computed by applying the following methodologies. The methodologies produce different results, since they are formulated to serve different governmental objectives. The tolls, if any, are exogenously specified. (The method proposed in Section 2 of this chapter can be used to compute the tolls). The methodologies considered are these.

i) Marginal Cost Pricing

The objective of the road authority is to equate the marginal costs of the road authority to the costs of truck operations. That is

$$\frac{\partial TCF_{ij}}{\partial Q_{ij}} = C_{ij} + P_j \qquad (4.9)$$

(ixj equations can be formulated)
where all variables have their previous meanings.
Solving equations (4.9) and (4.1) we find the values of Q_{ij} and P_j, for all i and j.

Therefore, the government can impose the appropriate road charge P_j for truck type j and allow the entry of Q_{ij} trucks having as country of registration i and being of type j.

ii) Total Revenues = Total Costs (excluding construction costs)

This implies that the road authority's objective is to cover its maintenance costs from the revenues collected from the traffic. Thus:

$$Q_{ij}P_j = MF_{ij} \quad \text{(ixj equations)} \qquad (4.10)$$

where all variables have their previous meanings.
Solving equations (4.10) and (4.1), we can find the values of Q_{ij} and P_j.

If there are tolls on the road link, equation (4.10) will become:

$$Q_{ij} \cdot (P_j + t_j) = MF_{ij} \quad \text{(ixj equations)} \qquad (4.11)$$

where: t_j : tolls collected from truck of type j.

iii) Total Revenues = Total Costs (including construction costs)

This implies that the objective of the road authority is to cover its total costs from the revenues collected from the traffic. Thus:

$$Q_{ij}P_j = TCF_{ij} \quad \text{(ixj equations)} \qquad (4.12)$$

or, if there are tolls:

$$Q_{ij}\,(P_j + t_j) = TCF_{ij} \quad \text{(ixj equations)} \qquad (4.13)$$

Solving equation (4.12) or (4.13) and equation (4.1), we can find the values of Q_{ij} and P_j.

As stated above, it is possible that there is no solution to the problem (i.e., there is no such charge which generates enough traffic to cover all costs).

iv) Maximize the Net Revenues of the Road Authority

This implies

$$\text{Max} \sum_{i=1}^{M} \sum_{j=1}^{n} (P_j Q_{ij} - TCF_{ij}) \qquad (4.14)$$

$$\text{s.t. } V_P + \sum_{i=1}^{M} \sum_{j=1}^{N} a_j \cdot Q_{ij} \leq \text{CAPACITY OF THE LINK (in p.c.u.)}$$

where

V_P : number of passenger cars, buses and domestic trucks, expressed in p.c.u.

M: countries considered

n: truck types considered

a_j: number of p.c.u. for truck type j.

This is a linear program to be solved simultaneously with equation (4.1). The solution will produce the values of Q_{ij} and P_j.

Furthermore, the TCF_{ij} costs could represent only the maintenance costs or both construction and maintenance costs. Also, equation (4.14) could be changed to (4.15) to include the tolls, if any:

$$\text{Max} \sum_{i=1}^{M} \sum_{j}^{n} \left[(P_j + t_j) Q_{ij} - TCF_{ij} \right] \qquad (4.16)$$

$$\text{s.t. } V_P + \sum_{i=1}^{M} \sum_{j=1}^{n} a_j Q_{ij} \leq \text{CAPACITY OF THE LINK (in p.c.u.)}$$

v) Minimize the Total Transport Costs to the System

This is a more socially desirable policy. The objective of the road authority is to minimize the total transport costs (both of the trucks and the road authority). The corresponding expressions are:

$$\text{Min} \sum_{i=1}^{M} \sum_{j=1}^{n} (C_{ij} + P_j + TCF_{ij}) \tag{4.16}$$

$$\text{s.t.} \quad V_P + \sum_{i=1}^{M} \sum_{j=1}^{n} a_j Q_{ij} \leq \text{CAPACITY OF THE LINK (in p.c.u.)}$$

where all the variables have their previous meanings. This is a linear program to be solved simultaneously with equation (4.1). The solution will produce the values of Q_{ij} and P_j.

Furthermore, the TCF_{ij} costs could represent only the maintenance costs or both construction and maintenance costs. Also, equation (4.16) could be changed to (4.17) to include the tolls, if any:

$$\text{Min} \sum_{j=1}^{M} \sum_{j=1}^{n} \left[C_{ij} + P_j + t_j + TCF_{ij} \right] \tag{4.18}$$

$$\text{s.t.} \quad V_P + \sum_{i=1}^{M} \sum_{j=1}^{n} a_j Q_{ij} \leq \text{CAPACITY OF THE LINK (in p.c.u.)}$$

CHAPTER FIVE

EVALUATION OF THE MULTI-NATIONAL TRANSPORTATION INVESTMENTS

1. Introduction

Evaluation may be defined as the relative and absolute assessment of the worthiness of a particular course of action or a planned investment. Several problems are associated with the evaluation of road infrastructure investments. The most important is to which group or groups of individuals (users of road infrastructure, all citizens of the country) the costs and benefits from the investments should be attributed. Further problems may be created by the fact that any improvement of a link or links in the road network affects the remainder of the transportation network.

Methods for evaluating transportation investments at the national level may be classified in two categories: the traditional economic evaluation, and the cost-effectiveness evaluation.

The methods of traditional economic evaluation compel the inclusion in the evaluation process of only those costs and benefits that can be monetarized.* Several issues here are controversial: (a) the appropriateness of representing the benefits, in economic terms, by the concepts of consumers

*A theoretical approach for evaluation at the national level is presented in Appendix E.

and producers surplus,* (b) the treatment of the temporal nature of transportation investment, (c) the selection of a method for calculating the trade-off between costs and benefits, and (d) the valuation of travel time-savings, accidents and other non-monetary costs and benefits. In general, the economic evaluation methods involve a strict accounting of costs and benefits over the life of each alternative investment option or policy. As such, they provide the decision-maker with a single numeric value for each option, thus permitting a rapid, one-dimensional assessment of each option. Each of the methods requires the estimation of a set of forecasts of travel volumes, operating costs, and initial capital costs, together with such data as numbers of fatal accidents, maintenance costs, and policing costs. Given these inputs, the determination of project life and the selection of one or more discount rates, a net present worth, benefit/cost ratio, or rate of return, can be computed.

The methods of cost-effectiveness evaluation attempt to circumvent the strong quantitative orientation of the traditional economic evaluation; they allow a much broader

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*The consumers surplus measures the difference of what consumers are willing to pay and what they actually pay, and it could be represented in a graph as the area between the demand curve and the price line.

The producers surplus measures the difference of what producers receive in revenue and their short-run costs of producing the good,and it could be represented in a graph as the area between the supply curve (short-run marginal cost curve) and the price line. (Producers surplus is also known as economic rent or quasi-rent.)

set of consequences of transportation plans and policies to be considered. In addition to broadening the set of consequences, the cost-effectiveness method also opens up the possibility of considering the consequences to a broader group of people (both users and non-users). The cost-effectiveness method is a framework within which the decision-maker can assess the various levels of achievement of objectives that may be obtained at various levels of costs. This enables the decision-maker to enter political and societal values to determine preferred plans and policies. Potentially, the cost-effectiveness method permits the consideration of the full set of consequences of any policy or plan, regardless of who may experience the consequences. Furthermore, the cost-effectiveness method can consider the impacts of the investment plans or policies, and measure their effectiveness.

2. Guidelines for the Evaluation of Multi-National Transportation Investments

The only reported study relevant to the evaluation of multi-national transportation investments was undertaken with regard to the construction of a tunnel under the English Channel. However, this study applied a simple benefit-cost analysis. The benefits over a fifty-year period were calculated for the users by estimating the diverted and generated traffic. As costs, only the construction costs and operating costs were considered. The evaluation was based on calculation of the internal rate of return.

Owing to limited research in the area of evaluation, the present study will focus on developing guidelines belonging to the general scheme. At the first stage, each participating country evaluates alternative investment plans for implementation within its own territory. Thus, it is the responsibility of each country to choose the design plan that it considers best in the light of its own particular national objectives and goals. This design plan must be compared with other investment plans concerning the remaining transportation network of the country. Thus, only the decision-makers of a country can assess whether an investment prepared by multi-national transportation investment planning is in their own country's best interests.

