Transport Policy and Planning

An Integrated Analytical Approach

Brian Bayliss
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The model illustrated in Chapter 4 was developed by Dr. V. Calogero of PTRC, who provided the information on which the chapter is based and also greatly assisted the author in ensuring continuity with earlier chapters.
Introduction

In 1983 the Economic Development Institute (EDI) of the World Bank made three important decisions concerning its transport activities. First, it planned to shift the emphasis in these activities from teaching project analysis to helping countries strengthen their capability for policy analysis, formulation, and implementation. This decision sprang from a desire to make more efficient use of existing transport facilities, whatever their type. Many at the EDI had also come to think that policy appraisal should precede any infrastructure planning, in the form of project appraisal—a point that is explored in this text. Second, the EDI decided to incorporate policy analysis into its transport activities as much as possible. And, third, it would try to develop this new strategy by using microcomputers to simulate policy options and explore their complex interrelationships, as well as the relationship between each policy and its stated goals. Because these objectives encompassed national and local policy along with a wide range of policy alternatives, a comprehensive transport model seemed appropriate.

The purpose of this document is to demonstrate how such a model can be used to evaluate policies, to compare it with other kinds of models, and to examine the use of models in the wider context of policy objectives and instruments. Chapters 1 and 2 consider the relationship between policy objectives and instruments, Chapter 3 places transport models in the context of policymaking, and Chapter 4 demonstrates the use of a comprehensive model for testing policy strategies.
2 Introduction

This manual is intended for the policymaker who has little modeling expertise; it is designed to make the policymaker aware of the possible use of models in decisionmaking.
Objectives of Transport Policy and Planning

The transport sector functions within an economic and social framework established by the state as a basis for meeting its overall objectives for the national economy. All sectors and parts of the economy operate within this framework under the specific policies designed for each.

National economic objectives would include the optimum use of scarce resources, and in many countries the mechanism adopted to achieve this would be a market economy. In pursuit of this objective, the state introduces regulatory measures in each sector to ensure the correct working of the market (market regulation).

In addition, the state may wish to promote efficiency in the operations of transport providers and users (operations management) and in the movement of traffic on the infrastructure (traffic management).

However, the state will also have certain social objectives and will introduce policies designed to realize these objectives through constraints on the market. The state will stipulate, for example, health and safety conditions for workers, environmental conditions, and educational regulations. These social policies may be general in nature, and relate to the whole economy, or they may be tailored to individual sectors.

Rationale of the Market

In the simplest kind of economy where the individual is both the producer and consumer, the individual will decide both the level and the combination of products that must be produced in order to use
resources efficiently and achieve maximum consumer satisfaction given available resources. Here, the individual knows both the costs of resources and how to meet his/her needs. In more advanced economies where consumers are separated from producers and producers are separated from each other, some mechanism is needed to achieve the optimum combination of resource use and consumer satisfaction.

The basis of the market economy argument is that such an optimum allocation of resources will take place if prices are allowed to reflect real economic costs and consumers of both intermediate and final products make their choice on the basis of those prices—that is, if the consumer is made aware of the resource cost through the price. Before prices can reflect real economic costs, the market must be competitive and all economic costs must pass through the market so that they are represented in the prices faced by the consumer. Market regulation therefore has two basic aims: first, to ensure that the markets are competitive, and, second, to ensure that all economic costs pass through the market.

As major parts of the economy are interdependent, with various sectors competing for scarce resource, market distortion in one sector can therefore lead to distortions in others. In a sector such as transport, which impinges on much of the social and economic life of a nation, market distortions can lead to the misallocation of resources in many other sectors of the economy.

Another significant feature of the market economy is that information (market transparency) plays an obviously important role in the proper functioning of the market.

**Market Regulatory Policies**

The causes of market failure can be divided into three categories: (a) market power, (b) externalities, and (c) lack of transparency.

a. Market power is exploited to distort markets where suppliers of goods or services use it to obtain a price that does not reflect the true economic cost. This may occur where the supplier has a monopoly of a particular service or a certain type of transport infrastructure. It can also occur where suppliers group together to fix common prices or decide to divide the market among themselves (e.g., by region or by type of service) so as to individually monopolize market segments.

If, as a result of such practices, prices are in excess of the real economic costs, some would-be transport users will not avail
themselves of the service and transport will not pass, even though it would have done so had price reflected the real cost; whereas other customers may use the service but will as a consequence have fewer resources to use elsewhere, so that other markets will be underutilized (in economic optimizing terms).

b. Externalities occur when certain elements of cost are not governed by the market, for example, when the costs created by one economic agent do not fall upon him (and are thus not part of his decisionmaking), but must be borne by another economic agent (and thus be taken into account in his decisionmaking) even though he has not been responsible for them. This type of market failure occurs frequently in the transport sector as a result of accidents, pollution of all types, and congestion. Thus when a firm with a major own-account transport activity locates in an urban area, for example, the increased level of traffic ensuing from the decision will cause increased congestion on the road, thereby raising the costs of all other road users, and will similarly raise the levels of pollution for not only other road users but all others located in the vicinity. The costs passed on to others do not enter into the costs of the firm, even though they are related to its activities, and they are not reflected in the decisionmaking and price-setting policies of the firm.

c. Market transparency (information supply) is essential to the proper functioning of the markets. If consumers are not informed about prices, for example, they are not in a position to make an optimizing choice. Furthermore, particularly in services such as transport, information can be asymmetric because one of the two negotiating agents (the supplier of the service) will have greater information than the other. Although informed of the price of the service, the customer may have difficulty judging the quality of a service before having used it and thus where two services are equally priced might choose the one of lower quality, either through complete lack of information or through misleading or incorrect information provided by one of the service operators.

It is the task of the policymaker to identify the causes or potential causes of market failure and to devise policies that will eliminate them by regulating the market. The optimum
allocation of resources depends on being able to identify market failure and target a corrective policy.

**Operations Management Policies**

Although the state creates the framework in which the market can operate optimally, the optimum can only be achieved for any given situation. Thus it might be possible to improve the use of resources by improving management and operating practices. This could include changing the nature of the services offered or having operators improve their vehicle or wagon scheduling. Or it might mean shippers changing their perception of transport from an isolated activity to part of a logistic chain involving purchasing, distribution, and sales.

Where operations are carried out through state organizations or parastatals, the state has direct responsibility for introducing such practices. Where operations are the responsibility of the private sector, it should be the policy of the state to promote good operating practices.

**Traffic Management Policies**

The objective of traffic management is to make the best use of existing infrastructure facilities. This cannot be achieved without physical controls on the use of that infrastructure to produce benefits such as shorter journey times, fewer accidents, and less environmental damage in exchange for relatively low implementation costs. Although the costs may sometimes include limited new works and improvements, the benefits can be substantial.

Such traffic management measures include signaling, junction and crossing controls, bus priority schemes, designated lorry routes, and road signs and markings.

The idea of giving infrastructure a specialized role is particularly important to consider in countries suffering from a lack of resources and illustrates a vital link between traffic management and infrastructure planning. Here, the basic question for the policymaker and the planner is whether all infrastructure such as ports, roads, rail, and airports should be required and equipped to carry all types of traffic or whether specialized (and expensive) facilities should be concentrated in key locations to provide better overall efficiency. The answer often depends on modal coordination and the role of individual modes. Examples of such facilities are lorry routes; specialized ports (containers, grain, passenger); the regional, national, or international role of airports, motorways, and ports; and nodes of modal interchange (bus-rail, rail-air, sea-rail).
Before a specialized role can be established for infrastructure, traffic management must be coordinated with national or regional master plans, which can be either multimodal or single mode. Furthermore, infrastructure planning and traffic management sometimes need to be coordinated with operations management. For example, given the existing networks, services can be designed in accordance with the "geography" of the system to improve capacity utilization. The basic elements to be considered for these services are routes; points of loading, unloading, and interchange along these routes; service frequency; and vehicle types to be assigned to each service leg.

Figures 1.1 and 1.2 provide an example of the type of service configuration that might be applied to a policy issue. In the configuration in Figure 1.1, the policymaking body allows services to grow on routes that have high levels of traffic (e.g., legs FB, BEDA, AC) and the body possibly subsidizes "slow services" (several stops) for points where demand is low (e.g., MLKJB, AGHI). This requires several service interchanges and intermediate stops for movements between starting points and destinations such as HL.

**Figure 1.1** Routes and Services with Many Intermediate Stops

![Diagram showing routes and services with many intermediate stops](image)
An alternative policy is to regulate the system toward the solution of Figure 1.2 (hub-and-spoke configuration). In this case, larger and faster vehicles can be used on frequent direct services between A and B; smaller services can be used on the spokes such as EB, MB, LB, and IA, HA, and so on; local enterprises in E, M, L, ... I, H, G, ... can be encouraged to provide the required services to link their zone with the nearest hub; and major transport "stations" (e.g., bus or rail stations, airports) are developed at A,B, possibly with the aid of public sector investment. Once the transport policy is established, the necessary regulatory instruments can easily be derived from it, at least in principle.

Infrastructure planning decisions and policy formulation of the three types (market regulation, operations management, traffic management) are interdependent in this case and must be fully coordinated by the decisionmaking body.

Social Policies

The social objectives of the state pertain to the general well-being of a country and therefore cover such areas as income distribution,
health, welfare, cultural activities and leisure, environmental conditions, and education.

The policies introduced to achieve these aims create constraints on the regulated market.

Policy and Infrastructure Planning

The function of policy is to achieve the optimum use of resources within the constraints of a social framework determined by the state. An integral part of this task is infrastructure planning. Poorly planned investment can distort markets in the same way as the exploitation of monopoly power by a transport operator.

Because the sectors within an economy are interdependent, incorrect investment in one sector leads to the misallocation of resources in others. Suppose that the state invests in a factory producing good A in region Z, thereby reducing its production costs and consequently increasing demand for its product as a result of lower prices. This will lead to an expansion of output in sectors providing inputs to good A and also in sectors using good A if it is an intermediate product. Activity in region Z will thus expand, and this will extend to the transport services in that region.

Ideally, a state's global planning must set priorities based on socio-economic rates of return on investment opportunities, both between sectors and within sectors. Also, infrastructure planning and policy are interdependent. When pricing is incorrect, some part of the transport infrastructure will be either over- or underutilized with regard to economic efficiency, and any resulting investment decision—whether to invest or not to invest, or what scale of investment to pursue—may be adversely affected.

Summary and Conclusions

1. The economic objective of the state is to make the best use of scarce resources.
2. The optimum allocation of resources is achieved through the market.
3. The aim of economic policy is to ensure that the market works as efficiently as possible, both with respect to the use of existing capacity and to the extension of infrastructure and mobile capacity.
4. In general, economic policy has four transport objectives:
   a. to regulate the market in order to remove market distortions,
Scale of Investment and Pricing

On the assumption that "normal" profit is incorporated in the cost curve, any profit over and above this can be considered a producer surplus. At the same time, consumers will frequently be prepared to pay more than they actually pay for a good or service, and this difference can be called consumer surplus.

Therefore, two alternative pricing strategies might be to set prices so as to maximize producer surplus or to set prices so as to maximize consumer surplus. In the former, prices would be set so that the marginal costs of production and marginal revenues are equal; in the latter price would equal average costs.

If investment decisions are made with a view to maximizing profit, the subsequent pricing should also be based on that criterion in order to avoid errors in the scale in investment. This is illustrated below, where $AC$ = average cost, $LAC$ = long-run average cost, $LMC$ = long-run marginal cost, $AR$ = average revenue, and $MR$ = marginal revenue.

