UNCERTAINTY IN URBAN TRANSPORTATION PLANNING

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ABSTRACT

Uncertainty can not be captured by applying existing transport planning techniques, which often depend on sensitivity tests. Based on an investigation of alternative techniques, from non- transport sectors, the paper proposes a scenario-oriented process suitable for transport planning application. The planning process requires developing demand scenarios to span the range of possible futures, and inventing system scenarios to provide physical solutions for likely transport and land use strategies. After scenario evaluation, the directions to be followed are formulated in form of future boundary conditions. The theoretical approaches, in a very simplified way, are presented with different illustrative examples.

INTRODUCTION

Concern about the sources and the consequences of uncertainty in long-term strategic transportation planning has been a persistent undercurrent in recent years.

Long-term transportation planning is based mainly on social and economical studies, which can generally be characterized by a high level of uncertainty. Such studies introduce detailed forecasts of many input data. Uncertainty and errors in inputs consequently mean uncertainty in outputs.

There is also uncertainty arising by the definition of long-term planning objectives. The existing objectives may be changed in the future due to, for example, greater public awareness for the environment, impact of new technologies, and other unexpected future policies and actions (internal or external).

A similar problem exists with forecasting and evaluation models calibrated on the basis of existing data. Conventional models lead commonly to uncertain results, because of their reliance on extrapolation of existing trends to picture the future. Furthermore, these models usually produce a single future plan due to their mathematical complexity and consequent time and computing costs.

A single long-term strategic plan with a bundle of projects (constructions, operating and policy measures) will frequently create severe problems after formal exhibition procedures. Future modifications of the approved plan (e.g. changing a particular project or introducing a new one) will surely lead to legal resistances and discussions on the degree of commitment to the plan. Such modifications indicate undermining the basic strategy and the assumptions of the plan. In such case, the realization may be interrupted or the whole plan may be aborted [6].

In addition, uncertainty about the future of the authorized plan results uncertainty about the progressive modifications of that plan.

Therefore, the consequences of a fuller identification of uncertainty can not only be a more defensible evaluation and selection of policies, but uncertainty must be incorporated in the planning process.

The intention of this paper is to present a process for transportation planning under uncertainty, and to set out working guidelines whereby planners may seek to incorporate an appropriate form and level of recognition of uncertainty in the planning process.

PLANNING UNDER UNCERTAINTY

Generally, there are various principal methods which can contribute effectively to the goal of including uncertainty within the framework of a planning process. The simplest and most common method of planning under uncertainty is to ignore it. This may be quite valid, for example if the decision is not very important, or if the benefits are clearly significant under even the most pessimistic future [7].

The other common method is the "sensitivity testing", in which the full process is repeated with varying the values of the individual uncertain parameters in order to identify the effects of such parameters. Where the range of uncertainty is significant in its relevance to decision-making, the reasons of this range of uncertainty should be described together with the steps which might reduce this uncertainty. As the model run is often expensive, the number of parameters to be tested is usually very limited [8].

"Risk analysis" can also be used to represent uncertainty [5]. Risk analysis is appropriate when it is possible to characterize uncertainty numerically through probability distributions. The set of input distributions gives a picture of the plausibility of the various possible output values. Risk analysis applications in transportation planning , to the best of the authors' knowledge, are unknown, perhaps due to the computational cost. It is a very expensive method, several hundred repetitions are usually needed to achieve reliable output results. The process from input to the final decision is based on a visual comparison of the probability distribution. It is a theoretically-attractive sophistication.

In case of strategic planning, where the future is not well-defined, "scenario techniques" can successfully be adopted. Scenarios do not constitute a forecast, either collectively or individually [2]. Rather than relay on probabilities to reflect uncertainty, scenarios are intended to span the range of possible futures and to provide different solutions for different developing strategies.

Although there is a few published applications of scenario construction, current techniques can virtually be divided into two major groups:

a) "Bottom-up" planning, which is based on the careful initial decisions about the relevant input variables needed to characterize the future scenarios (i.e. the future is reached from the present), and
b) "Top-down" planning, which is started with macro-level description of possible future scenarios, followed then by determining the individual characteristics of the elements of each scenario to cover the future demands.

