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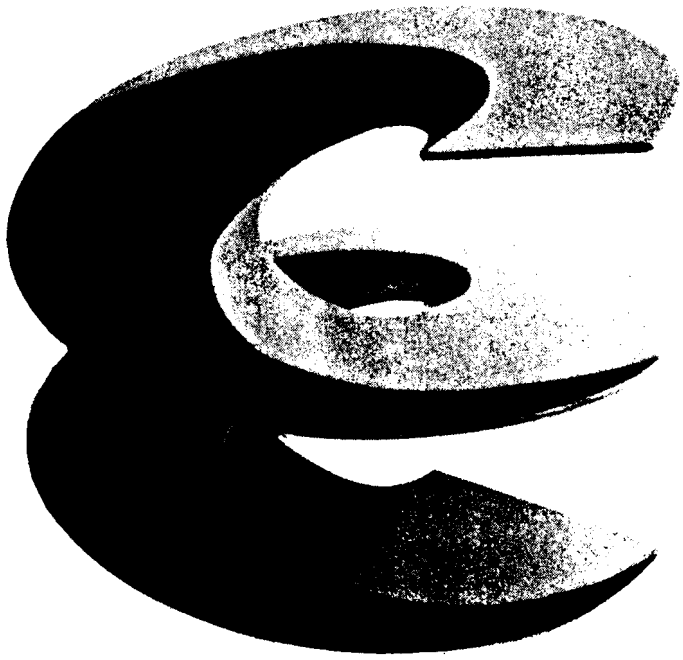
DYNAMIC ANALYSIS OF COMPLEX SYSTEMS



Collana scientifica

FrancoAngeli

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DYNAMIC ANALYSIS OF COMPLEX SYSTEMS

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Il presente volume raccoglie gli atti della Conferenza Europea di Analisi Dinamica dei Sistemi, patrocinata dal Dipartimento di Economia Aziendale e dall'Istituto di Metodi Quantitativi dell'Università Bocconi di Milano, dall'Ospedale Maggiore di Milano, Istituto di ricovero e cura a carattere scientifico, dall'Associazione Italiana di Analisi Dinamica dei Sistemi, dall'Istituto di Medicina Interna dell'Università Statale di Milano.
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A System Dynamics Road Provision Model

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1. Introduction

The growing conflict between the requirements of the road network and the available financial resources is one of the most serious problems with which highway authorities have to deal. There is a need for simplified planning techniques that are capable of testing alternative strategies for investing in the road network. These tools are meant to provide a powerful support to highway decision-makers so that they can make more rational and informed decisions.

The main purpose of this study is to construct a dynamic simulation model that describes the structural feedback interactions of the road system. The model is meant to analyse and show the impacts of alternative road strategies. This will eventually lead to a more efficient management of the funds available for roads as well as to a more effective road maintenance programme.

The paper attempts to indicate alternative ways for managing the allocation of the available road funds into major categories. The process involved in the evaluation of alternative road strategies is also introduced.

2. Model Description

The System Dynamics (SD) methodology is used in this study as the modelling framework within which the road provision model is developed. SD has become an appealing modelling style used by many different disciplines. A review of the potential applicability

of SD to modelling transportation systems as well as an extensive bibliographical list of the applications of SD to various transport issues are presented in Abbas (1990b).

The road provision model consists of two main parts, as shown in Figure 1. The first, is the user interface module, the second is the SD road provision model.

The user interface module can be described as a computerised friendly dialogue, designed to foster creativity in constructing alternative scenarios for the road network, and also to work as a flexible, easy-to-use medium to support the user in entering the exogenous parameters/specifiçations required by the model. It is also meant to act as a training tool for people unfamiliar with the road system. The options available for inputting the model parameters through using the user interface module are covered in Abbas et al. (1990c). It is worth noting that the options available through the user interface module allow the specification of the input parameters in different combinations of deterministic, stochastic and empirical forms.

A detailed description of the structural interactions of the road provision model is given in Abbas (1990a). The model simulates the effects of different road strategies. This is done by tracing the life-cycle costs of the activities which are necessary to develop and maintain the road system, and establishing the impacts that these activities have on the condition and performance of the road network. Activities involved include: construction, administration and the maintenance of roads. Maintenance measures include: routine, periodic and restorative maintenance of roads.