It is assumed there are two schemes for modernizing a rail station—one (AC1) is the most profitable for an expected throughput of 1,500 to 2,750 passengers. The other (AC2) is the most profitable for 2,250 to 3,500 passengers. If the planners were to build the former because it seems indicated by a policy of profit maximization and then shift to an average-cost pricing policy, roughly 2,600 passengers would use it at a price (average cost) of \( p_3 \); and that would maximize the consumer surplus less than if a station represented by (AC2) were built such that 3,000 passengers would use it at a price (average cost) of \( p_1 \).

b. to see that operations are managed in a way that ensures operators and users will act efficiently,

c. to see that traffic is managed in a way that ensures the best use of infrastructure,

d. to coordinate policies and infrastructure planning.

5. The causes of market failure are:

a. Market power

b. Externalities

c. Lack of transparency.

6. The social objectives of the state are realized through social policies, and these form the framework of constraint in which the market functions.

7. Policy and infrastructure planning are interdependent, as are the different types of policy (which may pertain to market regulation, operations management, traffic management, and so on).
Decisionmakers and Policy Instruments

The Decisionmakers

Chapter 1 stressed the interdependence of the entire economic and social structure. What this means is that all the policy and planning decisions made in the numerous departments at national, regional, and local levels must be carefully coordinated if the policy process is to yield optimum results. For the transport sector, it will be particularly important to cooperate with departments responsible for land use and the environment. Otherwise, serious errors may enter into both policy and planning.

Within the transport sector itself, most of the policymaking will occur in a single department at the national level, but many decisions relating to infrastructure planning, especially with respect to road infrastructure (including ancillary facilities such as services and parking), will also be made at the regional and local levels, and, as already pointed out, when infrastructure planning and the policy process are poorly coordinated, inappropriate decisions may be made.

Chapter 1 also emphasized that the state can make an important contribution to operations and traffic management. Where transport operations and traffic management are the direct responsibility of the state, state-owned organizations or parastatals acting as agents of the state are directly responsible for deciding how to make the best use of existing capacity. Where transport operations, on both the supply and demand sides, are in the private sector, the state must ensure that private sector decisionmakers have the technical ability to make optimum use of their capacity.
Policy Instruments

As pointed out in Chapter 1, transport policy attempts to make the best use of resources by equating prices and real costs and by encouraging efficiency among transport providers (both operators and traffic managers) and users. To achieve these ends, transport policy devises methods of regulating the market, managing operations, and managing traffic. Social policy acts as a constraint on the market and sometimes impinges directly on the transport sector, and sometimes indirectly. The instruments of market regulation, operations management, traffic management, and social policies are discussed below.

Market Regulation Instruments

The purpose of market regulation is to remove market distortions so that effective competition will allow prices to match real costs. Since the state itself is a major participant in the market through its provision of infrastructure, it must take care, both in planning and charging for that infrastructure, not to distort the market. And if prices should for some reason become distorted, the state must base its policies on shadow prices, that is, prices that reflect real costs, rather than market prices. Distortions may occur, for example, when exchange rates do not reflect the scarcity of foreign exchange to a developing country, or when a scarce resource such as energy is underpriced in the market in the sense that its price does not reflect its real cost. The shadow price is therefore a market regulatory instrument.

These shadow prices can sometimes be directly translated into the marketplace when infrastructure is being planned, in that they can be used in the evaluation of such plans. But in many instances shadow prices cannot be used directly and may have to be substituted by physical controls such as foreign exchange controls and import quotas. Such physical controls are market regulatory instruments.

Physical controls cannot directly replace correct pricing, however, as it is impossible to gauge how much control would achieve exactly the same result. The longer-term aim must be to see that the price mechanism works properly.

Market Power. Both transport operators and owners of transport infrastructure might exercise market power thereby distorting the price mechanism. A regional bus service might be in such a position when the costs of entry form an effective barrier to entry, as might the owners of a bus station in an urban area when suitable alternative sites are not available for competitors.
If the state is unable to restore competition by breaking up a monopoly, it may have to impose price and service regulations to establish conditions that would have existed in a free market. It is important, therefore, for the state to have a range of instruments to prevent, break-up and control monopoly.

EXTERNALITIES. Externalities are common in the transport sector and include congestion, accidents, air pollution, noise, and vibration.

The related costs could be internalized by requiring the transport mode imposing these costs to pay for them. Where the externality does not exist in the case of a competing mode, one might subsidize such a substitute provider of services. In the case of road congestion, for instance, road pricing would pass on the cost of congestion to the road user and demand would fall; a similar fall in road traffic might also be achieved if the substitute mode rail were subsidized. The subsidy, therefore, acts in this instance as a regulatory instrument.

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**Congestion Costs**

As noted earlier, if the market is to function correctly, prices must equal the real costs. In a congested network, however, prices will be below real costs unless an administrative authority adjusts the prices accordingly.

The cost of traveling the length of a specific link of the road network is composed of vehicle cost and time costs. Under the simplifying assumption that everyone has similar vehicle and time costs, the cost per car traveler in the absence of congestion is estimated at $10 in the example below.

Up to three cars can travel the link without congestion, the cost per car is $10, and the total cost of all cars $30. When the number of cars increases to four, congestion occurs, the cost per car rises to $11 (owing to increased journey time), and the total cost of all cars to $44. The increase in total cost is thus $14, which means that the real cost of this last (marginal) car is $14. Costs will continue to rise as congestion increases, as shown in the table below, where $TC = $total cost, $AC = $average cost and $MC = $marginal cost.
This means that the fourth and fifth cars, which pay on the basis of average costs, pay less than the real cost of the journey, with the result that more journeys will be undertaken than would have been the case had these car drivers been required to pay the real cost. This is demonstrated in the figure below, where $D$ equals the level of demand at different costs of travel.

Given the assumed shape of the demand curve, five cars travel at a price (cost) of $12, whereas if the real cost (marginal cost) had been charged, the number of cars traveling would have been four at $14.

This malfunctioning of the market can be corrected through a congestion tax ($ab$) equal to $3$. 

This concept of the subsidy can also be applied within a single mode. Thus, in the case of exhaust pollution caused by cars, instead of increasing the tax on motoring, the state can reduce taxes for those users whose cars have catalytic converters or who use lead-free fuel. Here the state is indicating that it would rather get rid of (or at least
substantially reduce) the externality than ask the user to pay for it through higher tax, and it is in this area that the interrelationship between pricing and physical control instruments is pertinent.

In the case of the environmental damage and pollution caused by trucks, the state can internalize these costs through taxation. Although this is the policy generally pursued, a limit is usually placed on the size of vehicles. In other words, the environmental policy of the state has created a physical constraint in which the road freight market must operate.

The state could also internalize accident costs by making transport operators pay for them; such a policy would force certain transport operators to take steps to reduce accidents through careful driving and maintenance of vehicles, but others would take no such measures. Or the state could still force the transport industry to pay for accidents through the legal process but at the same time attempt to reduce the total number of accidents through physical controls relating to speed, vehicle maintenance, and driver efficiency (in terms of both proficiency and maximum driving hours).

Physical control instruments could be expanded even further in order to enforce environmental and other social policies, and abandon any concept of economic pricing. For example, large vehicles could be restricted to designated routes, absolute quotas could be placed on the number of vehicles allowed on the roads, or vehicle operation could be confined to certain times of the day or week. This type of policy is discussed in the section below on social policies. Note, however, that because of the difficulties of implementing some pricing policies (e.g., congestion pricing), the state might use traffic management policies in their place (e.g., by restricting traffic or diverting it to less congested routes that are cheaper in real terms but more expensive to a user not currently paying for congestion).

TRANSPARENCY. In general the public knows little about the tariffs of competing modes or what it costs to operate their own cars. Various studies have demonstrated that shippers, too, know little about both the costs of alternative modes (i.e., modes they do not use) and the costs of operating their own vehicles.

Information on tariffs and training can play a vital role here, and the importance of training can be reinforced through qualification requirements. In the case of asymmetric information, for example, when the shipper or traveler is poorly informed about the quality of services being offered, the state can insist on a minimum standard of service from the transport provider with respect to qualifications, financing, or other aspects of service.
**Operations Management Instruments**

Even if the market is both transparent and free of distortions, the optimum use of both fixed and mobile capacity will only be achieved if providers manage their services in an efficient manner. The railway administration must decide on the appropriate lengths of trains and frequency of services, for example, and the road hauler must know how to schedule his vehicles to maximize their use. Two instruments the state can use to improve the efficiency of operations are training and stipulated qualifications.

The users of transport services should be concerned with efficiency as well. They should treat distribution, for instance, as part of a chain involving both purchasing and marketing, and should not view it in isolation.

Although the state cannot insist that personnel in the private sector have specific training and qualifications, it can do so in organizations directly or indirectly under its control and can encourage such standards in the private sector.

**Traffic Management Instruments**

As mentioned earlier, traffic management policies are aimed at improving the use of existing transport networks. The instruments used for this purpose—such as signaling, road marking, and junction layouts—pertain to the physical characteristics of the infrastructure and are the direct responsibility of the state. Sometimes traffic management can make improvements on its own, whereas at others it is best combined with operations management or infrastructure investment. The following three examples illustrate that substantial benefits can be achieved with limited capital outlay and that expensive infrastructure projects can be delayed or even rejected.

First, Bangkok created special bus lanes and found that car or bus times did not deteriorate on any roads. In the most successful areas, bus and car mean travel times were reduced by 25 to 30 percent (see Appendix 1, Case Study 1).

Second, Porto Alegre introduced not only bus lanes, but also a bus convoy system in which buses are coordinated and formed into convoys at the beginning of a corridor. The system resulted in 20 percent higher bus speeds and corresponding fuel savings (see Appendix 1, Case Study 2).

Third, infrastructure investment was combined with both traffic and operations management in Abidjan and included, among other things, the construction of a bus depot and primary roads, integrated traffic
signals, bus lanes, and a high-speed express bus network. As a result, bus running times were cut in half, even though rush-hour traffic increased by about a quarter (see Appendix 1, Case Study 3).

Social Policy Instruments

The constraints that the state imposes on the market are part of its social policies. These policies may be of a general nature in that they affect all sectors of the economy, such as conditions of employment, or they may be specific to the transport sector (such as regulation of drivers' hours).

In some instances the constraint on the market will be absolute in that the market is not allowed to function at all, whereas in other instances the constraint will be partial. In its environmental policy, a state may ban vehicles from certain areas of towns, restrict large vehicles to designated routes, place absolute quotas on the number of freight vehicles, or confine vehicle operation to certain times of the day or week.

In other cases there is no absolute restriction on operations but constraints are introduced. In the case of accidents, the state may not permit the market to determine the level of accidents but will insist on certain safety measures to restrict their number.

In many instances the state uses the transport sector as an instrument to pursue social and other policies. In such cases it relies on physical controls to manipulate the transport market. Freight operators may be required to carry certain classes of goods or export traffic at below cost; similarly, passenger operators may be required to carry certain classes of passengers at less than cost; and regional policy may require both passenger and freight movements to specified regions of a country to be below cost. In order to pursue such policies, dirigist measures are introduced to control official tariffs, licensing, and subsidies.

Such policies distort the operation of the market and lead to inefficiency. States argue, however, that the benefits accruing to, for example, poorer regions, exports, and certain classes of traveler will offset the increased costs occurring in the transport sector through the resulting market distortion.

When certain regional, social, and other policies are adopted, it is generally more efficient to assist the relevant target (e.g., region, passengers) directly rather than indirectly through the transport sector. Direct assistance to a low-income group, say, will enable the group to make its own choices between modes of transport, or
between transport and other alternatives outside the transport sector. This approach will not create distortions between modes within the transport sector or between transport and other sectors.

Similarly, if an industry in a particular region is to be given assistance, direct assistance will enable the industry to choose between transport modes for itself rather than being directed to a particular mode by the state. In this way, trade-offs can be made between transport and other functions within the industry.

At times, however—particularly in a sparsely populated rural area—a transport service will not result from the normal functioning of the market. Where this is due to the lack of infrastructure the necessary infrastructure will have to be provided by the state if it is pertinent to social policy; in other cases, the state may have to provide the service itself (e.g., a school or hospital service).

