Challenge of highway bridge evaluation, operation and maintenance

Challenge of Highway Bridge Evaluation, Operation and Maintenance

Défis dans l'évaluation, l'exploitation et la maintenance des ponts routiers

Ueberwachung und Unterhaltung von Autobahnbrücken: eine Herausforderung

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SUMMARY
Comprehensive bridge management techniques must be used to meet the challenge of bridge needs in the 1990's and beyond. Bridge maintenance and rehabilitation are more cost effective than replacement. Much larger portions of available resources must be directed towards rehabilitation and maintenance.

RÉSUMÉ
Les techniques globales de gestion des ponts doivent être appliquées pour répondre aux défis des besoins en ponts dans les années 1990 et suivantes. La maintenance et la restauration des ponts sont plus économiques que leur remplacement. Une plus grande partie des ressources disponibles devrait être utilisée dans des programmes de restauration et de maintenance.

ZUSAMMENFASSUNG
Umfassende Organisationstechniken sind erforderlich, um den Herausforderungen der Brückenunterhaltung über die 90er Jahre hinaus gerecht zu werden. Brückenunterhaltung und -Verstärkungen sind kosteneffektiver als Ersatz durch Neubauten. Deshalb ist ein weit grösserer Teil der verfügbaren Mittel für Verstärkung und Unterhaltung zu verwenden.

I. BRIDGE STATUS

The 576,000 existing highway bridges in the United States pose a formidable challenge to those of us responsible for their continued safe and efficient operation.

Continuing traffic growth, a few spectacular collapses and the general public perception that bridges should last forever contribute to this challenge.
The U.S. Secretary of Transportation reported last year that $50.4 billion would be required to bring all deficient highway bridges up to today's standards.[1] This estimate is based upon inspection data gathered by all States and submitted to the Federal Highway Administration for inclusion in the National Bridge Inventory.

2. ANNUAL PROGRAM

Each year the United States spends between $5 and $6 billion for new, replacement or rehabilitated bridges. Between 8,000 and 10,000 bridge improvement projects are begun each with these funds. About 6,500 to 7,000 of these bridge projects are funded through the Federal-aid highway program. The remainder are funded by individual States or local governments.

3. MAJOR QUESTIONS

While these are impressive figures for any country in the world, several key questions should be asked:

- Is the Federal program large enough?
- Are the right bridges being improved?
- Are the right replacement, rehabilitation and maintenance decisions being made?

4. FUTURE NEEDS

The National Bridge Inventory data, if properly structured, can provide a basis for answering these critical questions. The data included is described in the "Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges, January 1979."[2] Figure 1 shows a histogram of the Nation's highway bridges. It can readily be seen that the majority of bridges built in the United States are between 15 and 35 years old. A more dramatic histogram is shown in Figure 2. This illustrates the deck or roadway surface area in square feet or square meters. No matter which unit of measurement is used, the important thing to note is that a full 40 percent of the deck area of existing highway bridges in the United States is represented by bridges between 15 and 35 years old. The tremendous bridge building boom of the 1950's and 1960's as the Nation carried out its Interstate highway construction program is the principle reason for this anomaly in the histogram.

It should be noted that the widespread use of bridge deck protective systems to prevent chloride induced corrosion of concrete reinforcing steel did not begin in earnest until the mid 1970's in the United States. Because of higher priority demands on available funds, the majority of these pre-1975 bridge decks have not been retrofitted with protection systems. As a result, bridge deck and superstructure rehabilitation needs are expected to continue to grow in the near future.

