TRANSPORT PLANNING: 
SELECTION OF ANALYTICAL TECHNIQUES

By Robert E. Burns

INTRODUCTION
Transport planning means many things to many people. While definitions may differ significantly on many points, there seems to be general agreement that some type of formal planning exercise is desirable. Planning, like any other production activity, has a production function associated with it. The nature of the desired product determines the technology and the inputs required. It is at this point that confusion and conflicts arise. The exact nature of the desired product is rarely specified, and consequently the individuals and groups involved or interested in transport planning in a particular country may have different ideas about what the inputs and the finished product should be.

Once one gets beyond the more superficial versions of transport planning, two areas of analysis emerge. The first involves the production and evaluation of a time-staged investment programme; the second involves an analysis of the institutional environment in which the transport system must operate. The intention here is to discuss some of the analytical techniques that can aid the planner in producing and evaluating an investment programme, and then, as a practical example, to consider which would be most appropriate for planners in West Pakistan.

The difficulty of comprehensive transport planning springs from the necessity to predict future activities in time and space. Because of the obvious difficulties and complexities involved, planners have approached the problem in essentially four different ways.

The first approach, usually implicit, accepts that it is too difficult to make predictions in time and space, and that the vested interests involved will in any case invalidate plans that do not conform to their desires. For these reasons the planners concentrate on removing obvious bottlenecks in transport and making marginal improvements in the frequently irrational transport policies of the various modes and agencies. Since transport is a derived demand, the growth of the economy and the resulting pressure to move goods and people will create bottlenecks, and the function of the planner is to react as swiftly as possible with an efficient solution. This approach removes the necessity for predicting future activity in time and space, since the time is the present and the place is the physical location of the bottleneck. This approach cannot of course handle problems concerning modernisation or the introduction of new technologies such as the replacement of steam by diesel-electric locomotives.

A second approach is to adapt the investment analysis techniques of private industry to the transport sector. Here one needs predictions, just as a firm needs to predict sales, revenues and costs. The government can compare the benefits from a
new investment with the costs involved, the merit of the project being expressed as a benefit-cost ratio or an internal rate of return. Analysts then have the satisfaction of believing that if their assumptions and predictions are correct their recommended investments will be beneficial to the economy.

A third group, dissatisfied with the negativenss of the first approach and the narrowness of the second, has reached out for a grander design. They have tried to look at the transport system not as a hopelessly complex phenomenon, nor as a group of separate components, but as an integrated network, complex to be sure, but amenable to analysis. They consider themselves systems analysts or operational researchers who apply well developed analytical techniques to real world problems. To them transport is a physical thing with an underlying rationale. If they could understand this rationale they could employ it in making their predictions in time and space. The most powerful and appealing analytical tool at their disposal is linear programming and its variations.

The fourth and latest group to appear on the transport planning scene, while they also regard themselves as systems analysts, represent a radical departure from the linear programming approach. They have attempted to capture the rationale of a transport system by constructing simulation models, not only of the transport system but also of the economic system, and by allowing interaction between the two models. They not only accept the possibility of irrational action, but attempt to simulate it. Their chief effort is to predict the results of various policies and investments. They tend to leave the evaluation of the results to the policy makers.

The preceding generalisations cover the spectrum of approaches to transport planning. There can be an overlapping or a mixture of approaches in a particular planning effort, but usually one of the first two approaches tends to dominate the transport planning philosophy of a particular country.

The following sections will give brief, non-rigorous discussions of the four approaches, their advantages and disadvantages, and the logistics of their implementation. The final section will deal with their appropriateness in the context of the transport planning effort of West Pakistan.

**THE BOTTLENECK APPROACH**

The bottleneck approach assumes that the transport planning agency is chiefly concerned with identifying transport bottlenecks and alleviating them as quickly and efficiently as possible. The important characteristic of such an agency is the ability to perceive these bottlenecks and to do something about them quickly. If the country has the construction ability within its domestic industry, and the foreign exchange, many of the formalities of justification and financing can be dispensed with and the reaction can be swift. Such a reaction policy requires little planning talent but good engineering and organisation.

Allowing physical pressure on existing facilities to indicate when an expansion is in order is one way to be certain that the improvement is “needed” and will be utilised. The trade-off here is between certainty of demand and cost of congestion.

Examples of the bottleneck approach are more common than one might expect, especially in the more advanced countries. Narrow bridges, ferries, congested ports,
roads and airports, insufficient rail freight rolling stock, crowded buses, etc., plus political and commercial pressures, are often the deciding factors in the investment decision.

The two most popular bottleneck analyses are the Highway Sufficiency Ratings\(^1\) and the Criterion of Highway Capacity.\(^2\) Both methods set up a formal framework within which highways can be appraised in terms of the quality of service they provide. The latter is an extremely sophisticated tool, and gives a fairly accurate measure of the parts of a highway system that warrant immediate improvement for traffic reasons. It is extensively used in the U.S.A.