Despite that bottom-up scenario construction is expensive in manpower and computing costs, the literature in general recommends that scenarios to be built bottom-up rather than top- down [2]. However, in transportation planning the top-down seems to be not inappropriate, and it is easier to apply [9].

THE PLANNING PROCESS

Planning philosophy

The traditional transportation planning process analyzes the transportation demands of 20 to 25 years in the future and develops a system plan (or Master Plan) for an urban area. Project studies then prepare the detailed designs. Thus, there is a gap between system planning and project studies, as shown in Figure (1).

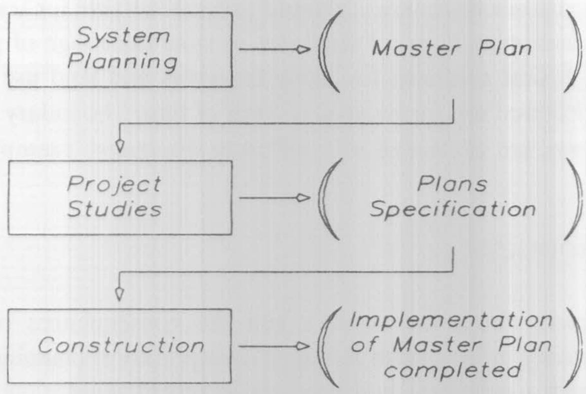

Figure 1. View of the traditional planning process

In addition to the sources of uncertainty associated with such long-term predictions (as mentioned previously), many problems arise largely as a result of treating system planning and project studies as sequential activities. These problems (uncertainty in planning process) can be summarized as follows:

- It is difficult to estimate the impacts on many projects (e.g. changes in travel patterns, housing displacements, and environmental effects) which can not be fixed before project design. Project design specify exactly the locations and the needed facilities.
- The impacts of many projects are indirect, and today there is a lack of understanding the complex cause-and-effect relationships.
- System planning implicitly assumes completion of the target plan. If the selected target plan can not completely be implemented, it could not be selected in the primary planning phase as the most feasible solution compared with other alternatives.
- System planning explicitly does not take into account the effects of implementing the target plan on a step-by-step basis. The same future may be reached by any of several scenarios; for example, in Figure (2) for developing a

future transport network both paths A and B reach plan X. This means that, by the traditional practice the implementation of the target plan do not yield to the actual demand development.

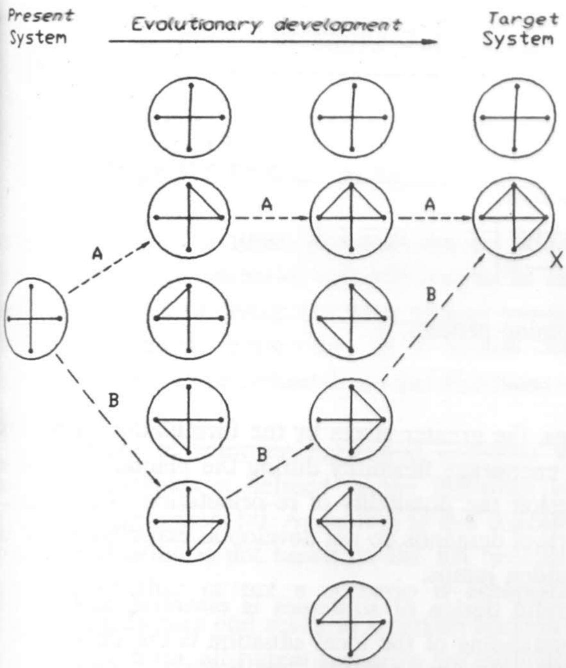

Figure 2. The implementation strategy and system planning

The process of long-term planning under uncertainty should not be based on "one shot" decision, but rather on a series of time-by- time decisions (Figure (3)). It should not be "once-for-all" activities, but an ongoing process. For example, a plan for a 20- year time horizon might be divided into 5-year stages. During the implementation of the measures required for a planning stage, the subsequent stages could be revised or updated in light of new information or changes that have occurred.

Thus, the planning process can include long-term, short-term, and intermediate-term assessments, as well as repetitions of these assessments.