3. Allocation of Road Funds

The main emphasis of this paper is on presenting ten different priority ranking strategies, considered by the model, for managing the allocation of road funds. The ten strategies are as shown in Table 1. In each time interval of the simulation, road funds are allocated among the five road system activities. This investment allocation process is performed in a dynamic fashion so as to be relatively consistent with the priorities and the changing demands of the road network system.

Road Activity \ Strategy Number	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)	(IX)	(X)
Road Administration Funds	1	1	1	1	1	1	1	1	1	1
Routine Road Maintenance Funds (Final)	3	3	2	2	2	2	2	2	2	2
Road Restoration Funds	4	5	3	4	3	5	5	4	3	4
Periodic Road Maintenance Funds	5	4	4	3	5	3	4	5	5	3
Road Construction Funds	2	2	5	5	4	4	3	3	3	4

Table 1: Ten Priority Ranking Strategies for Allocation of Road Funds

4. Policy Analysis

One of the main objectives of the model is to act as an experimental tool for testing and assessing the consequences of different road strategies on the physical development of the road system. The ranking of the priorities considered in the allocation of road funds is varied in accordance with the ten strategies introduced in Table 1. This permits the testing and analysis of the impacts of alternative combinations of priorities for the allocation of road funds on the condition and performance of the road

network system. This type of structural sensitivity analysis can establish the optimum funding strategy required to achieve a set of conditions for the road. This will assist in the management and control of the road system.

5. Evaluation of Road Strategies

One of the strengths of the simulation model is that it provides a set of performance indicators that can describe the state and development of the road system at any point in its life time. Evaluation of alternative road strategies is mainly carried out by comparing the output of the model, against the user criteria.

Strategies I & II produced similar results, as well as strategies VII & VIII. This is because these strategies are characterised by having construction of roads given precedence over some if not all of the maintenance measures. This is often the case with many road administrators, as the construction of new roads is looked upon as a prestigious activity to be appreciated by public opinion. Road Construction consumes the bulk of financial resources, and under scarcity of funds this leads to inhibiting the performance of maintenance measures and so their rank in the allocation structure will not have any significant effect.

The model is designed to keep the input data to a minimum, yet to produce a comprehensive output of the condition of, and expenditure on, the road network. Figures 2, 3 & 4 show three important performance indicators, namely, the ratios of road kilometres in good, fair and poor condition to the total constructed road kilometres. The decision-maker is left to scrutinise the output that shows the development of the road system over time and to choose the most optimum strategy that suits his required needs and conditions. The procedure involved

in the evaluation of alternative road strategies is presented in Figure 4. Policies are selected according to their ability to produce a level of service acceptable to decision-makers.

6. Conclusions

The road provision model is used to analyse different road policies and is meant to give information about the structure and performance of the road network system. Its overall objective is to serve as a management tool for designing, testing and assessing strategies that support the decision-making in the field of highway planning.

According to Coyle, 1978, SD, the modelling approach used in this study, seems to fulfil a need, which is not met by the standard planning and programming approaches, namely that of providing for the concept of controllability.

This paper focused on two main topics: firstly, to indicate how available road funds would be allocated into major appropriation categories; secondly, to introduce the procedure involved in the evaluation of alternative road strategies. The evaluation/ optimisation presented in this paper is heuristic in nature. Heuristic optimisation can help to familiarise transport personnel with the road network system, but over the long run it may become tedious. The development of computerised optimisation algorithms would be a major step forward in the sophistication and ease of use of the model described in this paper.

