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CONVENTIONAL TRANSPORT MODELS IN THE ANALYSIS OF INSTITUTIONAL ASPECTS OF NATIONAL TRANSPORT PLANNING

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1. Introduction

Many countries in Latin America and other parts of the developing world have commissioned national transportation studies, often carried out on a "ad hoc" basis under the technical guidance of teams of consultants from the industrialized countries. For instance, in the period since 1960, five of the seven countries of the Southern Cone of Latin America have had conducted studies of this type, some more than once. These studies have generally given particular attention to the identification of investment programs for the transport sector and, whilst they have not ignored other matters of concern to national transport planning agencies, they have certainly not assigned equal attention to them.

The studies have often had only a marginal impact on the conduct of the transport sector of the countries in which they were carried out and it is very likely that the way they have concentrated their efforts on investment programming is one of the reasons for this lack of penetration. The potential utility of national transportation studies themselves is not doubted, and it is even recognized that those carried out in the past have justified the resources invested in them, considering that these resources represent only a tiny fraction of the total transport investment budget. However, there is growing awareness that future studies should broaden their scope and direct their attention more evenly to all important matters of concern rather than to give the same concentration as in the past to investment programming.

These studies have employed mathematical models both to simulate how different feasible states of the transport system of the country concerned would function in various possible scenarios with different demand patterns and to evaluate the relative merits of each feasible future state of the transport system. The kinds of models used are particularly suitable for investment planning and have largely been developed bearing in mind that a market existed for them in this aspect of transportation studies, whether at the national, regional or urban level. It is pertinent to ask whether these models are applicable in the analysis of other problems confronting the transport planner or whether they are limited to the determination of investment plans. If they are not so applicable, there is likely to be a reduced need for them in the future, in a relative sense at least. On the other hand, if they are appropriate in the analysis of these other problems it will permit the more efficient functioning of future transportation studies than would otherwise be the case since the same basic model may be applied to serve various goals.

It is the purpose of this paper to discuss what are the matters which concern the national transport planner and which might be addressed in national transport studies and then to go on to determine to what extent the kind of transporation models used in past studies might be useful in analysing them.

2. Transport planning needs in Latin American countries

Transport planning needs are related to the State's role in the transport sector. In all countries of the Latin American region the government is deeply involved in the management of the sector, whatever its politico-economic orientation may be. Amongst the reasons for this are the following:

(i) The recognized interaction between economic development and the accessibility provided by the transport system. Goverments obviously seek to promote economic development and, therefore, must concern themselves with the transport sector.

(ii) Many components of transport systems are public goods in the sense that they can be utilized by various consumers at no extra cost, either to each other or to the operating authority. Examples include uncongested roadspace. Were such space to be provided by the private sector, in order to cover fixed costs it would be commercially obliged to charge each user for a service the marginal cost of which is zero. This might be inefficient considering the economy as a whole.

(iii) The transport system is of critical importance to national security, which is clearly a prime focus of government attention in any country.

(iv) Some transport projects must be provided on a grand scale or not at all, with few or no viable intermediate choices, i.e. they are, to a greater or lesser extent, indivisible. Examples include the road/rail bridge over the Paraná river at Zarate in our host nation of Argentina. When the choice is between no project or an inevitably large and expensive project, normal market mechanisms do not function efficiently, thereby making Government intervention desirable.

(v) The provision or use of transport facilities sometimes results in the generation of externalities, i.e. costs (or benefits) forced onto other members of the community but unpaid for by (or not credited to) the person or institution which generates them. For instance, the provision of new infrastructure may raise property values whilst users of congested transportation facilities impose costs on other users of the same facilities. Government intervention is desirable in these, and other similar cases.

(vi) The tendency towards monopoly in some parts of the transport sector, largely resulting from the indivisibility of investments and economies of scale. When the Government does not intervene as the supplier of the services concerned, it may see fit to control the prices charged and levels of services offered of airlines, port enterprises, railroad companies, etc.

These factors not only result in Goverment management of transportation systems but also in its ownership of large sections of it. In the Latin American region, all significant railways except one are owned by the public sector being controlled either by the central government, by provincial governments, or via state-owned companies. Highways are publicly owned in all but a very few cases. Air and sea ports are usually under some form of public ownership.

Moreover, in many countries, the government also participates as operator, or provider of transportation services, obviously so in the case of railroads. However, governments are also involved in airline operation, maritime transport companies, and the provision of river transport and bus service in urban areas. The state must clearly plan its own involvement in the ownership of transport infrastructure and the provision of transport services but also, for the reasons listed above, it must also plan the transport sector in general.

These planning responsibilities determine the activities of the planning departments of ministries charged with the transport sector. Many of these could, and arguably should, be dealt with by national transportation studies. Detailed specifications of the areas of responsability of such planning departments are rarely made known; however, the following is a listing of the responsibilities assigned to a transport planning unit recommended by the authors of one national transport study carried out for a Latin American country in the mid nineteen seventies.1/

(i) Intermodal transport studies

(ii) The collection of economic and technical data for transport planning, both by surveys and through the gathering of pre-existing information.

(iii) Policy formulation and the preparation of investment programs.

(iv) Studies of fares and taxes in the transport sector, including analyses of impacts.

(v) Technical assistance to public sector agencies in the transport sector.

Some of these areas of responsibility are suitable for treatment in national transport studies whilst others, such as (v) are best dealt with by other means. The above listing is, however, rather generic. At the more specific level, the following matters might normally be addressed by transport studies:

(a) Intermodal transport studies

The government generally has to plan intermodal transport since it is usually, to some extent, involved as an operator, and imperfect competition sometimes prevails in those intermodal transport markets left to the private sector.

b) General Policy formulation

Policy formulation where any of the six reasons identified previously (at the beginning of section 2 of this paper) is operative.

The specific areas include the following:

(i) The roles and responsibilities of the private and public sectors. Private operation is often more cost effective but may result in non- optimum production levels, undesirable effects on the income distribution, etc.

(ii) Transport and energy. National goals may be served by restricting energy consumption to less than would prevail in an unfettered market, particularly where liquid fuels are concerned.

(iii) Regulation or deregulation. Unregulated markets are often efficient, but it may be considered desirable to protect suppliers from cut-throat competition, avoid potential monopolistic situations, etc.

(iv) Rural and regional development and transport. It may be worthwhile providing new facilities or services were these to stimulate development in parts of the country where such development is desired.

(v) Infrastructure maintenance policy. The public sector should seek to optimize maintenance policy for facilities owned and operated by it, so as to minimize total costs, including those of users, who might form part of the private sector.

(vi) The interaction between transport and the macroeconomy. Transport decisions may have macroeconomic implications; for instance the financing of subsidies may be inflationary and some large transport investments increase significantly foreign indebtedness.

(c) Investment programs for the transport sector

There are two main aspects of investment policy which should be addressed in national transport studies:

(i) The determination of the optimal size of the transport sector investment budget.

(ii) The allocation of the budget between the various modes and the specification of the program by year.

(d) Fares, rates and tax policy

The specific aspects that might be dealt with in national transport studies include the following:

(i) The determination of user charges to cover externalities.

(ii) Tax policies for "second best" optima.

(iii) Tax policies to balance income and expenditure on transport.

3. National transport studies to date in Latin America

CEPAL has carried out an analysis, primarily from the methodological standpoint, of national transport studies carried out in the Southern Cone of Latin America during the past twenty years.2/ Of the seven countries included, five have commissioned studies (-some more than once-) partially financed by the United Nations (Special Fund, and later the United Nations Development Programme, UNDP) and led by consulting teams from Europe or the United States, generally with subsidiary participation by local consultants. The World Bank was also involved in these five countries as executing agency, a role that involves the general technical supervision of the study. The World Bank also participated actively in the drawing up of the terms of reference for the studies and in the selection of consultants.

Of seven studies examined in detail, five entailed the development of a conventional transport model of the general form described by diagram 1. (The two exceptions were studies conducted in Paraguay, by Argentinian and local consultants, which were essentially commissioned to update the results from a previous study which did make use of a model of the conventional type.) A brief summary of this model is given in the annex to this report. Other sources, including some in Spanish and Portuguese, explain the model in detail. 3/ Two countries (Brazil and Peru) have carried out similar studies using national professionals and technicians employed by the ministry responsible for transport. (Both earlier commissioned studies to be realized by foreign consulting teams, but only that in Brazil was completed.)

It is a characteristic of all studies examined that they gave much more attention to the development of investment programs for the transport sector than to other objectives of interest to national transport planners, such as those identified in the previous section of this paper. Only in the case of two particularly recent studies (in Argentina and Bolivia) was there much evidence of a lessening degree of concentration on the development of investment programs, and even in these cases the efforts of the analysts still focused their attention on this traditional subject area.

