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Transportation Planning Techniques: Problems and Prospects

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TRANSPORTATION PLANNING TECHNIQUES: PROBLEMS AND PROSPECTS*

This paper is concerned with giving an overview of some of the more recent developments in transport planning techniques and tries to outline where, to the author's mind, the thrust of future efforts in further extending these techniques should lie. Transport planning can be seen as consisting of four distinct, although closely interdependent aspects. They involve rather different conceptual issues and different planning techniques. The paper is divided into four parts accordingly. Part I deals with various methods of forecasting future traffic demand. Part II is concerned with the question of adopting the transport facilities both hardware and software to the changing transport requirements. Part III focuses on the locational impact of transport on the geographical pattern of production and consumption. Part IV discusses the possible use of transport policy in consciously influencing the regional distribution of economic and social activities.

I

On transport forecasting a tremendous amount of both theoretical and empirical work has been done. Essentially four approaches have been used, involving a successively higher degree of analytical sophistication: trend-extrapolation, correlation analysis, demand functions and equilibrium models.

Trend-extrapolation simply assumes that past growth trends or changes in past growth trends of traffic continue into the future. The validity of this assumption, especially in the long run, is always questionable.

Correlation analysis ties the expected traffic volume to some other economic magnitude, to which it appears to have been closely related in the past; such magnitudes include gross national product, popu-

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lation, fuel consumption, etc. The quality of the traffic predictions is
dependent on the quality of the forecast of the magnitude to which
the traffic volume has been linked and the consistency of the cor-
relation between them.

Demand models derive the expected traffic volume from the func-
tional characteristics of the transport facilities provided, by relating
transport users' utility functions of transport to different levels of serv-
ice. In the single mode models the demand is projected as a function
of the characteristics of one transport mode alone. The multi-mode
models take account of substitution effects between the modes. The
multi-modal split models relate the relative traffic volume for differ-
et modes directly to the relative levels of service. A typical example
is the McLynn demand model. The multi-modal cross elasticity
models operate with one or several resistance terms, the essential
difference being that the volume of competing modes is not explicitly
specified. For instance the Quandt-Baumol model gives resistance
as a product of price, frequency and travel time. Both kinds of multi-
modal demand models should be extended to include not only economic factors but also sociological and institutional aspects.

Equilibrium models are essentially microeconomic decision
models incorporating both demand and supply conditions. The ex-
licit equilibrium model determines equilibrium by locating,
through computer iteration, a traffic flow pattern that simul-
taneously satisfies both predetermined demand and supply relations.
One of the more impressive applications has been the Northeast


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Corridor Study for the U.S. Department of Commerce. The sequential equilibrium models revise the demand and supply conditions in successive approximations of the equilibrium by breaking up the analysis into trip generation, distribution, modal split and assignment. This approach is used in the Urban Transportation Model System, which has been extensively applied in many cities around the world.

The technique of setting up such micro-orientated models has, in a more general form, been presented adequately by Lane, Powell and Smith. The collection of information for these models may be excessively expensive, especially for smaller scale projects. But, by and large, they at least do not seem to pose major conceptual difficulties.

II

Analyses aimed at finding the minimum cost solutions in fulfilling the transport requirements as predicted by the forecasting models can be grouped under four categories: infrastructure, pricing, taxes and access restrictions. As for the planning of infrastructure various highway, railroad, and port cost performance models have been developed. The main break-through in recent years here seems to have been firstly the change from optimization procedures to simulation techniques and secondly, closely connected with it, the recognition that only a systems approach, involving a multitude of planning parameters simultaneously, can yield satisfactory results. At least at the project level, the presently available models seem not only structurally sufficiently differentiated for the study of real world problems but also the technical functions used in them are usually systematically tested so as to render these models immediately appli-


able in practice. Examples are the various modal cost performance models developed in the International Bank for Reconstruction and Development\(^6\). Typically such cost performance models included only operating cost and maintenance cost as endogenous variables leaving construction as the exogenous variable. A study done by Charles River Associates, however, also includes construction features, i.e. alignment, curvature, gradients, etc. as endogenous variables, by relating them to the topographical and geographical characteristics of the area under consideration\(^7\). While providing an important extension towards yet more comprehensive project planning, the empirical validity of the construction functions, will as yet have to be tested.

