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Autor: Hutchinson, B.G. / Shortreed, J.H.

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Evaluation of Multy-year Highway Investments as a Basis for Annual Construction Project Scheduling

Evaluation des investissements routiers pluriannuels en vue du programme annuel de construction

Investitionsplanung im Strassenbau im Zusammenhang mit dem Aufstellen von Jahresprogrammen

B. G. HUTCHINSON **J. H. SHORTREED**

Prof. Dr. Dr.
Department of Civil Engineering, University of Waterloo
Waterloo, Ontario, Canada

SUMMARY
This paper has outlined a procedure which is used to program projects for the annual highway construction program in Ontario, Canada. While the procedure had its origins in economic theory and in certain operations research techniques, it has been accepted as a management tool in a large and diversified transportation agency. At present the potential use of the methodology in other phases of transport budgeting are being explored.

RESUMÉ
L'article présente une méthode utilisée dans l'Ontario, Canada, pour la préparation du programme annuel de constructions routières. La méthode — basée sur la théorie économique et utilisant des techniques de recherche opérationnelle — a été introduite comme outil de gestion dans une vaste administration publique des transports. La possibilité d'emploi de la méthodologie présentée dans d'autres secteurs de la planification des transports est actuellement à l'étude.

ZUSAMMENFASSUNG
In diesem Artikel wird ein Verfahren beschrieben, das für die Erarbeitung des jährlichen Strassenbauprogrammes in Ontario, Kanada, verwendet wird. Das Verfahren wurde als Führungshilfsmittel in einer grossen öffentlichen Verwaltung des Sektors Verkehr mit Erfolg eingeführt. Es hat seine Wurzeln in der ökonomischen Theorie und basiert auf wissenschaftlicher Methodik. Im Moment wird geprüft, ob das Verfahren in anderen Phasen der Investitionsplanungstätigkeit angewendet werden könnte.

1. INTRODUCTION

The capital spending programs of many highway authorities present a classical problem of capital rationing. Normally there are many more worthwhile projects than funds available and a highway agency must select for any one construction year a set of projects whose costs during that year do not exceed the budget set for that year. In addition, a highway agency has the option of shifting worthwhile projects between budget years in order to maximize the return on its available budget.

This paper describes a method of construction project programming that is used by the Ontario Ministry of Transportation and Communications for programming highway construction projects. The approach outlined in this paper has been developed during the past 5-6 years.

The Ministry of Transportation and Communications of Ontario (MTC) is responsible for a variety of programs which involve the construction, maintenance, operation and regulation of a range of transport modes within the Province of Ontario. These transport modes include the highway system, third level air carriers, resource railways, ferries and the major components of urban transport systems. In 1976-1977 this organization had a total budget of $ 230.3 million.

2. THE HIGHWAY SYSTEM PLANNING PROCESS

In Ontario highway system planning is conducted with respect to a 20 year time horizon. Future highway travel demands are estimated and used to determine the future highway system needs. An origin destination survey is normally performed and used along with expected future land use in order to estimate future highway traffic demands.

The principal outputs of these highway planning studies are specific recommendations about changes to the highway system along with a broad indication of the desirable construction time horizon of the various elements of the highway system plan. These regional highway planning studies represent one input to the identification of potential project investments. Other inputs include information from regional offices regarding the needs of existing road sections, political inputs and so on. Information of this type from various sources is used to develop a set of potential construction projects.

The highway construction program within MTC is expressed in terms of three separate time spans and these are:

1. The Strategic Plan: this plan identifies and orders projects within a time period of 5 to 20 years where the ordering is determined principally from benefit-cost analyses.
2. The Advance Program: this program identifies a set of projects in order of reference over a 1 to 5 year time horizon where the ordering is determined principally by various constraints within the administrative process.
3. The Active Program: this program consists of the set of projects which have been identified for implementation within a 1 year period and involves coordination of all the pre-enginnering activities required before a tender document can be prepared.

The principal focus of this paper is the technique used to develop the strategic plan. Potential benefit and cost streams associated with each project are estimated and used along with the expected construction budget constraints to determine the optimum set of projects for each construction year. This schedule of projects provides the basic input to the advance program. It has been pointed out above that the ordering of projects within the advance program is determined largely by constraints such as engineering design time, ability to purchase necessary land from private areas, public hearing requirements and so on. The active program project schedule is adjusted to meet short-run issues such as the actual budget approved in a construction year, the actual prices tendered by contractors, immediate construction expenditures dictated by premature pavement failures, natural catastrophes, political commitments and so on.

3. BROAD TYPES OF CAPITAL IMPROVEMENTS

The capital investments made in a highway system may be classified into the following broad groups:

1. Highway Link Additions
2. Highway Capacity Improvements
3. Highway Pavement Reconstruction

Link additions are those highway projects which involve the construction of a completely new highway link between two points. This type of highway project may result in the reduction of trip times and may stimulate the location of new economic activities in the areas through which the new highway passes.

