Transport policy models and transport policy development a major challenge or a search for a "Philosopher's stone"?

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As I was going up the stair
I met a man who wasn't there
He wasn't there again today
I wish, I wish, he'd stay away

HUGHES MEARNS

INTRODUCTION

The last two decades have witnessed numerous attempts to develop formal comprehensive models in the field of transport policy.[1] "Comprehensive Models" are defined here as models aimed at the analysis of large (national, regional, metropolitan areas) transport systems which treat explicitly interactions between transport and socio-economic environment; they can be contrasted with "specific models", i.e. models dealing with the analysis and evaluation of individual projects or programs or the revision of a specific set of policy measures. Comprehensive policy models are essentially normative; their aim is to generate policy alternatives. Another common characteristic of this work is that the interrelationships taken into account are formalized as a relatively closed system of equations; the number of exogeneous inputs is kept to the minimum through the extension of the model to internalize most of the key variables; the assumed relationships are considered to be quantifiable and the models conceived as an exercise in quantitative economic policy modelling. The normative characteristics of the models and the stress on quantification force the model builders into an explicit formulation of the objective function, or at least into the development of quantitative policy assessment rules, which, in turn, assures that the objective function is known either by the model builders or that it can be explicitly displayed by the "decisionmakers".

The impressive effort by the model-builders has raised many expectations. It is not coincidental that the policy models' development had taken place at the time when "government efficiency through systems approach", benefit-costs analysis, PPBS and similar attempts to produce quantitative aids to the decisionmaking flourished. Yet, the promises of a major improvement in policy making which were explicit in all this effort have hot materialized. Admittedly, through the process of model building much has been learned about transport systems and transport/non-transport activities' interaction, and many important issues were classified in the process. Yet, doubts about the quantitative policy models have been growing, and are being, at least implicitly acknowledged even by most devoted model builders.[2] The question then arises whether we should continue to elaborate the models, include explicitly more inter-connections, search for more data, i.e. whether constructing better models is a major challenge which is to be met by more efforts, or whether we should admit that the task set by model builders is inherently impossible, and abandon it as the early scientists abandoned the search for a philosopher's stone.

It appears proper to close this introductory section by making explicit its intended limitations. Although a rather lengthy list of references is enclosed, this essay is not meant as a "survey article" or an assessment of the state of the art.[3] It should also be noted that references to studies by consultants and staff papers released by governmental organizations have been omitted although a large part of the pioneer work first appeared in this form; this material is too voluminous to cover and, eventually the findings and descriptions of methodology employed in these efforts are reflected in academic or professional publications.

2. THE NATURE OF TRANSPORT POLICY MODELS

In the analysis of policy models it is useful to make a clear distinction between the "positive" or "descriptive" models or parts of models and the "normative" or "prescriptive". This distinction, incidentally, does not necessarily reflect the policy use of a model. A transport demand model, for example, may be developed in response to expressed needs of the "policy maker" and the outputs of such a model may be used as important inputs into decision making. However, the model as such is strictly policy neutral, even if model builders put a special stress on modelling parts of the system which they know are likely to relate to major policy decisions.

Normative models must necessarily relate to an "objective function" of the decision maker.[4] From this objective function, choice or evaluation criteria are derived. Depending on the nature of the system analysed and specific needs of the decision maker[5] a policy model may have to identify policy instruments. Many transport policy models are in fact "transport investment policy models". In this case, a particular policy instrument has been chosen (transport investment); however, the existence of other instruments and controls which affect either transport system or activities which generate transport demand should be considered explicitly.