Network considerations in infrastructure planning complicates the mathematical structure of the infrastructure models considerably. Network planning techniques started at a rather abstract level by using linear programming\(^8\). To the author's mind the many attempts of using linear programming techniques for network planning have had limited success. For the simplest of cases, for instance planning a transport system in an agricultural area with homogeneous topography, the solutions provided by these linear programming models

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may provide some guidance to the policy maker. A recent example for a study under such simplified circumstances is the paper by I. Osayimwese on 'An Application of Linear Programming to the Evacuation of Groundnuts in Nigeria'. But in the majority of cases the complexity of the real world is such that this complexity cannot be adequately reflected in this type of model. In this sphere too, therefore, the simulation approach seems to be increasingly used. The 'Systems Analysis of Rural Transportation' prepared by Meta Systems may serve as an illustrative example. Although the simulation models do not provide optimal solutions in the strict sense they can usually give a fair indication as to which layout to choose from a number of alternatives and, by sufficient iteration, approximate the optimum adequately for practical purposes. These network studies on a simulation basis can furthermore make immediate use of preceding studies done at a project level. Since the models used for infrastructure project planning are essentially set-up at a purely technical level, their aggregation does not pose the usual problems with which the analyst is usually faced when combining the results of partial analysis in the economic field. What they do require is sound traffic forecasts, especially projections of traffic diversion, an issue touched upon before.

The fact that operational models for the planning of infrastructure are available does, of course, not imply that they are actually used by those engaged in practical infrastructure planning. On the contrary there appears to be a deep-rooted suspicion by some planners against their application. The reason can hardly lie in the difficulty in understanding the mechanism of the models. Their logical structure is usually, even in the more complex cases, sufficiently simple to be presented in the form of easily assimilable graphical flow dia-


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grams; their mathematical formulation involving as a rule but the basics of algebra, can pose no serious determent. One reason seems to be, rather, that the models frequently force the planner to provide figures, the basis of which are mere conjecture or ‘rules of thumb’. Any practical planner knows that such ‘guestimates’ are unavoidable for a whole range of empirical relationships. In such cases it seems reasonable to reduce the perfectionist claim of the model to concepts within which the planner does operate, for instance as regards the maintenance status of road rather than expressing it in terms of rut depth, slope variance and percentage of cracking and patching to simply state it in qualitative terms of good, fair and bad.

The second reason for the practitioner’s reluctance to operate with planning models is that it confronts him, by the very system approach which it entails, with the impact of his ‘guestimates’ on other parts of the model. Explicitly stating the consequences throughout the system makes him hesitant to give his guess in the first instance. One way to deal with this problem is not to confront the practitioner with the model at all, but merely to issue him with questionnaires, which, familiar to him in the concepts used, draws upon his expertise as much as possible, and then calibrates the model on the basis of these questionnaires. Recent attempts at the World Bank in developing such questionnaires for the highway-cost-performance model seem promising.

As to the question of pricing, taxes and access control, the main trend of current analysis still seems to run along quite different lines. Whereas Cost-Benefit Analysis has, especially in recourse to the social surplus, replaced the traditional notions of welfare economics in the planning of infrastructure for quite some time, the pricing controversy still seems to take place largely in terms of the old framework of marginal conditions, total conditions, second-best solutions, etc. Transport economics appears to be somewhat schizophrenic at this point. While long having abandoned the idea of utility measurement in favor of the social surplus or other operational concepts as far as investment decisions go, Paretian Welfare Economics still dominates much of the pricing discussion. Since the introduction