Short- Versus Long-run Policy and Infrastructure Planning

Another situation in which services may not arise from the normal operations of the market occurs when the returns on investment are only likely to be realized over a very long period. These returns may be considerable when related to the opening up and development of outlying inland regions or peripheral coastal regions, but may take so long to accrue that the private sector may not wish to participate in the development. In such instances, the state may have to invest, not because of social policy but because of the inability of the market to take a long-run position.

Enforcement of Policies

Policies are effective, of course, only if they are enforced. Surveys in both developing and industrialized countries have shown enforcement to be very lax in certain areas of traffic regulation. In the European Communities, drivers' hours are adequately enforced in only two of the twelve countries. Furthermore, in a number of developing countries 45 to 95 percent of all loaded trucks tend to be overloaded, frequently by substantial amounts.

Overloading can have serious repercussions on safety policies and on infrastructure planning. In certain developing countries, overloading has caused severe deterioration of pavements and bridge decks. In one country it was estimated that more than 120 highway structures were seriously damaged, and sections of freeways had 25 to 45 millimeters of deep rutting after less than two years of exposure to traffic. In view of such cases, infrastructure planning appraisals should be based on actual loadings rather than legal loadings. These
experiences clearly demonstrate the close interrelationship between policy and infrastructure planning.

Even traffic management has its enforcement problems. In the case of the bus scheme cited earlier, one-fifth of the vehicles in priority bus lanes were found to be illegal vehicles. Improved enforcement would have increased the benefits of the scheme (see Appendix 1, Case Study 1).

When deciding on a policy, the state must make sure that it will be able to enforce that policy. If a number of instruments is available to carry out the policy, it may be preferable to choose an inferior instrument when such an instrument ensures greater reinforcement.

Summary and Conclusions

a. The kinds of policy instruments available in the transport field are summarized in the following table.

<table>
<thead>
<tr>
<th>Policy Category</th>
<th>Rationale</th>
<th>Target</th>
<th>Policy Instruments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pricing</td>
<td>Prices equal to real costs to ensure optimum allocation of resources</td>
<td>Overall market</td>
<td>Infrastructure charges; taxation; subsidies; shadow pricing</td>
</tr>
<tr>
<td>Market</td>
<td>Removal of market distortions</td>
<td>Market power</td>
<td>Monopoly and merger regulations; tariff regulations</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Externalities</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Physical controls; pricing; taxation; subsidies</td>
</tr>
<tr>
<td>Transparency</td>
<td></td>
<td></td>
<td>Transparency controls; information provision</td>
</tr>
<tr>
<td>Operations management</td>
<td>Improved use of mobile equipment</td>
<td>Transport operators</td>
<td>Operator quality controls; training</td>
</tr>
<tr>
<td>Traffic management</td>
<td>Improved use of existing infrastructure</td>
<td>Network users</td>
<td>Physical controls relating to infrastructure use</td>
</tr>
</tbody>
</table>
b. Operations and traffic management policies can yield high returns for a relatively small financial outlay.

c. Where physical controls are used to place a constraint on the functioning of the market in pursuit of a goal external to that market (e.g., social policy), the costs of such a policy should be recognized.

d. A policy is only effective if it is enforced; the choice of policy instrument should therefore be considered in relation to its enforcement potential.

Notes
3. Ibid.
Policy Issues and Simulation Models

Three important themes emerge from the discussion in Chapters 1 and 2:

1. Policy and infrastructure planning are interdependent. Planning decisions pertaining to infrastructure must be made within a known policy framework.

2. The policy must be appropriate to ensure the efficient use of infrastructure and mobile equipment.

3. Transport policy can be divided into three broad types relating to market regulation, operations management, and traffic management.

In the view of the World Bank, the first concern of transport policy would be to improve the use of present transport capacity, before considering investing in new infrastructure. That philosophy is particularly appropriate for developing countries, which would benefit greatly from the savings on scarce resources such as energy, skilled labor, and mobile equipment. These savings would afford relatively higher returns than in industrialized countries. Also the scope for improved capacity utilization would be greater than it is in a highly developed transport system.

The success of a policy depends on other factors as well: accurate diagnosis of the problem, proper choice of policy, effective means of implementation, and adequate enforcement. These are far from simple tasks because of the complex interrelationships between sectors, regions, infrastructure planning, and policy; and they are particularly difficult for developing countries.
For one thing, these countries seldom have the necessary data to develop and prosecute such policies successfully, a problem compounded by the rapid changes they are experiencing. Not only are their populations growing fast, but urban migration is ever increasing, and agricultural and industrial output witness substantial variations between years on account of weather, foreign exchange shortages, and the prices of both imports and exports.

The complexity of the policy and planning processes has led the World Bank to encourage countries to use microcomputer-based simulation models as an aid to policymaking. Although such models have long been in use in infrastructure planning, they are more recently beginning to play a role in evaluating policy alternatives. Computer models have two important applications in the assessment of transport policy: first, to evaluate policy targets under consideration by policymakers, and, second, to simulate the effects of alternative instruments that could be employed to realize the policy targets.

Models do not themselves produce targets or suggest which instruments to use to achieve such targets. The policymaker must suggest both targets and instruments on the basis of experience and existing evidence. The alternative suggestions must be formulated as scenarios (forecasts) and strategies, which are then introduced into the model together with data on the current situation. This detailed picture of tentative targets and proposed instruments represents the alternative policies to be tested. Model outputs then provide an evaluation of the operational, economic, financial, or environmental aspects of a given strategy, which are used to determine the desirable targets and the most appropriate instruments for achieving these targets.

Transport Models

The earliest model to be applied to transport issues is the four-stage model, and it is the one most widely used after more than 30 years. In this conventional model, it is assumed that the traveler or shipper arrives at a decision in four stages: (1) the traveler decides whether to make a trip or the shipper decides whether to send a consignment; (2) they identify the destination; (3) they decide on the mode of transport to be used; and (4) they identify the actual route to be taken.

Except in specific cases it is generally not possible for the policymaker to take into account every freight shipment and every journey; assessments must be based on average freight and passenger flows. Thus in the conventional model, the analysis is based on flows between specified zones or regions rather than individual trips or shipments.
The policymaker would like to know how the total flow and the nature of the flow will be affected by changes in policy or infrastructure. When considering new infrastructure or traffic management procedures, the planner will try to determine what savings in journey time can be expected and how many people will benefit from them. If the target is to save energy, the policymaker will need to know the likely effect of any policy instrument used on the level of energy saved and on the total costs and flow of traffic.

The four stages of the conventional model are as follows: (1) the traffic generated (and attracted) by each zone is modeled (Trip Generation); (2) the traffic generated by each zone is distributed between the zones (Trip Distribution); (3) the interzonal flows are allocated to the different modes of transport (Modal Split); and (4) the interzonal flows by mode are assigned to the actual network (Trip Assignment). Freight and passenger traffic is modeled separately.

Travel or shipper behavior at each of the four decision stages is analyzed by introducing into the model all factors affecting the decision and related information.

Following are some of the important factors in each stage of modeling passenger transport:

**Trip generation and attraction:** Number and size of households; number, size, and types of firms; car ownership; age distribution; income; retail outlets; leisure facilities; schools.

**Trip distribution:** A measure of zonal separation usually related to journey time and cost; a zonal adjustment factor to cover socioeconomic factors not accounted for in the model (e.g., some zones will be much more attractive to certain types of people—who are frequently grouped by zone—than to others).

**Modal split:** Factors based on characteristics of the journey (e.g., time of day, length); the traveler (e.g., income, car ownership); or the competing modes (e.g., cost, frequency, journey time).

**Assignment:** Trips between specific zones and by a specific mode are assigned to the actual network on the basis of minimum cost and time of the
journey, or on some probability distribution of trip choice relating to cost and time.

The foregoing details indicate that the conventional four-stage model oversimplifies travel behavior and requires a great deal of data. In an effort to improve the basic form of the model, some analysts have integrated land-use models into the transport model, along with disaggregated models, household activity analysis (HATS), travel budget models, direct demand models, and dynamic models. However, these models have their own problems, as indicated below.

Clearly, transport and land use are closely associated. Thus, a new policy or infrastructure project could increase journey speeds: in the short run, this will lead to new sources of supply and markets for firms and to changes in shopping and recreational destinations for households; in the long term, the location of houses, retail outlets, and factories will be affected. The result of these activities will feed back into the transport system and thereby set off a new phase of readjustment. Integrated transport and land-use models can take into account this feedback, but they require accurate forecasting and abundant data.

Although disaggregation has allowed analysts to take a more behavioral approach, the consistency of the relationship patterns achieved at the zonal level have been difficult to achieve at the household level; furthermore, the intricate analysis involved in HATS has limited its application in practical policymaking.

Although the conventional model has been fairly accurate in replicating contemporary traffic flows in industrialized countries, shocks such as the various oil crises and the introduction of the birth control pill, which changed both household composition and behavior, have resulted in inaccurate forecasts.

The inadequacies of these models for situations in the industrialized world are compounded when they are applied in developing countries. In particular, rates of growth and change are much faster there than in industrialized countries, data are more difficult to obtain, and cultural and social factors may rule out household surveys and lead to different travel behavior. In Daka, the capital of Qatar, for example, a very low correlation exists between vehicle ownership, trip rates, and household income, whereas in industrialized countries income tends to be the dominant factor affecting both ownership and trip rate.2

The form of the transport network—a basic element of the transport model—can also differ greatly in the urban and rural environments in industrialized and developing countries. The central
part of urban areas in many developing countries is made up of narrow streets constructed before the age of mechanized transport. In rural areas there are three important factors to consider. First, these areas usually have extensive networks of tracks that offer a multiplicity of routes but that are difficult to survey and incorporate into a model network. Second, if there is a limited main road network, any extension of it can change accessibility greatly, can alter trip distribution, and generate high levels of traffic. And third, there may be a high latent demand for transport services because the original networks, built to suit colonial needs, do not necessarily correspond to the current population distribution and economic activity.

Finally, industrialized countries with well-developed transport systems may not be able to improve the utilization of the existing infrastructure and mobile equipment to any extent, whereas developing countries can still achieve substantial gains. Moreover, the policymaker in such countries may not be faced with the problem of long-range forecasts in a rapidly changing economy and society.

In sum, the conventional transport models have not been too successful in the industrialized world, and, on account of specification and data requirements, they are unsuitable for the developing world. Therefore, the emphasis here is on a range of simplified models geared to the needs of developing countries. It is clear, however, that policy models, as opposed to infrastructure planning models, offer a great deal in that the data requirements are fewer, long-term forecasting is not necessarily required, and the benefits may be substantial.

Common Features of Policy and Planning Models

Models may be classified according to their technical attributes, which, although of interest to researchers, are of less value to policymakers than a classification based on the intended application, for example: national, regional, local, chain; urban, interurban, rural; policymaking or infrastructure planning; and single-mode or multimodal.

Various categories of model may have the same basic concepts and stages of application, even though the object of the analysis may be quite different. This is illustrated in Figure 3.1, which is based on the following two examples:

A. Feasibility study for a new road, XY—planning application

B. Improved system of taxation (T) and fuel prices (P)—a policy application.
Figure 3.1. Context and Stages of Transport Models

Common procedures for two example cases:

**A:** feasibility study for a new road *XY*

**B:** improved system of taxation, *T*, and fuel prices, *P*.

1. **Study of Present Situation**
   - Networks, OD flow matrices, zonal data, costs, etc.

2. **Creative Planning, Proposals, Targets, Strategies**
   - **A:** alternative route locations/alignments for *XY*
   - **B:** alternative tax and fuel price structures *TP*

3. **Simulations and Forecasts by Models**
   - **A:** traffic on routes (*XY* and existing roads)
   - **B:** totals of travel (pax kilometers, ton kilometers) by mode, by vehicle type, distance range, and so on.