The concentration on the development of investment programs is an acknowledged weakness of studies carried out to date. It is interesting to consider why this concentration occured. Even though no conclusive answer can be reached, it is probable that the influence of the international financial institutions have been important. These institutions exist primarily to finance projects in developing countries and are thus obviously concerned with identifying potential sources for new business, i.e. with the specification of investment programs, comprising projects for which it might make loans. The international financial institutions can ensure that particular attention is paid to this aspect via the drawing up of the terms of reference, the selection of consultants, and the supervision of the work of the chosen team of consultants.

On the other hand, the influence of the international financial institutions should not be overestimated. For instance, the studies carried out in Brazil and Peru by local analysts also gave particular attention to the identification of investment priorities, which provides sufficient evidence that the countries of the region consider that this objective is of considerable importance. However, these two countries, along with others in the region, have also conducted analyses into various of the matters listed at the end of section 2 of this paper, although, generally speaking, they did so through separate studies and did not make use of conventional modeling techniques.

Of late, certain staff members of the World Bank have voiced their concern that this concentration of national transportation studies in developing countries on the specification of investment plans might be a failing of such studies. This feeling has been ably expressed in a recent paper by Gutman and Martinez of the Bank's Latin American and Caribbean projects department. 4/ They recall that national transport studies have had minor impacts on the conduct of the transportation sector in the countries in which they were carried out and that the listing of recommended investment projects tends to be cited by these countries when seeking international financing but not heeded when external financing is not sought. In the latter case a different set of priorities is often used. This reflects back on one conclusion of the CEPAL analysis referred to earlier that the criteria used by the foreign consultants hired for the development of national transportation studies in the Southern Cone generally differ from those used by those responsible for national transport plannming in the countries concerned. 5/ Were the two sets of criteria to coincide one might expect that the national planners would be able to make better use of the results obtained.

The paper by Gutman and Martinez included a list of other topics which should be given particular attention, along with the determination of investment programs, in national transport studies, which list generally agrees with the one suggested at the end of section 2 of this paper.

It should be mentioned that, in the Southern Cone at least, national transport studies have, in the past, not concerned themselves with the matter of gauging the most appropriate size of the transport sector investment budget, this normally being based upon past trends, policies in other countries, and, often, the hope that the amounts allocated to transport may increase in the future. Thus, the studies have attempted to answer, essentially, the question of how an investment budget whose size is determined independently should be allocated between competing projects rather than the related question of how much should be spent on transport.

4. The use of conventional transport models in generalized national transport studies

If the objectives of national transport studies are to be broadened, instead of concentrating on the identification of investment programs as they have done in the past, can conventional transport models extend their field of application to match? This is an important question given the amount of research which has been invested in breeding the current generations of such models and the amount of skill which has been acquired in their use. They have been developed for a specific purpose, i.e. investment planning, and, hence, are able both to simulate how the use of the transport system is likely to vary according to the investment made in it and to make corresponding economic evaluations. If they are sufficiently general, they should be able to simulate how the use of the system might respond not just to whichever investment program is carried out but also to other aspects of transport policy. Their ability to estimate the benefits accruing from one investment program rather than another might also be relevant when comparing one institutional arrangement with another.

If the models cannot be usefully applied to the analysis of other aspects of transport policy, beyond the identification of investment programs, can they be adapted to do so? And if they cannot be so adapted, what new variety of models might be developed to help? In this section we attempt to discuss if not to answer these questions by dealing in turn with the detailed areas of concern listed at the end of section 2.

Intermodal transport studies

Conventional transport models can be applied with little or no modification for intermodal studies. They are intrinsically multimodal and are designed to treat the transportation network as an integrated whole. However although they are designed to handle multimodal situations, in practice they are, perversely enough, often let down by the component which deals with modal split. Thus, whilst they are eminently suitable for the analysis of, for instance, the large scale introduction of containerization of traffics currently handled by traditional methods, or the introduction of specialized bulk handling methods, their results should be interpreted with considerable caution. Modal split models are normally calibrated to an existing situation, and are then used to simulate modal split for a hypothesized alternative state of the transport system, normally for a future year when demand conditions will be different too. One fundamental problem, given the current state of the art of transport modeling, is that one cannot calibrate a modal split function to an existing situation with existing qualities of service and expect that the calibrated function be wholly valid in a hypothetical future situation when the quality of service offered by one, or more than one, mode is different.6/

Most freight/modal split models used in national tranpsortation studies in the Southern Cone have addressed themselves particularly to the choice between road and rail modes.7/ Estimates of user cost by the two modes are developed and functions are fitted which determine what proportion of the total traffic flow will use each mode on the basis of the relation between these costs. By varying one, or both, of the costs, one can estimate the likely change in modal split. CEPAL has found that these models are rarely, if ever, satisfactorily calibrated. They are "doctored" to fit the existing situation by the addition of arbitrary additive factors to one or other of the modal costs, normally the cost by rail. By so doing the analysts implicitly recognize that there are "hidden" costs, related to the quality of service offered and often difficult to measure, associated with the railborne alternative which deter users from it. Probably, the arbitrary additive factors represent, for instance, the greater variability of transit time, when rail transport is used, higher breakage rates with rail transport, particularly at transhipment points (remembering that rail transportation rarely offers door-to-door service), etc. But how much of the additive factors is due to each one of these, and how much has other causes, normally remains unknown.

Consequently, the analysts rarely know how to modify the additive factors should a future situation be simulated in which service qualities are different, for instance, in which the traffic is dealt with by containers rather than in traditional packages. Containerization should reduce breakages, transhipment delays, and other costs, and thus help to minimize the relative disadvantages of rail transportation. But existing models do not generally permit one to estimate to what extent such disadvantages will be reduced. Similar problems occur, were the case being analysed that of the proposed introduction of new bulk handling methods. (Containerization is essentially one form of bulk handling.)

The only really satisfactory solution is to develop generalized, abstract, modal split models. Instead of thinking in terms of modes, one would analyze cost functions. All of the attributes which shippers consider when deciding whether to use any particular mode would be allowed to influence the cost associated with that mode. However, this is very difficult to do. Even were it achieved adequately the problem would remain of how to estimate accurately enough breakage and loss rates, transport costs and charges, and transit times and shippers' perception of these costs, for new methods of transportation in Latin American conditions.

The adaption of conventional models to the analysis of intermodal transport does not represent any new challenge, since the same models are normally used in multimodal investment analyses. The truth of the matter is that, to date, most conventional transport models of freight movements have been conceptually very weak in explaining modal split.

The roles of the private and public sectors

Conventional transport models are not capable of providing the transport planner with much useful assistance in defining the role of the private and public sectors in the operation of the transport system.

The arguments for and against private participation depend on the particular case being addressed but it is often claimed that unregulated private operation is more efficient in the sense that such a competitive environment results in lower costs and/or a better level of service. In specific cases private participation may be justified on other grounds, such as obviating the need for the public sector to maintain extra capacity used only in peak periods, or allowing a reduction in the investment needs of the public sector.

The arguments against private participation are also varied but amongst the most common is the one that the private sector may not provide commercially unattractive services considered to be socially desirable, and that it may exploit an imperfect market situation for its own ends. The arguments, and particular cases, are so varied that it is difficult in a short space to review the relevance of conventional transport models. However, the general conclusion is that they are not useful. Amongst the reasons for this are the following:

(i) The greater efficiency of the private sector centers on the fact that it can often achieve a lower level of costs for a given level of service than can the public sector, for reasons that we shall not go into in this paper.8/ Conventional transport models accept as input unit costs (from which they estimate the costs of particular services by what is basically simple arithmetic) and have no capability of estimating these costs internally. Hence they cannot determine how such costs are likely to vary according to whether the private or the public sector be the operator. Conventional models also treat service quality as given and have no ability to synthesize variations in such service quality according to whether the operator be from the public or private sector.

(ii) Transport models essentially estimate the amount of usage that is likely to be made of those services assumed to be operated. They have no real capability of determining which services would be provided by the private sector with any degree of accuracy.

(iii) Conventional models cannot reliably estimate to what extent private operators would charge in excess of their cost levels, and hence, they cannot indicate to what extent the private sector might be able to exploit any imperfect market situation. (However, see below).