The second stage evaluates investments at the multi-national level. It can be shown that the cost-effectiveness method, which takes into account non-monetary costs and benefits, might be more appropriate here. Since the participating countries may differ significantly with regard to politico-economic systems and national goals and objectives, the methods of economic evaluation, as applied at the national level, are irrelevant to evaluation at the multi-national level. Thus, some of the goals set for multi-national transportation investment might be common to all participating countries, others might be valid only for a specific country or group of countries, and some might even be unfavorable in themselves although accepted because the package as a whole is favorable. In the next section, the cost-effectiveness evaluation at the multi-national level is described in some detail.

3. Evaluation at the Multi-National Level

The evaluation of multi-national transportation investments at the multi-national level requires the active participation of all countries. Furthermore, the efficacy of the evaluation depends largely on the formation of a complete spectrum of goals and the development of pertinent objectives. Besides the goals set by each country, the following objectives should be included in this evaluation:

- cooperation between the participating countries;
- promotion of commercial, touristic and other relationships between participating and neighboring countries;
- accommodation of the pressing transport demand for long-distance and international traffic;
- creation of an economic and convenient mode of transport.

In addition, this evaluation requires an account of the consequences that will stem from the multi-national transportation investment. It may be advantageous to structure consequences into categories. Such categories might include the following:

a) Consequences of inputs:

- opportunities lost due to resource commitments;

- changes in employment;
- changes in real income;
- scarcities of material resources;
- promotion of previously unused resources;

b) Consequences of performance outputs:

- changes in community growth patterns;
- social unification due to increased accessibility;
- expanded social, economic and cultural realsm of people due to increased accessibility;
- modifications of human activities patterns and resource allocations due to changes in accessibility;
- lives and resources saved or lost due to changes in transporation safety;

c) Consequences of concomitant outputs:

- social and psychological effects of creation or destruction of physical barriers by transportation facilities;
- aesthetic impacts of facilities;
- effects of air pollution due to transportation;
- psychological and physiological impacts of sound and light emitted by transportation vehicles and facilities.

Two criteria can be used to help determine the consequences to be considered: the feasibility and the relevance of inputs and outputs of the multi-national transportation investment.

In conclusion, since the cost-effectiveness evaluation cannot use quantitative models, the development of a common subjective ranking scheme by all countries is needed.

4. Cost Allocation Approach

A related issue is that of allocating the costs caused by externalities which result from multi-national transportation investments. An approach is developed in such a way that it can be applied to all participating countries, regardless of their political and economic systems.

As was previously shown, the economic evaluation of multi-national transportation investments, at the national level, is the responsibility of each participating country. (A theoretical approach for evaluating such investments at the national level is presented in Appendix E.) Thus, the benefits and costs resulting from the implementation of multi-national transportation investment in a participating country will be provided by that country when the evaluation, at the national level, is completed.

4.1. Benefits

According to the evaluation method employed in a country, the total benefits for the country resulting from such investment will be calculated. Of these total benefits, some -- to be denoted as B_R -- are related to the users of the road infrastructure, improved according to the multi-national transportation investment. These benefits, assumed to be discounted to the present, can be computed for country A by applying the following equation:

$$B_R = B_D + \sum_{m=1}^{m} B_m \qquad (5.1)$$

where:

B_R : total discounted benefits to road users, being citizens of country A;

B_D : discounted benefits to road users, being citizens of country A, when they use the improved road infrastructure of country A;

B_m : discouted benefits to road users, being citizens of country A, when they use the improved road infrastructure of country m, participating in the multi-national transportation invesment;

$m=1,...m$: participating countries (country A excluded).

4.2. Costs

For a participating country, the costs resulting from the improvements in its road infrastructure, according to the multi-national transportation invesment planning are: (a) the construction costs, (b) the maintenance costs and (c) the costs of externalities (spillover effects). The latter costs reflect possible increases in travel times, caused by the traffic congestion on the road network of the country, and increases in air pollution and noise, caused by the growth of traffic volume.

Furthermore, the costs due to externalities, could be divided into those caused (a) by the country's vehicles, (b) by foreign vehicles registered in the participating countries, and (c) by foreign vehicles registered in other countries. Therefore, the costs of externalities, assumed to be discounted to the present, can be computed for country A applying the following equation:

$$CE = CE_D + \sum_{m=1}^{m} CE_m + CE_G \qquad (5.2)$$

where:

- CE : total discounted costs of externalities in country A;
- CE_D : discounted costs of externalities caused by vehicles of country A;
- CE_M : discounted costs of externalities caused by foreign vehicles registered in participating country m;
- CE_G : discounted costs of externalities caused by foreign vehicles in all other countries;
- $m=1,...,m$: participating countries (country A excluded).

4.3. Cost Allocation

The proposed approach is developed in such a way as to allocate the costs among two countries, participating in the mult-national transportation investment. It can be applied to any pair of participating countries, regardless of their political and economic systems.

To better illustrate the approach, it will be presented for a pair of countries A and B. The benefits accruing to country A from the improvements in the road infrastructure of country B were expressed in equation (5.1) by B_B. At the same time country A faces the costs of externalities caused by the vehicles, registered in country B, using its road network, which were expressed by CE_B in equation (5.2). Therefore, the rsulting benefits for country A with respect to country B from the joint transportation investments in both countries for improving their respective road networks can be expressed with the following equation:

$$CB^{AB} = B_B - CE_B \qquad (5.3)$$

The same procedure will be applied for country B. Thus, the resulting benefits for country B with respect to country A from the joint transportation investments in both countries for improving their respective road networks can be expressed with the following equation:

$$CB^{BA} = B_A - CE_A \qquad (5.4)$$

The resulting difference in these benefits among countries A and B is expressed by:

$$\Delta = CB^{AB} - CB^{BA} \qquad (5.5)$$

This is the fundamental expression upon which the cost allocation will be based, the objective of the proposed approach being to equate the costs and benefits generated by the international traffic on the road networks of the participating countries. Therefore, if

a) $\Delta > 0$, country A has to pay country B an amount equal to the value of "Δ" as compensation for the resulting excess costs in country B;

b) $\Delta<0$, country B has to pay country A an amount equal to the value of "Δ" as compensation for the resulting excess costs in country A;

c) $\Delta=0$, no payments are required.

The amount of compensation "Δ" can be paid as a lump sum directly to the government, according to the prevailing official foreign exchange rates between the two countries, or it can be credited to be used in "road charges" payments by the vehicles, or it can be exchanged for gasoline and diesel tax exemptions.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

1. Summary of Findings

The present study is a preliminary attempt to identify and analyze some of the most relevant issues in multi-national transportation investment planning, with particular reference to European road networks.

It is first established that the general scheme for multi-national transportation investment planning should include the most efficient institutional structure for the cooperation of the participating countries, a work plan for the coordination of activities related to realization of the investments, as well as the several technical tasks that the participating countries must agree upon in order to undertake them jointly. These considerations are applied to the case of the Trans-European North-South Motorway, a joint venture of ten European countries with different socio-economic and political systems.

The most important technical tasks included in the general scheme were the development of the methodology of forecasting international traffic, schemes for financing multi-national transportation investments, methods for pricing of international trafffic, and evaluation procedures for multi-national investments.

In particular, the methodology for forecasting international traffic was developed so as to take into account both international passenger and freight traffic. A model is proposed for both types of traffic, based on existing econometric traffic forecasting models at the national level, modified to capture the variables characteristic of international traffic.

Regarding the financing of multi-national transportation investments, it was found that, because there are salient differences in the economic, political, and administrative systems of each country, no significant changes could be imposed on their national financing schemes. However, a model was proposed for financing road infrastructure investments at the national level and approaches computing the optimal revenues to be collected from international traffic were elaborated in such a way as to be applied to any country.

Finally, it was demonstrated that multi-national transportation investments can be optimally evaluated in two stages. The first stage evaluates alternative investment plans at the national level, whereas the second stage evaluates non-quantifiable costs and benefits at the multi-national level. Furthermore, a theoretical approach for optimally allocating the costs of externalities resulting from the multinational transportation investments was developed in such a way as to apply to any country.

2. Recommendations for Further Research

Data collection is currently the most imposing constraint on the development of better models in the area of multi-national transportation investment planning. Therefore, it would be desirable to prepare a large, easy to use data base comprising many different countries.