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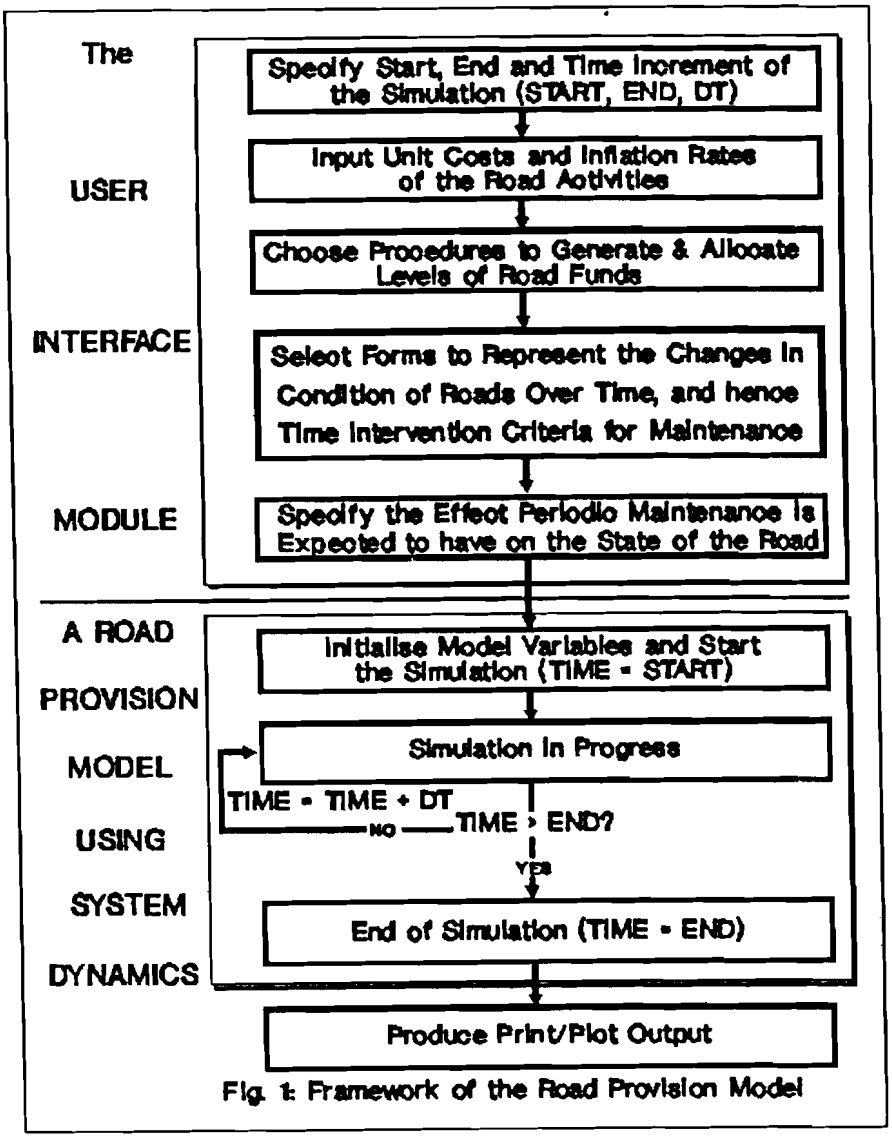