4. **Operational, Economic, Financial, Environmental Analyses by Models**
   - **A:** speeds, user costs/benefits, pollution, etc. for various links (*XY* and others)
   - **B:** consumptions of fuel, costs, tax revenues as national totals, by mode, type of vehicle, etc., for given *T, P*.

5. **Public Participation**
   - (Usual practice in the case of A)

6. **Decisions**

7. **Implementation**

Figure 3.2 shows a preliminary work phase that is usually necessary in order to adapt the formulas and parameters in the mathematical models to the specific situation to be modeled, that is, to the present-day ("base-year") data available. This phase of the work ("calibration") is applicable to a variety of models, for which the structure and content of "Data Base" shown in Figure 3.2 will be different (for example, data on national long-distance travel will be needed in one case, whereas data on urban movements and services will be required in another).
Figure 3.2. Preliminary Work Phase ("Calibration") before Planning Use of Models

Figure 3.3 shows the model application to policy/planning/project studies, which becomes possible only after calibration. In this phase, a new data base is created by the model for the future year ("design year") of interest, by applying the forecast models to the data base previously assembled and "refined" for the base year.

Figures 3.2 and 3.3 illustrate a modern approach to developing and using transport data bases in transport models. This approach allows planners and policymakers to make a variety of calculations and tabulations from the data assembled for the model, and also from data bases that are external to, and independent of, the model. This approach is particularly valuable when the relevant data base is kept up to date by the policy/planning agency, which can then continue to benefit from model reruns and data base processes after the more formal transport study has been completed.
Urban versus Long-Distance Travel Models

Urban models deal with movements within towns and with daily commuter movements to and from a town. These models consist of two main types:

- traffic models: the “assignment of traffic to links” is the main element to be studied in connection with, for example, junctions, queues, traffic lights, and parking
- transport models: new infrastructure, services, modal choice, and modal interchanges (e.g., stations, airports) are studied in addition to the elements contained in the traffic studies.

The World Bank has been primarily interested in interurban traffic, because the central government is the chief decisionmaker in this area and thus has a greater range of policy instruments under its control. The emphasis in this report is also on interurban models, although Appendix 2 does include a detailed analysis of urban models.

These interurban models can be classified into the following types:
• National-level models: These include international movements, and they are particularly relevant in cases of sustained economic growth (as in China, the Republic of Korea, and Thailand); priorities need to be established on a national basis as bottlenecks can be countrywide.

• Regional-level models: These are similar to national-level models but are smaller in geographic scope.

• Corridor studies: These normally consider all transport demand and supply between two towns and, although relevant in all instances of bottlenecks between two towns, they can be particularly important in relation to foreign trade when one of the towns is a port (for example, the "export corridor" established by the Brazilian government; see Appendix 2 for more details).

• Rural studies: These cover traffic movements and facilities that can affect a specific project location (e.g., a proposed new road or improved rural road).

• Commodity studies: Such studies are concerned with the flows and handling of a particular commodity or group of commodities (they are particularly valuable where the distribution of a key product such as fertilizer is hampered by operational rather than infrastructural problems; see Appendix 2 for a more detailed discussion).

Policy versus Planning Models

Planning (infrastructure) models are usually used in feasibility studies of new investment and at any of the levels discussed above, with two objectives:
To determine the traffic on new and old links in order to calculate user cost savings and other investment evaluation parameters (e.g., effects on pollution).

To determine traffic on a new link in order to design its main geometric elements (e.g., speed, capacity, cross section, junctions).

This type of model must provide traffic estimates on specific links that are as accurate as possible and consequently requires both accurate and extensive data. The use of this type of model is illustrated in Figure 3.4, while Figure 3.5 gives details of the economic appraisal procedure made possible by the model.

Figure 3.4. Objectives of Model Uses for Infrastructure Projects (Feasibility Studies)

- Choice of corridor and/or alignment
- Choice of cross sections
- Choice of speed/capacity
- Location and type of junctions/terminus
- Heavy/through traffic versus urban centers
- Evaluation of costs/benefits over 30 years
- Priority scores.

In contrast, policy models require less accurate and less detailed data, since they do not need to represent flows on links accurately. Their objective is to represent passenger kilometers and/or ton kilometers under different assumptions (e.g., by modes, vehicle types, and zonal or regional origins and destinations) and to analyze them in terms of several derived parameters (e.g., fuel consumption, total costs, and revenues). Such models must be sensitive to the policy issues to be studied and must represent the network, services, zones, and other
Figure 3.5. Details of Model Use for the Economic Evaluation of Infrastructure Projects

![Diagram showing the economic evaluation model]

\[ \text{Construction cost of new (or improved) infrastructure} \quad C \]

\[ \text{User benefits} = \text{reduction in user cost from new infrastructure} \quad R = E - N \]

\[ \text{User cost on existing network, discounted over project life} \quad E \]

\[ \text{User cost on improved network discounted over project life} \quad N \]

\[ \text{Economic criterion for project appraisal} \quad R - C = \text{Net present value} \]

Note: Adapted from the COBA Model of the Department of Transport (London.)

Important factors in a way that makes possible this necessary sensitivity. The issues involved may be

- national objectives and the effects of transport on development
- desirable target networks for future accessibility and other regional issues
- effect of future transport technology
- transport finance, taxation, regulations, and incentives.

Network- and Service-Based Models

Network-based models are ideal for "private" road traffic (passenger cars, own-account freight vehicles) because this kind of traffic can "uniformly" use any parts and any possible routes on the road network. In contrast, transport by bus, rail, air, sea, and by some types of road haulage depends on the availability and on the characteristics (e.g., cost, speed, frequency, convenience) of "services" for any given origin-destination. Network-based models
can still deal with this type of transport, assuming some average characteristics of services on the links of modal networks. However, this type of model cannot be sensitive to proposed improvements of individual services, nor can it calculate the resources (e.g. vehicles, energy, personnel) necessary to run each service.

Perhaps a more appropriate model is one that can handle public transport “lines” (normally suitable for bus lines in towns). However, such models use uniform service characteristics on each line given in the input (e.g., standard frequency, capacity, speed, locations of bus stops).

More recent models based on “individual services” can analyze transport in terms of departure–intermediate stops–arrival terminus on public transport (e.g., bus, rail, air, sea, passengers, freight), which can be different for each service. They can also differentiate between vehicle types for each service and for each “leg” (e.g., train compositions); can produce loadings (traffic) for each service; and can calculate required resources and revenues for each service. Such features are vital when one’s task is to assess policies (or investments or operations) that are dependent on the way in which services are organized by the transport operator, and the way in which market demand responds to alternative service arrangements.

**Summary and Conclusions**

a. Conventional models developed for infrastructure planning have not worked well in industrialized countries and are unsuited to developing countries, particularly because of their data requirements and the rapid rate of economic and social change in these countries.

b. Policy models require much less data than infrastructure planning models and in those instances where they are used to test strategies relating to immediate policy action, the complications of forecasting do not arise.

c. Service-based models can be particularly useful in testing strategies relating to operations management, or in evaluating proposed traffic management, market regulation, and infrastructure planning when the type of service being offered is pertinent.

**Notes**

1. A detailed but nontechnical analysis of the four-stage model is given in Appendix 2, which emphasizes the spatial implications of such models. The text
here offers merely general comments as a means of exploring the role and suitability of different types of models for policy purposes.


3. Ibid.

Example of a Comprehensive Transport Model

An example of a comprehensive system of models is shown in Figure 4.1. The system can be used to analyze both infrastructure planning and policy issues related to transport services. Here the example relates to the development of railway policy up to the year 2000. The proposed rail policy involves changes in the freight and passenger services offered (operation management), the elimination of the need for service interchanges (traffic management), and the updating and extension of track and rolling stock (investment planning).

It is assumed that the demand for rail will depend both on the socioeconomic characteristics (e.g., population, income, industrial structure, and output) of the zones (regions) served, and on the strategies and performance of competing modes (road and air). The road and air networks are expected to be improved by the year 2000.

The proposed rail policy needs to be compared with alternative strategies that emphasize factors such as service itineraries, frequencies, timetables, and investment.

The first part of the system in Figure 4.1, PTMS, comprises two multimodal models, PTMS-PAX for passengers and PTMS-FRT for freight, which produce origin-destination (OD) flows (passengers, tons) for the year 2000, for rail transport as well as road and air. By taking road and air into consideration, it is possible to explore the reduction in rail traffic that may result from future improvements in the road/air networks and services.
Figure 4.1 Relationship between Strategic Model (Multimodal) and Detailed Model (Rail or Other Services)

PTMS-PAX
Strategic model—passengers

PTMS-FRT
Strategic model—freight

TSAP

PM-TSSP
Transport services selection program

Choice of direct/indirect services for ODs

PM-PAX
Detailed model (long-distance—passengers)

PM-FRT
Detailed model—freight

PM-ASSIGN
Total load on rail links (or other links/routes, etc.)

Commuter traffic and services model

OD flows, elasticities

= separate models linked together
= data files used to link models

PTMS = Planning and Transport Management System
PM = Performance Model
TSAP = Transport Services Analysis and Planning System, comprising PM-TSSP, PM-PAX, PM-FRT, and PM-ASSIGN
PTMS requires base-year (e.g., 1989) OD flow matrices, which may be available only in part, as station-to-station flows for rail, airport-to-airport flows, and perhaps road flow matrices from older surveys. PTMS can "fill the gaps" in OD flow data using 1989 socioeconomic data on zones and statistical models (direct-demand models).

PTMS also needs "separation matrices," for example, zone-to-zone distances, times, and tariffs. If the number of zones is not large (e.g., 20 zones or so), these matrices can be assembled directly for input using distance or timetables that are often published by rail and airline authorities. In more complex cases, networks are produced in addition to the standard input to PTMS, giving, for example, times and distances on "links" that are then transformed into PTMS 1989 "separation matrices" by network programs.

Individual services are not taken into account by PTMS, and therefore times on links (and/or OD times) are average values for the variety of services that may operate on them (services need not be considered in detail for this strategic forecast).

PTMS requires a calibration phase using these 1989 data (socioeconomic data for zones, OD flows, OD time/distance/tariff matrices), as outlined in Figure 3.2.

Socioeconomic scenarios and intervention strategies for rail, road, air (summarized, for example, by improvements in travel times for each OD combination) are then entered into PTMS for various future alternatives.

PTMS uses its submodels (generation, distribution, modal split) to obtain OD flows for the year 2000 that reflect the railways' own improvements (i.e., the results of "rail policy"), which normally attempt to "gain traffic," and improvements in the competition. PTMS also produces "elasticity coefficients" that will allow subsequent models (e.g., TSAP in Figure 4.1) to calculate small variations in OD rail flows resulting from further changes of "separation OD"; these changes will produce, for example, estimates of gains in traffic that one would expect from further improvement to the year 2000 services.

The PTMS is comparatively easy to use because the required input is simple and there are only a small number of zones. A typical work plan would involve two weeks of data preparation, two weeks of calibration, and two weeks of "future strategies/scenarios," assuming that the background policy and strategy work is already available.

The various modules of TSAP calculate all choices of available services for each OD pair (in this example zone numbers are
considered station numbers for purposes of illustration), the shares of OD flows that choose each service ("assignment to trains"), the resources required (engines, wagons, personnel, energy) to run the services in question, and the traffic on each rail link. This traffic can also include "commuter trains," which are simply added if they do not fit into the zoning system (e.g., the national level system) used for the model.

With the detailed outputs for each alternative, the policymaker/planner is able to evaluate the consequences of various policies according to user satisfaction, system revenues, and running costs; capital costs are calculated outside the system of Figure 4.1 and used along with operational costs and revenues to conduct a comprehensive economic analysis. Furthermore, PTMS and TSAP data available in various computer files can be used to assess the benefits and costs not directly related to travel, such as those related to the environment, socioeconomic development, and accessibility.