Further research is clearly needed if models are to be developed for specific multi-national transportation investment projects. An effort could be made to expand the approaches developed in this study, so as to render them applicable to all countries irrespective of their economic, social and political systems.

Since this study is a first attempt at describing and analyzing some of the crucial issues related to multi-national transportation investment planning, some or all of the models and methodologies could perhaps be further improved by considering the uncertainties derived from the following:

- world energy supply and demand,
- rate of technological change in transportation modes,
- political upheavals that could affect the relations among countries,
- degree and orientation of economic development in the world as a whole and in particular countries,
- potential of international banking institutions to finance transportation investments.

None of these issues seems insurmountable.

TECHNICAL APPENDICES

APPENDIX A

DOMESTIC TRAFFIC FORECASTING MODELS

I. Passenger Domestic Traffic Models

According to the theory on which they are based they may be grouped into four categories: trip generation-distribution models, direct traffic estimation models, econometric models, and behavioral travel-demand models.

1. Trip generation-distribution models

The most commonly used models may be classified as i) Growth factor models, and ii) Gravity models.

i) Growth factor models

Growth factor models represent the simplest form of trip distribution model, based on a simple expansion of existing interzonal trips by means of zonal growth factors.

The growth factors are defined by the equations:

$$F_i^o = \frac{T_i^*}{T_i^o} \qquad (A.1)$$

$$F_i^k = \frac{T_i^*}{T_i^k} \qquad (A.2)$$

$$F^o = \frac{\sum_i T_i^*}{\sum_i T_i} \qquad (A.3)$$

The total trips (trips conservation) are defined by the equations:

$$T_i^o = \sum_j T_{ij}^o \qquad i \neq j \qquad (A.4)$$

$$T_i^k = \sum_j T_{ij}^k \qquad i \neq j \qquad (A.5)$$

where:

T_i^o: Total trips originating in zone i at the base year;

T_i^*: Forecasted total trips originating in zone i at the design year;

T_i^k: Computed total trips originating in zone i after the k^{th} iterations;

T_{ij}^o: Trips between zones i and j, in both directions at the base year;

T_{ij}^k: Computed after the K^{th} iteration trips between zones i and j, in both directions;

F_i^o: Initial growth factor for zone i;

F_i^k: Computed growth factor after the K^{th} iteration for zone i;

F^o: Initial growth factor for the study area (includes all zones);

F^k: Computed growth factor after the K^{th} iteration for the study area (includes all zones).

There are several models for the computation of the T_{ij} trips. The most sophisticated and computationally simple is the Detroit model. According to this model, the total trips between zones i and j, in both directions, are computed as follows:

$$T^1_{ij} = T^o_{ij} \frac{F^o_i \cdot F^o_j}{F^o} \qquad \text{(1st iteration)}$$

$$\vdots \qquad\qquad\qquad\qquad\qquad\qquad (A.6)$$

$$T^k_{ij} = T^{k-1}_{ij} \frac{F^{k-1}_i \cdot F^{k-1}_j}{F^{k-1}} \qquad (k^{th} \text{ iteration})$$

Therefore, applying equations (A.1) - (A.6) the total number of trips (both directions) between zones i and j can be forecasted for the design year.

ii) Gravity Models

Mathematically, these models are expressed by the following equation:

$$T_{ij} = O_i \cdot A_j \cdot B_i \cdot C_j \cdot f(R_{ij}) \qquad (A.7)$$

and the trip-conservation rules:

$$\sum_j T_{ij} = O_i \qquad (A.8)$$

$$\sum_i T_{ij} = A_j \qquad (A.9)$$

Where:

T_{ij}: Total trips between zone i and j, both directions;

O_i: Total trips produced by zone i;

A_i: Total trips attracted by zone j;

$f(R_{ij})$: Measure of the spatial separation of zones i and j;

B_i, C_j: Constants associated with the production and attraction zones respectively.

The total number of trips (both directions) between zones i and j can be forecasted for the design year by estimating the variables O_i, A_j, B_i, C_j for that year.

However, the total number of trips (T_{ij}) can be found through several iterations, since the trip-conservation rules of equations (A.8) and (A.9) must be met.

2. Direct traffic estimation models

The technique of direct traffic estimation attempts to obtain traffic volumes on a network link by a single estimating process after trip generation. This method is somewhat disassociated from individual or aggregate behavior of trip makers (passengers). It concentrates on the links in a transportation network and estimates traffic volumes on these links as a function of the potential traffic generation of the region under consideration for each link, as well as the availability of parallel links to accomodate this traffic. The analysis of each link proceeds independently of the analysis of other links.

The models are based on a generalized form of the gravity model. They take the form of the following equation:

$$V_{ij} = \frac{V_i \cdot F_{ij} \cdot V_j}{\sum_j F_{ij} \cdot V_j} \qquad (A.10)$$

Where:

V_{ij}: Trips between point i and point j;

V_i: Trips generated at i;

V_j: Trips attracted to j;

F_{ij}: Separation function between i and j;

$\sum_j F_{ij} \cdot V_j$: An accessibility function.

3. Econometric Models

These models were developed in such a manner as to apply the microeconomic theory of demand to travel. Thus, demand for travel by a transport mode is not dependent on the type of the mode, but on the characteristics that describe the level of service that each mode offers (travel time, travel costs, frequency, safety, comfort, etc.)

There several models developed, the best known of which is the Baumol-Quandt Model.

The formulation of the model is shown in the following equation:

$$T_{kij} = \alpha_0 \cdot P_i^{\alpha_2} \cdot Y_i^{\alpha_3} \cdot Y_j^{\alpha_4} \cdot M_i^{\alpha_5} \cdot M_j^{\alpha_6} \cdot N_{ij}^{\alpha_7} \cdot (H_{ij}^b)^{\beta_0} \cdot$$

$$(C_{ij}^b)^{\gamma_0} \cdot (D_{ij}^b)^{\delta_0} \cdot (H_{kij}^r)^{\beta_1} \cdot (C_{kij}^r)^{\gamma_1} \cdot (D_{kij}^r)^{\delta_1} \qquad (A.11)$$

where:

T_{kij}: Total trips between zones i and j with mode K;

P_i, P_j: Population of zones i and j, respectively;

Y_i, Y_j: Average income for zones i and j, respectively;

M_i, M_j: Institutional character index for zones i and j, respectively;

N_{ij}: Number of modes serving zones i and j;

H_{ij}: The least-possible-travel time between zones i and j;

C_{ij}: The least-possible-travel cost between zones i and j;

D_{ij}: The highest departure frequency between zones i and j;

H_{kij}: The travel time between zones i and j for the K^{th} mode;

C_{kij}: The travel cost between zones i and j for the K^{th} mode;

D_{kij}: The departure frequency between zones I and j for the K^{th} mode

$\alpha_0, \alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5, \alpha_6, \alpha_7, b, r, \beta_0, \beta_1, \gamma_0, \gamma_1, \delta_0, \delta_1$: Parameters to be estimated according to data.

4. Behavioral travel demand models

These models are based on an approach described as being disaggregate, behavioral, and probabilistic. The models developed from this approach are quite different from those described previously. The development of these models was based on the following:

i) the basic unit of observation for model calibration is the individual traveller and not a traffic zone;

ii) the approach is founded in two disciplines dealing with behavior: the economics of consumer behavior (utility functions), and the psychology of choice behavior;

iii) a probability is assigned to each possible outcome of a particular travel decision for a specific traveller, or potential traveller.

These models have an almost identical structure, known as the multiple-choice logit model, which is shown in the following equation:

$$P_j^i = \frac{\exp\left[V(\chi_j, S_i)\right]}{\sum_{k=1}^{m} \exp\left[V(\chi_k, S_i)\right]} \qquad (A.12)$$

where:

P_j^i: the probability that an individual i will choose alternative j from a set of m alternatives.

$\exp\left[V(X_j, S_i)\right] = U(X_j, S_i)$: The utility function of individual i;

X_j: Attributes of alternative j

S_i: Attributes of the individual i.