In a country where the transport system is well developed and there are no large regions to be opened up and exploited, an enlightened bottleneck approach could be a suitable transport planning philosophy. Good engineering and excellence of implementation, together with attempts to rationalise policies affecting transport and utilisation of capital, are fairly modest objectives within the technical and administrative competence of many underdeveloped countries.

This approach also relegates transport to a relatively passive role in the development process. To those who are familiar with the standard dynamic role cast for transport in the development process this may border on heresy. The example of the railroads pushing westward in the U.S.A. and the rapid economic development that took place simultaneously has supported a belief in what Fogel refers to as the "axiom of indispensability"\(^3\) for transport investments in the development process. The extent to which this is true in all underdeveloped countries at all stages of development is not yet clear.

**PROJECT ANALYSIS**\(^4\)

One of the big deficiencies in the bottleneck approach is the long lag between the perception of a bottleneck and the implementation of a solution when foreign lending agencies are involved in the financing. The formal process of feasibility study, final engineering, financing, prequalifying, tendering and construction demands the prediction of bottlenecks before they occur. Another peculiarity of international financing is its unpredictability. If a team from an international financing agency arrives and is anxious to finance transport projects, the recipient authorities are advised to have a backlog of feasibility studies ready, or the money may not be there by the time the feasibility studies are prepared.

Another situation requiring a formal project analysis is where a new transport link is being introduced into a region not previously served. Unfortunately, project

\(^{1}\text{Highway Sufficiency Ratings, Highway Research Board, 1952.}\)

\(^{2}\text{Highway Capacity Manual, Highway Research Board, 1965.}\)

\(^{3}\text{Robert W. Fogel, "Railroads and American Economic Growth", in Essays in Econometric History (Johns Hopkins Press, 1964).}\)

\(^{4}\text{It is assumed that the reader is familiar with the techniques of project analysis. For details concerning its application to transport projects see: The Economic Benefits of Road Construction and Improvement, by Lionel Odier, Estoup, Paris; Preparation and Appraisal of Transport Projects, by Clell G. Harral, Brookings Institution; "Cost-Benefit Analysis: A Survey", by A. R. Prest and R. Turvey, Economic Journal, December 1965.}\)
analysis under these conditions is at its most uncertain, requiring the utmost economic sophistication.\textsuperscript{5}

Though methods of project analysis are well developed, the great bulk of project analysis being done is inferior to what one would expect, given the widespread acceptance of the concepts and their relative simplicity. The reasons are fairly clear. First, consultants often do poor work because the alternatives are improperly conceived, or because of ignorance of the underlying concepts of shadow pricing, the opportunity cost of capital, existing, diverted, and generated traffic, and marginal costs of alternative existing operations. Secondly, consultants are often hired by foreign governments to justify schemes that are already judged desirable for any number of non-quantitative reasons. Knowing this, and knowing that future contracts may well hinge on a favourable report, some consultants may feel impelled towards producing a favourable report. It is unrealistic to expect consultants to be objective under such a system, since there is no reward for doing a good job per se.

Putting these problems aside for a moment and assuming that the analyst is objective and competent and employs all the “correct” procedures, there is still a large area of uncertainty in most feasibility studies. This, as we have mentioned before, concerns the prediction of future traffic in time and space, especially if there are project interdependencies and “system” effects. The tendency of project analysts has been to expand the analysis to include such concepts as the effect of other projects, the location and likely future level of economic activity, and the effect of the project on other modes of transport. This is often merely the laying on of hands to imply more sophistication in the project approach. Seldom are these levels of economic activity and the systems effects translated into traffic over specific routes. The more common result is that after discussing these factors the analyst chooses an annual compound rate of growth of traffic over his project, and then plunges into the more familiar computations of the discounted streams of costs and benefits, assuming that the unpleasant task of traffic prediction is over.

It would be unfair to imply that project analysts are insincere in their desire to do good analysis. On the contrary, one usually senses in their reports that they are groping for a better framework, but they revert to the accepted methods as a matter of necessity.

Economists themselves are unhappy with some of the “correct” procedures, especially in the area of the selection of discount rates. If a benefit-cost ratio is to be computed, some assumption must be made concerning the opportunity cost of capital. If the internal rate of return is to be computed it must be decided whether the resulting rate is acceptable. Willingness to make this decision seems to be a function of how long one has been away from an academic environment.

Project analysts would contend that, although their methods are not entirely satisfactory, they are a better framework for decision making than the subjective approach of the past. This is probably true if competent objective analysts are engaged.