The long-term assessment is essentially a learning phase, in which scenarios (demand and transport system scenarios) are formulated, and evaluated in order to indicate the preferred direction to be followed. The short-term assessment looks at the preferred direction in more detail and in a shorter time frame. It analyzes the impacts more precisely, indicates what decisions can be made now, and identifies how long this decision is likely to remain valid before the next decision has to be made. The short-term assessment can be carried out with conventional well-established procedures.

The intermediate-term assessment is concerned with preparing the basis for the next decision. It involves observation of changing the travel behavior and system performances, preparation of new data, and re-calibration of models.

Long-term, short-term and intermediate-term assessments are repeated when the next decision must be made. In this manner, the principal difference with currently used planning process lies in the type of integrating the three phases.

Planning guidelines

For the purpose of this paper (long-term assessment), a guidance procedure is established that can be used to formulate both demand and system scenarios, and to search out preferred directions without firm destinations (systemwide evaluation). All the three elements of this procedure are strongly interdependent.

Demand scenarios

A horizon year must be assumed that is far into the future. For urban strategic planning, a period of 20 years may be appropriate. Strategic planning is the preliminary screening of possible transportation systems with varying trend variables (demographic and socioeconomic options). The conception of developing quite different futures requires some assumptions to be made about these variables.

Regularly, the different future variables are not equally included in the demand scenarios. Various values should be assumed for each variable whose progress is uncertain in the future. By contrast, a unique value can be used for each of the other variables, if there exists a great degree of certainty on its development.

There are many ways in which the major economic and social future possibilities can be conceived [7]. The most successful way to face a set of demand scenarios is to specify a central scenario (medium growth rate), which

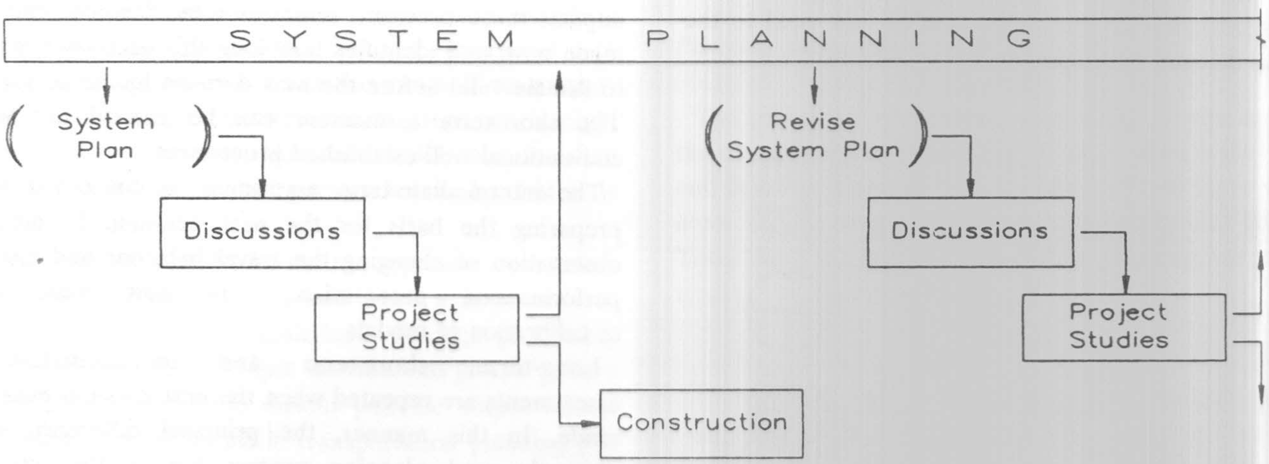

Figure 3. View of the suggested planning process

broadly corresponds to a continuation of existing trends, and two others (hign and low growth rates) up to the end of the short-term period, as shown in Figure (4). The high growth rate is assumed to be followed by either a high or medium growth rate up to the end of the study period. The medium growth rate is assumed to be followed by either a medium or low growth rate, and the low growth is assumed to be followed by continued low growth. These various combinations represent five long-term demand scenarios, each one is equivalent to a different possible future [3].