Fig. 1: Framework of the Road Provision Model

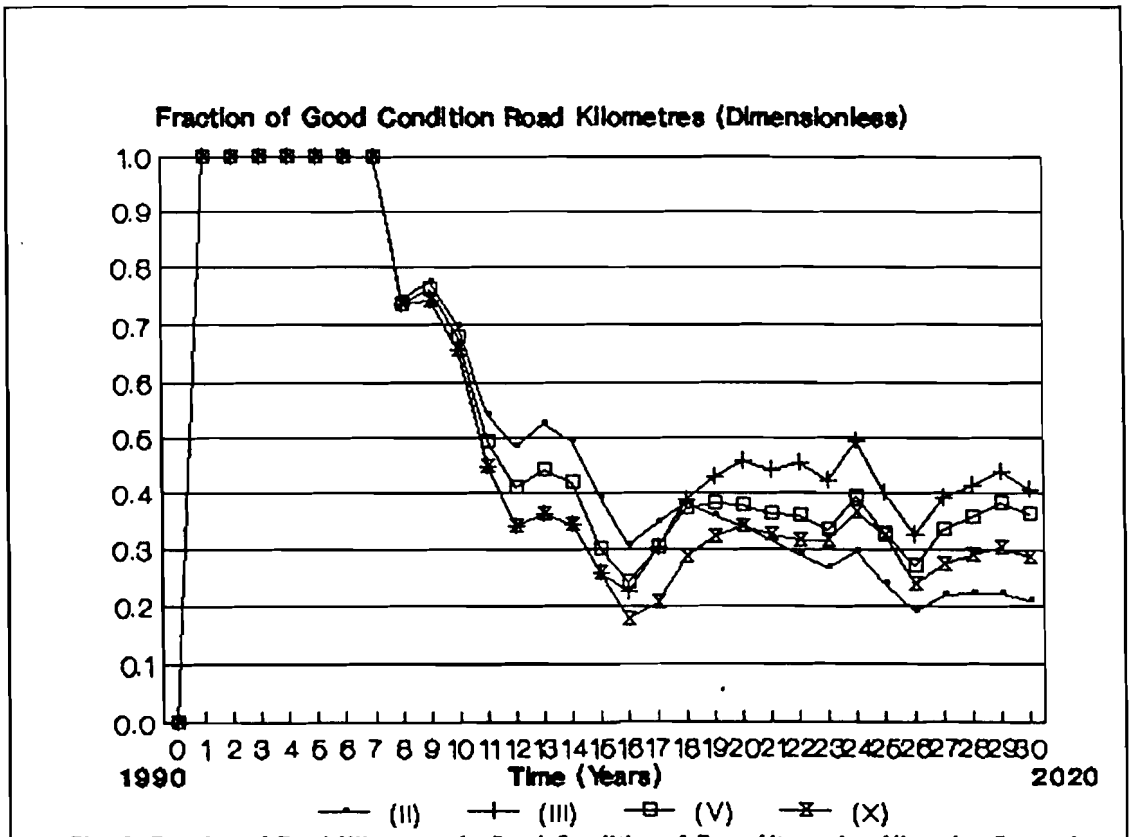

Fig. 2: Fraction of Road Kilometres in Good Condition of Four Alternative Allocation Strategies

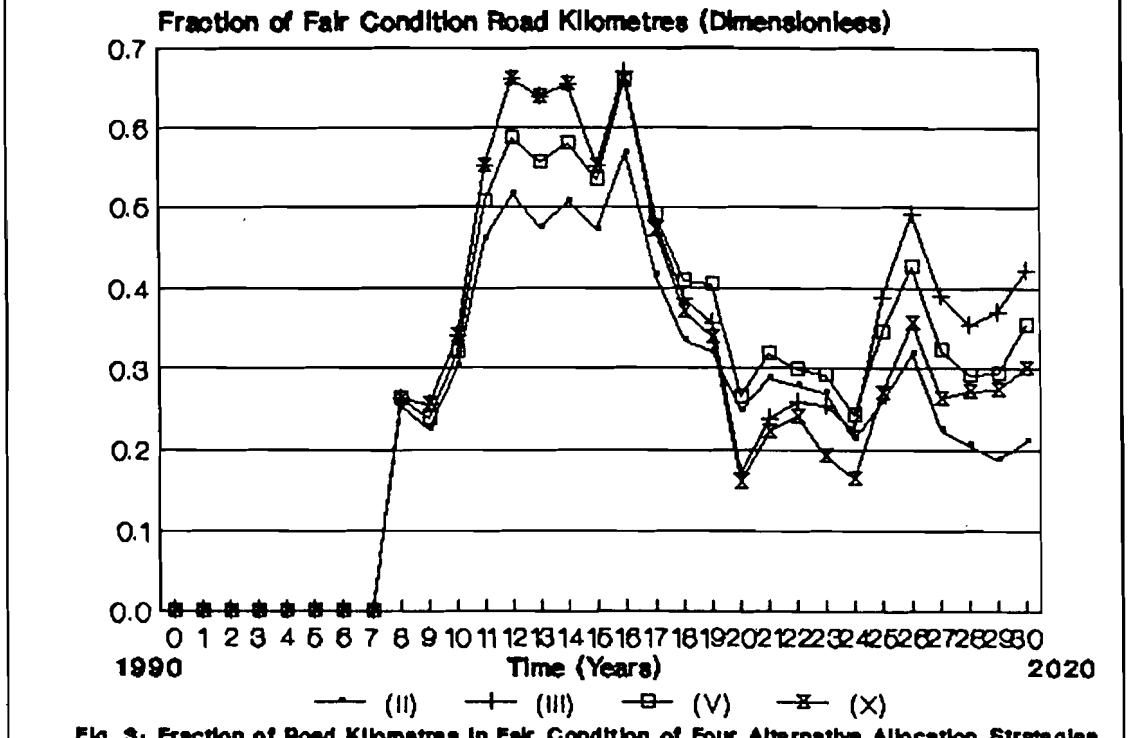

Fig. 3: Fraction of Road Kilometres in Fair Condition of Four Alternative Allocation Strategies