of total conditions, formulated in an operational way, is as controversial as ever, the conflict between the marginal cost and the average cost position with all its intermediate solutions still remains unsettled. It does not appear immediately comprehensible, why with the acceptance of Cost-Benefit Analysis as a criterion of decision making in the field of infrastructure, the same criterion could or should not also be applied to the question of pricing. Not only could this approach lead the way out of the rather sterile discussion of this topic but it would at the same time suggest the integration of the pricing and the investment question. The author's attempts in this direction of combined investment and pricing decisions in a presentation to the European Ministers of Transport were limited to graphical solutions under rather highly simplified assumptions concerning the cost composition. A technically more advanced study making use of computer simulation was presented more recently by M. R. Wigan and T. J. G. Bamford at the London Transport Research Laboratory. Their study too operated within a purely hypothetical network but research for its application to real world circumstances is presently in progress.

Reverting now to questions of tax policy as related to transport, most of the argumentation appears to have taken place in verbal or purely numerical form. Again, by way of example only, the studies be mentioned by P. Eklund on the 'Earmarking of Taxes for Highways in Developing Countries' or the more recent paper by A. Churchill on 'Road User Charges in Central America'. The somewhat non-analytical approach used for dealing with the problem of taxation could be considered a reflection of the fact that tax questions are largely debated in the field of political controversy, in


which there is little room for the economist to operate with seemingly complex theoretical analysis. Yet, in principle, the question of taxation is at least of the same relevance to the efficient construction and usage of a transport system as that of prices, in fact naturally more so in those modes where prices in the usual sense are the exception rather than the rule, as in the case of roads. The systematic integration of taxation questions into an analytical framework of infrastructure, prices and taxes would therefore seem to be of prime importance. While it is somewhat doubtful that any solutions obtained from any such extended analysis will have any immediate impact on the policy maker, it can at least provide him with a guideline of the economic cost incurred by deviating from them.

Access control, finally, has received hardly any analytical treatment at all. While doubtless as effective an instrument of planning as prices or taxation, this may be explained by the fact that quantitative market controls do not, within the framework of most market economies, again from a political point of view constitute a real choice even in the otherwise frequently heavily regulated transport sector. But even in those economies where access controls are in fact enforced, as for instance long distance road haulage in Germany, little analytical attention has been paid to this phenomenon. In countries that do have recourse to such quantitative measures the underlying economic analysis would seem an immediately necessary task for the evaluation of national policies; in countries in which such measures are apparently ruled out for political reasons they might receive attention either to provide the economic justification for the political a priori decision against them or again give at least an indication of the economic cost incurred should they, from an economic point of view, prove to be the superior one.

The four categories, namely investment, pricing, taxes and access control form, of course, a comprehensive whole in the context of transport coordination in reality. If they have been treated rather independently in planning analyses then this must be attributed to the dimension of the problem posed in dealing with all aspects simultaneously and up to recent years also by limitations in the analytical techniques available. But of late, studies which do attempt to incorporate all aspects simultaneously are coming forth. Given the geometric expansion of variables to be considered they must, by way
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of necessity, if individual modal aspects are to be given full treatment, be restricted in their regional scope, or if to be used in a wider national level, neglect some of the specific modal questions. An example of the former is the Singapore Mass Transit Study which tries to give an extensive analysis of investment and traffic restraint methods in a limited urban area. An example of the latter is the New Zealand Transport Policy Study, the final report of which is now available. In view of the increasing recognition of the high degree of interdependence between all planning parameters, it seems likely that similar studies will emerge elsewhere.

III

Studies on the impact of changes in the transport system on the geographic distribution of economic activities abound in the literature. The majority of them are but simple applications of econometrics. The most ambitious analytical research program in this field is doubtless the so called Harvard Transport Model. It tries to set up


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a model of the economy sufficiently sensitive to transport costs so as to respond to changes in the transport system, while at the same time it incorporates the feedback effects from the changing economy on the transport system, thus closing the loop transport system-economic system-transport system. The model doubtless has its merits, at least in stating analytical objectives. The specific mode of execution, especially in the Colombian case, has however been subjected to severe criticism as exemplified in the review by E. P. Holland and G. G. Harral. One argument was that the data basis was quite insufficient to arrive at the far reaching conclusions drawn from it. Information gaps were, in a number of cases, filled with rather arbitrary figures. Unfortunately this was, as Holland demonstrates in his more extensive appraisal of the model, done also for technical or economic functions for which a careful perusal of the transport literature would have yielded the desired empirical evidence. But most of these statistical deficiencies could in principle be overcome by a little more time and manpower invested.