\textsuperscript{5}For an excellent example of the complexities of analysis under these conditions see: “The Cochamba-Santa Cruz Highway in Bolivia”, by Barbara R. Bergmann, in \textit{The Impact of Highway Investment on Development}, by Wilson, Bergmann, Hirsch and Klein (The Brookings Institution, 1966).
The logistics of project analysis are also fairly modest. The methods are well
documented and available. The concepts can be explained to an intelligent individual
with some technical training. The data requirements are approximately at the limit
of what most countries can produce, and the computations involved are simple.
There is therefore no reason why these methods cannot be introduced in most
national transport planning efforts.

Project analysts may object to being excluded from the fraternity of planners who
consider themselves “systems” analysts, and indeed their data inputs can involve
some fairly sophisticated systems analysis. To attempt to define the point where
project analysis becomes systems analysis would be an involved exercise. Suffice it to
say that those who have done both are quite aware when they have moved from one
area to the other. This awareness involves the general expansion of scope, the absence
of “correct” procedures, consideration of the total transport system, and specific
consideration of the spatial location of economic activity and the resulting derived
demand for transport in time and space. On the other side there is consideration of
the existing location of transport facilities and appropriate locations for economic
activity. Finally, evaluation schemes may be radically different, and more general
constraints may be considered. The following sections on various systems approaches
should serve to clarify the delineation between them and project analysis.

THE LINEAR PROGRAMMING APPROACH

Linear programming has a great deal of appeal as a problem-solving tool because of
its rationality and computational feasibility. The idea of maximising or minimising
an objective function subject to several constraints is familiar to most planners. It
implies that the solution obtained is not only feasible, but the best within the feasible
set.

In the field of transport, oil companies were the first to use linear programming in
solving their own transport problems. For instance, given several industrial suppliers
of petroleum products and many commercial distribution points located over a large
geographical area, which supply points should ship to which demand points in order
to minimise total transport costs? This kind of problem was structured so that
supplies and demands were located in space. These locations were referred to as
nodes, and the transport system joining these nodes was referred to as a series of
links. The links and nodes together made up the network. A cost for traversing each
link was defined. The objective was to minimise total transport costs, and the chief

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6For a technical presentation of the techniques employed by systems analysts in transport see:
Northwestern University, June 1966). For the best example of linear programming techniques
applied to transport planning see: A Systems Study of Transportation in Northeast Brazil, by R. E. Lave,

7It is interesting to note that the project analysis approach can be expressed in a dynamic form by
incorporating a timing function. This endows it with an objective function of its own and enables net
benefits to be maximised in much the same way as linear programming enables total transport costs
to be minimised.
constraint was that demand must be satisfied at all demand points. A minimum path routine traced out the least cost paths from every supply point to every demand point. The linear programming routine then took this information, together with that concerning supplies and demands, and minimized the total cost of supplying all demand points. The resulting set of origins and destinations and the routing between them provided a least cost solution to the problem. The results must have been quite useful, since the major oil companies continue to invest money in the development of these techniques.

The natural thing to do after the success of the oil companies was to employ these developed techniques in the underdeveloped countries, where freight was by far the most important component of inter-city transport. This is an important consideration. Freight is, presumably, transported according to a fairly well defined rationale. The spatial location of supply and demand and the cost of overcoming the “friction” of space are certainly realities for freight transport. The problem becomes far more complex when private passenger transport, especially private automobile travel, becomes a significant component of inter-city transport flows. The spatial location of supplies and demands of people becomes an awkward concept. The factors lying behind the decision to make a trip, and the resulting routing for people, are not nearly as simple as the assembly of the physical components of production or the satisfaction of the final demand for production. The relative simplicity of many of the transport systems in the underdeveloped countries was also a factor, as computers were not able to handle the mass of computations necessary for a network as large and complex as that of the U.S.A. The idea was to analyse transport networks too complex for human beings to handle, but within the computational ability of the computers available.

The use of this tool as a planning aid was simple. Let the economists, geographers, and demographers predict the future location and amount of supplies and demands for the output of the economy, commodity by commodity. Let the engineers and planners produce several alternative transport systems, for the final year of the planning period, made up of the existing system plus any changes that seem interesting to the planners. With each scheme are associated the cost of traversing each link as well as the maintenance costs. Additions to the existing system also have the capital costs associated with them. The schemes may all be feasible from the financial, engineering, social, and political points of view. The only remaining task is to adapt the work of the oil companies to handle more complex networks and more commodities. The results are an origin-destination matrix for all commodities, the routing of each commodity and thus the flow on each link, the minimum costs for allowing the factors of production to be brought together as well as the satisfaction of final demand, and the investment and maintenance costs necessary to provide and maintain such a transport network. Each of these results is available for each network alternative.

This approach had an inordinate amount of appeal to planners. Presumably each alternative network had a set of quantitative results which planners and (more important) politicians would have to consider explicitly. The concept of an optimal, i.e., least cost, transport system from the set of alternatives provided, while not the optimal in the global sense, was a giant step forward when compared with previous efforts. Perhaps one of the greatest benefits to be derived from this approach was the
ability of the scientific planner to confront the politician with the costs of political and social constraints.