Waters [67] makes an interesting distinction between "impact" and "evaluation" studies: "the purpose of impact studies is to estimate (and preferably quantify) effects of a certain measure on other parts of the economic and/or social system or environment; given considerable interdependence and complex linkages of the modern socio-economic system and in particular numerous inter-relationships between transport and other sectors, impact studies (conducted at a different level of sophistication) are important inputs into a decision making process.[6] Evaluation studies are intended to assess the relative merit of one project as opposed to another... From the information contained in an impact study, items must be selected to be considered for evaluation purposes... Next it is necessary to assign weights or values to the various impacts to arrive at some measure of the net economic merit of this project... To do this it is necessary that planning or policy objectives be quite explicit (along with the relative weights if multiple objectives are being pursued)." Project or program or policy "evaluation" – as contrasted with "impact analysis" – may still constrain the scope of the study and require very limited information of the decision maker's objective function; for example, if the decision maker selected a specific set of projects for evaluation and stated evaluation criteria.

Obviously, once the scope of the analytical effort is extended to the review and analysis of the transport system, or its major sub-system, and this analysis is to be directly interpreted with the generation of a set of transport policies, the problem of identification of the over-all objective function becomes the key part of the effort. This logically should lead to explicit structuring of goals and objectives as well as formalization and ranking of "community-values."[7]

Depending on the scope of the model, and preferences of model builders, one of the following policy objectives are assumed[8]:

a. minimization of costs of a transport system (to be understood broadly as the minimization of transport and related social and private costs);

b. achievement of non-transport objectives, which can be understood in two ways, *viz.*

(i) shifts in transport patterns believed to be socially beneficial (eg. shift towards public transport) or

(ii) through the working of a transport system affecting the distribution of population and/or economic activities in a more desirable manner;

c. a mix of transport and non-transport objectives derived from formalized social and/or distributional goals.

Logically, a transport policy model will

a. model transport flows and inter-action between transport and other sectors of the economy and derive from it projections of the future states of the system;

b. rigorously compare probable states of the system in the absence of positive intervention with the desirable states of the system (which implies knowledge of the objective function);

c. identify *feasible* policy instruments and quantify to the largest extent possible the effectiveness of their use;

d. define targets.

Thus, the effectiveness of the policy model depends on:

a. adequacy of the analysis of the working of the system;

b. availability of an operationally meaningful set of objectives;

c. identification of feasible policy instruments and quantification of their efficiency.

Major failures of policy models tend to be associated with problems related to (b) and (c). However, it is the difficulty in formulating an adequate model of the actual working of the tranport system and its interactions which tends to be most stressed. Furthermore, the blame for the failure to model the working of the system is usually attributed to the "data problem".

Clearly, perfection is not achievable and the existence of failures need not preclude future successes. However, from the point of view of research strategy, it is important to consider the prospects for improvement of different areas of endeavour. It is my contention that, with the accumulated experience, the quality of positive or analytical descriptive models will continue to improve both because of better techniques and because of cumulatively increasing understanding of how the system works. Furthermore, the improvement of the knowledge of the system is bound to improve our ability to utilize available and to generate more efficiently the potentially available information. Paradoxically as it may sound, a good or more realistic model design is less likely to fail because of the estimating difficulties[9] and less likely to be frustrated by non-availability of data.[10] This general optimism should be tempered by the realization of the inherent difficulties in this field, some of which have been accentuated by over-ambitious design and often by the neglect of a simple rule that it is easier and more fruitful to start with simpler models and to accept "open ends", asymetries and inelegant linkages of sub-models and then progress towards greater realism, complexity and analytical elegance, than to start with over-complex structure which has to be simplified to meet arising estimating and data problems.[11]

If one can be moderately optimistic about future positive models, this guarded optimism appears not to be justified about the future of normative models; to quote the famous saying of a police recruit: "you can't get from here to there; to get there you have to start from somewhere else".

3. THE INTELLECTUAL ANTECEDENTS OF POLICY MODELS

It is an impossible task to attempt to determine the precise intellectual sources of a vast array of professional effort generated by specialists from different disciplines, together with a vast amount of cross-fertilization. It is possible, however, to identify major intellectual sources; these, I submit, are:

a. modern welfare economics;

b. the theory of quantitative economic policy, largely based on Tinbergen's work;

c. systems analysis and policy applications of operations research.