II. FREIGHT DOMESTIC TRAFFIC FORECASTING MODELS

1. Aggregate freight demand traffic models

Most of the freight demand studies to date have utilized aggregate data from government sources.

a) One of the best known studies of freight demand was elaborated by Eugene Perle in 1964. (30) He developed a model of modal split between common carrier trucks and railroads as a function of the rates. The model is expressed in the following form:

$$\log\left(\frac{V_{m1}}{V_{m2}}\right) = \beta_0 + \beta_1 \cdot \log\left(\frac{r_{m1}}{r_{m2}}\right) + \sum_{c=1}^{9} C_i \cdot R_i + \sum_{j=1}^{5} d_j \cdot Y_j + \sum_{k=1}^{5} f_k \cdot C_k \qquad \text{(B.1)}$$

Where:

V_{m1}: volume carried by truck

V_{m2}: volume carried by rail

r_{m1} average revenue/ton on truck shipments

r_{m2} average revenue/ton on rail shipments

R_i =i (for region i)

=o (otherwise)

Y_j =i (for year j)

=o (otherwise)

C_k =i (for commodity k)

=0 (otherwise)

i: region notation (9 regions considered)

j: year notation (s years considered)

k: commodity type notation (5 types of commodities considered)

b) Another study of modal split was conducted by V. Surti and A. Ebrahimi in 1972 (37) . They estimated a model of truck-rail modal split using data on the tons of shipments in each weight-mileage block of the 24 shipper groups in the 1963 Census of Transportation. Their model is of the following form:

$$\frac{V^K_{m1}}{V^K_{m1} + V^K_{m2}} = \beta_0 + \beta_1 \cdot d + \beta_2 \cdot q \qquad (B.2)$$

where:

V^K_{m1}: volume of commodity group K carried by truck

V^K_{m2}: volume of commodity group K carried by rail

d: distance in miles

q: shipment size in tons.

c) A somewhat wider variety of variables was included in a rail-barge modal split study conducted by A.D. Little, Inc. in 1974. (19) The model has the following form:

$$\sin^{-1}\sqrt{\frac{V^k_{ij,m1}}{V^k_{ij,m1}+V^k_{ij,m2}}} = \beta_0+\beta_1\ \log(V^k_{ij})+\beta_2\ \log(V)+$$

$$\beta_3\ \log(d)+\beta_4\ \log(L)+\beta_5\ \log(c)+\beta_6\cdot B+\beta_7\cdot S \quad (B.3)$$

Where:

$V^k_{ij,m1}$: volume of commodity group k carried from i to j by barge

$V^k_{ij,m2}$: volume of commodity group k carried from i to j by rail

V^k_{ij}: volume of commodity group k carried from i to j by both modes

V: value/ton of commodity group k

d: distance from origin i to destination j by rail

c: ratio of water distance/rail distance

S = 1 (for seasonal goods)
= o (otherwise)

B = 1 (for bulk goods)
= o (otherwise)

L: percentage of production facilities located on the water at the origin plus the percentage of consuming facilities located on the water at the destination.

d) B.Kullman in 1974 (15) developed a modal split model assuming that the cost of shipping by a given mode could be expressed as a linear function of the level of service attributes, commodities attributes and market attributes. The independent variables used in this model include highway distance, annual tonnage, commodity values, rates, mean travel times and a measure of the variation in travel times. The model can be expressed by the following equation:

$$\log\left(\frac{V_{m1}^{k}}{V_{m2}^{k}}\right) = \beta_0 + \sum_i \beta_i \cdot X_i \qquad \text{(B.4)}$$

Where:

V_{m1}^{k}: volume of commodity group k carried by rail

V_{m2}^{k}: volume of commodity group k carried by truck

X_i the independent variables (outlined above).

e) Finally, another important study in this area was conducted by J. Sloss in 1971 (34). Sloss developed a model for the volume of truck traffic as a function of the average truck rate, the average rail rate, and a proxy variable used to represent the demand for commodities. The model uses the following form:

$$\log(V_{m1}) = \beta_0 + \beta_1 \log(r_{m1}) + \beta_2 \log(r_{m2}) + \beta_3 \log(E) \qquad \text{(B.5)}$$

Where:

V_{m1}: volume of truck traffic

r_{m1} average revenue/ton on truck

r_{m2} average revenue/ton on rail

E: economic activity variable.

2. Disaggregate freight demand traffic models

Because of the lack of data, very few disaggregate freight demand studies have been conducted:

a) Antle L. and Haynes R. in 1971 developed one of the first such models. The form of the model is the following:

$$Z = \sum_{i=1}^{7} \beta_i \cdot X_i \qquad \text{(B.6)}$$

Where:

X_1: shipper's annual volume of shipments of given commodity between given O-D pair

X_2: length of travel

X_3: average travel time

X_4: average shipment size

X_5: rate on chosen mode

X_6: difference in rates between chosen and alternative mode

X_7: handling cost on the selected mode.

When this model is used, if the computed value of z from equation (B.6) exceeds a critical value, then the model predicts that barge will be chosen. Otherwise the model predicts that rail will be chosen.

b) The most recent attempt to construct a disaggregate freight demand traffic model was conducted by Chiang, Y. in 1979 (4, 6). This model includes the entire set of relevant short-run choices open to the firm in its logistics management process. A disaggregate model of mode, shipment size, and origin choice was developed at the level of the individual firm.

APPENDIX B

MODELS FORECASTING INTERNATIONAL ROAD TRAFFIC ON THE TRANS-EUROPEAN NORTH-SOUTH MOTORWAY (44)

In the following, the models for forecasting the international passenger and freight traffic on the Trans-European North-South Motorway will be presented in detail.

As a first step, the ten participating countries were divided into a total of 80 zones according to their administrative divisions; then the rest of the world was divided into 25 areas.

An average growth factor model was developed which used as base year data the traffic pattern existing in 1978, as established by an O-D survey and traffic counts carried out in that year. The traffic was expressed in terms of trips between areas or zones.

1. Model for Forecasting International Passenger Road Traffic

The future car traffic generated by each zone is calculated as the 1978 car traffic times a growth factor, which depends on the development of the car fleet and the per capita income.

The future car traffic attracted by each zone is calculated as the 1978 car traffic times a growth factor, which expresses the expected growth in arrivals of foreign tourists and excursionists by car, modified in such a way that the total number of trips attracted corresponds to the total number of trips generated. The resulting expressions are as follows:

$$T_{ij}^{target} = \frac{R_i + R_j}{2} \cdot T_{ij}^{1978} \qquad (B.1)$$

subject to:

$$\sum_j T_{ij}^{target} = R_i \cdot \sum_j T_{ij}^{1978}, \ \forall i$$

$$\sum_i T_{ij}^{target} = R_j \cdot \sum_i T_{ij}^{target}, \ \forall j$$

where:

T_{ij}^{1978}, T_{ij}^{target}: the number of car trips generated by zone i and attracted by zone j in 1978 and in the target year respectively;

R_i, R_j: growth factors for traffic generated by zone i and for traffic attracted by zone j respectively.

The growth factors were computed as follows:

$$R_i = \frac{C_i^{target}}{C_i^{1978}} \cdot \left[\frac{(GDP/hi)^{target}}{(GDP/hi)^{1978}}\right]^{0.25} \qquad (B.2)$$

$$R_j = \frac{P_{Aj}^{target}}{P_{Aj}^{1978}} \cdot \left(1 + \frac{\Delta TE_j}{100}\right) \cdot \frac{\sum_i R_i \cdot \sum_j T_{ij}^{1978}}{\sum_j \frac{P_{Aj}^{target}}{P_{Aj}^{1978}} \cdot \left(1 + \frac{\Delta TE_j}{100}\right)^n \cdot \sum_i T_{ij}^{1978}}$$

(B.3)

where:

C_i^{target}, C_i^{1978}: number of cars registered in zone i in target year and in 1978 respectively;

$(GDP/hi)^{target}$: gross domestic product per capita for zone i for target year;

$(GDP/hi)^{1978}$: gross domestic product per capita for zone i for 1978;

ΔTE_j the assumed annual percentage growth in arrivals of foreign tourists and excursionists by car to zone j;

n: number of years from 1978 to target year;

$P_{Aj}^{target}, P_{Aj}^{1978}$: zone j's proportion of total international car trips attracted by the country in question for target year and for 1978 respectively.

The above equations (B.1) - (B.3) are solved by the iteration method for each tearget year. The traffic assignment to the network applied the all or nothing rule.

