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Financial and Planning Considerations for Bridge Rehabilitation

Aspects financiers et planification de la rénovation de ponts

Finanzielle und planerische Aspekte bei Brückensanierungen

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SUMMARY
This paper reviews the current use of financial and planning considerations in bridge-rehabilitation decisions. The decision process includes factors such as available manpower and equipment capabilities, planning expertise, and political realities. It presents analytical techniques, such as payoff-matrix, opportunity-loss-table and decision-tree, to systematically incorporate financial and planning considerations for optimal decision making.

RESUME
Cet article considère les aspects financiers et de planification dans les décisions de rénovation de ponts. Le processus de décision comprend des facteurs comme la main d'oeuvre, les équipements disponibles, l'expérience de la planification ainsi que des réalités politiques. Il présente des techniques d'analyse tels que seuils de rentabilité, diagramme avantages-inconvénients et des arbres de décision afin d'incorporer systématiquement les considérations financières et de planification pour une décision optimale.

ZUSAMMENFASSUNG
Dieser Bericht behandelt die üblichen Aspekte für finanzielle und planerische Erwägungen beim Entscheid von Brückensanierungen. Der Entscheidungsprozess beinhaltet Faktoren wie verfügbare Arbeitskräfte und Ausrüstungsmöglichkeiten, Planungsexpertise sowie politische Gegebenheiten. Er behandelt analytische Techniken wie payoff-matrix, opportunity-loss-table und decision-tree, um finanzielle und planerische Erwägungen beim optimalen Entscheidungsprozess systematisch zu integrieren.

1. INTRODUCTION

It is widely known that many bridges in the United States need to be replaced or rehabilitated and that under the current fiscal constraints, most of these deficient bridges cannot possibly be replaced in the forseeable future. Therefore, increased emphasis on bridge rehabilitation is inevitable. Although much work has been done in recent years in systematizing analysis, planning and design of bridge replacement; very little attention has been given to similar considerations for bridge rehabilitation. As a result, bridge replacement/rehabilitation decisions are generally being made as a piecemeal synthesis of some, while underestimating or ignoring other relevant considerations. This paper focusses on systematically integrating structure sufficiency, financial and planning considerations into decision-making based upon reliable information, well defined criteria, clearly perceived constraints and uniform evaluation of available alternatives.

2. CONSIDERATIONS FOR BRIDGE REHABILITATION

2.1 Structure Sufficiency Considerations

The first consideration for any bridge rehabilitation/replacement decision-making is whether its structure geometry and load carrying capacity are sufficient to safely carry the present or projected traffic. The necessary information to facilitate determination of structure-sufficiency includes the following:

2.1.1 Structure Inventory and Traffic:

Type, age and geometric details (e.g.: length, width, number of spans, clearances, and alignment) of the bridge and its approaches, material inventory of components; ADT, HCADT and peak-hour traffic and posted load/clearance limits.

2.1.2 Structure Inspection and Appraisal:

Up to date information on condition, its rating, elevation of deterioration, and needed repairs for super and substructure components, professional estimate of structure's remaining life, evaluation of unsafe conditions (e.g.: steep grades, geometric deficiencies, excessive vibrations, etc.); and serviceability considerations such as drainage, rideability and lighting.

2.1.3 Structure Capacity and Functional Adequacy:

Original design and current load carrying capacity, adequacy for present and projected needs, waterway adequacy and protection, if any.

2.1.4 Maintenance Information:

Historical record of maintenance, future maintenance needs, available rehabilitation alternatives with their estimated costs and anticipated improvement in life expectancy.

Based on the above information, the structure is determined to be sufficient or insufficient to safely carry the present or projected traffic. Further, preliminary details of feasible rehabilitation options can be established that will make the structure sufficient for future traffic.

2.2 Financial Considerations

The second consideration, should a bridge need rehabilitation, pertains to available and projected flow of funds. A decision maker needs to consider not only the initial availability of funds for rehabilitation, but also requirements of future flow of funds that the rehabilitation alternate can be expected to create. Like analyses of other highway improvements, total cost basis should underlie rational economic analyses of rehabilitation alternatives. The most commonly used criteria that are useful for comparing total cost of alternate rehabilitation proposals are: present value, annualized costs and prospective rate of return [1,6]. Difficulties arise in application of these criteria while estimating future costs and life expectancies. These difficulties can be overcome by using past experience with similar structures, proficient judgement and probabilistic methods. Statistical techniques can be effectively used to account for element uncertainty in making estimates.