The two main themes of modern welfare economics have been:

(i) vigorous analysis of the limits of "value free," positive analysis and the legitimacy of policy recommendations which economists, as scientists, can give,[12] and

(ii) analysis of the nature and derivation of a social welfare function and its application to economic policy choices. These two themes are strongly inter-related; it is not difficult to name economists who having rigourously identified problems of derivation and application of social welfare function have also done extensive work in applied welfare economics and benefit-cost analysis. Essentially, the social welfare function is derived from individual preference functions, modified – in the case of public goods – through the working of the political system. In the growing area of public goods provision, the theory of public choice (which can legitimately be considered as an extension of welfare economics) relates individual to collective preferences. In spite of the recognition of analytical difficulties inherent in the formulation of a social welfare function, an objective function of the decision making is asserted to exist, and this objective function should correspond to the subjective valuation of the members of the society.[13]

From the very beginning of welfare economics – Pigou's *Economics of Welfare* – the problem of external or indirect effects and the divergence between private and social costs has been one of the central issues discussed; indeed the existence of externalities was according to Baumol [7] a major justification for state intervention. The identification and evaluation of externalities is, of course, the essence of benefit-cost analysis which has played an important part in planning of public investments. The step from analysis of externalities in project evaluation to a comprehensive investigation of interactions between the transport sector and the economy has been logical, and the identification of divergencies between private and social costs could be accepted as indications of government actions within the framework of criteria of economic efficiency.

Tinbergen's work on theory of economic policy can well be regarded as an operational extension of welfare analysis.[14] The introduction of the concept of policy instruments, target variables and the strong stress on quantification (at least potential quantification) provided the framework within which policy analysis, policy administration and empirical investigation could be logically integrated.[15] The greatest impact of this work was on macro-economic policy analysis, but this approach provided challenge and inspiration to sectoral planning model builders. However, in the latter applications new problems arise, some of which relate to a much greater specificity, an increased number of policy instruments, lengthening of time-lags, and the irreversibility of major decisions.

Systems analysis influence on transport policy modelling is direct. Transport policy analysis by its very nature implies investigation of a great number of interdependencies. Successful application of systems analysis, operations research and computers to the resolution of complex management problems created great expectations and ambitions to adapt management tools to transport policy problems. The background of the first practitioners of systems analysis and operations research was close enough to that of planning engineers to facilitate what appeared to be a technological transfer. Two important group characteristics of system analysts have to be stressed here:

(i) insistence on direct relevance for problem solving or decision making – thus models are conceived not as general aid to the decision maker by providing him with a set of relevant information and improved understanding of the reality which he may use for a variety of purposes but as an input for specific recommendations; the goal: "design a system which meets a given objective" is translated as "design a policy which meets a given objective";

(ii) "the logical precision of the model enforces corresponding precision of the objectives that the operation is intended to attain" (Dorfman [17]).

4. THE SEARCH FOR OBJECTIVES

The key importance of a rigorous definition of the objective function has been admitted by the policy model builders. Considerable effort has been expanded in this area and the difficulties have been recognized.

One of the major approaches to an operational identification and definition of the objective function is directly related to the theoretical work of welfare consultants. This intellectual tradition has profoundly affected benefit/ cost analysis.[16] The social welfare function considered is derived from individual preferences corrected for externalities. In its operational application, economic evaluation analysis relies heavily on market generated prices and costs, supplemented, and if necessary, substituted by a consistent set of macro-economically determined shadow prices.

An approach, which stems from a different intellectual tradition, but is not necessarily in conflict with that of the economists, is an engineering systems analysis, which is primarily geared to the identification and evaluation of system bottlenecks. Its aim is to optimize system efficiency; the evaluation criteria tend to be user benefits and costs of improvements – in this way one can view this approach as an operational and restricted version of benefit-cost analysis.