2. Model for forecasting international freight road traffic

The future numbers of generated and attracted truck trips for each zone are calculated as the 1978 trips times a growth factor, which reflects the development in exports and imports, respectively. Individual consideration is given to agricultural and industrial products.

The breakdown factors for generated and attracted truck trips are calculated as follows:

$$g_i = \frac{P_{Aj}^{1978} \cdot T_A^{1978} + P_{Ii}^{1978} \cdot T_I^{1978}}{T_A^{1978} + T_I^{1978}} \quad \text{(B.4)}$$

$$\alpha_j = \frac{P_{Pj}^{1978} \cdot T_A^{'} + P_{Ij}^{1978} \cdot I_I^{'1978}}{T_A^{'1978} + T_I^{'1978}} \quad \text{(B.5)}$$

where:

g_i: breakdown factor for generated truck trips in zone i;

α_j: breakdown factor for attracted truck trips in zone j;

$P_{Ai}^{1978}, P_{Ii}^{1978}$: zone i's proportion of 1978 national employment in agriculture and industry, respectively;

T_A^{1978}, T_I^{1978}: number of truck trips with agricultural and industrial commodities, respectively, generated by the country, according to 1978 data;

$P_{Pj}^{1978}, P_{Ij}^{1978}$: zone j's proportion of 1978 national population and employment in industry, respectively (for i=j, $P_{Ij}^{1978} = P_{Ii}^{1978}$);

$T_A^{'1978}, T_I^{'1978}$: number of truck trips with agricultural and industrial commodities, respectively, attracted by the country, according to 1978 data.

Following these calculations, the number of truck trips between zones i and j is computed for 1978 according to the following equations:

$$T_{ij}^{1978} = T_{i'j'}^{1978} \cdot g_i \cdot \alpha_j \qquad (B.6)$$

subject to:

$\sum_i g_i = 1$ and $\sum_j \alpha_j = 1$

where:

T_{ij}^{1978}: truck trips between zones i and j as defined in the model, in 1978;

$T_{i'j'}^{1978}$: truck trips between zones i' and j', as defined in the 1978 survey.

As for the car trips, the number of truck trips between zones i and j in terget year (T_{ij}^{target}) is computed according to equation   The corresponding growth factors R_i and R_j are computed as follows:

$$R_i = K_{Ai}^{1978} \cdot \frac{P_{Ai}^{target}}{P_{Ai}^{1978}} \cdot \left(1 + \frac{\Delta X_A}{100}\right)^n + K_{Ii}^{1978} \cdot \frac{P_{Ii}^{target}}{P_{Ii}^{1978}} \cdot \left(1 + \frac{\Delta X_I}{100}\right)^n \qquad (B.7)$$

$$R_j = C_{Aj}^{1978} \cdot \frac{P_{Pj}^{target}}{P_{Pj}^{1978}} \left(1 + \frac{\Delta M_A}{100}\right)^n + C_{Ij}^{1978} \cdot \frac{P_{Ij}^{target}}{P_{Ij}^{1978}} \cdot \left(1 + \frac{\Delta M_I}{100}\right)^n \qquad (B.8)$$

where:

$K_{Ai}^{1978}, K_{Ii}^{1978}$: proportion of truck trips generated by zone i in 1978 and loaded with agricultural and industrial products, respectively, computed according to equations (3.19) and (3.20);

$P_{Ai}^{target}, P_{Ai}^{1978}$: zone i's proportion of total national employment in agriculture in target year, and in 1978, respectively;

$P_{Ii}^{target}, P_{Ii}^{1978}$: zone i's proportion of total national employment in industry in terget year, and in 1978, respectively;

$\Delta X_A, \Delta X_I$: annual percentage growth in export (tons) of agricultural and industrial products, respectively;

n: numbers of years from 1978 to target year;

$C_{Aj}^{1978}, C_{Ij}^{1978}$: proportion of truck trips attracted by zone j in 1978 and loaded with agricultural and industrial products, respectively, ($C_{Aj}^{1978} + C_{Ij}^{1978} = 1$), computed according to equations (3.21) and (3.22);

$P_{Pj}^{target}, P_{Pj}^{1978}$: zone j's proportion of total national population in target year, and in 1978, respectively;

$\Delta M_A, \Delta M_I$: annual percentage growth in import (tons) of agricultural and industrial products, respectively.

The K- and C- factors are computed as follows:

$$K_{Ai}^{1978} = \frac{P_{Ai}^{1978}}{P_{Ai}^{1978} + P_{Ii}^{1978} \cdot \dfrac{T_I^{1978}}{T_A^{1978}}} \qquad (B.9)$$

$$K_{Ii}^{1978} = \frac{P_{Ii}^{1978} \cdot \dfrac{T_I^{1978}}{T_A^{1978}}}{P_{Ai}^{1978} + P_{Ii}^{1978} \cdot \dfrac{T_I^{1978}}{T_A^{1978}}} \qquad (B.10)$$

$$C_{Aj}^{1978} = \frac{P_{Pj}^{1978}}{P_{Pj}^{1978} + P_{Ij}^{1978} \cdot \dfrac{T_I^{'1978}}{T_A^{'1978}}} \qquad (B.11)$$

$$C_{Ij}^{1978} = \frac{P_{Ij}^{1978} \cdot \dfrac{T_I^{'1978}}{T_A^{'1978}}}{P_{Pj}^{1978} + P_{Ij}^{1978} \cdot \dfrac{T_I^{'1978}}{T_A^{'1978}}} \qquad (B.12)$$

where:

T_I^{1978}/T_A^{1978}: the ratio between generated truck trips with industrial and agricultural products, respectively at the national level;

$T_I^{'1978}/T_A^{'1978}$: the ratio between attracted truck trips with industrial and agricultural products respectively at the national level;

and, all other symbols have been defined before.

Finally, the above equations (B.1) and (B.4) - (B.12) are solved for each target year with the iteration method. The traffic assignment to the network is done applying the all or nothing rule.

APPENDIX C

EXAMPLES OF EXISTING PRACTICE IN FINANCING ROAD INFRASTRUCTURE INVESTMENTS

In the following, the financing and pricing approaches related to road infrastructure investments in several countries will be described:

i) United Stages: Funds for highway investment are drawn mainly from road user charges at the state and federal levels. About 75% of the federal gas taxation accrues to the Highway Trust Fund, which redistributes it to the states in such a way that it finances 50% of the costs of the federal-aid roads and freeways, and 90% of the Interstate Highway System. The states' share for major roads and freeways, and the whole for the secondary system is derived from state gas taxes, property taxes, general taxation, bond issues, and other vehicle-related fees. Specific authorities are created to finance and operate specific projects at the state level; they issue bonds to the market with the state guarantee. Several turnpikes financed this way have been incorporated into the Interstate Highway System. Road construction and maintenance is a responsibility of the states, in spite of any grants from the federal government.

ii) Canada: Except for the Trans-Canada Highway and the Yukon and North-West Territories, the federal government has no responsibility for road financing. This responsibility rests with provincial governments which use the annual budget. There is no formal relationship between road user taxation and investment, but both magnitudes are similar.

iii) United Kingdom: Since 1937, all finance for roads has been voted annually by the Parliament. The so-called trunk roads are the financial responsibility of the Ministry of Transport. The principal roads are financed up to 75% of total costs of construction and improvement from government funds. The remaining 25% and all maintenance expenses are met by each local authority, though the Rate Support Grant from the Government actually covers most of them. The other roads category is directly financed by the local authorities.

iv) West Germany: Gas taxes accrue to the federal government and vehicle fees to the state governments. Federal routes are financed by a special government fund to which 50% of gas taxes are delivered. The state administers these funds on behalf of the government. Other first class roads are under the responsibility of state governments, which finance them from their annual budgets. The rest of the highway network belongs to local authorities. All authorities use loan financing for road construction, especially for freeways and local roads. No tolls are levied anywhere in the system.

v) The Netherlands: Road user taxation consists of two main parts: the fuel tax and the supplementary special road tax. Only the latter tax is earmarked to the state road fund, which also receives budget allocations from other automobile related fees. This fund finances the primary roads network, including freeways, and is administered by the Ministries of Transport and Public Works. The secondary and tertiary roads are built and maintained by the provinces and municipalities and financed partly by the government subsidies. No tolls are charged in the system.

vi) Belgium: Road user taxation is directly received by the state, although there is a road fund for financing all roads. This fund is endowed through the floating of loans by the Ministry of Finance and other budget allocations. The fund provides the provinces and municipalities with approximately 60% of the expenditures, including major roads. Freeways are financed by loans raised by the

"Intercommunales," autonomous organizations formed by all local and provincial governments affected by each freeway project. The loans are paid back through grants to the Intercommunales by the road fund, according to traffic figures and previously agreed rates. No tolls are charged throughout the system.

vii) Sweden: An automobile tax fund collects all gas and vehicle taxation, except some small taxes paid directly to the state. The Ministry of Communications disposes of these funds through a special budget account to finance all of the construction and maintenance of public roads. The planning and management of the projects is undertaken by the National Road Board. No tolls are charged in the network.

viii) France: Approximately 12% of gas taxation accrues to a special road fund which finances the construction and improvement of national roads (except freeways) through the Ministry of Public Works. Maintenance expenses are met through budget allocations. Expressways are financed by two different approaches: 10% of them are toll free, directly under the Ministry of Public Works, and so financed by budget allocations. The remaining 90% are turnpikes and independent semipublic or private firms finance, build, maintain, and operate them along a concession period.