Capacity additions on the other hand involve the expansion of an existing facility to accommodate a greater volume of traffic and to improve traffic flow conditions. This type of project is aimed primarily at the highway system users where a typical example might involve the expansion of a 2-lane road to 4-lanes.

Highway pavement reconstruction projects involve the renovation or complete reconstruction of a pavement which has deteriorated. Essentially, a capital investment is being used as a substitute for a high level of existing maintenance expenditures.

4. ESTIMATING BENEFITS

The development of a highway construction programming process requires the formulation of procedures for estimating the benefits likely to accrue from these broad types of investment. Three broad classes of benefit are estimated and these are:

1. User Benefits: these are the benefits to road users from decreases in vehicle running costs, accident costs and travel time costs.
2. Production Benefits: these are the benefits that might result from increases in the production of existing economic establishments due to their improved accessibility to markets.
3. Regional Development Benefits: these are the benefits that would result from

new economic establishments being started in areas with improved accessibility.

4. Pavement Benefits: these are the benefits that would result from reductions in annual maintenance costs and the reductions in user costs due to smoother pavements.

Methods for estimating these benefits are based on accepted econimic principles and these methods are discussed in the references listed at the end of the paper.

5. PROJECT TIMING

The rate at which a project yiealds benefits at any particular point in time depends on two factors and these are the age of the project and calendar time. In the case of a highway project the age of the project has an importand influence on the magnitude of the maintenance costs. Calendar time influences the size of the demand for highway travel and through this influences the rate at which benefits are generated.

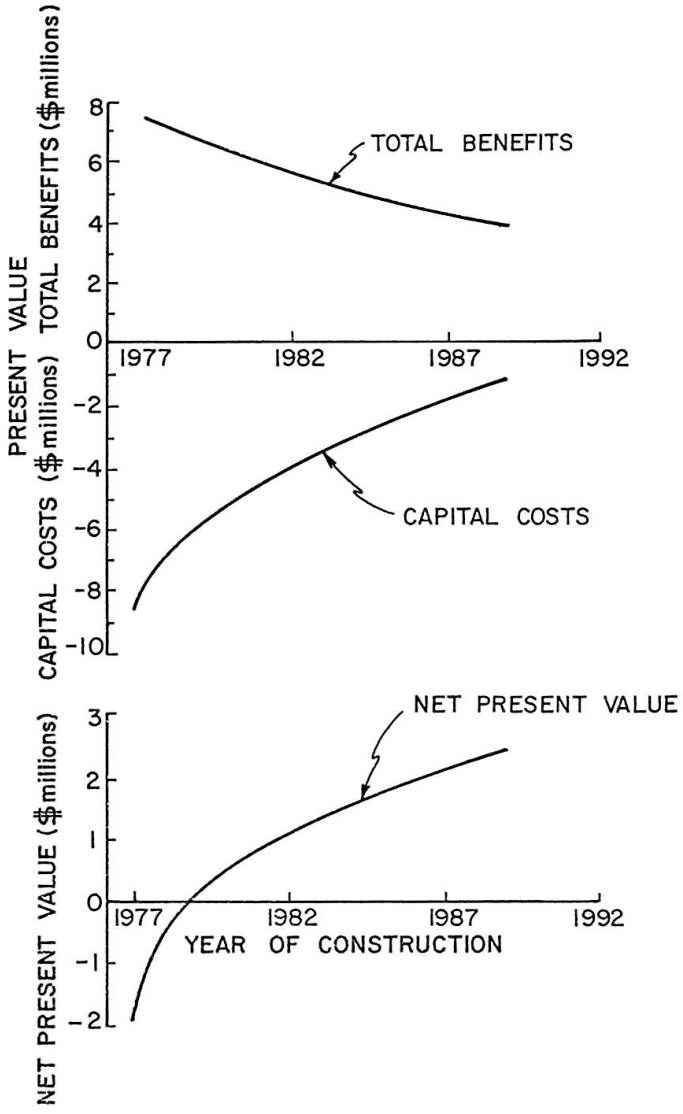

Figure 1 Variations in Total Benefits, Capital Costs and Net Present Value

Figure 1 illustrates the variations in the present values of benefits and costs of a highway project with year of construction. This diagram demonstrates that if the project were constructed in 1977 then the net present value will be negative. However, as the year of construction of the project is delayed, the net present value of the project begins to increase and becomes positive for construction in 1979. With this project the net present value continues to increase but at a decreasing rate.

It should be recognized that different projects will habe different profiles of net present value depending on the context into which they are introduced. In some cases the net present value may decrease with the delay of construction. In other cases, it may increase to a maximum value and then begin to decrease with further delay of construction. The basic programming problem is to select for a given construction year that set of projects which maximizes the net present value for the set of potential projects.

In general, the optimal set of projects for any year of construction will exceed the construction budget available for that year. When budget constraints exist the programming problem becomes one of assigning projects to construction periods such that the sum of the net present values is a maximum and the budget constraints are not violated for any one period. This problem is illustrated in Figure 2.