The criticism relating to the structural approach in that part of the model which simulates the locational impact of the transport system on the economy is more severe. It not only states that the necessary empirical evidence is lacking, but that given the present analytical approach it can, for conceptional reasons, not be found. The level of aggregation in the model is such that empirically meaningful relationships in this part are impossible to establish. Broadly speaking the argument is based on the recognition that satisfactory answers for macroeconomic models can only be found at the microeconomic choice-theoretical level, a recognition that seems to have become quite widely accepted in the field of general economics. In the absence of such a choice-theoretical basis, however, the simu-

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lation of the economic system's response to the transport system must operate with aggregate functions with little or no statistical reliability. Later applications of the Harvard Model, for instance those in Dahomey24, Sudan25, Brazil26 and Thailand27, have avoided these shortcomings essentially by concentrating on the transport system rather than on the economic system part and have, somewhat reduced in their objective, been rather successful.

As concerns more detailed research into the locational impact of the transport system on the economy, however, to the author's knowledge no large scale efforts have been launched since. The question hence arises, both from an operational and an analytical point of view, which course to pursue from here. Given the lack of analytical knowledge three possibilities seem to exist, none of them mutually exclusive, but rather referring to different stages concerning their implementation. The immediate consequence for the operational transport planner, i.e. those involved with having to reach decisions at the present, is to accept the fact that the locational effects of changes in the transport system are but insufficiently known and hence to explicitly reduce the analytical models in this aspect to a so-called consistency analysis. In these no attempt is made at integrating the economic feedback into the model structure. Rather, the path of general economic variables is introduced exogenously or at least is determined exclusively by factors other than the transport system. However, especially where a multitude of projects is under consideration, a cross-check is made whether the combined change effected by the entire program can be consistent with those exogenously given data. If so, no further problems arise. If not, then obviously the 'exogenous' data has to be adjusted. This, in principle, can involve all the problems of predicting the consequences of changes in the economy resulting from changes in the transport system just

discussed. But for many practical purposes, the problems will not be quite so severe. For in many cases the inconsistencies detected will refer but to one or two economic variables. For example, the analysis may suggest that the transport program under review will cause the price of labor to change from the figure predicted assuming the absence of the program. A simple adjustment can then be made in realigning the expected cost. Similar considerations may hold for the market prices of individual commodities, individual production figures, etc. Of course neither the further impact of such changes of individual variables on the rest of the economic performance, nor interdependencies between them can be given sufficient treatment. The consistency model must thus be unsatisfactory to the analytical purist. But for the operational planner, who can hardly be expected to wait for further research to provide more comprehensive answers, it would appear as the immediate course to pursue in the evaluation of larger scale programs.

The second course of action would be to turn to so called dynamic planning methods. Dynamic in this context refers not to the analytical set-up of these models - following the course of variables through time by computer simulation - but to the time-consecutive way in which changes in the transport system are staggered to achieve given objectives. The economic objectives, broken down by regions or zones, are stated at the outset. Again it is recognized that no precise statements as to the effect of changes in the transport system towards the approximation of those objectives can be given. But use is made of conjectures and qualitative indications concerning the direction in which the impact in relation to those economic objectives will occur. The changes in the transport system are then devised in small steps, each successive one dependent on the effect of the preceding one. The subsequent steps are only undertaken if the objectives stated at the outset have not already been achieved by the preceding one. The analysis must thus be closely connected to a monitoring system, keeping track of the economic changes that have taken place. A more detailed description of this type of dynamic planning has, although at a rather theoretical level, been given recently by H. L. Beenhakker. An application at the more practi-

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A technical level would be for instance opening up a hitherto untouched region for development, firstly by constructing a gravel road, extending it by feeder earth roads, followed by paving of the gravel road, then graveling the feeder roads, extending the feeder road system by a secondary system of earth feeder roads, then further upgrading the main road, etc. Any such dynamic plan need, of course, not be confined to the transport system itself but may include agricultural, industrial, public utility projects, etc.