The difficulties associated with the determining of an operation version of a social welfare function from welfare analysis, led to a search for an identifiable policy-maker's objective function. Basic to this approach was viewing an analyst as a technical advisor to the decision maker whose role is "to select the optimum course of action from a number of complex action alternatives available to a certain decision maker by weighing the degrees of realization of the decisionmaker's multiple objectives that can be achieved with alternative strategies . . ." [56] p. 157. Identification of the policy maker's objective function is by no means a trivial problem. Where policy instruments are reasonably well identified and their efficacy reasonably well appreciated, the problem can, to some extent, be reduced to the one of the "subsidiary decisionmaking", i.e. target choice. Assuming a consistency in the policy-making process, through the selection of specific targets, the objective function can be revealed. Or, to put it in common sense expression – through the participation in a continuous decisionmaking process, the analyst acquires an implicit, but adequate, appreciation of the policy maker's objectives, and both the analyst and the decision maker acquire increasing knowledge of the efficacy of policy instruments and the type of information inputs required. It may be useful to make such a process explicit, and formalize it into quantitative policy model.

The problem becomes inherently more difficult if either "the policy maker" is difficult to identify – i.e. the policy process involves a number of actors, with some common values and goals, but also with conflicting goals; or if the decision making process is discontinuous. This is particularly difficult in the case of urban transport planning where the preparation of "comprehensive plans" is infrequent, where planning work is performed by outsiders, and where direct expression of views by affected groups is less institutionalized than in the case of more senior governments. The analyst is therefore often forced into a consideration of "community values" or community objective functions.

Attempts to determine community objective functions and to produce an operational assessment tool led to the evolvement of the "planning balance-sheet"[17] and "Goal Achievement Matrix"[18] approaches. There has also been extensive discussion of analytically different but conceptually related approaches, based on weighing the desirability of possible outcomes, but also introducing probability evaluations.[19] Somewhere in the middle, between a pragmatic or "revealed preference of the decisionmaker's" approach and attempts to construct a rigorous and quantified (or at least ordinal) explicit objective function, one may classify Manheim's "search and choice" work [43] [44] [45]. Some initial knowledge of the objective function is assumed, and used in the generation of a preliminary plan; the results of such a plan are subsequently displayed and discussed. This may lead to a re-definition of objectives and introduction of new objectives of constraints, i.e. to a reformulation of the objective function, (or "fuller revealing of the community or decisionmaker's preferences").[20]

5. ANALYTICAL WORK AND THE DECISION-MAKING PROCESS

Since the developers of comprehensive transport policy models consider their work as a contribution to improved decisionmaking, it is appropriate that this effort be judged according to the criteria of usefulness in a "real life" context. The obvious limitations of specific, narrowly defined project appraisal efforts were early recognized. Firstly, transport itself can properly be considered as a system of inter-connecting and inter-dependent elements. Secondly, obvious and important inter-relationships exist between transport and other sectors, especially between transport and spatial policies (whether viewed as transport and land use or transport and regional planning). In the context of development policies, these realizations led to serious large scale modelling efforts, conceived either as network models with transport developmental impacts explicitly recognized (eg. [16]) or as large scale macro-economic/transport models.[21] On the other side of the spectrum, urban road models started initially as network models with user benefits as the evaluation criteria and later developed – at least in theory – into more comprehensive urban transport/land use models.[22] Comprehensive transport planning also became generally accepted in regional and nation-wide system planning in developed countries.[23]

Extensive effort, profusely financed, must have borne some relation to the need. It is interesting to observe that this need, in many cases, has not been precisely stated. True enough, in the case of developing countries, a system of general and sectoral planning mechanisms establishing overall priorities and relating to available resources was necessary to meet the requirements not only of the countries concerned but of international and national lending and aid agencies. To some extent, a parallel can be drawn between the role of lending and aid agencies and senior governments' financial contributions to urban administrations. Major review of problems, priorities and programs has given rise to other large scale modelling exercises.