The major underlying requirements of such an approach are:

1. Reasonable predictions of future location and level of supply and demand for each commodity.
2. The ability to specify the relevant transport network, and the cost and performance characteristics of each node and each link of the network.
3. The assumption that commodities are in general shipped according to some economic rationale, i.e., least total perceived cost to the shipper.\(^8\)
4. Homogeneity of commodity groups, i.e., all commodities within each commodity group must be perfect substitutes.

This is a formidable group of assumptions which one should keep in mind before becoming too enamoured with the intricacies of the linear programming approach. Perhaps the most difficult assumption to accept is the ability to predict the future location and amount of supply and demand for each commodity. Prediction of total commodity outputs for the country alone is a difficult enough task. The process of spatial location over time is complicated by the fact that the provision of transport facilities itself affects the location of economic activity. Faced with a set of interdependent relationships, we are assuming away these relationships, or at least assuming them to be insignificant.

To specify the relevant transport network of links and nodes as well as the cost performance characteristics of each link for each commodity is conceptually straightforward, but in practice extremely difficult. Different commodities have different transport requirements, which involve different costs and performance characteristics. Complicating the whole analysis is the fact that for route and modal selection the price and not the cost of transport is the relevant factor. One must therefore assume the pricing conditions over time, and become involved in such matters as irrational pricing systems imposed by the government and the likelihood of their being rationalised. One of the advantages of this approach is that one can explore the distortion of transport choices resulting from various pricing policies. This does not remove the necessity to assume some kind of pricing environment when the predictions are made.

In order to make the network amenable to analysis one invariably has to make simplifying assumptions. For instance, one must assume that scheduling of services, size of shipment, total length of shipment, and such intangibles as travel time variability and travel time have little or no influence in the route or modal choice. That the “friction of space” can be collapsed into the price or cost of travel over one link is a difficult assumption to accept. It is also difficult to consider inter-modal transfer operations, such as highway to rail, as the cost performance of such an operation is rarely known and often not even considered. The empirical fact that once a shipment enters the transport system by one mode it usually remains on that mode shows that the operation is not without significance.

Once one begins to think of objections to the linear programming approach to transport planning, it becomes difficult to enumerate them all. Those who espouse it

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\(^8\)In addition to linear program distribution models, there is a set of models referred to as “gravity” or inverse impedance models, which perform the same function but must be calibrated empirically.
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usually end by stating that it is unlikely to solve a country's transport problems but is a useful tool in analysing the complexities of a particular system, and that anyone who becomes involved in linear programming soon has a good feel for the system. This may be true, and the data needed is useful in any case.

With the systems approach to transport planning the planner must be concerned with the logistics of employing this methodology in the planning machinery of a country. The big inputs into a linear programming model are data, expertise, organisational talent and computational sophistication.

The data requirements for this model are of an order of magnitude beyond the project analysis approach. In addition to engineering and economic data for the entire transport system, such as transport costs and pricing, origin and destination data, maintenance costs and construction costs, large amounts of economic data concerning the supply of and demand for different commodities must be gathered for the present and predicted for the future.

The expertise needed to collect and organise the data is considerable, and requires the talents of engineers, economists, and statisticians. This implies organisational talent capable of obtaining cooperation from many agencies. In a developing country this type of talent is at a premium, or it may not exist.

Like any industrial process, transport planning can be imported. Much of the project analysis and all the systems analysis to date has been exported from the developed countries. The desirability of this and the possibilities of developing a domestic product open up another area of controversy, which will be dealt with in the final section on appropriate planning techniques for West Pakistan.

THE INTEGER PROGRAMMING APPROACH

Linear programming has its advocates, but most of them more or less admit its limitations. The most interesting limitations are those which seem to be amenable to further analysis involving more analytical sophistication. Integer programming techniques have made it possible for analysts to consider a particularly vexing problem. One characteristic of the approach is that one gets only a snapshot of the network at some future date with the flows on each link. Also, one is forced to choose from a group of alternative networks exogenously specified. The question arises whether there is any way to choose an optimal network from a group of projects exogenously specified; if so, how does one reach that particular network configuration over time? In order to answer these questions certain additional assumptions are necessary, and some changes have to be incorporated in the existing linear programming codes. The procedure is this: Take the existing network, and specify upper limits or capacities on each link. Then specify all interesting link additions or improvements with their attendant capacities, capital costs, maintenance costs and

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operating costs. For example, one could specify three alternative improvements to
an existing gravel road – pave the existing one, realign and pave with low standards,
and realign and pave with high standards – each with its attendant cost and capacity
characteristics. It is still necessary to predict the location and amount of supply and
demand for each commodity for a particular year in the future. The changes made in
the linear programming formulation are as follows. The capacity of a link cannot be
exceeded. Any one project must be completely built or not built at all; hence
the integer nature of the programme. In addition to the constraint changes, the
objective function is altered from the simple minimisation of transport costs to
include the capital and maintenance costs of alternative improvements considered.
In this manner total transport costs can be minimised. Each solution under the
linear programming system has a figure for total charges or costs and a separate
figure for the capital and maintenance costs associated with the network. The planner
has to decide which combination is best. With the integer programme this decision
becomes an internal one.