These firms get their concessions through bids called by the Ministry of Public Works and therfore have full financial liability. Toll revenues pay these liabilities back. All facilities must become toll free (in theory) at the end of the concession.

ix) Italy: All revenue from road taxation accrues to the government with no earmarking to road expenditures. National roads (except expressways) are directly financed by the budget. Regional and local roads receive about 30% of their costs from government grants. Expressways are financed by two different approaches. First, some of them are directly operated by the state, through an agency called ANAS (AZIENZIA NAZIONALE AUTONOMA DELLA STRADA), endowed by government grants. These facilities are toll free and are located mainly in the underdeveloped south. Second, ANAS calls for bids for the rest of the network (turnpikes) and actually half of it is controlled by Autostrade, S.P.A., a company owned by the IRI (Instituto di Ricostruzione Industriale), which is a state-owned authority controlling the Italian nationalized industries. The other half of the turnpike network is financed, built, maintained, and operated by private companies through a concession period. Both Autostrade, S.P.A. and the private companies get about 80% of their funds from bond issues and loans, to be repaid from toll revenues as well as state loans and grants.

x) Greece: The government collects the tax on gas (for gasoline 500% tax on price from refineries), the user taxes, and the import and related taxes on vehicles (200-300% on the CIF price of an automobile). There is no earmarking to road expenditures. The freeways and the primary network is the responsibility of the Ministry of Public Works and the secondary network (local roads) of the local authorities, supervised by the Ministry of Interior. The Ministry of Coordination allocates the funds -- according to the Public Investment Program -- to the Ministry of Public Works and to the Ministry of the Interior, to further distribute them to local authorities. Tolls exist only on the principal freeway (Patrai-Athens-Thessaloniki-Yugoslavian border).

xi) Yugoslavia: This is a socialist country; however its approach to freeway financing is similar to those used in some Western nations. The initiative for building a freeway rests within each state of the Yugoslav Federation. When a given state decides that an expressway section must be built, it calls all the municipal, regional, professional, and labor organizations of the area affected by the project, which merge into a corporation for the purpose of financing the facility. Funds are drawn from contributions by all these organizations up to 90% of the costs, including loans within the country. In particular, professional and labor organizations draw their share from personal contributions from their members. The remaining 10% is obtained by floating loans abroad, in the Western countries. All freeways are toll free. However, a portion of the already constructed turnpike between Novi-Sad-Belgrade-NIS has tolls. Also, there will be tolls on the Trans-Yugoslav Turnpike under construction, linking Italy and Austria with Greece.

xii) Eastern European Countries: These are socialist countries, with quite similar financing approaches. Their economies are centrally controlled. The construction of roads is based on their five-year plans. The central government is financing the construction and maintenance of all rods with limited participation of the local authorities. There are no tolls.

APPENDIX D

MODEL FOR FINANCING

ROAD INFRASTRUCTURE INVESTMENTS AND ROAD USER PRICING

This model was developed by Graells-Ferrandez in 1977 (10). It is formulated as a welfare function. Its objective is to find the optimal values of tolls and fuel taxes as well as the optimal level of investment (expressed in lane-miles of road construction) in order to maximize the welfare function.

The model, without constraints, may be expressed by the following expression:

$$\max w = \int_{P_{1A}}^{P_{1A}(X_{1A}=0)} X_{1A} \cdot dP_{1A} + \int_{P_{1F}}^{P_{1F}(X_{1F}=0)} X_{1F} \cdot dP_{1F} + \int_{P_{2A}}^{P_{2A}(X_{2A}=0)} X_{2A} \cdot dP_{2A} + \int_{P_{2F}}^{P_{2F}(X_{2F}=0)} X_{2F} \cdot dP_{2F} + (t_A + f_A) \cdot X_{1A} + (t_F + f_F) \cdot X_{1F} + f_A \cdot X_{2A} + f_F \cdot X_{2F} - C_{m1} - C_{m2} - C_{c1} - C_{c2} - C_{r1} - C_{r2} \qquad \text{(C.1.)}$$

where:

P_{1A}: price of vehicle-mile on expressway

P_{1F}: price of truck-mile on expressway

P_{2A}: price of vehicle-mile on road

P_{2F}: price of the truck-mile on road

and

$P_{1A} = t_A + F_A + g_A + m_A + t_{1A}$

$P_{1F} = t_F + f_F + g_F + m_F + T_{1F}$

$P_{2A} = f_A + g_A + m_A + T_{2A}$

$P_{2F} = f_F + g_F + m_F + T_{2F}$

where:

t_A: toll per vehicle-mile on expressway

t_F: toll per truck-mile on expressway

f_A: gas tax for autos per vehicle-mile

f_F: gas tax for trucks per truck-mile

g_A: gas price before tax for auto per vehicle-mile

g_F: gas price before tax for truck per truck-mile

m_A: variable maintenance cost for auto per vehicle-mile

m_F: variable maintenance cost for truck per truck-mile

T_{1A}: time cost for auto on expressway per vehicle-mile

T_{1F}: time cost for truck on expressway per truck-mile

T_{2A}: time cost for auto on road per vehicle-mile

T_{2F}: time cost for truck on road per truck-mile

Also available(as annual variables) are:

$X_{1A} = X_{1A}(P_{1A}, q_1, P_{2A}, q_2)$: demand for vehicle-miles on expressway

$X_{2A} = X_{2A}(P_{2A}, q_2, P_{1A}, q_1)$: demand for vehicle-miles on roads

$X_{1F} = X_{1F}(P_{1F}, q_1, P_{1A}, q_1)$: demand for truck-miles on expressway

$X_{2F} = X_{2F}(P_{2F}, q_2, P_{1F}, q_1)$: demand for truck-miles on roads

$C_{m1} = C_{m1}(X_{1A}, X_{1F}, q_1)$: maintenance and toll collection costs for the authority on expressways

$C_{m2} = C_{m2}(X_{2A}, X_{2F}, q_2)$: maintenance costs for the authority or roads

$C_{c1} = C_{c1}(q_1)$: capital costs for expressways

$C_{c2} = C_{c2}(q_2)$: capital costs for roads

$C_{r1} = C_{r1}(q_1)$: land acquisition cost for expressways

$C_{r2} = C_{r2}(q_2)$: land acquisition cost for roads

q_1 = lane-miles of expressway in service

q_2 = lane-miles of road in service

APPENDIX E

EVALUATION OF TRANSPORTATION INVESTMENTS AT THE NATIONAL LEVEL*

1. Introduction

The proposed theoretical approach is based on the theories developed for public investments in a second-best environment.** It tries to measure the changes in the utility function of each individual and in the production function of every firm as a consequence of the investment. These changes will capture the net benefits to the country's economy. On the other hand, the costs associated with the investment should be computed so as to reflect the costs to the country's economy.

According to the economic theory of second-best, the utility function of an individual, U_h, the production function of a firm, Y_k, and the government production function, G, are used to represent the country's economy. However, to simplify the approach, for the purposes of the present study,

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*Parts of this presentation are based on: (a) Trech, "Public Economies: A Normative Theory," (mimeo), 1980 (40), (b) Little and Mirrless, Project Appraisal and Planning for Developing Countries, Heinemann Educ. Books, Ltd., (20), (c) Mishan, E., Cost-Benefit Analysis, Praeger, 1976 (24).