In general, policy development and administration is a continuous and adoptive process, something much more than the implementation of a comprehensive long range plan or a grand policy design (especially, since the rate of obsolence of long range plans is quite high). The success of policy implementation depends on the institutional ability to "learn by doing" and to absorb new information inputs.[24] (New information inputs also affect objectives and assessment of constraints). The continuity and adaptability of the policy process has a number of implications for analytical work:

1. The stability of the objective function is likely to be low, not only because social or economic goals, objectives, aspiration levels and concerns change over time, but also because the increase of knowledge changes social preferences. Ability to construct a "synthetic" objective function by analogy with the theory of individual decision under conditions of perfect knowledge is crucially dependent on the assumption that all relevant objectives are known and can be ordered, and that additional knowledge will not introduce new objectives or constraints, which in turn will not affect ordering of objectives previously taken into account.[25]

2. The key role which knowledge of an objective function plays in normative models, and the difficulty in identifying an objective function becomes somewhat spurious – the key role is now occupied by the continuous interchange of information and policy instructions.

3. Policy process is largely a steering and control process; even decisions, such as large investment decisions, which appear as discontinuities from the point of view of sectorial management are affected by the continuous steering process of the economy as a whole.

4. The role of large scale sectorial or system models is to provide information relevant to the decision process – this implies continuous adaptability of the model to provide *inter alia* information on specific, direct and indirect effects of policy changes, to monitor the working of the system and to give advanced warning of arising concerns.

Viewed in this context, a "comprehensive policy model" should not be considered as a once-for-all exercise, but as a framework for provision of information on the workings of the system, the directions of change and the interactions of relevant elements. This implies not only periodic re-estimation of the model, i.e. re-estimation of relationships specified by the model's structure, but also the restructuring of the model itself. Thus, the adaptability of a large scale policy model becomes a matter of concern. Complexity in the structure (as indicated by the number of feedbacks and assumed inter-relationships) tends to adversely affect adaptability. In addition, a model whose structure dictates rigid and highly specific data inputs is likely to be prone to "data failures". A "modular structure", which permits easy partitioning of the model and changing one part without forcing an overall model reformulation, may produce a less satisfactory initial version, but be more adjustable with time.

6. CONCLUSIONS

In 1965 Garrison speculated about the nature of urban transportation planning models which would exist in 1975 [23]; his conclusions were:

a. "not much will be available in 1975 which is not already on view to-day";

b. "while we can speak quite articulately about goals and the measurement of goals and about formal decisionmaking schemes, it is difficult to believe that the next decade will see great strides in these areas";

c. "with respect to information, however, it would appear that a considerable amount of development and new flexibility is in view"

d. the need, neglected so far, is for greater exploration of self-adapting models for current adjustment and control.

In the light of developments in the last ten years, it is difficult to fault Garrison's 1965 assessment. Regarding the future, the following conjectures may be made:

a. We have indeed made great strides in our ability to digest and use information, even if we have made little progress in understanding available and potentially available information. It is probable that we shall see in the next decade significant progress in this respect which will affect the methodology of model building.

b. Intensive exploration of goals-objectives formal decision making structures has produced a large literature but few relevant worthwhile results.[26] If one were optimistic, one might expect that systematic investigation of actual decisionmaking processes could have a fruitful effect on the uses of models and hence on their structures.

c. One may expect significant results in evaluating the efficacy of policy instruments and the reaction-lags associated with their use. In transport, this problem is particularly bothersome – in a nutshell, we have a situation where reaction time to determine and implement transport policy changes can be larger than the terms of office of elected politicians, and even longer than the period of stability of social goals and aspirations.

d. One would hope that the problem of self-adapting mechanisms and short-term instruments for "steering" the sytem will receive increasing attention.

e. Lastly, one can expect some good results from the current disillusionment and questioning of existing main-stream methodologies.

The question posed in the title of this paper was: are large scale transport policy models a useful development or a "search for a philosopher's stone"? Undoubtedly, much of the activity in this field was similar to that of alchemists of the past – goals set were often unrealistic, conceptual difficulties in constructing complex large scale models were underestimated, and the relationship of model-building to the actual policy-making process was often at best tangential. However, at the same time much has been learned about the proper framework within which transport problems should be discussed and about the actual working of the transport system.