On the other hand, conventional transport models can be used to ascertain to what extent throughput (of a facility) would vary as the price charged for its use varies. For instance, one may simulate an increase in the charge for the use of a transshipment point, and estimate to what extent users would change their travel behavior to avoid it by running the distribution, modal split and assignment sub-models. For a privately owned port, one could vary the price charged and estimate the resultant variation on flow of traffic through the port. Conceptually one could determine price and flow were the port enterprise to maximize its profits. But in practice the utility of the information so attained would be doubtful for various reasons. First of all, the models used in national transport studies are rarely precise enough to be used in this way for a particular facility. Secondly, to run the sub-models mentioned for various different charges might be cumbersome and costly; economies could be made by, for instance, leaving out the distribution sub-model from the tests, but this would result in the underestimation of the elasticity of demand. And thirdly, it would be necessary to have an accurate knowledge of the cost funtion of the facility under consideration; it is common practice in national transport studies to assume that the cost per ton handled by a port does not vary with the volume handled (over the range considered) whilst in order to determine profit maximizing behavior one needs to know both fixed and marginal costs. 9/

The identification of what (socially desirable) services would be left unattended by (unregulated) private sectors operators is another field in which conventional models are theoretically able to provide useful information whilst being considerably less useful in practice. They are generally insufficiently explict about the nature of the services being provided to enable one to estimate the costs of operating them. Demand for any particular service, such as bus or truck between a pair of cities, is estimated without the analyst having to specify frequency, an essential datum in the calculation of how much it costs to operate the service. Most models applied in urban areas do require bus frequencies to be input, and make patronage dependent on them. These could be adapted for use at the national level, and would permit analyses to be made of the commercial viability of particular services. Fares, frequences, and vehicle characteristics could be varied to see if a commercially viable combination of these factors could be found. However, each re-run of the model would require time and money and, moreover, in some circumstances, there may be a tendency to overestimate patronage.10/

Transport and energy

The usual question posed regarding the energy implications of alternative transport networks and policies is how much energy, by type, would be consumed with each alternative. Conventional transport models are able to answer such questions without modification. Energy consumption varies with the mode (or sub-mode) concerned, with kilometerage travelled, and with speed. Conventional models can output distance travelled by speed band for each mode (or sub-mode- depending on how disaggregated the model is-) to which the appropriate energy coefficients can be applied to estimate the energy consumption of the various alternatives analysed. (Adjustments could be made to recognize consumption in railway yards, transhipment operations, etc., again by applying coefficients to information generated by the model.)

Another question might concern the extent to which energy consumption would vary were energy prices adjusted, or were physical restraints on consumption imposed. It is a simple matter to adjust the energy component of unit costs for a conventional transport model and rerun it accordingly. However, in order to do this, assumptions have to be made regarding the extent to which rates charged by public sector operators, such as railway companies, vary according to changes in unit costs. Moreover, the accuracy of the results obtained depends on how desaggregated the model is, and how firm is its behavioural base. Most national transport models do not compare very well in these respects. For example (probably insignificant) errors are likely due to the unknown way in which private motorists will react to higher fuel prices, and others (probably more significant) due to the impact of higher prices on changes in the vehicle mix and fuel types.

In the annex reference is made to optimizing transport models. Such models generally simulate that traffic pattern which would result were costs minimized subject to particular restraints. Optimizing models are sometimes used in national transport studies, for instance in one conducted for Uruguay.11/ With only slight adaptions they can be used to simulate what travel patterns would result were energy consumption or costs minimized.

Regulation and deregulation

Parts, at least, of the transport sector of most countries have been subject to regulation of varying degrees of severity in the past, largely as a result of the perceived need to protect users against the once monopolistic powers of railways, to restructure urban transport, to protect government owned airlines, etc. Recently, in the past twenty years or so, there has been a notable worldwide tendency towards deregulation; substantial parts of the transportation systems of various countries, including the United States, the United Kingdom, Chile, Australia, Belgium and Canada, have been deregulated. However, the subject continues to be one of intense debate, both at the academic and lobbying levels. In certain countries, existing trucking enterprises have been very foreceful in advocating regulation. In Brazil regulation of the hitherto free trucking industry now seems destined to take place.

The arguments for and against regulation are many and varied. Amongst those in favor of regulation is the one that alleges that the degree of competition between suppliers in an unregulated environment is often too intense to be desirable in economic or social terms. Sometimes it is claimed that if regulation were imposed operators would be able to offer services on routes socially beneficial but commercially unprofitable through cross subsidization financed out of their excess profits on other routes. Regulation is also advocated where monopolistic supply situations still exist.

The arguments against regulation include the belief that the protection which regulation affords to existing operators results in undesirable consequences, such as higher prices, lower qualities of service, socially indefensible excess profits to these existing operators, and inefficient operation at the level of the firm. There might also be inefficiencies at the level of the industry; for instance, regulation often makes it difficult or impossible for truckers to reduce their unit costs by picking up back hauls on their return journeys.

It is interesting to note that regulation was initially invoked to defend the user against the operator, but now it is more often than not advocated to defend the operator against the user.

The utility of conventional transport models in the investigation of the impacts and desirabilities of regulation or deregulation in the transport sector is severely limited, for reasons related to those which have already been mentioned in the paragraphs on public versus private operation. These models cannot simulate how the supply side of the transport market will react to changes in the way the market is managed. It is noteworthy that when the urban transport market was deregulated in Chile, no formal models were used. Deregulation proceeded, and still continues to proceed, in a step-by-step fashion, with careful monitoring at each stage to make sure that there are no unforeseen adverse consequences. Similarly, a recent official Brazilian study, which found that regulation of trucking would be undesirable, made no use of mathematical models. 12/

Rural and regional development

Transport facilities are recognized to be necessary, but not sufficient, prerequisites for rural and regional development. Without the accessibility provided by transport facilities, development cannot occur. However, it is unlikely to take place unless other essential ingredients are provided as well, for instance, agricultural credit, schools and health facilities and adequate communications. A few conventional transport models (at all levels, from the urban to the national) have incorporated linkages between accessibility and the production and/or consumption of goods and between accessibility and personal trip generation rates. However, the precise linkages are very difficult to identify with worthwhile accuracy. That this be so is scarcely surprising when one considers that there may be no linkage at all unless other basic facilities over and above transport are also provided. The problems are less serious in urban studies, since in urban areas such basic facilities are not likely to be completely absent. In some Latin American urban studies, models relating land usage to accessibility have been employed. 13/ Nevertheless, even here the identification of the time lags between changes in land use intensities and changes in accessibility remains a very difficult problem.

In national transport studies, there is little doubt that the necessary adjustments can be made to conventional models to allow development to depend on accessibility, but the practical usefulness of so doing is doubtful since it is extremely difficult to calibrate the required relationships. Even if they were successfully calibrated, for them to be successfully applied, one would have to be able to predict the future availability of credit for agricultural development, the future school and hospital construction program, when projected rural electrification schemes will be implemented, etc. This is not easy to do in the frequently changing Latin American economic and political environment.

Infrastructure maintenance policy

In recent years it has become evident that investment in the maintenance (and rehabilitation) of existing infrastructure, at least existing highway infrastructure, often generates mugh higher returns than does the provision of new facilities. In some cases expensive investments in new infrastructures have been largely nullified by inadequate maintenance. This increased awareness pf the importance of maintenance policy has generated in turn a desire to deal with it in national transportation studies, along with the related topics of reconstruction and rehabilitation.

Conventional transport models, especially in the way they have been applied in the past, have not been able to analyse maintenance and reconstruction policy, except in the broadest sense. Many studies sought to determine the best type of surface for each road and, in order to do this, in their project evaluation phase, the costs of vehicle operation were made dependent on speed and whether the road was paved, gravel or earth. In others they were also made a function of the condition of the road surface, rather than just the material from which it was composed, in order to identify also the benefits from improvements in maintenance. However, even when this further distinction was made, the accuracy of the results obtained cannot have been particularly high since the variation of operating costs according to the state of the surface was specified only very approximately. The main source document for vehicle operating costs was until quite recently a report in which no costs were tabulated by surface condition. 14/

There are two fundamental reasons why conventional models are intrinsically weak at analysing maintenance and highway reconstruction projects:

(i) They do not estimate internally either unit vehicle operating costs on different types of road and surface condition nor the surface condition of the various highways in the network, both of these having to be provided as input data.

(ii) Maintenance and reconstruction projects have lives of between one and ten years, and the quality of the project, from the standpoint of the user of the transport network, is likely to vary from one year to the next, as, for instance, an asphalt pavement ages. Conventional transport models applied at intervals of ten or more years, as is common practice, are not suited for the analysis of such projects.

In recent years, some national transport studies, including one carried out in Bolivia 15/ ,have made use of a model which has come to be known as the HDM (or RTIM) whose full title is the Highway Design and Maintenance Standards Model (or Road Investment Model). There are two versions of this model, which are closely related and which have a common origin. 16/ Both have been updated since the first versions to incorporate the results of subsequent research findings and, at least in the case of the TRRL version (i.e. RTIM), to enable it to be run on a smaller computer. Important research findings from Brazil can be expected to result in a further version, particularly suited to Latin American conditions.17/ Essentially, the model accepts as input data on the existing road state, maintenance and reconstruction policy, traffic levels and growth, and environmental conditions in order to simulate road state year by year during the analysis period. Having determined the road state in each year, operating speeds and costs are determined. Total discounted costs of vehicle operation, maintenance costs, and any reconstruction costs are then calculated. In this way the total costs of different options can be estimated, thereby providing valuable information for decision making.