**The second-best environment represents better the real world conditions since it includes possible market distortions and non-optimally imposed taxes by the government.

we could ignore the government production function. This is a fair assumption, since the government production function is included to reflect any tax increases needed to generate the needed capital for the investment. Thus, if the needed taxes are included in the prices of goods and factors, there is no need to use the government production function in our analysis.

2. Benefits

The benefits are measured by adding up the consumers and producers surpluses during the time horizon of the investment. The traditional approach for computing consumer surplus is based on the Marshallian demand functions. However, this approach assumes that the consumer demand depends only on the prices of goods; thus it ignores any changes in the consumers' income. The approach proposed here will use the Hiskian demand function where income effects are included.

If the private sector exhibits constant returns of scale, the government balances the budget and all factor supplies are variable, this will allow us to ignore income effects and specify individual consumer demand as $x_{hi} = \dot{x}_{hi}(\vec{q})$, solely in terms of prices (including tax), considering the Marshallian demand relationships. If the above assumptions do not hold (or they do not approximate the

the economy of a particular country), we must use the compensated demand relationships.

Thus, in a general formulation:

$$L(\vec{q}^{1},\vec{p}^{1},\vec{\bar{U}}^{o}) = \left[\sum_{h=1}^{H}\left[M_h(\vec{q}^{1},\bar{U}_h^{o}) - M_h(\vec{q}\ ,\bar{U}_h^{o})\right]\right] - \left[\sum_{k=1}^{N}\int_{P_k^{o}}^{P_k^{1}} Y_k \quad dp_k\right] \qquad (5.1)$$

where:

$L(\vec{q}^{1},\vec{P}^{1},\vec{\bar{U}}^{o})$: measures the welfare loss as the change in lump-sum income necessary to compensate the consumers (h=1,...,H) for the change in prices, less the actual change in lump-sum inclme they received from production;

$\vec{q}^{1}$: vector of prices (including tax) of all goods and factors, at state "1";

$\vec{p}^{1}$: vector of producers prices (net of taxes) of all goods and factors at state "1";

$\vec{\bar{U}}_h^{o}$: utility function at state "O" of consumers (vector, include all consumers, h=1,...,H)

$M_h(...)$: the expenditure function of individual h

Y_k: general equilibrium supply function of good (factor) k

h=1,...,H: individuals considered

k=1,...,N: factors and goods considered.

If L(...) $\geq$ 0, the investment will not be undertaken. If L(...) < 0 the investment should be undertaken, and the next step is the computation of the costs and benefits resulting from the implementation of the investment, as shown in the following.

In order to find L(...) over the time horizon of the investment, required for the above described comparisons with 0, we have to add the values of L(...) for each year until the T^{th} year (time horizon). Thus, initially we denote by:

"0" the state at the last year before the investment,

"1" the state at the end of the first year of the analysis. Applying the equation (5.1) we obtain L_1 the L(...) for the first year. Proceeding we denote by:

"0" the state at the end of the first year of the analysis,

"1" the state at the end of the second year of the analysis. Applying again the equation (5.1), we obtain L_2 the L(...) for the second year. Repeating the same procedure for all years until the T^{th} (end of time horizon), we could obtain the total undiscounted benefits (losses) from the investment L_{TOTAL}:

$$L_{TOTAL} = \sum_{t=1}^{T} L_t \qquad (5.2)$$

The result of the aggregation of the expenditure function $M_h(\ldots)$ over all individuals for all goods and factors is the consumers' surplus (if positive is a loss, if negative is a gain). The following expression included in equation (5.1) denotes the consumers' surplus:

$$\sum_{h=1}^{H} \left[M_h(\vec{q}^{\,1}, \bar{U}_h^{o}) - M_h(\vec{q}\ , \bar{U}_h^{o}) \right] \tag{5.3}$$

On the other hand, it is known that the compensated demand for good (factor) k of an individual h can be expressed as:

$$X_{hk}^{comp}(\vec{q}, \bar{U}_h) = \frac{\partial M_h(\vec{q}, \bar{U}_h)}{\partial q_k} \tag{5.4}$$

Therefore, the expenditure function of an individual h is:

$$M_h(\vec{q}, \bar{U}_h) = \sum_{k=1}^{N} q_k \cdot X_{hk}^{comp}(\vec{q}, \bar{U}_h) \tag{5.5}$$

Based on the above expressions, (5.2) could be written in terms of $X_{hk}^{comp}(\vec{q}, \bar{U}_h)$ as follows:

$$\sum_{h=1}^{H} \sum_{k=1}^{N} \int_{q_k^{o}}^{q_k^{1}} X_{hk}^{comp}(\vec{q}, \bar{U}_h) \, dq_k \tag{5.6}$$

If there are no income effects, $X_{hk}^{comp}(\vec{q}, \bar{U}_h)$ could be replaced by $X_{hk}(\vec{q}, \bar{I})$, the Marshallian demand.

The producers surplus (positive if it is a gain, negative if it is a loss), is expressed by:

$$\pi(p^1) - \pi(\vec{p}^o) = \sum_{k=1}^{N} \int_{p_k^o}^{p_k^1} Y_k \cdot d\rho_k \qquad (5.7)$$

where:

$\pi(p^1)$: profits at state "1";

$\pi(\vec{p}^o)$: profits at state "O"

p_k^o, p_k^1: producers price (net of tax) for good (factor) k at states "o" and "1" respectively;

Y_k: general equilibrium supply curve of good (factor) k, where:

$$Y_k = \frac{\partial \Pi(\vec{p})}{\partial p_k}$$

Concluding our analysis, the benefits from the investment over a time period of T years could be expressed by the formula:

$$B = \sum_{t=1}^{T} \left(\frac{1}{1+r_t}\right) \left[\left[\sum_{h=1}^{H_t} \sum_{k=1}^{N_t} \int_{q_{tk}^1}^{q_{tk}^o} X_{thk}^{comp} (\vec{q}, \bar{U}_h) \, dq_{tk} \right] + \sum_{k=1}^{N_t} \int_{p_{tk}^o}^{p_{tk}^1} Y_{tk} \, d\rho_{tk} \right] \qquad (5.8)$$

where:

r_t: discount rate for year t;

N_t: goods (factor) at year t;

H_t: population at year t;

q^o_{tk}, p^o_{tk}: consumer and producer prices at year t-1;

q^1_{tk}, p^1_{tk}: consumer and producer prices at year t.

For simplicity we could write (5.8) as follows:

$$B = \sum_{t=1}^{T} d_t \cdot B_t \qquad (5.9)$$

where:

d_t: the discount rate at year t;

B_t: the benefits at year t.

3. Costs

For each participating country in the multi-national transportation investment, the resulting costs could be grouped into the following categories: (a) the construction costs, (b) the maintenance costs and (c) the costs from externalities (increase in travel times due to traffic congestion, increase in air pollution and noise caused by the traffic).

Before computing these costs the shadow prices for goods and labor used are needed. Furthermore, if there is a foreign exchange component, the shadow price of foreign exchange is necessary. (Shadow prices are discussed in Section 5).

Once the shadow prices have been established, the annual costs can be computed. Finally, these costs will be discounted to the present applying the appropriate discount rate.

Therefore, the total discounted costs for a country resulting from the investment can be computed as follows:

$$TC = \sum_{t=0}^{t} r_t \cdot (C_t + CM_t + CE_t) \qquad (5.10)$$

where:

TC: total discounted costs;

C_t: construction costs at year t;

CM_t: maintenance costs at year t;

CE_t: externalities costs at year t;

r_t: discount rate at year t. This differs from the discount rate d_t used for discounted benefits.