Once planners/policymakers have used the systems of Figure 4.1 and other evaluation procedures to choose the most suitable policy or strategy they can start a more detailed planning and design work phase. This will involve, among other things, the study of operations, the accurate scheduling of services, equipment acquisition, engineering considerations, and marketing studies. These procedures follow the same concepts of TSAP and the other policy models described so far, but can deal with the many details required for design and implementation.

The Model in Use

This section presents the results from actual analyses performed with the model discussed earlier. The case studies relate to rail issues and are made up of two parts: the first part considers a package of infrastructure and operating improvements for a national network with projections to the year 2000; the second part examines in detail the service and operating modifications of a key corridor in the network.

National Study

The national rail authority has put forward a package of proposals designed to reduce door-to-door times, improve reliability, and provide more frequent service. The package focuses on long-distance (noncommuting) trips and hauls. The objectives are to improve rolling stock, geometric standards, signaling; introduce double-line working on some sections and expand some stations; and improve the
The use of the model is illustrated selecting a number of the tests that were carried out on the rail proposals. During these tests the proposed package was evaluated against: (1) a "do-nothing" situation, (2) improved air service; and (3) improved road access to the stations for freight.

DO NOTHING: If no improvements are made to rail, changes will still take place in the flow of passengers and freight up to the year 2000 because of changes in such factors as the population and industrial output. If no improvements are made in road and air services and changes are forecast in the key socioeconomic variables, the analysis suggests that rail passenger traffic will increase by 57 percent, which is slightly higher than for road and slightly lower than for air (for details, see Table 4.1).

In the case of freight, it was estimated that rail would increase by 25 percent by the year 2000 in a "do-nothing" situation, compared with 23 percent for road (see Table 4.2).

THE RAIL POLICY PACKAGE: The total proposed package of improvements would increase the number of rail passengers by 16 percent over and above what would happen in a "do-nothing" situation, with the share of rail traffic in total passenger traffic increasing from 27 percent to 31 percent. In the case of freight, there would be a 6 percent increase in both rail tonnage and ton kilometers.

If, in addition, operating changes were made that might reduce travel times by 20 percent, the number of rail passengers would increase by 71 percent.

However, if the air services responded to the rail strategy by reducing journey time by 15 percent, then the number of rail passengers would increase only 12 percent as a result of the rail packages, as opposed to 16 percent.

These examples demonstrate how the policymaker can use the model to test various strategies, and in the corridor study below emphasis is placed on testing rail operating strategies.
Table 4.1 Present-Day Passenger Traffic (Base Year) and Future-Year (2000) Traffic for the “Do-Nothing” Strategy

<table>
<thead>
<tr>
<th>National Total</th>
<th>Base Year</th>
<th>Year 2000</th>
<th>Difference</th>
<th>Difference %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passengers: road</td>
<td>114,850</td>
<td>179,621</td>
<td>64,771</td>
<td>56</td>
</tr>
<tr>
<td>Passengers: rail</td>
<td>26,361</td>
<td>41,391</td>
<td>15,030</td>
<td>57</td>
</tr>
<tr>
<td>Passengers: air</td>
<td>5,175</td>
<td>8,258</td>
<td>3,083</td>
<td>60</td>
</tr>
<tr>
<td>Total passengers</td>
<td>146,386</td>
<td>229,270</td>
<td>82,884</td>
<td>57</td>
</tr>
<tr>
<td>PAX.km: road</td>
<td>46,844</td>
<td>73,519</td>
<td>26,675</td>
<td>57</td>
</tr>
<tr>
<td>PAX.km: rail</td>
<td>12,448</td>
<td>19,592</td>
<td>7,144</td>
<td>57</td>
</tr>
<tr>
<td>PAX.km: air</td>
<td>2,448</td>
<td>3,911</td>
<td>1,463</td>
<td>60</td>
</tr>
<tr>
<td>Total PAX. km</td>
<td>61,740</td>
<td>97,022</td>
<td>35,282</td>
<td>57</td>
</tr>
<tr>
<td>Road:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average trip length (km)</td>
<td>408</td>
<td>409</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Average trip time (mins)</td>
<td>298</td>
<td>299</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Average speed (km/h)</td>
<td>82</td>
<td>82</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Rail:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average trip length (km)</td>
<td>472</td>
<td>473</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Average trip time (mins)</td>
<td>483</td>
<td>484</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Average speed (km/h)</td>
<td>59</td>
<td>59</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Air:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average trip length (km)</td>
<td>473</td>
<td>474</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Average trip time (mins)</td>
<td>300</td>
<td>300</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Average speed (km/h)</td>
<td>95</td>
<td>95</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>National Averages:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trip length (km)</td>
<td>422</td>
<td>423</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Trip time (mins)</td>
<td>332</td>
<td>333</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Speed (km/h)</td>
<td>76</td>
<td>76</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ratios (%):</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pkm rail/pkm road</td>
<td>26.6</td>
<td>26.6</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Pkm air/pkm road</td>
<td>5.2</td>
<td>5.3</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

Note: Units of measurement have not been disclosed because of the need for confidentiality. Average trip lengths relate to long-distance (noncommuting) interregional trips based on centroids of very large zones (see Appendix 2, Figure A2.4, and text): hence the high values.
Table 4.2 Present-Day Freight Traffic (Base Year) and Future-Year (2000) Traffic for the “Do-Nothing” Strategy

<table>
<thead>
<tr>
<th>National Totals</th>
<th>Base Year</th>
<th>Year 2000</th>
<th>Difference</th>
<th>Difference %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tons, road</td>
<td>168.4</td>
<td>207.6</td>
<td>39.2</td>
<td>23</td>
</tr>
<tr>
<td>Tons, rail</td>
<td>16.4</td>
<td>20.5</td>
<td>4.1</td>
<td>25</td>
</tr>
<tr>
<td>Total tons</td>
<td>184.8</td>
<td>228.1</td>
<td>43.3</td>
<td>23</td>
</tr>
<tr>
<td>Ton.km, road</td>
<td>56,579</td>
<td>70,532</td>
<td>13,953</td>
<td>25</td>
</tr>
<tr>
<td>Ton.km, rail</td>
<td>6,956</td>
<td>8,995</td>
<td>2,039</td>
<td>29</td>
</tr>
<tr>
<td>Total ton. km</td>
<td>63,535</td>
<td>79,527</td>
<td>15,992</td>
<td>25</td>
</tr>
</tbody>
</table>

Road
- Average haul, length (km): 336 → 340, 4 → 1
- Average haul time (mins): 426 → 429, 3 → 1
- Average speed (km/h): 47 → 48, 0 → 0

Rail
- Average haul, length (km): 424 → 438, 14 → 3
- Average haul time (mins): 3,122 → 3,143, 21 → 1
- Average speed (km/h): 8 → 8, 0 → 3

National averages:
- Haul length (km): 344 → 348, 4 → 1
- Haul time (mins): 665 → 674, 9 → 1
- Speed (km/h): 31 → 31, 0 → 0

Ratio:
- Ton km, rail/ton km, road: 12.3 → 12.8, 0 → 4

Note: Units of measurement have not been disclosed because of the need for confidentiality. Average haul lengths relate to long-distance interregional hauls based on centroids of very large zones (see Appendix 2, Figure A2.4, and text): hence the high values.

Corridor Study

A wide range of operational modifications is open to railways, and in this example two of the important ones for improving capacity utilization are tested—namely, the daily frequency of services and train capacity.

The passenger services within the corridor range from high-speed nonstop end-to-end services to local services. Some existing service types are discussed below together with new high-speed services that would be possible if the investments proposed by the rail authority were carried out fully. This demonstrates that the model can be used
42 Example of a Comprehensive Transport Model

to test operational changes both for an existing situation and for a
future situation that may exist after investment.

Details of the six service types involved in the basic plan are given
in Table 4.3; these are based on projections for the year 2000.

Table 4.3 Operational Details of Services in Basic Rail Plan,
Strategy A

<table>
<thead>
<tr>
<th>Service Code</th>
<th>Average Speed (km/h)</th>
<th>Frequency (daily)</th>
<th>Capacity (Pax)</th>
<th>Maximum Flow (Pax)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>88</td>
<td>5</td>
<td>600</td>
<td>237</td>
</tr>
<tr>
<td>2</td>
<td>59</td>
<td>5</td>
<td>600</td>
<td>102</td>
</tr>
<tr>
<td>3</td>
<td>126</td>
<td>6</td>
<td>700</td>
<td>306</td>
</tr>
<tr>
<td>4</td>
<td>154</td>
<td>7</td>
<td>700</td>
<td>567</td>
</tr>
<tr>
<td>5</td>
<td>154</td>
<td>5</td>
<td>700</td>
<td>700</td>
</tr>
<tr>
<td>6</td>
<td>119</td>
<td>15</td>
<td>700</td>
<td>354</td>
</tr>
</tbody>
</table>

a. Identification number of a service that runs several times per day.
b. Average speed excluding stop time at intermediate stations.
c. Frequency is the number of departures per day.
d. Capacity is the number of passenger seats on train.
e. The flow of passengers varies on each leg of the service; the figure in the
table relates to the most loaded leg; values are year averages; therefore a value
close to capacity implies overloading and congestion during some parts of
the year.

From the projections for the year 2000, it is possible to identify
services at or close to capacity that may be able to make a case for
increasing frequency and other services where a decrease in frequency
would still retain sufficient capacity for the projected flows but would
result in economies in operation. In Strategy B, therefore, which is
detailed in Table 4.4, service frequencies have been changed, with
reduced frequencies for services 1, 2, 3, and 6, and increased
frequencies for services 4 and 5.
### Table 4.4 Operational Details of Service Frequency Changes, Strategy B

<table>
<thead>
<tr>
<th>Service code</th>
<th>Frequency (daily)</th>
<th>Capacity (Pax)</th>
<th>Maximum flow (Pax)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3 (-2)</td>
<td>600</td>
<td>319 (237)</td>
</tr>
<tr>
<td>2</td>
<td>3 (-2)</td>
<td>600</td>
<td>125 (102)</td>
</tr>
<tr>
<td>3</td>
<td>4 (-2)</td>
<td>700</td>
<td>389 (306)</td>
</tr>
<tr>
<td>4</td>
<td>8 (+1)</td>
<td>700</td>
<td>539 (567)</td>
</tr>
<tr>
<td>5</td>
<td>8 (+3)</td>
<td>700</td>
<td>556 (700)</td>
</tr>
<tr>
<td>6</td>
<td>13 (-2)</td>
<td>700</td>
<td>377 (354)</td>
</tr>
</tbody>
</table>

a. The numbers in parentheses show the change of frequency with respect to Strategy A.
b. The capacity of trains in Strategy B has not changed with respect to Strategy A.
c. The figures in parentheses are the maximum flows obtained for Strategy A.

An alternative policy is to change the capacity of the trains rather than alter the frequency and maintain the same capacity. The model's results concerning the effects of this on the maximum flows are shown in Table 4.5.

### Table 4.5 Operational Details of Train Capacity Changes, Strategy C

<table>
<thead>
<tr>
<th>Service code</th>
<th>Frequency (daily)</th>
<th>Capacity (Pax)</th>
<th>Maximum Flow (Pax)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>500 (-100)</td>
<td>231 (237)</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>500 (-100)</td>
<td>101 (102)</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>500 (-200)</td>
<td>291 (306)</td>
</tr>
<tr>
<td>4</td>
<td>7</td>
<td>800 (+100)</td>
<td>596 (567)</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>1,000 (+300)</td>
<td>831 (700)</td>
</tr>
<tr>
<td>6</td>
<td>15</td>
<td>500 (-200)</td>
<td>334 (354)</td>
</tr>
</tbody>
</table>

a. The frequency of trains in Strategy C has not changed with respect to Strategy A.
b. The numbers in parentheses show the change in capacity with respect to Strategy A.
c. The numbers in parentheses are the maximum flows obtained for Strategy A.
The model produces details of the resource requirements, operational data, and financial data for the three strategies; these are given in Table 4.6. Of course, frequency changes could be combined with capacity changes, but it is not necessary to go into this possibility here.