System scenarios

A System scenario is a logical and plausible set of projects which describe the internally consistent view of the transport system in the future. As a set, the system scenarios are intended to span the range of possible futures (in physical forms) which may be assessed under different conditions.

System scenarios do not provide a basis for comparing alternatives. The whole emphasis in their use and their contribution to evaluation is different. The scenarios explore likely strategies (transport and land use options) and highlight more the potential shifting from one strategy to another rather than the final ranking of alternatives.

Thus, the greater stress by the formulation of scenarios is to encourage flexibility during the planning period and to exploit the possibility of re-orientation of strategies, if the travel demands do not develop as expected and in case of sudden jumps.

Careful design of strategies is essential, and the clear understanding of the local situation is the major input to effective strategy definition. Strategy design should start from existing-transport-related problems and anticipated development.

For planning under uncertainty, the significant recommendations are to do more with what exists, and to make small rather than large scale projects [1].

System scenarios can be formulated by specifying the different components of a proposed transport system. For example, the principal elements of a road system are link locations, road categories, number of lanes, type of intersections, desirable service levels, and traffic management schemes. In addition, level of funding should be estimated. In this way, various system scenarios can be generated.

Systemwide evaluation

The evaluation of alternatives in traditional transportation planning is based often on an attempt to maximize expected net benefits. It would be difficult to utilize the same concept for evaluating transport

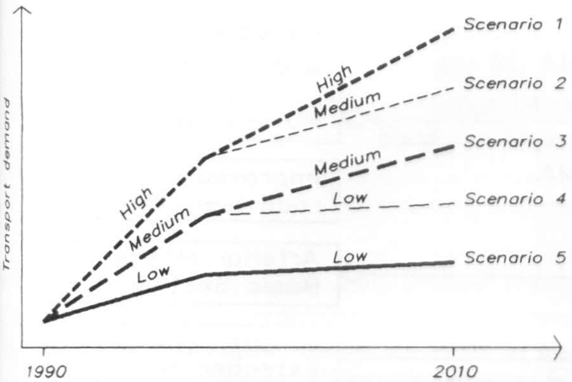

Figure 4. Demand Scenarios

scenarios, because the future demands can not accurately be determined. The scenarios are only created to suggest possible directions of divergence from present trends, and the aim of scenario evaluation is to screen out the direction which may be followed and the directions which should be kept open.

The problem of selecting sequential decisions within long-term strategies is defined in the literature as the "concept of robustness" [4]. According to this concept, the scenario evaluation is not based on the net benefits, but rather on whether or not a scenario is acceptable to achieve a satisfactory end result at a certain horizon year. In its simplest form, all system scenarios are evaluated for the target year against all demand scenarios (Figure (5)). The approach is to score zero if a system scenario fails to meet the requirements of a demand scenario, and to score 1 when it can meet them. The first priority system scenario is the one with the highest score across demand scenarios.

System Scenarios	Demand Scenarios LL	ML	MM	HM	HH	sum	
1	1	1	1	0	0	3	Status Report
2	1	1	1	1	1	5	
3	0*	0*	0*	1	1	2	

* not acceptable: low demand and high capacity

Figure 5. Systemwide evaluation according to the "concept of robustenss"-an example

The systematic evaluation of possible outcomes and impacts can be exceedingly complex in both conceptual and computational terms. Computer interactive approaches may hold promise in the longer term planning, but as the evaluation is carried out for the purpose of learning, intuitive procedures may be sufficient [9]. Undesirable or improbable relations can be detected, conflicting values can be revealed, and information needs for future decisions can be identified.

The major effects of such method are (a) to push forward the policies which look to be best able to cope with a range of possible demand scenarios, and (b) to pay special attention to the dynamics of the decision making of system scenarios.

It should be noted, that the more correct the timing of a decision, the more robust the decision.

The results of the systemwide evaluation can be summarized in a simple status report. It identifies the assumptions made, the proposed projects, possible impacts, system scenarios that appear to keep open, and the general direction to be followed.