Combinations of new and improved links are considered until the solution
is found satisfying the constraints with least total (i.e., construction plus maintenance
plus operating) cost. The result of the analysis is an optimal network chosen
from an existing network and a collection of projects exogenously specified. This
means that the interdependence of projects as well as the intensity of utilisation of
the network is considered explicitly by the analyst in arriving at a least cost solution
for some future date, say 20 years hence.

The next question to be answered is: how does one arrive at such a network over
time? Clearly, one cannot build all the future additions at once. This requires the
breaking up of the twenty-year planning period into smaller stages, say four five-
year periods, and the specification of the amount and location of supplies and de-
mands for the last of each five years. If five-year periods are chosen, economic data
must be generated for the last year of each period. The procedure then is to solve for
the final network in, say, 1989, using the economic data for that year. This network
will be made up of the present (1969) network plus those projects that were included,
considering capacity and minimum total costs. All the alternative projects that were
not selected in the 1989 network are discarded. The 1984 network is then solved for,
using the 1984 economic data. This network will be made up of the 1969 network
plus those projects selected from the alternatives that were not discarded after solving
for the 1989 network. The same process is repeated for 1979 and 1974. The analyst
then has four snapshots of the optimal network at different periods in time. Compari-
son of the 1969 network with the resulting 1974 network provides him with the
construction programme for that period, and so on up to 1989. Periodic updating of
economic projections and re-runs of the model will of course change the 1989 net-
work from its original form, and unless the original economic projections are correct
the original 1989 network will never be attained. The chief advantage is that at any
point in time planners have a short-range plan that is consistent with a perspective
plan based on the best data available. With new and better data the old perspective
plan can be extended. The planner is not wed to the provision of an ultimate
network. The commitment is to the short-range plan, which in this case would be 1969
to 1974. The question whether to provide a budget constraint for capital expenditures
depends on how responsive the budget is to the needs of the transport system. If the
budget constraint is imposed without regard to the results of the analysis, it should be included at each stage. If the budget allocation is responsive to the needs implied from the results, it should not be included. In either case it can be handled.

The logic of such an approach is extremely attractive, especially to planners who have been struggling with the complexities of project interdependencies and the timing of investments and at the same time trying to provide a perspective plan which does not become obsolete in a few years. One should not forget that the same assumptions that underlie the linear programming approach apply to the use of integer programming. In addition, economic projections must be provided for intermediate periods, independent of the effects of the changing transport network. A further complication is the specification of the “capacity” of a link. This involves a number of arbitrary assumptions concerning peaking characteristics on a link, as well as vehicle size and load factors. Finally, the price in terms of computational complexity increases greatly as one moves from the simple linear programming techniques. Real constraints are felt on the size and complexity of the network that can be considered. This may be alleviated with the development of better computational methods, which are sure to come in the future.

SIMULATION MODELS

An attempt to define a transport simulation model and to explain how it differs from a linear programming model, which does indeed attempt to simulate some components of a transport system, would be as involved as the distinction between project analysis and systems analysis, and would be arbitrary at best. Again it can be stated that people who have worked with both types of models are very much aware of the differences, so much so that they have made a distinction between the two approaches in their own minds.

Both types of models consider the spatial distribution of economic activity in the future and the resulting derived demand for transport in time and space. Both models analyse the transport network and exogenously specified link additions. Both employ minimum path routines in the network analysis, and both may use linear programming routines to distribute flows on the network according to a least cost criterion. The fundamental difference between the two types of models is that, while the economic projections for the linear programming model are estimated exogenously and independently of the type of network, the transport simulation model is allowed to interact with the economic model and to influence the spatial distribution as well as the profitability of economic activity. Secondly, with simulation models a time-staged transport investment programme can be evaluated by macro-economic measures, since the effects of various programmes are allowed to

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10 This discussion is based entirely on experiences with the transport simulation model developed by the Harvard University Transport Research Program. For a formal presentation of the transport model see: *Transport Planning Models for Developing Countries*, by P. O. Roberts, Jr. (unpublished Ph.D. Thesis, Northwestern University, Evanston, Illinois, June 1966). For an example of the application of this model to transport planning see: *Simulation of Transport Policy Alternatives for Colombia*, by P. O. Roberts and D. T. Kreuge (Discussion paper Number 55, Harvard Transportation and Economic Development Seminar, Harvard University, December 1967).
work themselves out over time and to influence such measures as GNP, regional production levels, profits and wages. No formal attempt is made to evaluate particular schemes. The emphasis is on the prediction of measures that can be used in the evaluation procedure. The outcome of an evaluation procedure depends very much on the value system of the individual or group performing the evaluation. If a government for social or political reasons wishes to increase wages in a particular region, even at the expense of national growth, this can be reflected in the evaluation procedure.