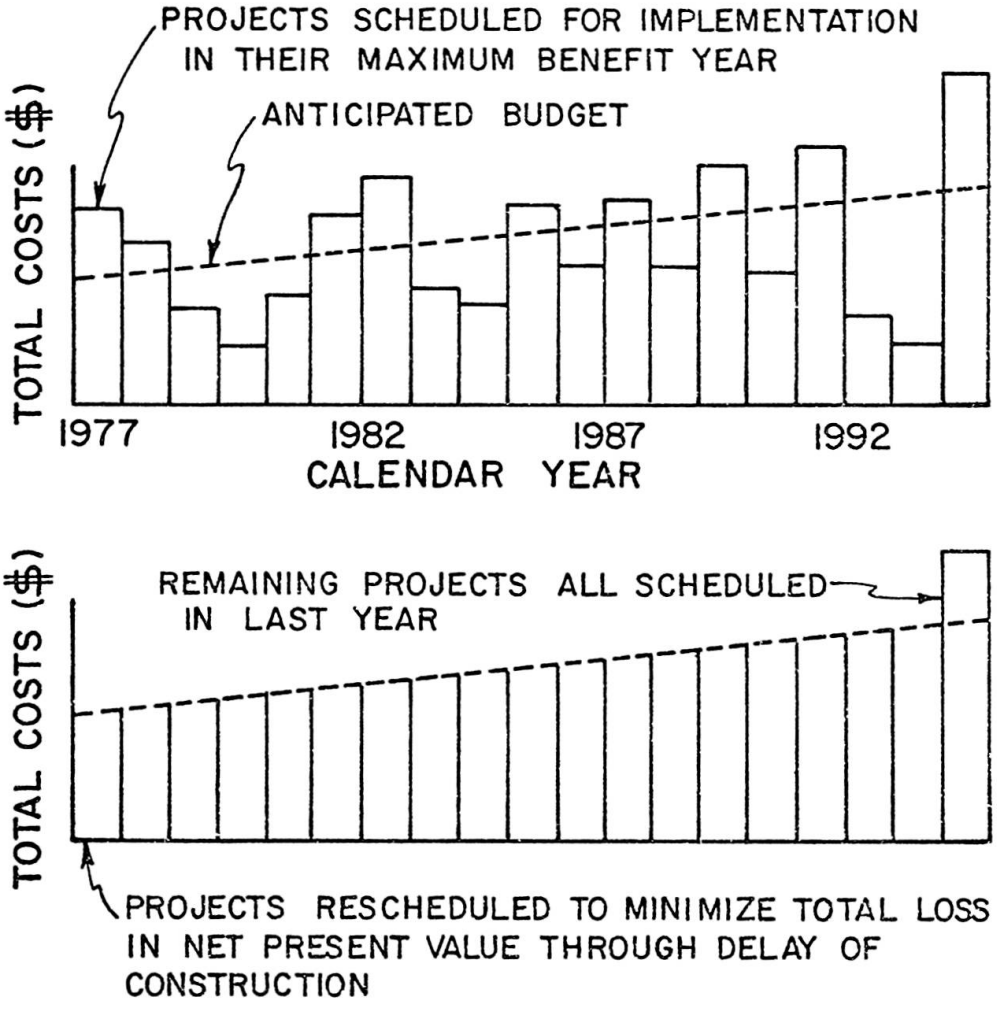

Figure 2 Graphical Illustration of Linear Programming Technique

In the upper graph all projects may be thought of as competing for implementation in their construction year of maximum benefit. The lower graph illustrates that the programming process fills in the spaces below the budget line so as to minimize the loss in benefits due to the delay of projects because of budgetary constraints. This process is achieved through the use of a linear program the details of which are described in the references.

6. IMPLEMENTATION OF THE PRIORITY PLANNING PROCEDURE

A significant time span was involved in moving from the initial formulation of the technique to its routine use as a programming tool. The original theoretical work was completed in 1970 while the method was tested on an area of one-twentieth of the Province in 1972. A decision to implement the procedure was taken in 1972 and a further two years was required to integrate the procedure with existing programming procedures and to obtain the necessary input information. The method was being used for actual programming decisions on a Province-wide basis towards the end of 1975.

Since 1975 the benefit calculation procedures and the linear programming method have been used on a system wide basis annually. The method has been well accepted and has been extended into more detailed analyses of pavement design and the functional design of highway links.

7. THE PROCESS AS A MANAGEMENT TOOL

While the programming procedure was originally conceived in theoretical economic terms the programming procedure has proved very useful as an aid to the senior management of the Ministry. The linear programming formulation allows managers to test quickly the implications of reduced budgets, regional budget constraints, political commitments, and so on.

In 1972 the highway construction budget represented about 41 percent of the total budget of the Ministry. In 1976-1977 this proportion had fallen to 23 percent and the estimate for 1977-1978 is 21 percent. During this period of rapid budget contraction the programming procedure has been found to be most useful. The Ministry is now considering broadening the technique from a construction priority setting method to a procedure for the general control and priority setting of the entire budget.

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