From Table 4.6 it can be seen that the resources required for Strategy B have not increased in terms of rolling stock and personnel, and although total resource costs have gone up slightly—mainly because of the higher energy costs resulting from the greater service frequencies—there has been a substantial increase in revenue compared with Strategy A.

Table 4.6 A Comparison of Resources, Operations, and Financial Performance of Alternative Strategies

<table>
<thead>
<tr>
<th></th>
<th>Strategy A</th>
<th>Strategy B</th>
<th>Strategy C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Resources</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engines</td>
<td>16</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>Coaches</td>
<td>189</td>
<td>189</td>
<td>175</td>
</tr>
<tr>
<td>Driver personnel</td>
<td>43</td>
<td>41</td>
<td>43</td>
</tr>
<tr>
<td>Other personnel</td>
<td>48</td>
<td>47</td>
<td>46</td>
</tr>
<tr>
<td>Energy consumption</td>
<td>0.334</td>
<td>0.358</td>
<td>0.331</td>
</tr>
<tr>
<td><strong>Operational Data</strong> (daily values)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Passengers</td>
<td>0.016</td>
<td>0.017</td>
<td>0.017</td>
</tr>
<tr>
<td>Passenger/km</td>
<td>3.702</td>
<td>3.951</td>
<td>3.835</td>
</tr>
<tr>
<td>Travel time, aggregate for all passengers (hours)</td>
<td>0.053</td>
<td>0.055</td>
<td>0.055</td>
</tr>
<tr>
<td>User utility score</td>
<td>0.938</td>
<td>0.988</td>
<td>0.959</td>
</tr>
<tr>
<td><strong>Financial data</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total revenue</td>
<td>130.00</td>
<td>139.00</td>
<td>135.00</td>
</tr>
<tr>
<td>Energy cost</td>
<td>8.70</td>
<td>9.30</td>
<td>8.60</td>
</tr>
<tr>
<td>Cost of engines used</td>
<td>3.20</td>
<td>3.20</td>
<td>3.20</td>
</tr>
<tr>
<td>Cost of coaches used</td>
<td>9.45</td>
<td>9.45</td>
<td>8.75</td>
</tr>
<tr>
<td>Cost of driver personnel</td>
<td>6.88</td>
<td>6.56</td>
<td>6.88</td>
</tr>
<tr>
<td>Cost of other personnel</td>
<td>7.68</td>
<td>7.52</td>
<td>7.36</td>
</tr>
<tr>
<td>Total resource costs</td>
<td>35.91</td>
<td>36.03</td>
<td>34.79</td>
</tr>
<tr>
<td>Net revenue</td>
<td>94.09</td>
<td>102.97</td>
<td>100.21</td>
</tr>
</tbody>
</table>

*Note:* Units of measurement are excluded for reasons of confidentiality. Net revenue is calculated before incorporating a number of important overhead costs such as administration, investment, and maintenance.
In contrast to Strategy B, Strategy C produces a fall in operating costs, including a slight fall in energy costs, and at the same time an increase in revenue.

The examples show three strategies tested by the policymakers. With the help of the model, the policymaker can attempt to achieve an optimum strategy, given certain targets. One target might be to reduce energy consumption. Mention should also be made of the “user utility score” based on the quality of the service (in terms of frequency, speed, and crowding levels), which provides the policymaker with a summary of user benefits in the same way as net revenue provides a summary measure of operator benefits.

The policymaker can also use the model to test freight strategies. Because the same infrastructure is used for passenger and freight traffic, both types must be considered simultaneously in the model. Thus a freight strategy was assumed to be in operation when the three passenger strategies were considered. Depending on his targets, the policymaker will change both freight and passenger strategies in order to obtain an overall optimum strategy.

Summary and Conclusions

a. Nontechnical policymakers must be able to understand the basic assumptions of the modeling process. Otherwise, they cannot be expected to put their trust in black-box output.

b. The output of the modeling process should present clearly both the resource implications of a policy and the benefits to both operators and users.

c. The case studies demonstrated the important traffic and revenue benefits that can result from changes in the frequency of rail services and the capacity of trains, without the need for additional operating costs or rolling stock.

Notes

1. The model described in this chapter was developed by Dr. V. Calogero of PTRC and has been employed in a number of developing countries. The descriptions and the case studies are based on information supplied by him. The case studies are actual cases but units of measurement have been removed to maintain confidentiality.
Appendix 1

Case Study 1: Bangkok Bus Lanes

In order to deal with the widespread and growing congestion in Bangkok, the Thai government in 1978 embarked on a comprehensive urban transport scheme. The project was designed to strengthen urban transport management, increase the capacity of the road network, and improve public transport. Extensive priority bus measures were very important in the project. At the time of project appraisal, bus trips in the central area during peak periods were as slow as 10 kilometers per hour, while cars did little better at 12 kilometers per hour. As in other cities, more than 60 percent of all personal trips on the main roads in Bangkok were made in buses and minibuses, which together accounted for only 6 percent of all passenger vehicles. Private cars, which made up more than half of the traffic (57 percent of all vehicles), carried only 26 percent of the commuters. Both types of vehicles were constantly caught in traffic snarls. Then, in 1980, 145 kilometers of traffic lanes were set aside for the exclusive use of buses.

As a result of these comprehensive measures, both bus and car travel times improved significantly in almost all cases. In areas where the most success was achieved, bus and car mean travel times were reduced by 25 percent to 30 percent. On none of the streets surveyed did bus or car travel times grow worse.

Observed bus flows were very high, with up to 250 standard buses and 150 private minibuses using a single bus lane during an average peak hour. All told, these vehicles had a carrying capacity of about 18,000 passengers per hour. Such intensive utilization of a single
traffic lane indicates that road space can be used efficiently if the appropriate measures are introduced.

According to a study of bus lane violations, some 20 percent of the vehicles in the priority bus lanes were illegal users, mainly slow-moving nonmotorized vehicles. This suggested that strengthened enforcement might lead to even better results.

The success of the project illustrates the benefits of priority bus lanes. The project cost less than US$1.5 million, yet it has provided substantial benefits to the majority of Bangkok's road users, particularly bus and minibus passengers.

Case Study 2: Exclusive Busways in Porto Alegre

In 1978 the administration of Porto Alegre set aside 30 kilometers of road as exclusive busways. In this way, the city has been able to accommodate high passenger flows in the central business district without having to invest in costly elevated or underground systems. Expressways have been paved, bus stops erected, and signs posted at a cost of US$500,000 per kilometer. The right-of-way has been marked by curbs or low reflectors.

Because the designated expressway is narrow, it is impossible to pass at bus stops, and buses are often held up by those stopped ahead. The solution to this problem in São Paulo as well as in Porto Alegre has been the bus convoy, or Comonor. At the beginning of a corridor, buses are coordinated in a fixed sequence according to their route and form convoys of up to six buses. The buses travel together, stop simultaneously, board their passengers, and depart in a queue or convoy. At each bus stop, a passenger awaits his bus at a "subgroup" bus stop coinciding with his bus location in the convoy. Because buses are operated privately in Porto Alegre, a convoy may be composed of buses run by several operators.

A convoy can almost double busway capacity in congested areas. The combined use of the bus expressway and bus convoys has achieved peak-hour one-way passenger flows of 28,000 passengers on 260 buses, at an average speed of 19 kilometers per hour in the most heavily traveled corridor.

Higher speeds (with lower flows) have been achieved on other bus expressways in Porto Alegre with the use of another innovation, the transfer terminal. It was found that unnecessary congestion resulted when feeder routes overlapped in the downtown area. This problem was solved on one expressway with the building of two transfer terminals, where passengers transfer between the smaller buses serving feeder lines and larger, articulated buses serving the bus expressway.
This system resulted in 20 percent higher bus speeds and corresponding fuel savings.

**Case Study 3: Comprehensive Transport System in Abidjan**

The Ivory Coast adopted a comprehensive approach to improving the transport system in Abidjan as follows:

1. Traffic was improved by creating one-way streets; installing integrated traffic signals, signs, and road markings in the central business district; and extending traffic management programs throughout the city.

2. Traffic management measures were introduced to improve the movement of pedestrians and buses in high-density, low-income communities.

3. Pedestrian facilities were constructed, including footbridges.

4. Busways and reserved bus lanes were established in the central business district.

5. A high-speed express bus network was created by constructing new road links.

6. Bus terminals and bus stops were upgraded and a bus depot constructed.

7. Primary roads were constructed to improve public transport access to low-income areas.

Before these improvements, key sections of the city’s road network were seriously overloaded and the congestion lasted for as long as 12 hours each day. Considerable all-round improvement has occurred as a result of the project. Buses now cross the central business district in half the time and other traffic has benefited from the elimination of congestion caused by the loading and unloading of buses. The city was able to achieve these improvements even though rush-hour traffic increased by roughly 20 to 30 percent. By making better use of the existing road network and other transport facilities, Abidjan found it possible to forgo or defer several expensive infrastructure projects.

**Notes**

1. The case studies in this appendix have been provided by Dar Al-Handasah Consultants (Shair and Partners), although they were not responsible for the original studies.
Appendix 2

Form and Spatial Focus of Transport Models

It is important to remember that all sectors of the economy are interdependent and to recognize the interrelationships between different policies, and between transport policies and planning, not just at the present time but also over the lifetime of a particular scheme.

Because of these complexities, modeling can be of great assistance in establishing quantitative relationships. As industrialized countries have discovered, however, some model results may be unreliable; this problem may be even more pronounced for developing countries. For this reason, the examples in this section have been drawn from both developing and industrialized countries.

Transport policies and planning directly affect the transport sector, but they also affect other sectors indirectly, through the transport system. The model must therefore seek to quantify both kinds of effects, which must then be evaluated.

The output of the transport sector is measured in terms of traffic flows; the first task of the model is therefore to determine how supply and demand factors are related to traffic flows. The second task is to identify the indirect or secondary effects of the original transport policy or project, both sectorally (i.e., into other sectors) and spatially (i.e., the spatial range). The third task is to evaluate both the initial impact and the secondary effects.

It follows that both the form of the model (used to establish behavioral relationships) and its spatial focus (used to establish spatial
relationships) are of vital importance. However, one must be practical in deciding on the degree of complexity in both these areas. The fact is that the greater the detail in modeling behavior and spatial impact, the more difficult it will be to quantify the relationships, obtain the necessary data, and produce results. Since less complex approaches will often be more practical, it is important to try to ascertain how accuracy will be affected.

The following sections concentrate on model form and spatial focus, beginning with the simplest case.

If a project is unlikely to have any effect on other parts of the transport network or sectors of the economy, a model will not be necessary to appraise it. Such a case is illustrated in Figures A2.1 and A2.2. Figure A2.1 gives current traffic flows in a rural town, and Figure A2.2 gives projected flows following the construction of a proposed bypass.

**Figure A2.1** Current Traffic Flows in a Rural Town

Flows are in vehicles/16-hour day
(May 1981)
Figure A2.2 Projected Flows Following Construction of a Bypass around a Rural Town

Flows are in vehicles/16-hour day
(May 1981 levels)


The 12,000 vehicles that previously made up the through traffic now all take the bypass, and no other changes have occurred. The first-year benefits will be assessed in terms of time savings, accident reduction, and environmental factors; and future-year benefits will be assessed on the basis of the growth in traffic in relation to national growth rates.

The results of building a bypass or ring road around a major town in a nonrural area could be much more far-reaching—affecting the distribution of traffic across the network inside and outside the urban area, the distribution of traffic between modes, traffic growth within various parts of town or external subregions, and the location of economic and social activity. Furthermore, new kinds of traffic may even be generated as a result of the improvement.