Staggered investment programs in transportation have factually been put into effect in some developing countries in the sense that investments in infrastructure, insufficient in generating the desired development effect, have been followed up by further investment in the same sector, frequently flanked by simultaneous investment programs in other economic activities. The disadvantage of such a 'fac-tual' i.e. unplanned procedure is two-fold. Firstly considerable time is lost between the successive investment stages both, because of the absence of an appropriate statistical monitoring system and because preparation of the succeeding investment is normally not even started until it has become obvious that the preceding step did not achieve the desired effects. Secondly because when planning the initial investment the possibility of the subsequent steps are not given systematic consideration. Construction work is then frequently undertaken which is of limited value, often causes high cost for its removal, when extensions become necessary. Systematic planning of such extensions would constitute a major improvement over the traditional approach. Its main advantage is the flexibility of the investment programs. The staggered plan may, of course, involve the loss of some economies of scale, but if part of a long-term plan these losses can be kept relatively small. They should in any case be outweighed by the advantages occasioned by avoiding either bottleneck situations in case the development effects were overestimated or underutilization of infrastructure in case they were underestimated.

The third possibility in trying to account for the feedback effects from the transport system in the economic system, to be considered only on a long-term basis, would be to redvert attention to the analysis of precisely those locational phenomena that seem to have eluded satisfactory explanation so far. There seems to be a consensus amongst transport planners, that the only way to deal with the
locational aspect is first to go out into the field and gather extensive detailed base line data. In the absence of reliable analytical guidelines, essentially information is to be collected on any magnitudes that could relate to the locational pattern. As a first classification it might prove useful to fall back on a suggestion by G. W. Wilson\cite{29}, to differentiate between magnitudes indicating what he calls 'economic opportunity' and 'responses to economic opportunity'. The former would include geological and topographical conditions, availability of inputs, access to markets, etc., the latter actual production pattern, behavioral characteristics, social structures, etc. It is important in this context that effects of migration should also be taken into consideration. The Harvard Model, for instance, completely ignores this aspect. While perhaps indeed the most difficult component in analyzing the locational impact of changes in the transport system, past experience seems to suggest that the movement of population can be of major importance in the assessment of development effects.

Examples of detailed field investigations of the kind described are the study on feeder roads in Yemen (Arab Republic of Yemen) undertaken by O. Dunant and others\cite{30}, and the feeder road survey on Ethiopia as prepared by G. J. Gill\cite{31}. Both these studies have so far yielded a host of highly interesting information, but unconnected as they are, the results are of course difficult to compare. To get more information on a cross-sectional basis a study group has been set up by the International Bank for Reconstruction and Development, whose objective is to examine a larger number of cases trying to use standard terms of reference so as to make them comparable. The difficulty with this undertaking is of course that since it is really unknown which information is to be collected, the only consequence seems to be to collect all the information available. Some facts will prove useful, others not. It stands to reason that such a rather ex-

\begin{footnotesize}
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\item O. Dunant et al., Yemen Arab Republic Feeder Road Study, Report on Phase I, Zürich, April 1973 (mimeographed).
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tensive approach is fairly costly and will therefore have to be restricted to a limited number of cases.