Needless to say, the mechanism for affecting all this is complex and extensive. There is an economic simulation model, whose function is to provide the transport simulation model with the annual regional breakdown of supplies and demands for commodities, in addition to detailed macro-economic information on the performance of the economy on a national and regional level. The economic model is based on an input-output table with the components of final demand determined by a set of behavioural functions.\(^\text{11}\) The model operates on a combination of endogenously determined lagged data and exogenously specified data. In simulation, the model ages year by year and provides a detailed set of economic measurements from which the lagged data for future years are obtained.

The transport simulation model operates in series with the economic model. The annual inputs to the transport model are the spatial distribution of supplies and demands from the economic model together with any changes specified exogenously for the transport network for that particular year. The exogenous specification of a time-staged investment programme is another unique feature of the model. Physical changes in the initial network are made according to the plan, and are incorporated into the network by the transport model. Investment in an improvement may take several years, and this information is presented to the economic model as a component of total transport investment, permitting the simulation of the stimulus provided to the regional economy by the construction activity. The physical implementation programme is then fed exogenously into the transport model while the financial implementation programme is fed into the economic model.

The transport model is similar to the earlier linear programming models, but in terms of the network analysis techniques it represents a significant departure in two other areas. First, the “friction of space” associated with each link takes into consideration five components: waiting time, travel time, travel time variability, probability of loss, and finally the cost or price of traversing the link. Each commodity is then given a preference vector defining the value placed on each of the five components of the link performance vector. The product of these two vectors provides a measure of the “friction of space” for each commodity. For instance, the preference vector for a high-value, light-weight commodity will put a relatively high weighting on the probability of loss and on travel time, and a relatively low weighting on the price or cost of travelling over a link. If this preference vector is combined with a link performance vector having a high probability of loss and a long travel time, the resulting friction factor will be high. The same link performance vector combined


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with a commodity preference vector with a low value placed on probability of loss and travel time, as would be the case for coal or other ores, would produce a much lower friction factor. Thus the high value commodity might travel by truck or by air, and the low value commodity by rail. In this manner the basic network is transformed for each commodity before the network analysis begins. This allows specific attention to be given to a particularly difficult problem, the prediction of modal choices.

Another significant departure from previous methods employed in transport models is the development of a set of sub-models simulating the operation of particular modes. The chief function of these sub-models is to provide the cost performance characteristics of each link in the network. As stated previously, each link has a cost performance vector associated with it to aid in computing the friction factor for a particular commodity. This cost performance vector is recomputed for each year by the modal sub-models. For each link, the relevant sub-model takes the physical characteristics together with the measure of utilisation in the previous time period and computes the new values of the link performance vector.

These modal sub-models also enable one to examine the effects of investments other than new construction or the improvement of a link: for instance, the rail sub-model considers such things as the length and spacing of sidings and the type of signal system. Investments in sidings or signal systems can be reflected as changes in the data fed into the sub-model. Similarly, the sub-model for intermodal transfer operations can reflect investments in loading or unloading equipment by changes in the assumed loading and unloading rates. None of these factors could be handled specifically in any previous model.

The final task of the transport model is to produce a summary of the transport simulation for each year, showing the amount of transport purchased by each industry in each region. In this manner the costs and profits of an industry in a particular region can be influenced by transport decisions. The amount of transport purchased by each industry at the national level is then placed in the domestic flow matrix of the input-output table. The table is then reinverted and the economic model continues with the simulation of the next time period.

Simulation models represent an attempt by transport planners to expand and improve their powers of prediction. This has been the thread running through the evolution of transport planning models. The entire effort is based on the assumption that the rationale governing the operation of a transport system can be captured if the essential physical and behavioural relationships can be defined, and if values for the variables in these relationships can be determined. Because the rationale underlying the operation of a transport system is complex, and because transport is intimately related to the operation of the economy, it was inevitable that there would evolve a very complex model closely related to the economic system.

The usefulness of such a model depends on the validity of the relationships assumed and the possibility of quantifying the variables contained therein. It would be premature to make any judgment at this time, as the model is just being given its first full-scale test on the transport system of Colombia in South America. One particularly troublesome problem, however, afflicted all the "systems" models and is not avoided by the simulation models. This is the problem of reproducing the existing pattern of commodity flows. If the predictive mechanism cannot correctly reproduce
the existing pattern of flows, then there is no reason to believe that it will correctly predict future flows. An example of an unsuccessful attempt to explain the flow of one supposedly homogenous commodity was the attempt to explain the pattern of coal flows in India. The trouble arose from the fact that some coal mines were "captive" mines of industries which preferred to purchase coal from their own controlled sources regardless of transport cost.