The next section discusses how these changes in urban and interregional transport can be assessed.
Urban Models

The Conventional Four-Stage Model

The early transport models were primarily intended for appraising projects. One of these was the conventional four-stage model, which is still the model most frequently used to gain insight into the effects of a proposed project (policy). The decisionmaker in such cases needs to

1. Know the existing flows in the network.
2. Determine how the flows will change when the scheme is introduced.
3. Determine how the flows will change over the lifetime of the scheme.
4. Evaluate the changes.

The traffic flows are determined by the demand for and supply of transport services. The first task, therefore, is to establish the factors that influence this supply and demand and to quantify the relationship between them and the traffic flows. This is accomplished by observing the current situation and then synthesizing it.

During the observation stage, the main task is to define the study area and transport networks, record current flows in the network, prepare an inventory of land use, and survey households, industry, and public and commercial operators. The resulting data on land use, industry, households and operators will be used to explain the current observed flows in the individual links of the network.

In order to make the exercise manageable, the study area is divided into zones. The synthesis then proceeds through the four stages of the traditional model.

First, the traffic generated (and attracted) by each zone is modeled (trip generation); second, the traffic generated by each zone is distributed between the zones (trip distribution); third, the interzonal flows are allocated to the different modes of transport (modal split); fourth, the interzonal flows are assigned, by mode, to the actual network (trip assignment). Freight and passenger traffic is modeled separately.
Study Area and Zones

The study must focus on the area that will feel most of the impact of the planning or policy. Any effects outside the area must also be taken into account, but in less detail.

Since it is impossible to represent every individual trip in a model, trips are aggregated on the basis of zones. These zones must therefore be as homogeneous as possible in terms of socioeconomic makeup. Clearly the smaller the zone, the more homogeneous it is going to be. The zones within the study area should therefore be small. This small size will not be a problem in gathering data because special surveys will be used for this purpose. The zones outside the study area are larger, with the nearest ones (the intermediate zones) being smaller than the more distant ones (the external zones). The larger zones are usually delineated in a way that allows data collected for other purposes on a regular basis to be used, e.g., these large zones could correspond to national planning regions. This yields substantial cost savings in areas where less accuracy is required.

Because individual trips, with their individual origins and destinations are not being modeled, all trips are said to start and finish at a zonal centroid, which is joined to the network node or nodes via a centroid connector. Therefore the zone needs to be small so that traffic can be realistically allocated to the network. The network is analyzed in terms of flows in links; ideally, the links should start and finish at important junctions (since there is only one flow figure per link, adjoining roads along a link would mean different flows in different parts of the link, and this could not be accounted for in the model). In addition, the number of links in a zone should be limited.

Figures A2.3 and A2.4 illustrate ideal zoning in relation to links and the concept of centroids.
Appendix 2

Figure A2.3 Links in an Ideal Zone

Trip Distribution Matrix

The data on trip generation and attraction are used to provide the total row and column trips in the matrix (Figure A2.5); the trip distribution model then distributes these totals between the individual zones (Figure A2.6).
**Figure A2.5** Format of Trip Distribution Matrix

<table>
<thead>
<tr>
<th>Generation</th>
<th>Attraction</th>
<th>Zone 1</th>
<th>Zone 2</th>
<th>Zone 3</th>
<th>Zone 4</th>
<th>Total Generation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>400</td>
</tr>
<tr>
<td>Zone 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>Zone 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>300</td>
</tr>
<tr>
<td>Zone 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>200</td>
</tr>
<tr>
<td>Total Attraction</td>
<td></td>
<td>200</td>
<td>500</td>
<td>200</td>
<td>100</td>
<td>1,000</td>
</tr>
</tbody>
</table>

Trips beginning and ending in the same zone are excluded (they can be added in later).

**Figure A2.6** Details of Trip Distribution Matrix

<table>
<thead>
<tr>
<th>Generation</th>
<th>Attraction</th>
<th>Zone 1</th>
<th>Zone 2</th>
<th>Zone 3</th>
<th>Zone 4</th>
<th>Total Generation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone 1</td>
<td></td>
<td></td>
<td>300</td>
<td>80</td>
<td>20</td>
<td>400</td>
</tr>
<tr>
<td>Zone 2</td>
<td>25</td>
<td></td>
<td></td>
<td>45</td>
<td>30</td>
<td>100</td>
</tr>
<tr>
<td>Zone 3</td>
<td>150</td>
<td>100</td>
<td></td>
<td>50</td>
<td></td>
<td>300</td>
</tr>
<tr>
<td>Zone 4</td>
<td>25</td>
<td>100</td>
<td>75</td>
<td></td>
<td></td>
<td>200</td>
</tr>
<tr>
<td>Total Attraction</td>
<td></td>
<td>200</td>
<td>500</td>
<td>200</td>
<td>100</td>
<td>1,000</td>
</tr>
</tbody>
</table>

The 25 trips entered for Zone 4 in Column 1 of Figure A2.6 flow from Zone 4 to Zone 1. During the modal-split stage, these trips are allocated to modes and during the assignment stage they are allocated to specific routes, usually on the basis of cost/time minimization. The flow in this example is asymmetric (i.e., flows from each zone are different from the flows to each zone). This occurs when peak problems are being analyzed or when a home-based return trip is used.
The following kinds of factors are considered important in modeling passenger transport:

**Trip generation and attraction:**
Number and size of households; number, size, and type of firms; car ownership; age distribution; income; retail outlets, leisure facilities; schools.

**Trip distribution:**
A measure of zonal separation, usually related to journey time and cost; a zonal adjustment factor to take into account socioeconomic factors not accounted for in the model (e.g., some zones will be much more attractive to certain types of people—who are frequently grouped by zone—than others).

**Modal split:**
Factors based on characteristics of the journey (e.g., time of day, length); of the traveler (e.g., income, car ownership); of the competing modes (e.g., cost, frequency, journey time).

**Assignment:**
Trips between specific zones and by a specific mode are assigned to the actual network on the basis of minimum cost/time of the journey.

Although a wide range of mathematical forms is used for these models, certain fundamental points can be made about them.

1. Zones are used to simplify the modeling process; this means that intrazonal traffic is excluded from the link analysis, and that "average" socioeconomic characteristics of the zone are used. The smaller and more homogeneous the zones, the less that these will be problems.

2. Because travel behavior is very complicated, the model usually takes a simplified form. Another drawback is that the four-stage structure suggests a sequential decisionmaking process, whereas in practice these decisions will be made simultaneously. Recent models have attempted to overcome these problems but they are demanding of resources.

3. The data requirements are substantial.

This stage of the modeling process is concerned with establishing the parameters to be used in determining the relationship between the
factors in the models and the current traffic flows. These parameters are normally assumed to remain fixed (but not always, as is explained later in the text) and in the next stage of the process the proposed project or policy is entered into the model. This might involve banning trucks from certain roads, building a new road, or changing the frequency of public transport. The new distribution of traffic flows that follows from this action is then ascertained. The manner in which this is done is illustrated below for the three examples given above.

To ban trucks on certain roads, one must remove the roads where the ban applies from the model of the truck network. The total number of journeys generated and attracted to each zone is assumed to remain constant, and the assignment model is rerun to determine the least costly routes between the zones. Trucks will have been forced to reroute because certain routes will now be excluded, but cars will also reroute because, with trucks absent from certain roads, these will now become the new least-cost routes.

The policy is evaluated by calculating the increased costs to trucks and by comparing these costs with the cost reductions to other road users, plus any other environmental factors.

A new road is placed into the model network, and the assignment model is rerun to determine which routes will be taken to minimize costs in view of the new road. Some models employ a fixed trip matrix such that the total number of journeys generated and attracted to each zone is, as in the previous example, assumed to be the same both before and after the improvement. In many developing countries, however, the new road may have a strong impact on traffic generation, and in such cases a modified generation model incorporating an accessibility measure must be rerun to produce newly generated traffic, and the distribution model must be rerun to produce new matrix cells, before the diversion of traffic between routes can be shown at the assignment stage.

The project is evaluated by comparing the cost of the new road with the value of the savings in journey times, accident rates, and any environmental factors.

When the frequency of public transport is improved, passengers will switch from private cars to public transport. If zonal flows are assumed to remain unchanged, the modal-split model is rerun with the new quality of service in order to determine the new split between modes. If increased traffic is assumed to be the result of the improvement, the generation model (of the type discussed above)
must also be rerun. Because there will now be fewer vehicles in the network, the assignment model will also have to be rerun.

The policy is evaluated by comparing the increased costs of public transport with the benefits to all road users, and accident and environmental improvements.

A number of salient points can be drawn from the above examples concerning the use of this particular type of model:

1. If the traffic generated by the scheme is substantial, certain types of models may not be able to take this into account adequately, if at all.

2. Only limited changes in travel behavior are permitted between modes or routes, whereas in practice improved frequency or journey times could give rise to multiple activities during journeys, with travelers no longer going directly from A to B, but now going there via C.

3. With respect to the before and after (with and without) situation, the analysis compares the "before" equilibrium with the "after" equilibrium. Thus the dynamic process of moving from one to the other is excluded, even though in urban areas this can be an important factor to consider, particularly in relation to the peak traffic periods. With regard to trip generation, behavior will adjust over time, and this will also be the case with modal choice, where the choice will depend on the cumulative knowledge gained from successive journeys.

New types of models are now being used in an effort to overcome some of these weaknesses For example, accessibility measures are being introduced in the generation models (see above), dynamic procedures are being added to allow for changes in the relationship between factors over time, and direct-demand models are being used. In this last type of model, traffic is generated through the distribution model without the constraints imposed by trip-generation models.

The effects of policy reforms and new infrastructure will not, of course, be restricted to the year they are introduced. There will be a stream of benefits and costs over time. Changes in the factors (variables) in the models must therefore be forecast including changes in land use; socioeconomic factors relating to households, industry, and commerce; and transport supply factors (price and quality).
Two examples serve to demonstrate the enormity of this forecasting task. First, travel behavior is highly sensitive to the makeup of households; yet unexpected changes can occur quickly. Consider what happened when the birth-control pill was introduced in industrialized countries: household size declined; the numbers employed per household increased; and incomes and car ownership increased. As a result, there were some serious errors in the forecasts. Second, the rapid rise in oil prices in 1974 followed by a recession had, of course, been omitted from forecasts of industrial activity.

The Fixed Trip Matrix

The row and column totals of Figure A2.5 show total trips generated and attracted. In the early traditional transport model, these remained fixed. When the base year is compared with the forecast year, however, these totals will change wherever changes are forecast in the socioeconomic variables. But in a fixed matrix model, totals will not change under a new scheme. They will remain fixed, and the model will only allow them to be redistributed within the body of the matrix under the new scheme.

If new traffic (i.e., traffic that did not exist before) is in fact generated by the scheme, this will have implications for both the forecasting of future traffic flows and the evaluation of the scheme. The implications for evaluation are shown in the diagram below:
The curve $D_1$ shows the true relationship between the cost of travel and the actual level of travel. Before the road improvement, the cost of travel is $P$ and the observed traffic flow is $F$; following the improvement, the cost of travel is $P_1$ and the traffic flow increases to $F_1$. New traffic $(F_1 - F)$ has been generated by the scheme. The conventional transport model assumes, however, no increase in demand as represented by the demand curve $D$. The benefit to this generated traffic, represented by the shaded area, is thus excluded.

Where the new scheme itself is likely to generate new traffic, it is important to rerun a generation model incorporating an accessibility measure, or to use a direct-demand model, in which traffic is generated through the distribution model without the constraints imposed by trip generation models.

As soon as the longer-term effects of policy and planning are taken into account, the interaction between transport and other sectors becomes significant. For one thing, the new policy or project could initially increase journey speeds; in the short run, this will change shopping and recreational destinations. In the longer term people will change houses and jobs, and in the long term, the location of new houses, retail outlets and factories will be influenced by the transport project or policy. The result of these activities will feed themselves back into the transport system, thus setting off a new phase of readjustment.