The HDM or RTIM can be used in conjunction with the conventional transport model, which can provide it with traffic forecasts. The conventional model can be run to yield estimates of traffic in the base year, t, and maybe, in year t plus 15, from which the traffic data needed by the HDM can be interpolated. Since the HDM normally needs input traffic flows at a higher level of disaggregation than usually produced by the conventional model, the relevant components of the latter should be refined in this respect when being used in conjunction with the HDM. It is especially important to estimate flows by category of truck, since road deterioration is increasingly sensitive to axle loads in excess of eight tons. In at least one national transport study in Latin America the assignment sub-model was modified in order to predict traffic flows by size of truck. 18/

There is as yet no equivalent of the HDM for railroads, although the World Bank has made some progress in this direction.

Macroeconomic impacts of transport policy

Conventional transport models are largely restricted to the analysis of different transport policies from the point of view of the transport sector itself. Hence, their utility in assessing any macroeconomic impacts that transport policy may have is limited. What happens in the transport sector can have such widespread influences. For instance, were better accessibility to promote greater agricultural production, it may have a favorable impact on the balance of trade; subsidies to railroads may be inflationary and/or may dampen economic growth by reducing activity in those sectors more highly taxed than they otherwise would be in order to finance the subsidies; and changes in taxes on car ownership and usage may have wider repercussions via impacts on the car market and fuel consumption.

Such impacts should be gauged by other means, involving macroeconomic models of the economy. Conventional models may, however, help to identify some of the relationships involved. For instance, they might be invoked to determine to what extent higher subsidies to railroads which result in lower rates lead to greater usage of the rail system. The models can also provide estimates of the extent to which changes in vehicle user taxation result in modified usage patterns, but on the other hand, they generally cannot forecast how much changes in taxes on ownership are likely to affect usage because the fleet size is rarely made a function of vehicle price.

Size of the transport sector investment budget

Conventional transport models are, of course, normally used to determine how the capital resources expected to be available should be allocated between projects. They are not, however, generally invoked to make recommendations as to the optimal size of the transport sector investment budget. The normal practice is to estimate the volume of resources likely to be available for investment in transport, sometimes by mode, on the basis of past trends and the proportion of the national product devoted to such investment in other countries.

In principle, there is no reason why an evaluation should not be made of the adequacy of the amount so estimated. If the projects analysed by the study include all those likely to yield positive returns at the prevailing social discount rate, i.e., if there is no appreciable chance that some economically feasible projects are not considered, and the most marginal of those able to be implemented with the resources estimated to be available shows a rate of return significantly in excess of the discount rate, this would indicate that there would be benefits from investing more in transport. Conversely, if the most marginal of those projects able to be implemented with the independently estimated investment budget shows returns significantly less than the prevailing discount rate, it would be indicated that the size of the investment budget is excessive.

In practice, however, certain problems preclude the optimization of the size of the transport budget in so simple a manner, the most important of which is the validity of the discount rate adopted by the study. The discount rate is sometimes specified by the team of analysts contracted for the transport study and is sometimes recommended by the national economic planning agency. In any case it should represent the returns foregone by the nation were the marginal peso, cruzeiro, sol, etc., invested in the particular project being analysed rather than in its alternative use (although other definitions are possible). 19/ Two problems which complicate the quantification of the disount rate are, (i) it is often not known what is this alternative use and, (ii) even if it were known one probably does not know what social returns it would yield. The rate can, theoretically, be calculated (in more than one way) but it is generally not practical to do so. Some governments specify standardized rates for all investment projects, or all within a particular sector, whilst, if the rate is not specified, transport planners tend to settle for 10% or 12%, per annum, because these rates have been used elsewhere.

If the discount rate is estimated in such a casual manner, there is no guarantee that it is even approximately accurate, and thus it cannot be reliably used in the gauging of the optimal size of the transport budget.

The potential returns, which may be negative, from varying the size of the transport investment budget, can be demonstrated more forcefully by applying a method developed by the World Bank and programmed for computer in the previously mentioned Bolivian National transport study. 20/ This procedure to determine economically balanced highway expenditure programs under budget constraints 21/ has as its principal function the selection from a set of projects, each one of which is economically viable at the given discount rate, that sub-set which maximizes net present value at this rate. By varying the budget restraint the procedure can be made to calculate the corresponding losses or gains in net present value. As conceived, and as applied in Bolivia, it was designed to be applied only to highway projects, but it is also capable of being applied at the level of the transport sector in general.

The principal reason why the procedure was not applied at the level of the transport sector as a whole in Bolivia was that it would have resulted in the recommendation that investment should be more concentrated in certain modes of transport than would have been politically acceptable. It would, for instance, have selected very few railway projects, because such projects had relatively marginal rates of return. This intrasectoral problem, i.e, the political difficulty of making fundamental changes in the amount of the transport sector investment budget allocated to each sub-sector, has an equivalent at the intersectoral level. If the procedure were to show, for instance, that more should be invested in transport than in the past, it would normally be very difficulty to occasion the required transfer of resources, either from the investment programs of other ministries or from the country in general in the form of higher taxation. However, the transport planners would stand a greater chance of transfering such extra resources to their sector if they can demonstrate that this would be economically beneficial. Also, the possibility should be recognized that, as the countries of the region develop, as the basic national transportation networks are completed, and as the population becomes more urbanized, it might be worthwhile to reduce the proportion of national resources devoted to the provision of non-urban transport infrastructure.

Externalities caused by the use of the transport system

In the area of fares, rates and tax policy, one specific role of national transport studies is the determination of user charges to cover externalities, such as congestion, pollution, accidents, and track costs, caused by users of the transport system. Conventional transport models can provide useful help to the transport planner in some of these cases, but not in others. They are especially useful regarding highway congestion, which is, however,not a signficant problem outside urban areas in most Latin American countries, although congestion is important at some transhipment points and in particular instances elsewhere.

The user charge or tax attributable to a vehicle due to the highway congestion it causes, is equal to the extra cost forced onto other users of the road system by its presence. When it is necessary to analyse congestion, conventional models incorporate (in the assignment sub-model) relationships which trace the interaction between speeds and traffic volume on particular facilities, known as speed-flow curves. Through these curves one can estimate by how much speed would increase, were the vehicle under consideration not to travel and, hence, the delay caused to other vehicles by its presence. The product of this delay and the operating cost per unit of time of the vehicles delayed results in an estimate of the user charge or tax needed to cover congestion externalities.

Unfortunately, the conventional model cannot generally be used to determine congestion costs in the same way for transhipment points, particularly ports, where congestion is occasionally severe in the Latin American region. Conventional models do not normally incorporate relationships for transhipment points equivalent to the speed-flow curves for highways. Usually they assume that the cost per ton handled is a fixed amount (over the range of throughput considered). In some cases a maximum throughput per period of time is specified and any traffic simulated as desiring to use the facility over and above this maximum is diverted elsewhere. For instance, in a recent Argentinian study a particular form of distribution model was developed which directed such excess demand for any one port to other ports. 22/ If the use of port "A" by one ton of cargo implies that another ton has to be dealt with by another port, the extra costs of shipment via this other port represent the marginal congestion cost. 23/ The Argentinian model can be used to estimate these marginal costs, and hence, appropriate user charges or tax rates. However, in general, to estimate such taxes by conventional models is more cumbersome in the case of transhipment points than their use to estimate similar costs in the case of highways.

The conventional model is not very useful in determining user charges to cover other types of externality. National transport studies sometimes assess accident costs but the accident rates on which they are based are generally determined exogenously and applied to particular output from the model (e.g. vehicle-kilometers by mode and type of facility) to yield estimates of numbers of accidents, and, hence, accident costs. But this provides no real guide as to the accident costs attributable to different type of road user. Atmospheric pollution is not normally considered in transport studies in Latin America, except in urban areas, since it is rarely an important issue.

Conventional models provide little help to assess the track costs attributable to highway users 24/; on the other hand the HDM or RTIM can. Models of this type can be used to determine the deterioration caused to a road by the passage of different types of vehicle and, hence, the extra costs forced onto other users of the same highway. Alternatively, such models can be used to estimate how much extra must be spent on road maintenance to counteract the damage caused by each vehicle. Either way they yields an estimate of the marginal track costs generated by each type of vehicle, which can be used to determine appropriate user charges, or tax rates.

Once appropriate user charges or taxes have been estimated, the transport planner is then confronted by the problem of how to devise a suitable taxation system to levy them. It is obviously desirable that the tax be charged at the margin, i.e. as a function of vehicle use, so that for each kilometer travelled the user pays the costs of the congestion, track costs, etc. he may be causing. He could then compare the costs he would force upon society by travelling, which should equal the tax he would have to pay, with the worth of his trip, maybe deciding not to travel if the cost is high or the trip not essential. It is not easy to devise a tax system which does this adequately; one might tax fuel, tires, spare parts, etc., but none of these alternatives is wholly satisfactory.25/ Thus, an annual tax which varies according to the type of vehicle might be a more practical alternative. In order to specify the correct amounts, one has to know the congestion costs and track costs attributable to each type of vehicle each year. In principle, the conventional model can help provide this information, since it produces estimates of how many kilometers each type of vehicle travels over different type of road. In practice, however, the model is less useful since many roads, for instance, unpaved ones in rural areas (on which track costs would be high), are not normally included in the networks used in national transport studies.