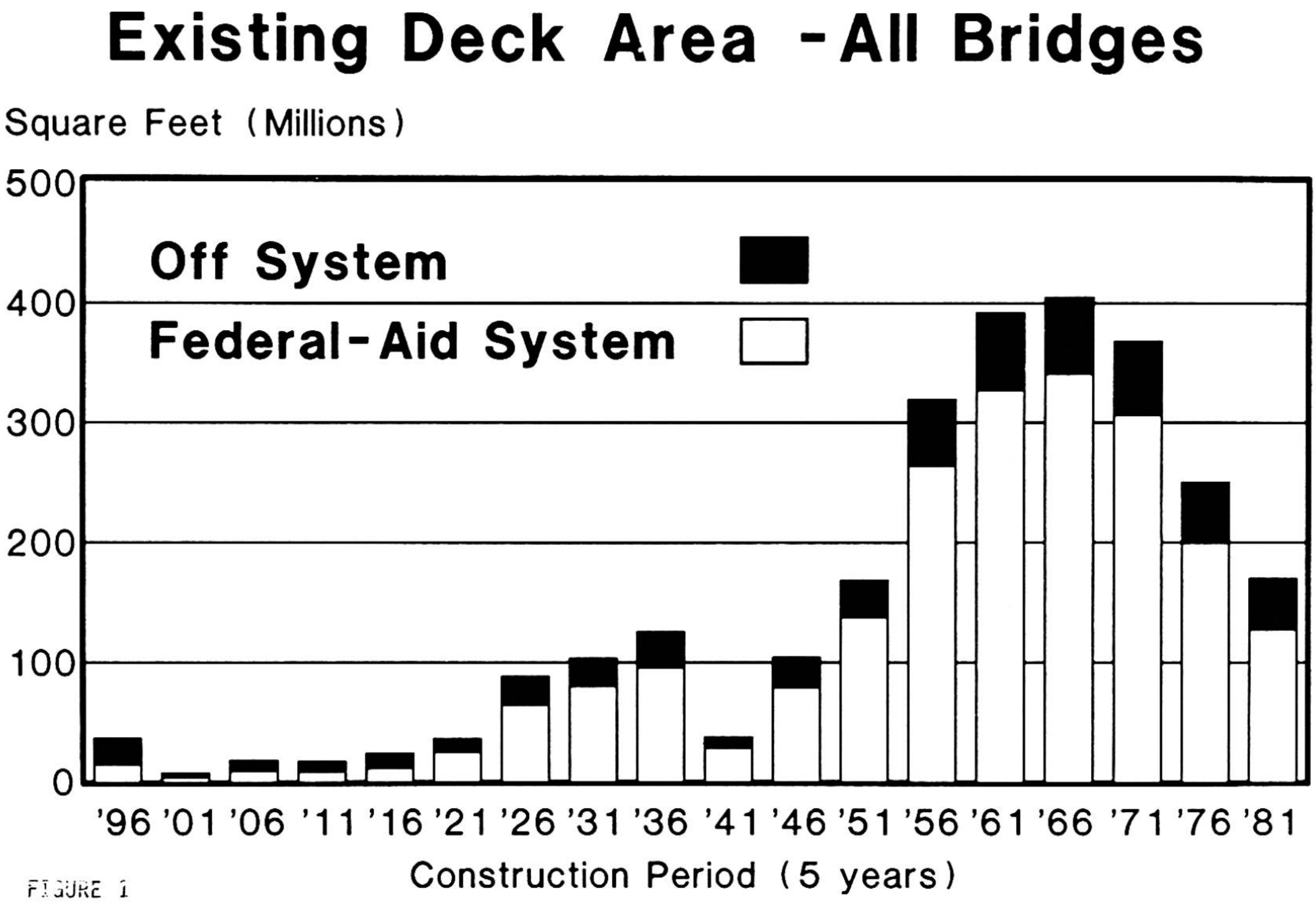

FIGURE 1

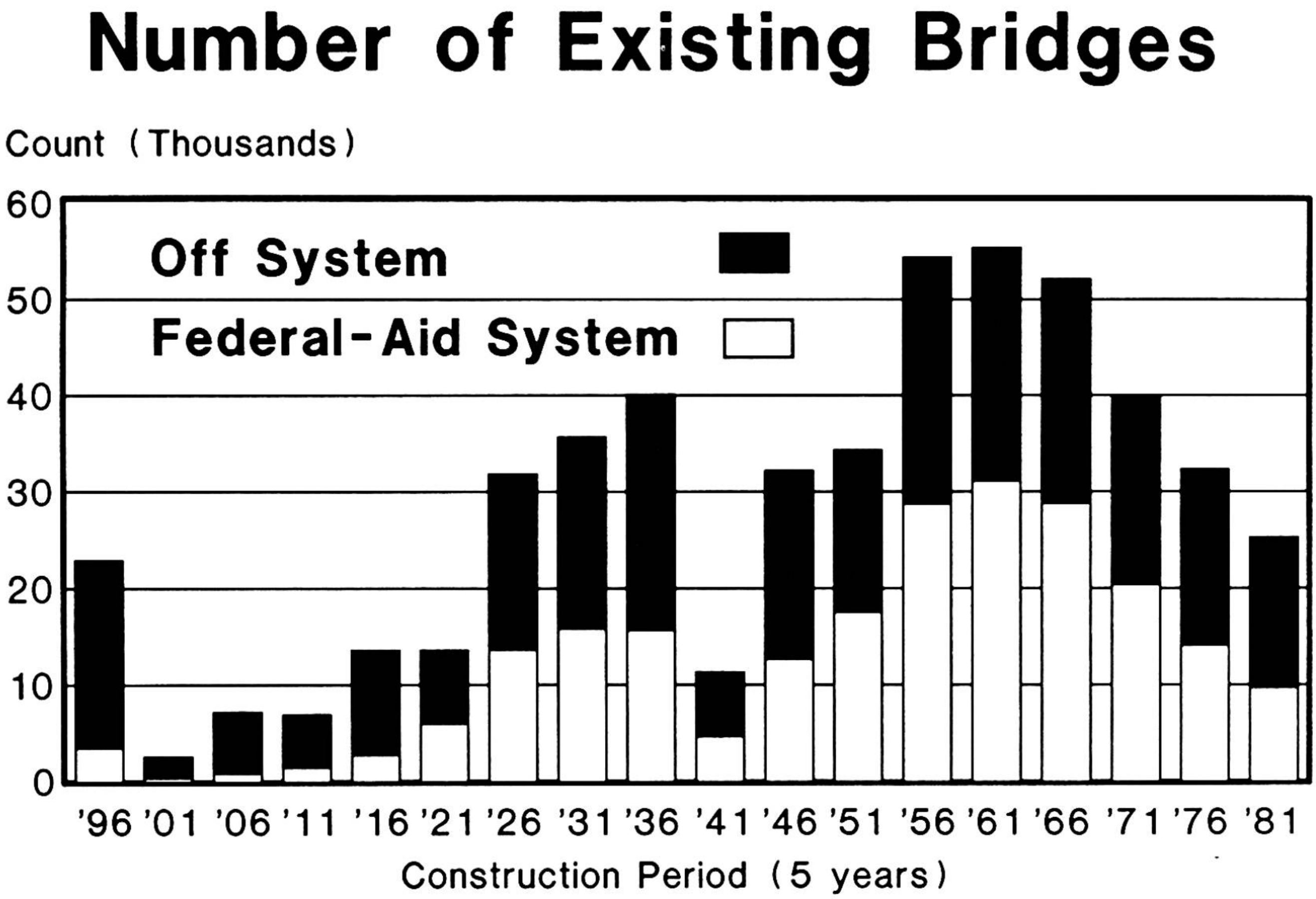

FIGURE 2

A recent study of the useful service life of existing bridges by the staff of the Federal Highway Administration indicates that the average bridge in the United States is replaced when it is about 70 years old and must be rehabilitated sometime during its midlife. Comparison of this life expectancy with the fact that 40 percent of the deck area of existing bridges is represented by bridges between 15 and 35 years old suggests strongly that bridge replacement, rehabilitation and maintenance needs will rise sharply during the next 10 years and beyond.

5. FUTURE PROGRAM SIZE

Current fiscal policies indicate that while Federal programs to improve bridges will not decrease in the immediate future, they are not expected to increase significantly either.

6. THE CHALLENGE

Therein is the challenge. Bridge needs are predicted to increase but resources are predicted to stay about constant.

7. COMPREHENSIVE BRIDGE MANAGEMENT PROGRAMS PROVIDE THE ANSWER

Comprehensive bridge management systems which incorporate the most current engineering, managerial and systems technology will provide the basis for meeting the challenge. A comprehensive bridge management system must include the following elements:

- Data collection and management
- Data Base
- Analysis
- Needs, predictions, options and costs
- Program formulation and Planning

Fortunately most States can use the National Bridge Inventory data as a beginning for their bridge management systems. Methods for manipulating and evaluating the data base are available. Several States have defined minimum tolerable levels of service of bridges and have developed formulas, based upon engineering judgement and empirical studies, to measure relative deficiencies of their highway bridges. Figure 3 illustrates the minimum and desirable levels of service used by the State of North Carolina.

It cannot be overstressed that the validity of any system depends largely upon the uniformity, accuracy and currency of the data base. If the inventory data is flawed, the entire system will suffer. The integrity of any management system for a large array of structures depends principally upon the validity of the inventory and appraisal data.