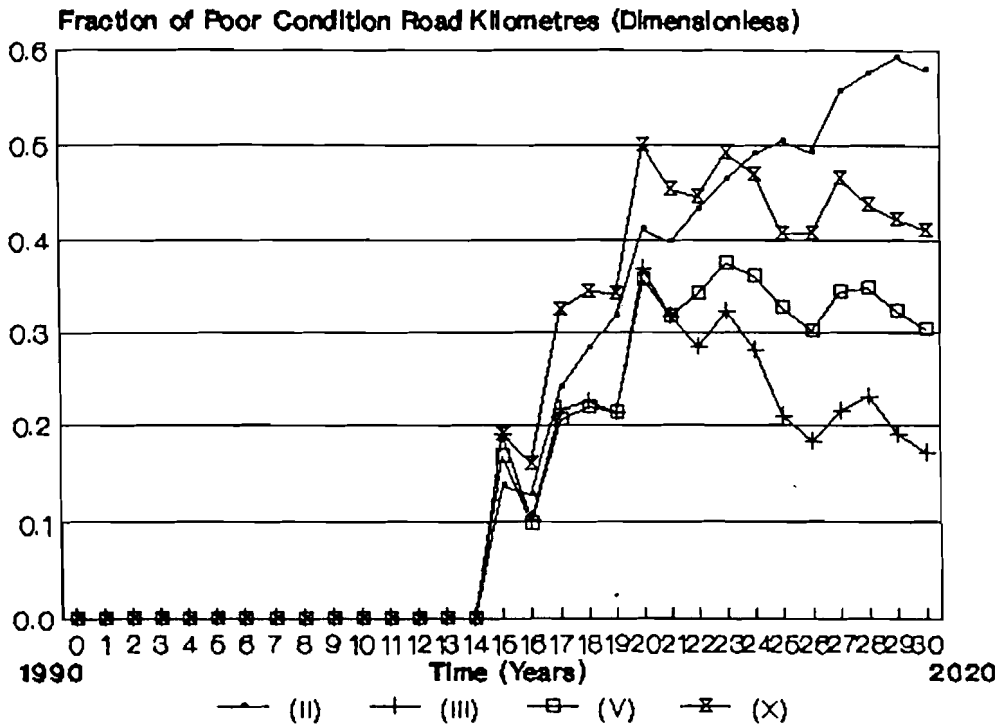

Fig. 4: Fraction of Road kilometres in Poor Condition of Four Alternative Allocation Strategies

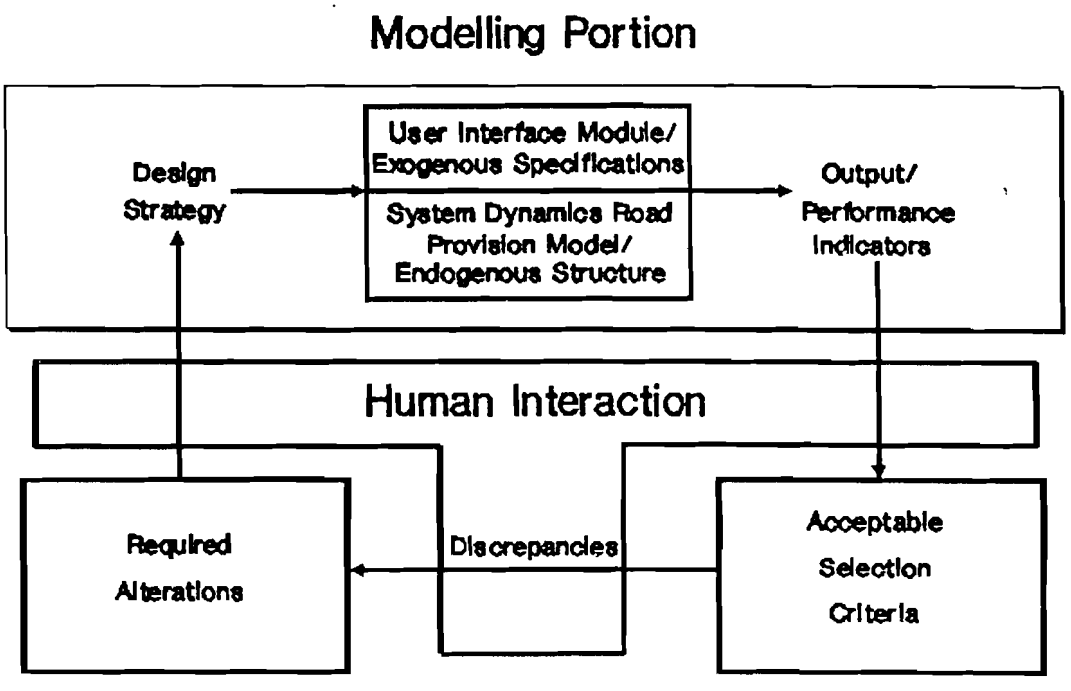

Fig. 5: The Evaluation/Optimisation Feedback Loop