"Second best" tax policies

Taxation policy in the transport sector is rarely, if ever, optimized, for various institutional reasons. One common sub-optimality is the under-taxing of heavy trucks in relation to their track costs. There are various reasons why this is often so (for instance, to attempt to reduce the consumer price of the goods transported or because the tax rates have not been adjusted since the era when the variation of road damage and axle loading was less well understood) but one of the most important is probably the simple one that, particularly for the heaviest trucks, it is very difficult to identify a practical and satisfactory way of collecting the tax, which should vary with vehicle type and type of road (earth, gravel or paved). 26/ Rail rates may also deviate from the appropriate marginal cost for various reasons. As a result of differences between user costs and user charges, shippers may pay less (more) than the value of the economic resources consumed in providing the transport services they consume. Thus, the total cost of transportation would be reduced by charging less (more) for competing services, for instance, by granting subsidies (levying taxes), i.e., by invoking "second best tax policies,") if this were to result in traffic switching from expensive to cheaper modes (given that any generation of traffic is so little that it can be ignored).

The problem is complicated, and it has no solution if both taxes on trucks and rail rates are inflexible, as they might be in some countries. However, in others railway rates are sometimes treated as policy variables.

There is no point in trying to solve the problem (from the standpoint of economic efficiency) if the demand elasticity for each mode is very low with respect to its price or competing prices, since variations in rates and taxes would have little effect on total tranportation costs. However, in other cases second best tax policies are worthy of consideration. In Latin America there are cases of rail routes paralleling unpaved highways or paved highways, in bad condition, which carry heavy truck traffic. Here, reduced rail rates for some products might lower the total costs of the transport system.

In order to estimate second best rail rates for a particular route, one has to know the marginal cost and freight rate charged for transport by rail and the marginal track costs (which we assume, for simplicity, to equal marginal social costs) and marginal taxes paid for the truck transport alternative. The conventional transport model can be used to calculate the marginal cost by rail and the marginal taxes by road for any particular origin-destination movement given the unit cost by rail and the tax paid per kilometer by type of road.27/ These unit rail costs and taxes per kilometer would normally be available from the set of information collected for the transport study. The railway rate would be available from the appropriate tariff manual, and thus the only problem outstanding is the marginal track cost for the journey by road. As we have already pointed out, the HDM (or RTIM) can provide accurate estimates of marginal track costs and, even if such a model is not applied in the case being analysed, estimates of road maintenance costs per vehicle-kilometer (by vehicle type and road type) might be approximately calculated from other sources. In either case, the conventional model can sum these costs to yield marginal track costs on particular routes. The second best rail rate would be that which results in the difference between the rail rate and the marginal costs of the journey by railroad being equal to the difference between the taxes paid and the marginal social costs by the trucking alternative.

The balancing of transport budgets

It is sometimes sought to balance transport budgets in the sense that either users of the transport system in general, or specific categories of user, contribute to the public agencies responsible for the provision and maintenance of infrastructure as much as the costs borne on their behalf by these agencies. If there is an overall balance between taxes paid by road users and expenditure on the road system, it signifies that the highway transportation pays its own way and does not represent a drain on the public purse. If there is also balance at the level of different types of vehicle, it might be said that the system of vehicle taxation is, in some sense, just. However, if some classes of vehicles pay relatively more than others there may be some switching between vehicles types leading to economic inefficiency.28/

If it is desired to balance budgets at the level of different types of vehicle, there are two principal problems to be tackled: firstly; the costs incurred on behalf of each type of vehicle must be estimated, and, secondly, suitable taxation systems have to be identified. Conventional transport models might help to solve the former, although they are not directly relevant to the latter.

The allocation of costs to different types of vehicle is, to some extent, a rather arbitrary exercise; for instance, there is no simple and unique way to allocate the costs of drainage, highway policing, sign-posting, or lighting between different vehicles. On the other hand, certain important cost elements can be attributed to particular vehicle types, for instance maintenance and construction costs, which depend, amongst other things, on axle-loadings (higher loadings require higher quality pavements), and speeds and vehicle size (slower and larger vehicles require more road space). Transport models involve the assignment of traffic to the highway network, thereby resulting in estimates of traffic flow by vehicle type and category of road. Hence they are potentially useful in allocating maintenance and construction costs, given data on vehicle axle loadings, dimensions, etc. On the other hand, most models used in national transport studies are not sufficiently detailed to be able to provide all the information necessary to allocate these costs since, for instance, they include only the major components of the highway system and not secondary and minor roads and, moreover, they do not normally distinguish between particular types of truck. The latter is an important limitation since the heaviest trucks have a very much more damaging impact on highways than trucks in general and the use they make of the highway system is often significantly different from that of the average truck.

5. Conclusions

The summary of the findings of this paper is presented in table 1. Of the 12 subject matters selected the conventional transport model is very useful in three cases. In three more it is fairly useful, whilst in the remaining six it offers little assistance. In five of the twelve subject areas, national transport studies sometimes include other models which provide useful help, whilst in one case the conventional model is capable of being developed so that it lend further assistance.

The overall conclusion must be that conventional transport models, and even developments of them, do not adapt themselves well to the analysis of many of the particular matters that one might expect to be undertaken in future national transport studies. One might say that they are necessary but not sufficient components of the mechanics of transport studies. They are needed for tasks such as the development of investment programs and investigation of ways to further intermodal integration, but they provide little or no help in other analytical activities, for instance the identification of the roles of the private and public sector and the matter of regulation or deregulation.

The reasons why transport models are not of more general relevance to the transport planner might be categorized under two headings. Firstly, there are those reasons which also limit their usefulness in their traditional role of identifying investment plans, and, secondly, there are those which are related to requirements of little relevance when they are used in their traditional role.

Consider first the former of these two categories. Amongst the specific reasons which can be placed in this category are the following:

(i) The models are applied at too aggregated a level to produce results immediately applicable at the operational level. One of the factors which played a large part in past decisions about the level of detail at which models were applied was the need to aggregate in order to economize in terms of computer capacity, and running time required. This restriction may be expected to be increasingly less important. Nevertheless, others will continue to be binding, and will ensure that the models used in national transport studies continue to be lacking in detail, implying that their results cannot always be trusted at the level of the individual highway, railway, or transhipment point; for instance, more detailed models require the expenditure of more resources in data collection, in model specification, and in calibration.

(ii) The models simulate user reaction to changes in fares or freight rates and transit times, but not to other measures of the supply of transport services. The probability of loss or damage, service reliability, and service frequency are amongst the factors not considered in the calculus. They effectively imply that these quality of service variables remain fixed during the planning period, which is often unrealistic. More generalized models are being developed, but these will not solve the problem of how to evaluate forecast changes in the quality of service offered in a way that can be compared with costs and travel times. It will be necessary to do this in order to adequately gauge user reaction.

Secondly, there are those factors which do not have to be considered in detail by a model were it to be used solely for investment planning, but which are relevant were it to be more generally useful to the transport planner.

(i) Of paramount importance is the concentration of conventional models on simulating how the user will react to changed market conditions, whilst little or no attention is given to estimating how the supplier will react. To a limited extent this deficiency also restricts their usefulness in their investment planning role, for instance, they cannot model changes in the make-up of the vehicle fleet as fuel prices change, but such restrictions are not normally important. They are important, however, when using models to assist in planning institutional changes. Little research is being carried out in this very important area.

(ii) The treatment of transport independently, or nearly so, of other sectors of the economy. Transport is a service sector and, as such, is intimately linked both to the productive and household sectors which it serves and to the government sector and other parts of the productive sector which provide it with inputs. Changes in the transport sector may have significant ripple effects on these other sectors, but to model even the more important of these linkages is rarely practical. However, the inability to do so puts a further limitation on the models used.29/

(iii) The inadequacy of conventional models to analyse maintenance projects and rehabilitation projects with relatively short lifetimes. This deficiency may have contributed to an overconcentration on the provision of new infrastructure and a corresponding relative disregard of projects designed to conserve existing facilities, although political factors have undoubtedly been more influential in this respect. As has been pointed out, supplementary models have been developed to correct this deficiency.

The probability of developing in the near future a type of transport model that may be more generally useful to the transport planner than those applied in the past is small. Some of the problems listed above are too difficult to resolve for one to expect much progress to be made in the short term, and it may need a change in the attitude of mind on the part of research institutions before research is orientated in the required direction. Hence, in the medium term, it is probable that national transportation studies will be required to deal with a wider range of aspects of transport policy than has traditionally been the case whilst, for the most part, they have have to be carried out with little assistance from formal quantitative models.