The last activity of the long-term assessment is determining the future boundary conditions, formulated in form of evolutionary framework. It is an option-commitments diagram, which describes the incremental development of the proposed transport system. In other words, it shows the different ways in which the future transport system can be phased. For instance, if a planning strategy includes the construction of a new road and there is a commitment to the corridor, one can formulate quite different system scenarios starting from an arterial road with many intersections at grade to an expressway with potential grade separation (Figure (6)).

CONCLUSIONS

In recent years, specialized techniques in the transportation planning sector rapidly expand. This will be a valuable development, when the planning proceeds on a solid base, and on a sufficient understanding of the nature of the future.

This will be difficult in the 1990's which is characterized by a great level of uncertainty, as the social and economical conditions will extremely change in different directions and consequently the forecast

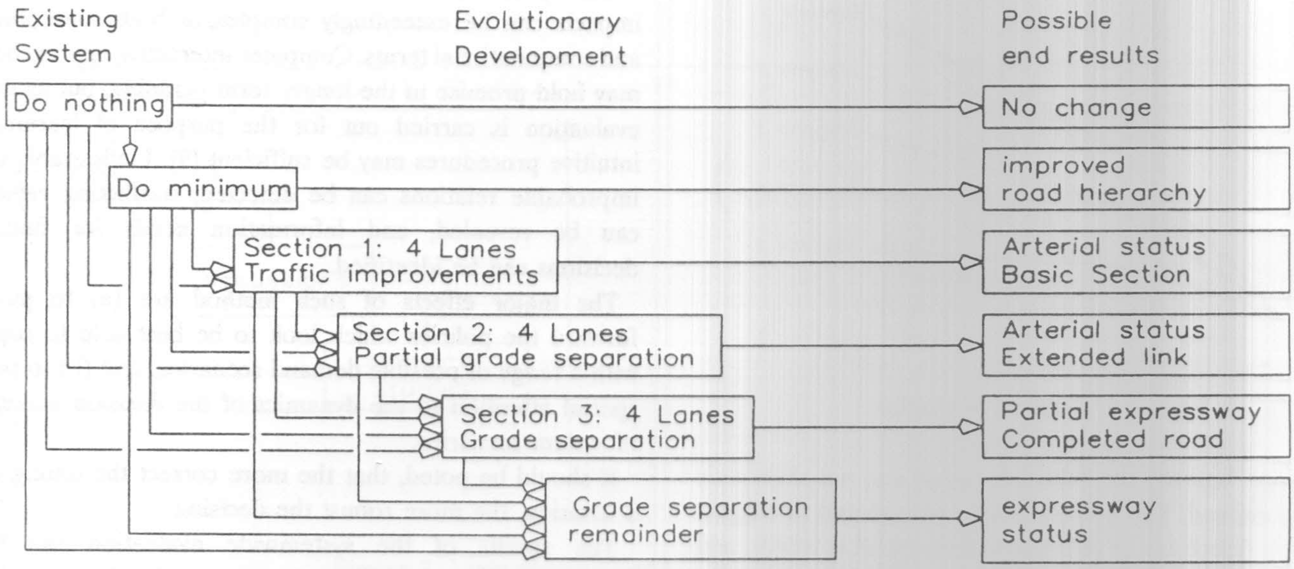

Figure 6. Evolutionary development framework -an example "construction of a three-section road"

travel demand. The natural reaction in such situation to deal with the planning on the basis of time-by-time isdecisions in the framework of an "open-end" and flexible process.

The scenario-oriented approach outlined in this paper does not produce firm projects, but rather options and limited-time-based commitments. It is an incremental process of collective knowledge and selective decisions, in which transportation and land use strategies can respond to such modifications needed to match the real demand trend with the development of the transport supply.

The paper describes the working guidelines for preparing the integrated phases of this planning process; i.e. formulating and evaluating both demand and transport system scenarios. Generally, scenarios do not constitute a forecast. Demand scenarios view possible future at macro-socioeconomic level, and system scenarios present likely strategies in physical form. Scenario evaluation tests and encourages the flexibility during the planning period, and the re-orientation of strategies if circumstances do not develop as expected.

The proposed planning process appears to be a powerful instrument for depicting the types of uncertainty encountered in strategic transport planning in urban areas.

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