These changes in land use can be modeled in land-use models. Although these models have been employed in tandem with transport models, the argument above suggests that the two kinds of models should be integrated.

Land-Use and Transport Interaction Models

In models that integrate land use and transport, the interaction between transport and the spatial distribution of housing, employment, and shopping, for example, is achieved by linking the trip distribution and modal-split stages of the conventional transport model with a land-use model.

It has been argued that land-use and transport models used in tandem "are logically inconsistent: land-use models may neglect all congestion effects while network models explicitly include speed-flow relationships. It is extremely difficult to justify further work on nonlinked models in the light of this problem."
Support for this argument can be found in an official analysis of 41 road schemes in the United Kingdom, which concluded from a comparison of actual and projected flows that in only 22 cases were the actual flows within 20 percent of the original forecast. In the remaining 19 cases, flows ranged from 105 percent above the original estimate to 50 percent below. In the case of the £1 billion London orbital road, actual flows in 21 of the 26 three-lane sections ranged from 81,400 to 129,000 vehicles a day, compared with forecasts of 50,000 to 79,000 vehicles in the fifteenth year after opening. This discrepancy was attributed to major flaws in the forecasts, which failed to take into account the fact that new roads might generate new traffic, or that new roads opened up surrounding areas to traffic-generating industry and commerce.

Furthermore, a comprehensive series of tests on integrated land-use and transport models showed that the second- and third-round effects were significant. In one case, the land-use effects of the transport policy in question accounted for about one-third of the total economic benefits.

These same series of tests also showed that the most detailed model was the least transferable (i.e., to other study areas), and that those with modest data requirements were easy to use and the most easily transferable.
The findings on transferability are particularly important. When the LILT model (see earlier box) was tested on three different study areas, it was concluded that “different but feasible results have been obtained from the model for the three study areas. Hence the responses cannot be completely intrinsic to the model structure, but must be strongly influenced by the study area characteristics.”

In a further test three models originally designed for three different study areas were all tested using the data for a single area. Here it was concluded that “three experienced modeling teams, given identical data of a by no means exceptional urban region in Europe, have not yet succeeded in producing a set of ex-post forecasts for that region that are sufficiently compatible with each other and with the known past reality.”

There is no question that a complex model is far easier to build than to run. That is why commentators have argued that conventional transport models should continue to be used if fairly short time horizons are involved and data are a problem. Also, the problems of forecasting the variables in some models are another reason for estimating only the first-year effects, with forward projections being made on the basis of indicators external to the model.

Two caveats should be mentioned concerning these suggestions. First, if the construction period of a project is long, its completion can be anticipated by both the industry and travelers, with the result that land use can change when a project is barely completed. It was this anticipation that led planners to underestimate flows on the London orbital road. Not too long after its opening, a major retailer commented that 7 out of 15 depots of a particular type were very near the road and a further three within easy striking distance.4

Second, the problems of rapid change and the lack of data can be much greater in developing countries than in industrialized ones. As others have pointed out, such models are of limited use in developing countries, where incomes and land uses change frequently and rapidly, particularly in the cities, and where data are often inadequate. In addition, the models cannot easily handle major changes in transport policies, such as changes in transport prices, and they tend to have difficulty incorporating feedback on the number of trips when the supply of transport is changed.5

The urban area is, of course, compact and the influence of factors outside that area is much less important than the effect of those within; the impact of external effects is consequently analyzed in much less detail. However, the effects of major interurban projects and national transport policies can cover wide areas. Where the impact is spatially
large, urban models have been adapted to cover regions, corridors, or whole countries. These interregional models are considered in the next section.

**Interregional Models**

Assuming the policy will affect the entire nation, the study area represents the whole country; but in the same way that the urban area is not self-contained, "ripples" outside the area must be taken into account (even if in less detail); also, a country is not self-contained, and international trade and tourist traffic cannot be excluded.

The analysis of urban models emphasized that the individual zones of the study area need to be as homogeneous as possible. If a zone is very heterogeneous and is home to completely different types of industry, land use, and social structure, the "zonal averages" of these heterogeneous factors will be of little use in determining travel behavior. This situation can be compared to an individual who acts randomly in his travel behavior instead of rationally, as supposed in modeling theory; that is, the individual can be said to be made up of a range of different personalities instead of one personality.

Clearly, the smaller the zones the more homogeneous they will be, but in practice data availability will be the deciding factor. In contrast to urban studies, which collect data through special surveys, interregional models have to rely on data that are collected on a regular basis for non-transport purposes. Special traffic and traveler surveys can be undertaken, but much of the socioeconomic data will have to be those collected in the planning or economic regions of concern. Even where the zones are relatively small, heterogeneity can create serious obstacles for modeling. One attempt to model rail freight movements in Great Britain identified 134 zones from administrative areas. Data on the flow of rail freight were obtained as a by-product of British Rail's accounting system and thus constituted a 100 percent sample. But even with this level of detail, it was concluded "that conventional models of freight generation and distribution are not very successful and, in fact, are unsuited for prediction of the demand for railway infrastructure. This is largely because tonnages and distribution patterns are heavily dependent on the policies of a comparatively small number of large freight users, meaning that tonnages on particular rail routes may be susceptible to discrete fluctuations over time, for instance when contracts need renewal."  

Zonal averages cannot, of course, be used to predict changes in demand when shippers in the zones differ and where such shippers can individually have a strong impact, or when key customers have a
powerful influence. In such instances, the “zones” must be centered around the individual shipper and individual customer, and this suggests a chain approach.

*The Chain Model*

The chain model is organized around the chain of physical distribution from the producer to the final destination. The spatial distribution of industry and agriculture and their respective markets in developing countries resembles that in the railway case mentioned above to some extent and thus is frequently amenable to the same kind of analysis.

This type of model is most useful when operational inefficiencies, rather than the lack of physical capacity, are thought to be the main cause of delays, bottlenecks, and high transport costs. The chain analysis may enable policymakers to identify operational problems, the misuse of existing capacities, and solutions that either do not require investments, or if they do they are small and specialized for use only, or largely, by the commodity being studied. Therefore, any proposed investment can be analyzed purely in connection with that particular commodity. If the study reveals a need for substantial investments, they are likely to be multipurpose; that is, they can be used by other commodities. Therefore the suggested investment will require investment analysis, which in turn will force planners to look at all possible demands for the proposed new facility or equipment.

Studies of chains or commodities are likely to use more time-series analysis/data, as opposed to cross-sectional data, which are widely used in spatially based transportation studies.

*The Corridor Model*

The corridor is somewhat similar to the chain concept. Both freight and passenger traffic in the corridor are analyzed, but the transport corridor differs from the wider regions through which it passes. It is sometimes argued that modal-split models are inappropriate for passenger transport in developing countries because car owners would never consider traveling by public transport, which they see as inferior. But if a high-quality train service exists along the corridor between the two principal cities, the choice between modes of travel becomes an important factor to consider in planning and policymaking. In such cases, the corridor must be separated from the remainder of the regions for analysis. This is not to say that the remaining regions are omitted but, as in the case of urban areas, that external regions will be considered in less detail. Frequently the
zoning of areas near the corridor will be finer than those further away, since they have a greater impact on the corridor.

The Brazilian Transport Planning Agency (GEIPOT) has created key corridors for analyzing investment and monitoring operational efficiency. This concept has been applied to “export corridors” in particular in an effort to keep transport costs for key export commodities to a minimum.

Corridor studies have also been used effectively to analyze the transport alternatives/problems/efficiency/investment requirements of landlocked countries.

A recent World Bank study of this type in Africa focused on the following subjects: the composition of direct overall generalized costs incurred in the transportation of goods to and from an overseas destination; the determinants of shipper choice and the cost-efficiency of transit movements; the institutional framework and the role of the government in route allocation; the facilitation procedures in place; and the existing transit bottlenecks. Using a generalized cost function, the study determined the indirect and direct net benefits generated by the use of each alternative transport corridor and identified specific actions that could improve the efficiency of transit movements. As in most corridor studies, key commodities were analyzed individually.

Another recent corridor study of this type by the World Bank in a Latin American country identified a set of marketing, institutional, operational, and infrastructure constraints hampering efficient transport in the corridor. The strategy for addressing such constraints depends on the level and distribution of demand, which are in turn affected by the relative prices of transport alternatives and the corresponding level of service as perceived by the users.

**Heterogeneity of Zones**

One drawback of interregional modeling on a national scale is that the zones to be analyzed are frequently very large. In the policy simulation model of the EC Commission, for example, the Community is divided into 108 zones, which is typical of the number of zones used in an urban area of some 150,000 inhabitants. In contrast, Portugal is divided into only 3 zones in the model, Greece into 4, and Spain into 10.

Zones of this size, with the long links used to model the networks, make it virtually impossible to assess the transport networks within them. It is simply not feasible to determine how a policy or infrastructure project will affect individual parts of the network, for
example, where a bottleneck might occur in the network. Two observations serve to demonstrate this.

1. In the distribution stage of the model, trips are allocated between zones on the basis of centroid-to-centroid information. If the bulk of economic and social activity in the zones takes place around the centroids, this need not be too unrealistic, but if activities are scattered, there will be problems of calibration (i.e., calculating the model parameters). Moreover, the assignment model assumption that every trip diverts to start and finish at a centroid is quite unrealistic when large numbers of trips originate and end at points distant from the centroids.

2. Long links do not necessarily create a problem where the basic aim of the model is to forecast interzonal movements, since a great deal of interzonal traffic will be moving over the whole length, providing there is no substantial economic activity on the periphery of the zone. But if the aim is to identify possible bottlenecks, for example, the long links do create a problem because intrazonal traffic, which in the case of roads could well constitute nine-tenths of the total traffic and is excluded from the modeling process, varies substantially over short distances; that is, in the case of interzonal traffic there might be a relatively constant loading over the link, but this will not apply to intrazonal traffic.

The modeling process only permits one flow figure per link, but the flow will in practice vary by points on the link (because of local factors), as well as by the season, day, and hour.

Large zones should only be considered where they serve to support corridor studies or where the results sought do not relate to specific parts of the network. Frequently, however, large zones do not overcome data problems because the data themselves do not exist.

Seven European countries have studied the data required for interregional passenger modeling. The study concluded:

The comparison between the data needed and the data available in interregional travel demand analysis has revealed serious gaps. Only a small fraction of all priority data are actually available; these are primarily data on traffic and trip volumes for cross sections of modal networks or for total networks. Other data are largely incomplete or are available only as rough estimates. Even if data such as terminal-terminal flows in air and rail travel exist, they are not always available to planning authorities, nor are they very reliable. Data problems have been found for O-D flows by mode, purpose, and category of travelers, both in a base year situation and before-and-after situations concerning important supply changes. There are few data banks of the characteristics of travelers in modal networks and of their
trips. Even fewer data are available on international travel than on domestic travel. This is a serious disadvantage for prospective demand studies, since important empirical evidence is missing.

Summary and Conclusions

a. Because of the complex interrelationship between the factors that determine the outcome of policy and planning measures, together with sectoral and spatial ripple effects, the analysis of policy and planning proposals can be assisted by a simulation model.

b. Models must of necessity simplify travel and industrial behavior and thus may omit important aspects affecting traffic or categories of traffic.

c. Major problems arise in forecasting variables and collecting data.

d. Because of forecasting, data, and transferability problems, the model used should be as simple as possible. However, this does not mean that key variables and relationships should be omitted, for example, if there are important land-use and transport interactions or vehicle-service-transport regulation effects—they must be taken into account.

e. Where zones are very large and heterogeneous, intrazonal effects cannot be measured reliably. However, simple models of intrazonal traffic (e.g., forecasts of aggregate passenger kilometers) can be used for policy evaluation.

Notes


7. Commission of the European Communities, COST 305 Data System for the Study of Demand for Inter-Regional Passenger Transport (Brussels: 1988). The countries were Belgium, Finland, France, Germany, the Netherlands, Sweden, and Switzerland.