Conventional models are undoubtedly going to play a smaller role in future transportation studies than they have in those conducted in the past. It follows that the breed of transportation engineer that has been concerned with the development of these models and the interpretation of their results is likely to see his role modified, by, for instance, having a greater involvement with more detailed models, such as the HDM. On the other hand one might expect a greater reliance on the development and usage of less formal models that do not necessarily work at the network level and are not always mathematical in their nature. For instance, analyses of the relative roles of the public and private sectors will be, for the most part, handled without formal models. Instead, enquiries will be made into the organization, cost structures, and market reactions of public and private entities in the relevant parts of the transportation industry both of the country concerned, if possible, and of other comparable nations. Such investigations require a kind of business analysis hitherto rarely undertaken in transportation studies at the national level.

An extended role is foreseen for the HDM (or RTIM), due to the increased awareness of the importance of adequate road maintenance. The HDM, may well come to be considered a component part of the conventional transport modelling procedure in future years. There is likely also to be an increasing need for extensions of the HDM/RTIM and for the development of allied models. For instance, the HDM/RTIM might be generalized so as to recognize the effects of congestion on traffic speeds, thereby being able to determine what improvements are needed not only to counteract the consequences of wear and tear caused by the impact of traffic on the road bed, but also to identify what improvements are desirable to handle increased volumes of traffic. Of greater importance is the need to further develop the model to enable it to synthesize the deterioration of concrete pavements. Whilst it recognizes as many as four different kinds of unpaved road (sandy earth, clayey earth, normal gravel and coral) it cannot tackle concrete pavements, which is an important defficiency in many Latin American countries. In the future, given that petroleum (and, hence, asphalt) will become more expensive,

:oncrete pavements are likely to become more cost-effective and, :herefore more common, hence increasing the need that the HDM/RTIM ›e able to handle them.

Other types of models, for instance those which have an .nherent capability of optimization, might be useful in certain .nstances, but they have limited applicability since, to be able to ›rovide results sufficiently detailed to be useful, they might have .o be so complex so as to be unwieldy. There appears to be 'omparatively little scope for developing further the conventional ıodel in order to make it more useful; only in one subject area, :he relationship between the transport system and rural and regional .evelopment, can the conventional model be developed to generate 'urther useful information, and even here, for reasons mentioned in .ection 4, there are valid doubts as to whether such development is 'orthwhile.

To sum up, it may be expected that the conventional transport .odel will continue to be used, and further refined, 30/ and that a omplementary model to analyse highway maintenance problems will be .ore frequently employed in the future. But many of the tasks which hould be dealt with by national transport studies and which have .ot received sufficient attention in the past cannot be dealt with ıy network models of the type employed to date. They generally equire a kind of economic analysis that has rarely formed an mportant part of transportation studies in the past and which will end to change the nature of such studies in the future.

Notes

/ Estudio Integrado de Transporte, undertaken by the consulting company otecni for the Ministerio de Transporte y Obras Públicas of Uruguay, 1977.

/ La Planificacion del Transporte en los Paises del Cono Sur, Evaluación omparativa de las metodologías aplicadas en cinco países (E/CEPAL/R.287).

/ Por ejemplo, Planificacion analitica del transporte, por Lane, Powell Smith, Instituto de Estudios de Administración Local, Madrid 1973.

/ See The role of national transport planning from investment lans to policy planning, by Gutman, J. and Martinez, M. of the World ank, and presented in the Primer Seminario Latinoamericano de Planeamiento el Transporte, CEPAL/Argentine Government, Buenos Aires, June 1982.

/ See R.287, CEPAL, op. cit.

/ By "quality of service" we mean factors which affect the attraction of he mode concerned over and above those explicitly incorporated in the odel. Most models applied in the Southern Cone explictly recognize only the freight rate, sometimes including as well a variable reflecting transi time.

7/ See R.287, CEPAL, op.cit for a discussion about inadequacy of existin modal split models.

8/ See for instance, Ownership and Efficiency in Urban Buses, by Charle Feibel and Alan Walters, World Bank staff working paper 371, Feb. 1980.

9/ Network optimization models do exist which are theoretically capabl of estimating in a less cumbersome manner, the extent to which operators o facilities can raise prices, for instance, CEPAL shipping technolog optimization model, E/CEPAL/VP.192, for a description of a relatively simpl model of this type. However, optimizing models generally trade realism fo their ability to optimize. Therefore, their results would usually be eve less precise than those of conventional simulation models.

10/ The models usually assume that the amount of travel generated by, o attracted to, any one zone is fixed. When modal competition is limited they imply that the traffic would bear high fares, whereas, in reality, som of it might be surpressed.

11/ See La planificacion del transporte en los paises del Cono Sur; la metodologias aplicadas en Uruguay, E/CEPAL/R.287/Add.5

12/ Avaliacao de Regulamentacao Economica do Transporte Rodoviaria de carga, GEIPOT, Ministerio dos Transportes, Brasilia, 1980. I spite of the findings of this study, the trucking sector in Brazil appear likely to be regulated.

13/ See, for instance, Land Use and Transport Planning for Sao Paulo, b Marcial Echeñique, Department of Architecture, University of Cambridge England, 1982, or Teste de um modelo de uso do solo para a regia metropolitana do Recife, by Mara Mónica Andrade, Secretaria da Habitacao Recife, PE, Brasil.

14/ Quantification of Road User Savings, World Bank Staff, Occasiona Paper 2, by Jan de Weille, World Bank, Washington, D.C., 1965.

15/ Estudio Integral del Transporte en Bolivia, carried out by Wilbu Smith and Associates for the Governmet of Bolivia, 1979-81.

16/ (1) Highway Design and Maintenance Standards Model (HDM), availabl from the Transportation, Water, and Telecommunications Department of th World Bank and, (2) The TRRL Road Investment Model for Developing Countrie (RTIM2) developed by the United Kingdom Transport and Road Researc Laboratory (TRRL).

17/ This will result from a study entitled Pesquisa d inter-relacionamento entre custos de construcao, conservacao e utilizaco d rodovias carried out by GEIPOT, Ministry of Transport, Brasilia.

18/ Wilbur Smith and Assocs. op.cit. The particular way in which it was done was rather superficial. See La planificacion del transporte en los paises el Cono Sur: las metodologias aplicadas en Bolivia, E/CEPAL/R.287/ Add.2,1982.

19/ See for instance, Analisis coste-beneficio, by D.W. Pearce, Editorial Vicens Vives, Madrid, 1973, pag. 49.

20/ Wilbur Smith and Assocs., op.cit..

21/ See, Determination of Economically balanced Highway Expenditure Programs under Budget Constraints,, by T. Watanakada and C. Harral of the World Bank, presented at the world Conference on Transport Research, London, April 1980.

22/ See La planificacion del transporte en los paises del Cono Sur: las metodologias aplicadas en Argentina, E/CEPAL/R.287/Add.1, or Plan Nacional de Transporte, Contrato VI, Interaccion entre Oferta y Demanda de Transporte, Dirección Nacional de Planeamiento de Transporte, Buenos Aires, 1981.

23/ These marginal costs are not strictly congestion costs. The congestion cost would be the increase in total costs of handling all cargo shipped via port "A" were the second ton to use this port (due to delays, overloading of equipment, etc.) less the costs of handling this second ton itself. The Argentinian model assumed that port "A" operated at constant marginal costs up to a certain level of throughput, beyond which it couldn't handle any more, and so any extra tonnage had to be diverted elsewhere. Although not strictly a congestion cost, it does have conceptual similarities to it.

24/ Except insomuch that some models, in the evaluation phase, estimate the maintenance costs of each alternative network analysed by the application of an (exogenously determined) monetary amount per vehicle kilometer for different categories of road. These costs are attributable to road users. As mentioned in the text above, the HDM model does this in a much more refined manner.

25/ See, The economics of road user charges, by Alan Walters, World Bank staff occasional paper number 5, Washington D.C., 1968.

26/ Pavement damage varies with approximately the fourth power of axle loadings; this means, for instance, that a truck with ten ton axle loadings should pay 144% more than one with eight ton loadings. No conceivable tax on tires, fuel or spare parts could reflect this variation. See Road Test Report 5 (Pavement Research, American Association of State Highway Officials.

27/ This is done by "skimming" the respective monetary values along th appropriate "trees", i.e. summing costs specified for each link over thos links which comprise a particular route.

28/ However, if the government is concerned that road users should pay i taxes as much as the government spends on them, economic efficiency is no necessarily a prime motivation for this concern. If economic efficiency i of paramount importance, marginal social costs and taxes paid should b brought into line. If, for each journey, vehicles pay in taxes as much a the marginal social costs they impose, the result would not generally impl that each vehicle type pays in taxes a sum equal to the costs expended b the government on its behalf, for instance because some of the margina social costs are not borne by the government but by other road users (in th form of higher operating costs due to congestion delays or damaged roa pavements).

29/ Attempts have been made to do so, see for instance, Model Multiregional insumo-producto para Venezuela, presentado por el Ministeri de Transporte y Comunicaciones de Venezuela en el Primer Seminario d Planemiento de Transporte, CEPAL, Gobierno de Argentina, Buenos Aires, Juni de 1982.