Two other difficult cases come immediately to mind in West Pakistan. The first concerns wheat imports. If transport cost were the sole criterion, practically all wheat imports would be consumed in Karachi, and the Punjab production would be consumed in the Punjab. The problem is that the local people prefer the domestic product. As a result, the wheat from the Punjab flows to Karachi and imports flow upcountry. This is a problem of non-homogeneity. Domestic and imported wheat are really two different commodities. Yet there must be a limit to the commodity breakdown employed in the model.

The second case arises when the Pakistan government makes the modal and routing decision. Practically everything sent by the government in West Pakistan is sent by rail because the railway is government-owned. It is quite likely that many of the short haul consignments are irrational from an economic viewpoint.

The present experiments with a macro-economic transport simulation model should show how significant is the interdependence between the transport system and economic growth. The assumption that this interdependence is important is responsible for much of the complexity of the model. If the case could be made that in some countries there is no very significant or sensitive relationship between transport investment strategy and the regional and national growth rates, then much of the complexity could be dispensed with.

Putting aside theoretical objections to the use of this model, or any model for that matter, the real difficulty in making it operational in an underdeveloped country is one of logistics. While the vision of having a facsimile of the economy and the transport system that can be experimented with over twenty-year periods in a matter of minutes is appealing to any planner, the problems involved in getting to that point should not be taken too lightly. In some cases it may not be possible to achieve the goal; in other cases it may not be worth the expense of achieving it.

The data requirements for a simulation model are staggering, far beyond the normal inputs to any modest national planning effort, let alone transport planning efforts. The economic model requires a set of historical data for at least the previous five years, including an input-output table, sectoral information on capital-output ratios, wages and profits, time series on the components of final demand, and an investment flow matrix, to state a few of the more important. At the regional level the minimum requirement is the regional distribution of output by sector. The transport model requires the physical characteristics of the links in the transport system, as well as historical information on traffic counts and origin-destination data for each commodity. Detailed information is required on the amount and characteristics of vehicles and rolling stock. The existence of origin-destination data is particularly crucial, since the calibration and evaluation of the distribution models depend on the existence of past data and the ability of the model to replicate it.

Given the data, the organisation of the data and the calibration of the economic and transport models with the historical data is a difficult and time-consuming task,
requiring competent individuals intimately familiar with the internal workings of both models. It is during this calibration period that the rationale governing the economic and transport system must be captured, as this rationale is the basis for the projections of future economic and transport activity.

The economists must decide on the exogenous inputs to the economic model when making projections. Similarly, the transport planners must decide what time-staged investment programmes will be considered. All these activities require imaginative, competent individuals and close cooperation.

Finally, there must be access to a large and sophisticated computer facility, the likes of which few under-developed countries in the world have or could operate. This requirement makes it almost mandatory for their computations to be undertaken elsewhere.

The problems of data and computations are considerable, but probably the most serious logistical problem concerns the personnel required to construct the model and use it intelligently. The individuals engaged on the simulation model in Colombia comprised some of the most competent and imaginative people available in the fields of economics, transport economics, civil engineering, systems analysis, operations research and computer programming. Practically all had knowledge and experience outside their own speciality. Much of this expertise was necessary both for the initial development of the model and for its subsequent utilisation.

In spite of these difficulties, the simulation approach is the most exciting and possibly the most significant development in transport planning for years. But the difficulties do limit the immediate usefulness of the model for transport planning in many of the developing countries.

**TECHNIQUES APPROPRIATE FOR WEST PAKISTAN**

The appropriate methods to employ for transport planning depend very much on what sort of plan is required by the decision makers. The plan specification plus the logistical constraints will determine the nature of the planning effort. If the decision makers do not know exactly what they want, the planner has the opportunity to educate them in what a plan should be and how it should be arrived at. There is, however, a limit to the educational impact that a planner can have.

In order to assess the decision-making environment for transport in West Pakistan, it is necessary first to identify the principal decision makers and their objectives in transport planning. There are essentially four main parties involved: the Provincial Planning Department, the Pakistan Western Railway, the Highway Department, and the Chief Executive of the Province.

The Planning Department have a well defined objective. They need a rationale for allocating funds between the highways and the railways. Since they have almost no information or expertise concerning transport, they have little choice but to accept the investment programmes of the two transport agencies and attempt to reconcile the requests with the funds available on almost entirely subjective grounds. As planners they feel they should be able to provide some overall guidance to the transport investment programme, since they can take a broader view than either of
the two agencies. They are interested essentially in the economics of the two modes and in their appropriate roles. They have no direct control over central government policies concerning taxes or imports, both of which affect greatly the economics of the two modes. They are therefore interested in removing these distortions by means of economic analyses employing economic costs, net of taxes, and shadow prices. The effect of these distortions on the demand for transport cannot really be considered.