The alchemists did not find the philosopher's stone but, in searching for it they made worthwhile discoveries. Similarly, while I doubt whether an adequate comprehensive transport policy model serving metropolitan, regional or national transport policy needs will ever be developed, we have made significant progress in developing models analyzing traffic movements and transport demand as we have improved our understanding of the structure of the transport industries on the "supply side" and the linkages between transport and other sectors. One may also be optimistic about future work on transport policy instruments and the efficacy of using transport as an instrument for the achievement of non-transport objectives. Progress in all these areas has been vastly increased through large scale policy model building – *ex tenebris lux!*

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List of Abbreviations

AER: *American Economic Review*
ARS: *The Annals of Regional Science*
EC: *Economica*
EJ: *Economic Journal*
HRR: *Highway Research Board: Highway Research Record*
HSGT: *High Speed Ground Transportation Journal*
IJTE: *International Journal of Transport Economics*
JTEP: *Journal of Transport Economics and Policy*
JAIP: *Journal of American Institute of Planners*
JTPI: *Journal of the Town Planning Institute*
JWHCE: *Journal of the Waterways, Harbours and Coastal Engineering Division, ASCE*
OEP: *Oxford Economic Papers*
OR: *Operations Research*
PDR: *Population and Development Review*
QJF: *Quarterly Journal of Economics*
RE: *Regional Studies*
SEPS: *Socio-Economic Planning Sciences*
TEJ: *Transportation Engineering Journal* TEJ/PASCE: *Transportation Engineering Journal* Proceedings of ASCE
TJ: *Transportation Journal*
TPT: *Transportation Planning and Technology*
TQ: *Traffic Quarterly*
TR: *Transportation*
TRF: Transportation Research Forum, *Papers,* after 1970: *Proceedings*
TRR: *Transportation Research*

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FOOTNOTES

1. Drake [18] [19] quotes estimates of costs of transport modelling by US government of the order of $800 mil. in the Decade of the 1960's. Adding the expenditures of other national governments, states, provinces, municipalities, international institutions etc. transport modelling expenditures may well exceed $150 mil. p.a., with large scale policy models accounting for at least a quarter of this sum.

2. For example, in an introduction to a recent symposium, Per Holm writes: "we can mention why the extensive planning contributions have not given the expected results. The first is that theoretical foundations for policy decisions are rather weak ... and secondly, there is a scarcity of planning models which are applicable [to] practical planning problems and which can be used in the decision process. [25] pxvi. Interestingly enough, similar criticism has been raised in other fields; for a critique of population policy models see Arthur and McNicoll [4] and for a reasoned reply Rogers *et al* [54].

3. Aspects of transport modelling work, mostly in the urban context have been reviewed, *inter alia*, by Alain Bieber [8], K.W. Gwilliam [24] and S.H. Putman [5]. "The concepts of systems analysis as they may be applied to the transport planning process" is reviewed by E.N. Thomas and J.L. Schofer [62], which contain extensive bibliographies. International Bank for Reconstruction and Development released a number of staff summaries/staff assessment reports dealing with more important models prepared by the Bank's consultants dealing with transport-economic development aspects.

4. However, in practice such an "objective function" may have to be deduced from either observations of past choices ("revealed preferences of decisionmakers") or from the choice and establishment of policy targets, "The fixation of Ω (objective function) is a difficult matter; generally it will not be considered consciously but intuitively by those responsible for policy ... In practice the stage of fixing Ω and trying to maximize it will often be paved over and the targets chosen directly" Tinbergen [64].

5. The term "decision maker" is used here wisely – which is a normal practice of the policy model builders. Later on the term will be discarded, and we shall refer to the "decision making process"; at this stage "decisionmakers or makers" are defined as those directly and substantively involved in the decision process.

6. Impact studies of highway projects have been particularly numerous; for a review of U.S. practice see [66].

7. For a comprehensive presentation of this approach and extensive review of the literature of this genre see Thomas and Schlofer [62].

8. An interesting and somewhat different approach was adopted in Transport Canada policy document [65]: over-all goals of transport policy were stated, but the objectives and intensity of government intervention varies depending on the state of a particular part of a transport system which is described by the use of two scales: "maturity" and "competitiveness".