4. <u>Appropriate Discount Rate</u>

The literature of discount rates implies that the appropriate discount rate to be used for discounting the benefits to the present (expressed as i_t) is the consumers' private Marginal Rate of Substitution (MRS). This rate is not constant over the time horizon (i.e., $i_t = i_{t+b}$, b = 1, ...,T). Furthermore, it should be adjusted for the inflation. Thus, if e_t is the expected inflation rate at year t, in comparison with the previous year t-1, the appropriate discount rate to be used for country A is:

$$d_t^a = \frac{1}{1 + i_t^a\,(1 + e_t^a)} \qquad (5.11)$$

The above expression could be simplified, assuming i_t^a and e_t^a constant over time:

$$d^a = \frac{1}{1 + i^a(1 + e^a)} \qquad (5.12)$$

The discount rate to be used for discounted costs (r_t) is not the same as the discount rate for benefits. This depends on the specific economic conditions of the country, the interest rate paid on the loans (bonds) issued to finance the investment, the prevailing interest rates in the country, the return of investment in the private sector. (Usually this may be taken to be 20%)

5. Shadow Prices

In order to assess the construction and maintenance costs for each country, we have to find the appropriate shadow prices of the several components (goods, services, and foreign exchange) that are considered for the computation of these costs.

5.1. Shadow Price of Foreign Exchange

If C_t^F is the foreign exchange component of construction and maintenance costs, and C_t^D the domestic component (local currency), we could proceed as follows:

A formula that gives a good approximation has been developed by P.Dasgupta, A.Sen and S.Marglin (UNIDO, Vienna 1972) (43):

$$P^F = \sum_{l=1}^{n} f_i \cdot \frac{P_i^D}{P_i^{cif}} + \sum_{i=n+1}^{n+h} x_i \cdot \frac{P_i^D}{P_i^{fob}} \qquad (5.13)$$

with $\sum_{i=1}^{n} f_i + \sum_{i=n+1}^{n+f} x_i = 1$

where:

P^F: the shadow price for foreign exchange (for country A, at year t, we could write it P_t^{AF}), expressed in percentage;

f_i: the fraction of foreign exchange allocated to the import of i^{th} commodity (out of n commodities) at the margin (f_i are different for each country);

P_i^D: the domestic price of the i^{th} import (reflecting the marginal willingness to pay for the i^{th} import) or the domestic price of the i^{th} export commodity. (P_i are different for each country);

P_i^{cif}: the c.i.f. price for the i^{th} import commodity (P^{cif} are the same for all countries, since they reflect world prices). However, if ther are no tariffs or quotas, for each country $P_i^{cif} = P_i^D$;

P_i^{fob}: the f.o.b. price for the i^{th} export commodity (P_i^{fob} are the same for all countries, since they reflect world prices). However, if there are no export subsidies or quotas, for each country $P_i^{fob} = P_i^D$.
(Note that P_i^{cif} and P_i^{fob} are measured at the official rate of exchange for each country's currency);

x_i: the fraction of foreign exchange earnings by the export of i^{th} commodity (out of h commodities). (x_i are different for each country).

There are several assumptions underlined in this formula:

a) the trade policies of the countries are the actual and the projected ones, not the optimal ones;

b) the increments of supplies measured by the ratios

$$\frac{f_1}{P_1^{cif}}, \ldots, \frac{f_n}{P_n^{cif}}, \quad \frac{x_{n+1}}{P_{n+1}^{fob}}, \ldots, \frac{x_{n+h}}{P_{n+h}^{fob}}$$

are net additions;

c) the import goods (commodities) are consumer goods and not capital goods;

d) the governments look upon foreign exchange as an instrument to the goal of aggregate consumption and not as a goal itself (to acquire as much foreign exchange as possible).

Applying expression (5.13) for the foreign exchange component of construction and maintenance costs, the resulting costs could be found from the following expression:

$$C_t^{AF} = P_t^{AF} \cdot C_t^{FA} \qquad (5.14)$$

in order to reflect the shadow price of foreign exchange.

5.2. Shadow Prices of Goods and Factors

a) Shadow Wage

Little and Mirrless in "Project Appraisal and Planning for Developing Countries" developed a general formula for computing the shadow price of labor (20):

Thus:

$$SW = \left[c + d - e + L \cdot \frac{\partial c}{\partial L} \right] - \left[V(c) - V(a) + U(a) \cdot (a-m) + U(c) \cdot L \cdot \frac{\partial c}{\partial L} \right] \qquad (5.15)$$

where:

c:	consumption of the wage-earner;
a:	previous average consumption of those who move into employment in the organized sector;
d:	transport-cost allowance in consumption cost, and other urbanization costs;
e:	employment premium (cost-savings and other public benefits);
U(c):	consumption weight for people at consumption level c
U(a):	consumption weight for people at consumption level a
$L\frac{\partial c}{\partial L}$:	the increased commitment to consumption caused by the "bidding up" of other wages;
V(c)-V(a):	the increased "utility" of consumption c compared to a (which the worker has received previously);
u(a)(a-m):	the extra consumption of the group from which the worker is drawn, weighted appropriately;
m:	marginal productivity of the wage-earner;
$U(c).L.\frac{\partial c}{\partial L}$:	the increased consumption of other urban workers, weighted by the weight appropriate to their standard of living.

The above expression (5.15) is a very general one and it could be simplified according to the conditions prevailing in each country.

A good approximation of (5.15) is given by:

$$SW = m + d + \frac{(c-a)^2}{c} \qquad (5.16)$$

if $c > a$, $\frac{\partial c}{\partial L} = 0$, $e = 0$, which are fair assumptions.

b) Shadow Prices of Goods

If the taxes are set optimally by the government, then the shadow prices of goods are the producers prices.

$$\Theta_k = P_k, \text{ where } P_k\text{: the producer price of good } k \qquad (5.17)$$

If the taxes are not set optimally, or if we cannot establish whether they are set optimally, then the theory of second best sets the shadow prices:

$$\Theta_k = P_k + t' \, M_{ij}E^{-1}, \qquad (5.18)$$

where:

P_k: the producer price of good k;

t': the vector of taxes;

$$M_{ij} = \frac{\partial x_i^{comp}}{\partial q_j} \quad : \quad x_i^{comp} : \text{ compensated demand for good } i$$

q_j: consumer price of good j

M_{ij}: is an ixj matrix

$$E^{-1} = \left[M_{ij} - \Pi_{ij}\right]^{-1}, \quad \text{a jxi matrix with}$$

$$\Pi_{ij} = \frac{\partial Y_i}{\partial P_j}, \quad Y_i = \frac{\partial \Pi}{\partial P_i}, \text{ supply of good } i$$

P_j: producer price of good j.

Expression (5.18) could be simplified if we assume that all cross-price derivatives in demand and private production are zero -- a good approximation, since they are close to zero.

So:

$$\Theta_k = q_k \cdot \frac{1}{1-a} - P_k \cdot \frac{a}{1-a}, \qquad (5.19)$$

where:

q_k, P_k: consumer and producer prices, respectively for good k;

and

$$a = \frac{\dfrac{\partial Y_c}{\partial P_k}}{\dfrac{\partial x_k}{\partial q_k}}$$

The shadow prices either computhd with the above expressions or supplied to the consultant by the government officials should be used to compute the domestic component of construction and maintenance costs.

6. Revenues from International Traffic

The revenues from international traffic may differ from one country to ther other, being an important source for foreign exchange for several countries. (Usually developing countries, short of foreign exchange, count on these revenues.) We could exclude any revenues from tourists during their stay in a particular country A, or the expenditures of the citizens of country A, when outside their country, since these are included in expression (5.1).

The revenues of a particular country A from international traffic should include:

a) tax revenues from gasoline and diesel sales to cars and trucks registered in other countries; to be denoted by G_t, for year t;

b) tolls collected, if any, from foreign cars and trucks; to be denoted by T_t, for year t;

c) any other road charges to foreign cars, if any; to be denoted by A_t, for year t;

d) any road charges to foreign trucks, if any; to be denoted by F_t, for year t.

So the benefits from international traffic could be expressed:

$$IB^A = \sum_{t=0}^{T} P_t^{AF} \left[G_t + T_t + A_t + F_t \right] \cdot d_t^a \quad (5.20)$$

where:

P_t^{AF}: the shadow price of foreign exchange;

d_t^a : the discount rate at year t

7. Net Discounted Benefits

For each country A, following the above analysis, the net discounted benefits could be computed. So:

$$NB^A = B^A + IB^A - TC^A \quad (5.21)$$

where:

B^A : total discounted benefits over the years t = 1,...,T that include the consumers and producers surpluses at country A;

IB^A : discounted benefits (revenues) over the years t = 1, ..., T, from international traffic;

TC^A : total discounted costs of construction and maintenance over the years t = 0,...,T and of externalities over the years t = 1,...,T.

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