30/ The conventional model may be replaced in the future by simultaneous model which examines the demand and supply for transport b developing an equivalent optimization problem. See, for instance, A equivalent optimization problem or combined multiclass distributio assignment, and modal split which obviates symmetry restrictions, by Terr L. Friesz, Transportation Research, Series B, volume 15, 1981.

Annex. A description of the conventional model used in national transportation studies

Introduction

Diagram 1 of this report shows graphically the structure of the transport model traditionally used in transportation studies at the national level. Similar models are also often applied at the regional and urban levels, with differences of accentuation. For instance, at the urban level the accentuation is on personal travel whilst in national transportation studies, in Latin America at least, the concentration is on freight movement.

The model can be traced back to simple models of highway traffic developed in the United States in the nineteen fifties. Both in the latter country, in the United Kingdom and, to a lesser extent, elsewhere the model has since been considerably developed. Apart from ever increasing refinements to the original components of the model, which were essentially limited to the simulation of vehicle movements, the model has acquired new modules, for instance it now universally includes an element to simulate model split and it embraces not just simulation but also the evaluation of alternative networks.

The model is first of all applied to a base year situation, during which application it is adjusted until it is capable of adequately reproducing the behavior observed in this year, i.e. it is calibrated. Conceptually, calibration is equivalent to the fitting of a regression equation to a set of data; the form of the equation is at first selected (linear, exponential, logarithmic, etc.) and one then proceeds to estimate the most appropriate coeficients given this basic form. Similarly, when a transport model is being calibrated the underlying form of the model is not changed but it is manipulated in various ways in order to get it to synthesize as closely as possible the observed data. Furthermore, in regression analysis one sometimes resorts to the inclusion of dummy variables to arrive at an equation which fits well the data. These dummy variables do not represent anything that can be measured quantitatively in cardinal form; they simply reflect that the underlying conditions changed and that such change must be recognized in order that the equation satisfactorily explain the dependent variable. The equivalents of dummy variables in the conventional transport model have no generally accepted name, but they are often invoked by transport planners. They help give the model an ability to reproduce existing behavior but (implicitly) they make predicting by means of the model a hazardous task; because nobody knows exactly what they represent, nobody knows exactly how their values might change in the future.

If any event, after the model is calibrated to the base year situation, it is then used to simulate travel behavior in hypothesized alternative situations normally envisioned as occuring at some future date. In order to specify an hypothesized situation, one has to characterize both the level of demand for travel and the supply conditions associated with it. The model is applied with the new demand and supply data as input and it produces a simulation of the way this demand and supply might interact, estimating, for instance, how much traffic will be likely to use each section of road, each rail link and each port.

The model also yields information which can be used to compare in economic terms one possible future state of the transport system with another. One of the items of information it outputs is the total cost of operation of the transport system in the different situations. In the simplest case, the difference between the cost of operation of one system, which may include, for instance a projected new highway connecting the capital city with a pole of development, and another, which incorporates no change from the present system, is a measure of the benefits to be derived from the construction of the projected highway. If the model is run for both systems in different years, i.e. for two supply conditions with two different levels of demand, one can estimate the savings in operating cost permitted by the new highway in two distinct points in time, from which a discounted stream of benefits can be estimated. By comparing the present value of this stream with the present value of the capital costs involved in constructing the highway, one can make an economic assessment of it.

A brief description of the model

There are a relatively large number of published texts which describe the standard transport model, although, for the most part they deal particularly with urban variants, which, as we have noted, concentrate on personal travel rather than freight movement. Some of these texts are available in Portuguese or Spanish. 1/ In these languages, the variants used in planning at the national level are adequately explained in some reports of national transportation studies conducted in the Latin American region. 2/ Also, CEPAL has published a report which summarizes the methodologies used in the national transportation studies of the Southern Cone of Latin America. The CEPAL report also indicates some of the failings of conventional transport models and indicates ways in which they might be improved. 3/

In the short description which follows reference is made to diagram 1. The different stages of the modeling procedure illustrated therein are identified in this description by using a simplified matrix notation, e.g. "calibrate distribution function" is referred to as stage or activity 4B, whilst the estimation of "user costs by mode between each pair of zones" in the base year is state 2C.

Column "A" refers to the demand side of the model and column "C" to the supply side. Column "B" deals with the interaction between supply and demand. The first stage on the demand side in the base year, 1A, is the specification, for each zone into which the country has been divided up, of the magnitude of these variables upon which transport demand is to be made dependent in the model. For instance, the volume of agricultural produce sent from each zone might be related to the area sown and yield of the different crops and, thus, these variables must be quantified for each zone. Similarly, the number of personal trips attracted to each zone might be related to the population of the zone and, possibly, the mean income level or another secondary variable; each of these would have to be quantified at the zonal level.

In stage 2A the amount of transportation generated by and attracted to each zone is quantified. the exact procedure used depends on the type of product or person trip and whether productions or attractions are being considered. In the case of agricultural crops, the amount generated might be calculated by multiplying the area sown by estimated yield and subtracting from the result the volume likely to be consumed locally (for each product separately). The amount attracted to each zone might be made dependent on variables such as population, milling capacities, port capacities, population and mean income, etc., according to the particular case. The number of person trips generated is usually determined by the application of trip rates to the population in the zone, (possibly categorized by income level) the rates being quantified from household interview surveys.

Over on the supply side, activity 1C amounts to the description of the existing transportation system in a form suitable for computer analysis. Each zone is represented by a "centroid" from which all trips are assumed to originate or terminate. These centroids are portrayed as being connected to highways, the railway system, etc. by imaginary "links" called "centroid connectors". The real transportation system itself is represented by a series of links, which denote parts of the road, rail or water transport network of common characteristics, and is known as a "network". Between any one link and the next is a node, which represent intersections, transhipment points, etc.

In stage 2C one calculates the minimum cost to the user (i.e. shipper or traveler) of moving from each zone to each other zone by each mode of transport. The relevant cost is the cost perceived by the user, which may differ from the amount he actually pays, due to, for instance, subjective dislike of shipment via a mode which involves many transhipments, each one of which can result in delay or loss, or, in the case of personal car transport, the probability that the user may not have a clear idea of exactly how much his trip costs. There are standard algorithms for calculating minimum zone-to-zone costs given appropriate unit costs for each link. Most transport studies at the national level estimate only the cost by the cheapest cost path between each pair of zones, although some studies, particularly urban ones, involve the estimation of the cost by closely competitive paths too. Both the minimum costs and the corresponding paths (i.e. the routes taken) are stored on computer disk or tape for use in later stages of the model.

They are used first of all in activity 3B, in which functions that explain modal split, or the proportion of the flow between different pairs of zones that use each mode, are calibrated. There are various ways of doing this. The simplest functions deal with the bimodal case and can be graphed as "S" shaped curves which determine what proportion of the traffic will use mode "a" rather than mode "b" as a function of the relative costs of these two modes. Other, more sophisticated, alternatives are described in various texts. 4/

It is also necessary to calibrate the distribution sub-model, stage 4B. The distribution sub-model is concerned with the estimation of origin - destination matrices, which tell how many trips are made between each pair of zones by all modes taken together. There are various ways of doing this. The most popular is the gravity model, which exists in various different guises in transportation planning. The gravity model makes the number of trips from an origin zone to each possible destination zone depend on, (i) the number of trips generated at the origin zone, (ii) the number of trips attracted to each destination zone, and, (iii) a function of the travel cost between the origin zone and each destination zone. In calibrating the gravity model, one has to estimate one or more parameters which govern the particular form of the travel cost function.

The final operation to be performed for the base year is the assignment of the trips to the network. This is really implicit in the previous stages, since one would have by now estimated the total number of trips between each pair of zones, the proportion of these which use each mode, and the minimum user cost paths between each pair of zones.

As we have already mentioned, the model calibrated to the base year situation is then applied to different alternative states of the transportation network in future years with different corresponding levels of demand. Essentially, the same activities described above for the base year are repeated for with the fundamental difference that those sub-models calibrated for the base year case are not calibrated for future years (which would be impossible) but rather applied in the calibrated form, using new input appropriate to the situation being analysed.

Stages 6A, 7A, 6C and 7C are repetitions of 1A, 2A, 1C, and 2C, respectively, with certain modifications to reflect that one is dealing with a future, unobserved, situation and not an existing, observed, one. In 6A, the demographic and economic variables have to projected and in 6C the future transportation network has to be specified, which involves, for instance, the estimation of prevailing travel speeds on the various links in the future network. For stage 7C assumptions have to be made regarding transportation costs and prices in the future, which is, obviously, a difficult task. Whilst some cost components, such as vehicle production cost or fuel costs, might be projected by economic analysis, other factors which influence user costs, such as railway freight rates and fuel taxes, require a knowledge of future transport sector policy. If one wishes to analyse, for instance, two alternative fuel tax rates, in effect one must specify two different states of the transport network, which requires two different runs of the transport model.