The object of these very detailed field surveys is, to state it again, not the gathering of information as such, but to gain conceptual insights. Reading through the two above mentioned reports, already a number of unconventional working hypotheses spring to mind. Naturally, as more such hypotheses emerge it would be possible and perhaps tempting to the analyst to try and assemble them in some sort of model. Whether the model approach at this highly disaggregate microeconomic level is appropriate for practical planning purposes appears questionable. For if the microeconomic approach were to be applied at a wider regional, let alone national level, the statistical requirements for the calibration of such large models would for all practical purposes lie beyond the limits of reasonable planning costs. The objective must be, after the completion of some more highly detailed empirical studies, to first sift the large amounts of data available from them by way of the sensitivity studies on a qualitative or simple correlation basis. Then, only after the most important factors of influence have been detected, should efforts be redirected towards building more aggregate and hopefully more realistic models of locational impact.

IV

If the economic system responds to changes in the transport system, and not knowing the precise format of those responses does of course not preclude the existence of such responses, then it is clear that planning the transport system can be used as a policy tool in influencing that system. The effectiveness of this tool may be smaller in the so called mature economies, in Western Europe and North America in which the geographical pattern of economic activities is only marginally variable both for economic reasons, the factual pattern constituting a large element of sunk cost, and for political considerations. It seems of greater immediate relevance in developing countries whose economies are only now taking shape, or in developed economies with large underdeveloped areas. While plans exist in most of these countries for development as such, the absence of
any conscious planning of the geographical location of development leads to bringing about the problems, which the developed countries, already confronted with them, have difficulty in solving. England is finding it excessively costly to decongest the South East region, Germany is faced with similar problems in the 'Ruhrgebiet', to quote but two examples. At the same time the very unchecked growth that gave rise to the present regional problems in the developed countries, is allowed to occur in the Sao Paulo region of Brazil, in Lagos, Teheran, etc.

Hardly any studies involving the conscious use of the transport system in shaping the economy exist. The insufficient knowledge concerning the precise locational effect of changes in the transport system may have been one of the reasons. Also using the transport system as a conscious tool of guiding economic development geographically, requires of course geographically specified objectives. Given the importance of the issue, these can only be formulated at the highest political level. But as a matter of fact, other than the purely enumerative and frequently antinomous statement of various goals, such a formulation is usually not obtainable. Finally the fact that the results of systematic analysis would in many cases have but marginal impact on the political decision process as concerns the regional pattern of economic development – if in fact explicit decisions are taken at all – may have deterred the researcher from indulging in this field. But in view of the fact that it would in many cases be easy to prevent the problems, the solution of which in the future will cause high cost or which may in fact prove to be insoluble once they have arisen, it would seem of primary importance to devote more efforts in transportation economics towards the systematic analyzation of such regional policy models.

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SUMMARY

The paper reviews and assesses recent developments in transport planning techniques and makes suggestions on those aspects on which further research could most productively focus. Part I deals with various traffic forecasting methods, a field in which newer microeconomic decision models appear to provide promising results. Part II analyzes the use and limits of various planning techniques at the project, modal network and intermodal level, with particular emphasis on multiparametric simulation models; special attention is directed at the interdependence of investment, pricing, taxes/subsidies and access control. Part III is concerned with some ambitious but rather unsatisfactory attempts of predicting the locational impact of changes in the transport sector on other sectors of the economy; consistency analysis, dynamic planning and further basic line data collection, necessary to formulate models of higher predictive value, are suggested. Part IV discusses the implications of using transport policy as an instrument for explicitly influencing the desired regional pattern of economical and social activities, an area to which priority of further research should be given.

ZUSAMMENFASSUNG


RÉSUMÉ

L'article passe en revue les développements récents des techniques de la planification du trafic et propose des recherches à poursuivre. Partie I s'occupe des pronostiques du trafic: c'est un domaine de recherche où les modèles de décision micro-
Other World Bank reprints

No. 11. Hollis B. Chenery and Helen Hughes, "The International Division of Labor: The Case of Industry," *El Trimestre Economico* [available in Spanish as published and in English translation]

No. 12. Bension Varon and Kenji Takeuchi, "Developing Countries and Non-fuel Minerals," *Foreign Affairs*


No. 14. Gabriel J. Roth, "Regulation of Buses in Cities," *Highway Research Record*


No. 16. Hollis B. Chenery, "Restructuring the World Economy," *Foreign Affairs*