9. Alonso's [2] thoughtful remarks are relevant here.

10. Contrary to common complaint, the transport sector generates vast amounts of information; with a systematic improvement of the management information systems, volume and quality of information is likely to improve further. Secondly, the understanding of the logic why some data are generated while others are not throws considerable light on the decision process within the sector. Complaints that data are not available, while large volumes of information are not utilized is likely to be a symptom of poor model design!

11. The related problem is that in order to salvage an over-complex model low quality data derived from doubtful estimates may impair the overall reliability of empirical material. A mixture of low and high quality data in the same set of estimates introduces unknown biases. A less ambitious model may give us fewer answers but in many circumstances will produce less trash.

12. The classic contribution is by Little [40]. Also see Archibald [3].

13. The following quotations from Mishan, a leading welfare economist are relevant here: "If there is to be any consensus on the weights to be used in a cost-benefit analysis, it should be reached in advance, and therefore independently of, the critical sets of weights yielded by any particular project" ([47] p. 94), i.e. objective function ranking all relevant factors for public choice exists prior to and independent of the evaluation process. Regarding the nature of the welfare function: "[economists] should not overlook the fact that once they accept from the political process prices or weights that have no necessary correspondence with the relevant subjective valuation of the members of the society, they not only cease to offer the public an independent economic appraisal of any plan or project ... they may be unable to provide a coherent interpretation of their resulting calculations ..." *ibid* p. 95. Derivation of the "necessary correspondence" since it is necessary must be feasible – or at least that is what Mishan believes.

14. "As the broadest object of the theory of economic policy we consider the determination of the optimum policy, given the individual preference indicators of the citizens of the community. The object is very broad and implies, among other things (i) the fixation of a collective preference indicator" Tinbergen [64] p. 3.

15. For a comprehensive discussion of theory of quantitative economic policy see Fox *et al* [21]. The difficulties inherent in Tinbergian formulation which permitted no trade-offs between

targets and required equality between number of targets and instruments for the existence of an optimum policy was removed through reaction function analysis, which assumes the existence of a suitable form of policy maker's welfare function; see Makin [42] and sources quoted by him.

16. The literature of the subject is quite extensive and cannot be reviewed here. The comprehensive review is by Poest and Turvey [49]; recent definitive work is by Mishan [46]; for a review of applications to urban transport see Barrel and Hills [5] and Gwilliam [24]; for "manual approach" related to developing countries see Alder [1] and US Department of Transportation [67]; also see Hutchinson [31] and Wohl [70] for an engineer's view of the problem. An important critical contribution is by Feldstein [20]; for application of economic controls to transport see Blanwens [9].

17. See Litchfield [38] [39].

18. Hill [27] [28].

19. See Khan [32] [33] [34] [35] for useful sympathetic review of this work; on specific application to an airport problem see de Neufville and Keeney [15].

20. Numerous contributions stress the iterative nature of goals or objectives determination through planned/community interaction, inter-sectoral or inter-disciplinary interaction.

21. The most influential was the "Harvard Model" [53] [45a] which led to the development of a wide range of planning models, usually simplifying the "Harvard Model" structure and substituting "judgmental" or "sector assessment" inputs for large, systematic and "closed" macro-economic part. Although formally quasi-Harvard models differ from, and are less elegant, than the original, the intellectual influence of the Harvard Model is discernible.

22. See Starkie [59] [60], Catanese [12], survey by Putman [50].

23. See Bauer [6], Bruck, Manheim and Shuldiner [10], Bruck, Putman and Steger [11], as examples.

24. For the elaboration of the relationship between institutional structure, absorption of information and selection of solutions see Studnicki-Gizbert [61].

25. Hayek's essay on "Economics and Knowledge" [26] is highly relevant here. Imperfect knowledge is quite distinct from uncertain outcomes and cannot be handled through a scheme of probability assignments.

26. "Real life" applications of formal decision/choice analysis have often produced interesting theoretical contributions; solutions obtained, however, have tended to be trivial, or obvious from problem statement.