The Pakistan Western Railway dominate the decision-making environment for transport in West Pakistan. They have employed the bottleneck technique for planning almost exclusively. The management inherited a railway in rather bad condition at the time of partition; by concentrating on the procurement and maintenance of locomotives and rolling stock they provided capacity for the steadily growing freight and passenger traffic. Following the 1960 decision to allow trucks to operate freely, growth in demand has not continued at the previous pace, and the railway planners have become particularly concerned with future rail traffic projections, since most of their new investments, locomotives and rolling stock, are determined by this variable. The chief planning objective of the PWR is therefore the projection of rail freight and passenger traffic. They are less concerned with the formal justification of investments or the economics of transport, for two reasons: first, they have no traditional interest in these things, and secondly, they have no expertise in them. The PWR also enjoy a unique position in the province in that they are directly answerable to the Chief Executive of the Province alone.

The Highway Department are controlled by the Ministry of Works and Communications. Unlike the PWR, they play almost no role in the decision-making environment. As a new agency recently organised from the bifurcation of the former building and roads department, they have no tradition of planning or organisation. The engineers in the field have had much more autonomy than have the divisions within the railway, and are not anxious to relinquish their power. The Highway Department therefore have several planning objectives. They need a plan, a time-staged investment programme and an ultimate network for some period in the future around which they can organise their implementation effort. The plan must be in the form of a collection of feasibility studies if international financing is to be obtained. Recognising this need, the Highway Department entered into a long-term contract with foreign consultants to aid in plan preparation. Unfortunately no economist was included in the team, and a long-range plan emerged devoid of economic content. There was also a lack of expertise in project analysis. The Highway Department's first experience with scientific planning from the west was therefore disillusioning.

The Chief Executive of the province has the final word on matters of transport. He is a politician, and transport is only one of several sectors he is concerned with.

A feature of the power structure is the lack of a single individual who could impose a uniform and coordinated approach to transport planning on the railways and highways. Cooperation from the two transport agencies is largely voluntary. Under these conditions the PWR emerge as the key to the nature and quality of the planning effort. Without the active cooperation of the railways a reasonably sophisticated approach to transport planning is not possible. Much therefore depends on the ability of the planning group to convince the PWR management of the desirability of a more formal attempt at planning.

The desire to impose some coordination of railway and highway planning has
TRANSPORT PLANNING: SELECTION OF ANALYTICAL TECHNIQUES

Robert E. Burns

led recently to the setting up of the Provincial Transport Coordination Board. It remains to be seen how effective this body will be.

The logistical constraints on transport planning are particularly relevant in West Pakistan because of the unusual complexity of the transport network and the lack of both computational facilities and personnel. The link-node configuration of West Pakistan's transport network, especially in the Punjab, is very complex from the viewpoint of network analysis. The parallel rail and highway links, together with the large number of possible intermodal transfers, makes traffic prediction difficult. It is doubtful if the existing computer routines for the integer programming or the simulation model could handle this network. In order to make the network amenable to analysis the regional nature of both the model and the network would have to be emphasised to the point where the results might be of little use.

Allied with this problem is the fact that there are no computers in West Pakistan that could handle the simulation model, nor will those arriving in the near future be able to do so, although they could probably handle the linear programming analysis.

Personnel is probably the most severe constraint. West Pakistan lacks a group of systems analysts accustomed to the use of computers. The engineering university, usually the most likely source, has no tradition of this kind. Even if experts were imported there would be no one to work with them and learn how to use the techniques. This constraint pretty well precludes any systems analysis unless the decision makers allow the importation of the entire team of analysts. Failing this, the traffic projections which the railways would most like to have from transport planners are unlikely to be forthcoming. All that can be done is to make some hand computations of the major flows, such as that from the Punjab to Karachi. A similar hand analysis might be used to estimate the changes in flows due to the investment in major new industrial plants.

This leaves project analysis as the major analytical technique available. Here too the complexity of the transport network makes reasonable traffic predictions difficult. Traffic diverted from another route or mode can be a major component of future traffic on a new route. The relevant cost saving in using the new route is the marginal cost of operating on the alternative. This is a difficult concept to get across. It is also a difficult item to estimate. Even at the project analysis level there is a severe personnel constraint: there is no one in any agency of the provincial government who understands project analysis and can properly apply it to a range of transport investments. This means that domestic project analysis is impossible; consultants must be employed, although it is impossible either to write reasonably detailed terms of reference for them or to evaluate their work.

Project analysis therefore seems to be the most appropriate analytical technique for West Pakistan to adopt in its transport planning effort. The requirements of the international lending agencies make this a minimum level of analytical sophistication. In the short run foreign consultants and advisers will be needed, and they should help to train local people to take over this sort of work in future.