While general revenue funds may sometimes be used for small rehabilitation work, major bridge rehabilitation requires some form of bond or federal and state spending. Conditions and guidelines attached to such funding can effectively restrict feasible rehabilitative alternatives. Prevailing interest rates and availability of local matching funds can make phased rehabilitation a desireable alternative.

2.3 Planning Considerations

Once it has been decided that a bridge needs rehabilitation and financial considerations have established feasible rehabilitation alternatives, planning considerations should be aimed at reaching an acceptable and truly optimal or near optimal decision. Being a major investment decision, to be acceptable, it has to be consistent with the overall agency objectives and policies. Similarly, to be a realistically acceptable alternative, objectives of the rehabilitation proposal should be to make the structure adequate for projected future use. Development plans and projected future needs of the area served, influence functional adequacy of the rehabilitated bridge. These plans can change traffic patterns and influence the type of frequency of traffic at the bridge-crossing. Inadequacy to sustain the projected traffic may eliminate a simple and economical rehabilitation alternative in lieu of a replacement alternate. In addition to adequacy for present and projected traffic, the rehabilitated structure must also meet the minimum requirements of horizontal and vertical clearances, roadway width, waterway opening, if any, and safety.

The bridge rehabilitation work requires innovative approaches as much as, if not more, than a new bridge construction does. Availability of skilled manpower, sometimes of special materials and unique equipment can be very important in the cost effectiveness of a rehabilitation decision. Systematic and expert planning can help overcome real and perceived hurdles in successful rehabilitation. Local and legal constraints can substantially influence the decision making process. In recent years, political realities have increasingly dictated the outcome of what otherwise would have been a very sound decision-making process. As a result, involvement of local groups and consideration of their concerns during the entire decision-making process has become necessary.

Where a major rehabilitation is intended, some state and federal laws may require mandatory compliance with extensive environmental considerations.

A number of cost inputs may be required for planning considerations. These include direct costs for land acquisitions construction easements, project engineering and costs to set up and maintain detours for bridge replacement alternatives. In some cases, inputs may require quantified estimates of economic, special or environmental losses that may result because of different alternatives. Other economic costs that need consideration are costs related to temporary loss of use, traffic delay, accelerated deterioration of structures on detour routes and impact of inflation due to longer duration of construction [7]. Peculiar site conditions, historical significance of the bridge, and technological limitations are some of the other planning considerations. A careful evaluation of these planning considerations can yield a set of acceptable and optimal or nearly optimal rehabilitation alternatives.

3. ANALYTICAL TECHNIQUES FOR EVALUATION

In recent years, increasingly sophisticated methods have become available for analyzing investment decisions. The most widely known of these new developments are the analytical methods that take into account time value of money. A payoff table indicates all alternatives available to the decision-maker, events that can happen, probability destribution of these events, and monetary payoff (+ sign: benefits, - sign: costs) that result from each alternate/event combination. Although it is not easy, it is necessary to convert non-economic consequences into their monetary equivalent before the decision analysis process can continue. A very useful decision criterion for many decision problems under uncertainty is expected monetary value (EMV). In order to compute the EMV for a given alternate, the payoff is simply multimplied by the probability of that event's occurring, and products for each event are added. The expected value of a chance event or random variable X, which can take on any one of n values, is defined to be:

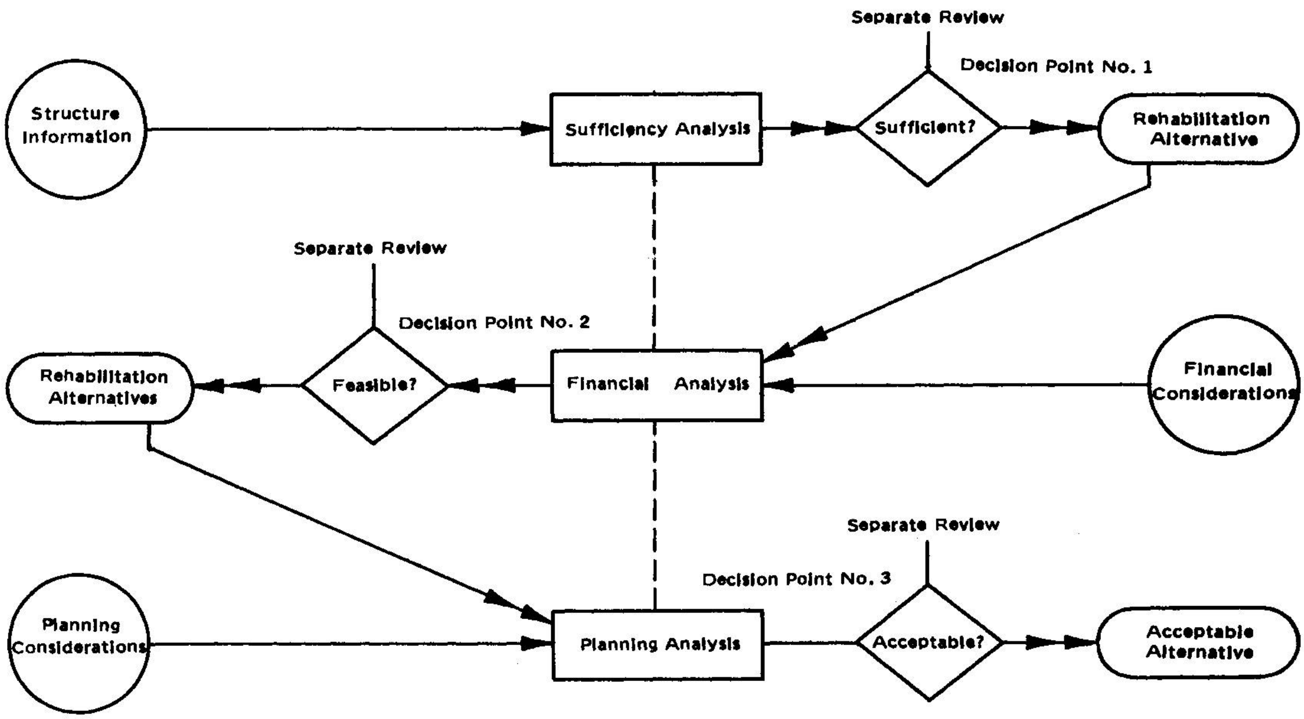
- Expected Value of X = $E(X) = \sum_{i=1}^{n} X_i \; P(X_i)$

Where X is the monetary outcome of a decision problem under uncertainty, the expected value of X is usually called Expected Monetary Value, or EMV. The optimal alternative in the payoff table is indicated by the highest EMV.

Another way of analyzing decision problems under uncertainty is to construct an opportunity loss table [6]. The opportunity loss for an alternate/event combination is the difference between payoff for that combination and the best payoff for that event. To construct an opportunity loss table, each event is considered one at a time. All rows of the opportunity loss table are thus completed. The bottom row shows the Expected Opportunity Loss, EOL, for each of the alternates. The EOL is calculated from the opportunity loss table in the same way as EMV is calculated from the payoff table. An alternative which has the lowest expected opportunity loss is the optimal alternative. This optimal alternative will also have the best expected monetary value.

The decision tree approach analyzes a sequence of separate but interrelated events over a time period. The decision tree represents chance events and alternatives to be chosen at decision points [2, 3, 4] . Proper use of decision trees depends on identifying problem and alternatives, practical time spans and obtaining the necessary data. The preferred alternative is the one which has the greatest net present value (NPV).

4. FLOW CHART OF REHABILITATION DECISION MAKING



FLOW CHART OF REHABILITATION DECISION MAKING

4.1 A step by step procedure as outlined in this paper is shown in the above flow chart.

5. CONCLUSIONS

This paper has presented a system for bridge structure rehabilitation decision-making. The decision-maker can systematically evaluate a structure on the basis of sufficiency, financial and planning considerations and arrive at a set of acceptable rehabilitation alternatives. This system is simple, adaptive, and the rehabilitation decision process is easy to control.

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