In stage 8B the modal split and distribution models, already calibrated, are applied. In 9B trips are assigned. 5/ This process is not as straight-forward in the analysis of a future, projected, network state as in the treatment of the base year situation. Since the operation of a future network cannot be observed, one can only make reasonable guesses as to what levels of efficiency the different links in the network would function at. For instance, one has to guess traffic speeds on (any) link "x". Having guessed these speeds (and similar speeds on other links) one calculates user costs (stage 7C) and runs the modal split, distribution, and assignment sub-models (stages 8B and 9B). Then, by comparing the amount of traffic assigned to link "x" (and all the other links) one may conclude that this volume is either too high, or too low, to be compatible with the speeds associated with it. One should then revise speeds on links such as "x" and repeat stages 7C, 8B and 9B until the resultant traffic flow, calculated by the model, is consistent with the speed associated with it (in stage 6C). This requires an iterative procedure, being necessary when congestion exists.. When it does not, it should be possible to estimate the correct link speeds in the first place (in stage 6C).6/

The final stage is the socio-economic evaluation of networks, 11B. For the evaluation, one network, or transportation system, is selected as the basis for comparison, this normally being the existing system. This is often called the "do nothing" alternative, because it involves no further development of the transportation system from its present state, although it is reasonable to assume that some minimum amount of expansion takes place if no investment at all in new capacity would result in intolerable congestion and bottlenecks. The other possible states of the system are compared with the do nothing alternative, by comparing the marginal benefits in relation to the latter alternative with the corresponding marginal investment costs. In this brief description no thorough explanation of the complexities of the economic evaluation of transportation networks is offered. The interested reader can refer to various texts. 7/

However, basically, the "do nothing" network and various alternative networks are examined by the transport model in two or more different years, with correspondingly different levels of demand. From the results for any one year one can calculate the amount by which transportation costs are lower with the particular alternative network being examined, compared with the do nothing alternative, plus any extra benefits generated by the larger network, due to, for instance, more trips taking place or trips being made by their preferred mode if the latter were so congested in the do nothing option that trips had to divert from it to other modes. These extra benefits represent changes in "consumer surplus". 8/ In this way one can estimate the benefits from the larger network in one particular year. If the benefits are also calculated for another year, by applying a discount rate to their estimated time stream, one can derive their present value, which can then be compared with the extra capital costs of the larger network over and above the do nothing alternative. In this way the returns from the marginal investment can be determined and the net worth of the larger network established.

Other models used in national transportation studies

The model outlined in the previous section of this annex is the one typically used in national transportation studies. However, apart from the many variants of what is basically the same model, some studies use different approaches. For instance some place reliance on optimization routines whilst other estimate flows per link directly without the aid of distribution and modal split sub-models, by trend analysis or by other means. We shall say very little about these other approaches in this annex, since space is limit optimizing models are called for.

The conventional model outlined in the previous section, involves little explicit optimization. Essentially, it attempts to estimate how the users of the transport system will adapt to the particular transport system being analysed recognizing that people either do not always behave optimally or that it is practically impossible to build a model which simulates optimizing behavior since either insufficient information is available or the resultant model would be too complicated. Nevertheless, some studies have attempted to use optimizing routines. Often optimizing sub-models are invoked to replace a non-optimizing sub-model whilst maintaining the overall structure of diagram 1. On the other hand, in the future, one may expect that transportation studies be conducted by a new category of model, currently in the relatively early stages of development, which combines the various sub-models described in the previous section into one, and which effectively simulates by constructing an equivalent optimizing problem, which is then solved by a suitable algorithm. 9/

Although it is not universally so, many optimizing sub-models used in national transportation studies are not calibrated. The transport planner who uses optimizing models accepts, explicitly or otherwise, that the users of the transport system do optimize and that the variables which are important in their process of optimization are considered in the model used. Hence, he accepts the results emitted by the model. One simple optimizing sub-model which is frequently used as part of the conventional transport model is the assignment procedure. Traffic is basically assigned to the cheapest path with little or no verification if users really do choose such a route.

An optimizing routine which has found various applications in transport modeling is the linear program. This has the practical advantages of being accessible, through widely available software packages and of being computationally efficient via appropriate solution algorithms. On the other hand, it has various compensatory disadvantages which rule it out for some potential applications; for instance, it produces a systems optimum, which, in some conditions, differs from the result of individual users each optimizing from their own particular viewpoints.

Linear programming is sometimes employed in trip distribution. In such usage the objective function, to be minimized, is the total transportation cost of the system, whilst the constraints ensure, respectively, that the sum of the trips from each origin zone to all destination zones equals the predetermined number of trips produced in the origin zone and that the sum of the trips to each destination zone from all origin zones equals the predetermined number of trips attracted in the destination zone. The use of linear programming in trip distribution is particularly appropriate when the product being dealt with is homogeneous in quality, for instance, hard wheat or steam coal, since in these cases consumers are likely to buy from the cheapest source, which would be the one from which transportation costs are lowest, if selling prices are the same everywhere. On the other hand, a gravity model might be preferable in the case of heterogeneous products, such as chemicals or machinery, where consumers might have to buy from distant zones in order to get the particular product they require.

In a few studies mathematical programming, of different kinds, has been employed, although, to date, such techniques are not yet common. In one recent study in the Southern Cone a dynamic programming routine was used in the evaluation phase. 10/ By such means the optimal investment program was identified by selecting from a set of projects specified as input each one of which was viable at the given discount rate, that sub-set which maximizes the present value of benefits, subject to a budget constraint for different periods throughout the planning horizon.

Another study conducted in the Southern Cone used a different type of optimizing model which replaced the modal split, assignment, and a large part of economic evaluation stages of the conventional model. The model accepts as input a list of possible investment projects, one each for various of the links in the network, and a budget constraint. The total cost of all the projects would exceed the budget constraint and the problem is to select that set of projects which would lower transportation costs the most, subject to the constraint. Basically, different networks are successively formulated within the model, each one comprising a different set of projects, and all of which must be consistent with the budget limitation. For each network an assignment is made (including modal split, since, in this particular application, a different mode was treated in the same way as a different route) and that network which results in the lowest transportation cost is selected. The model seeks to be as efficient as possible from the computational standpoint by eliminating from consideration those networks which stand no chance of reducing the transportation cost below the lowest previously attained. 11/ Even so it consumes relatively large amounts of computer time, even when the size of the problem posed has been reduced to possibly unrealistic proportions. The use of such optimizing models in national transportation planning, however, is steadily becoming more practical as computers become bigger and faster.

Notes for Annex

1/ See, for instance, (1) Planejamento dos Transportes Urbanos, por José Carlos Mello, Editora Campus, Rio de Janeiro, 1981. (2) Planificacion Analitica del Transporte por Powell, Lane, y Smith, Instituto de Estudios de Administración Local, Madrid, 1975. (This is a translation of an original in English).

2/ See, for instance, (1) Estudio Integral del Transporte en Bolivia.Informe final, Wilbur Smith y Assocs., etc., for the Government of Bolivia, La Paz, julio de 1981. (2) Plan Nacional de Transporte, Contrato VI, Demanda, Interacción oferta-demanda y evaluación, esquema del estudio, parte técnica, marco analitico del Estudio, Tomo 1, Dirección Nacional de Planeamiento de Transporte, Ministerio de Obras y Servicios Públicos, Buenos Aires, República Argentina, 1981.

3/ La Planificacion del Transporte en los Paises del Cono Sur: evaluacion comparativa de las metodologias aplicadas en cinco paises, E/CEPAL/R.287, Junio 1982.

4/ CEPAL, 1982, op.cit.

5/ The assignment model is not normally calibrated as such. However, in applying it to the base year condition, one may find that too much traffic is assigned to certain links. One may, therefore, increase user costs on such links, which increases can be forwarded to the analysis of future networks.

6/ Simpler, but less satisfactory, ways of dealing with congestion exist. See CEPAL, 1982, op.cit

7/ See, for instance, The economics of transport appraisal, by A.J. Harrison, Croom Helm, London, 1974.

8/ Consumer surplus is the difference between how much a consumer is willing to pay for a good or service and its price, being positive when the 'ormer exceeds the latter.

)/ See, for instance An equivalent optimization problem of combined ıulticlass distribution, assignment and modal split which obviates symmetry 'estrictions, by Terry L. Friesz, in Transportation Research, Series B, 'olume 15, 1981, Pergamon Press, Oxford, England.

.0/ See Determination of economically balanced highway expenditures programmes under budget constraints: a practical approach by Watanatada and Iarral, World Bank, presented at World Conference on transport research, ,ondon, England, April 1980.

.1/ See, La planificacion del transporte en los paises del Cono Sur; las ıetodologias aplicadas en Uruguay, E/CEPAL/R.287/Add.5, especially annex 1.