8. NEEDS DEFINITION

Needs cannot be determined without a universally accepted definition. One governmental unit's definition of needs will be another's luxury. One Country's substandard bridge may be entirely adequate in another Country. This is also true for States within the United States. The best definition of needs that we have been able to agree on is one which defines needs on the basis of benefits to the

North Carolina Level of Service Goals
Bridge Capacity Goals

Road Over Functional Classification	Single Vehicle Capacity (Metric Tons) Acceptable	Desirable
Interstate & Arterial	NP	NP
Major Collector	45.4 Tons	NP
Minor Collector	14.5 Tons	NP
Local	14.5 Tons	NP

NP = Not Posted (capacity = 30.5 Tons for single vehicles)

Clear Bridge Deck Width Goals
for Two Lane Routes

Road Over Functional Classification	Current ADT	Clear With (Meters) Acceptable	Desirable
Interstate & Arterial	ADT ≤ 800	6.7	9.8
	801 - 2000	7.3	11.0
	2001 - 4000	7.9	12.2
	Over 4000	8.5	12.2
Major & Minor Collectors	ADT ≤ 800	6.1	7.3
	801 - 2000	6.7	8.5
	2001 - 4000	7.3	9.1
	Over - 4000	7.9	9.1
Local	ADT ≤ 800	6.1	7.3
	801 - 2000	6.7	8.5
	2001 - 4000	7.3	9.1
	Over 4000	7.9	9.1

ADT = Average Daily Traffic

Bridge Vertical Underclearance Goals

Road Under Functional Classification	Underclearance (Meters) Acceptable	Desirable
Interstate & Arterial	4.27	5.03
Major & Minor Collectors	4.27	4.57
Local	4.27	4.57

FIGURE 3

user of the facilities. This definition of needs is universal to any array of structures. Two forms of this definition of needs are:[3]

- Needs are the least cost actions to make up the gap between existing conditions and standards which are socially optimal by virtue of maximizing net benefits to society.
- Needs are the actions that maximize the net benefits for each bridge, and thus represent the socially optimal choices from a broad range of alternatives.

Applying either of these definitions to a number of improvement options for an individual bridge should result in a unique choice for improvement which is optimal for the bridge users.

A comprehensive bridge management system will provide a systematic procedure for making bridge programming decisions which is markedly different from applying engineering expertise on a bridge-by-bridge basis.

9. INCREMENTAL BENEFIT/COST RATIO

One of the best methods of applying bridge management techniques to bridge improvement decisions is to determine the alternative improvement options for each substandard bridge, estimate the improvement cost for each alternative and estimate the user costs incurred by the public for each alternative. Often the higher cost improvements result in net benefits which are smaller than less costly improvement alternatives.

The incremental benefit/cost ratio is determined by taking each increment of benefit and dividing it by each increment of cost. At some point there will be an increment of benefit which equals the increment of cost. This the optimal point for improvement. Figure 4 illustrates this procedure.

If this process is repeated for all substandard bridges and the projects are listed in the order which lists the highest incremental benefit/cost ratio projects first, the resulting list will be the optimal list of projects in priority order.

The process can be readily computerized.[4]

Most recently, researchers from North Carolina State University applied the process to a group of 25 bridges and made some interesting observations.[5] Some of the conclusions are:

- The process is sound and superior to use of empirical priority ranking methods.
- The process provides near optimal sets of alternatives under budget constraints and optimal project sets under conditions of no budget restraints.

10. POLICY IMPLICATIONS

The use of the incremental benefit/cost techniques to select the best bridge improvement options on a system-wide basis has some interesting policy implications. Some of these are:

- For the normal range of discount rates, it is almost always better to rehabilitate or perform heavy maintenance on a bridge than replace it.
- It is in the public interest to spend about 6 percent of the replacement cost of a bridge each year to keep it in service. Put another way, if the discount rate is 6 percent, it is in the public interest to spend up to 6 percent of the replacement cost of bridges each year to keep them in service for an additional year.
- The long term trend in the United States should be to increase bridge maintenance budgets dramatically. Bridge rehabilitation budgets should be significantly increased and bridge replacement budget needs should drop correspondingly.
- Better bridge rehabilitation and maintenance techniques coupled with comprehensive bridge management systems are required to meet the challenge of bridge operations in the 1990's and beyond.
- Similar conclusions will probably apply to the evaluation, operation and maintenance of other large groups of structures such as buildings, dams, airfields and the like.

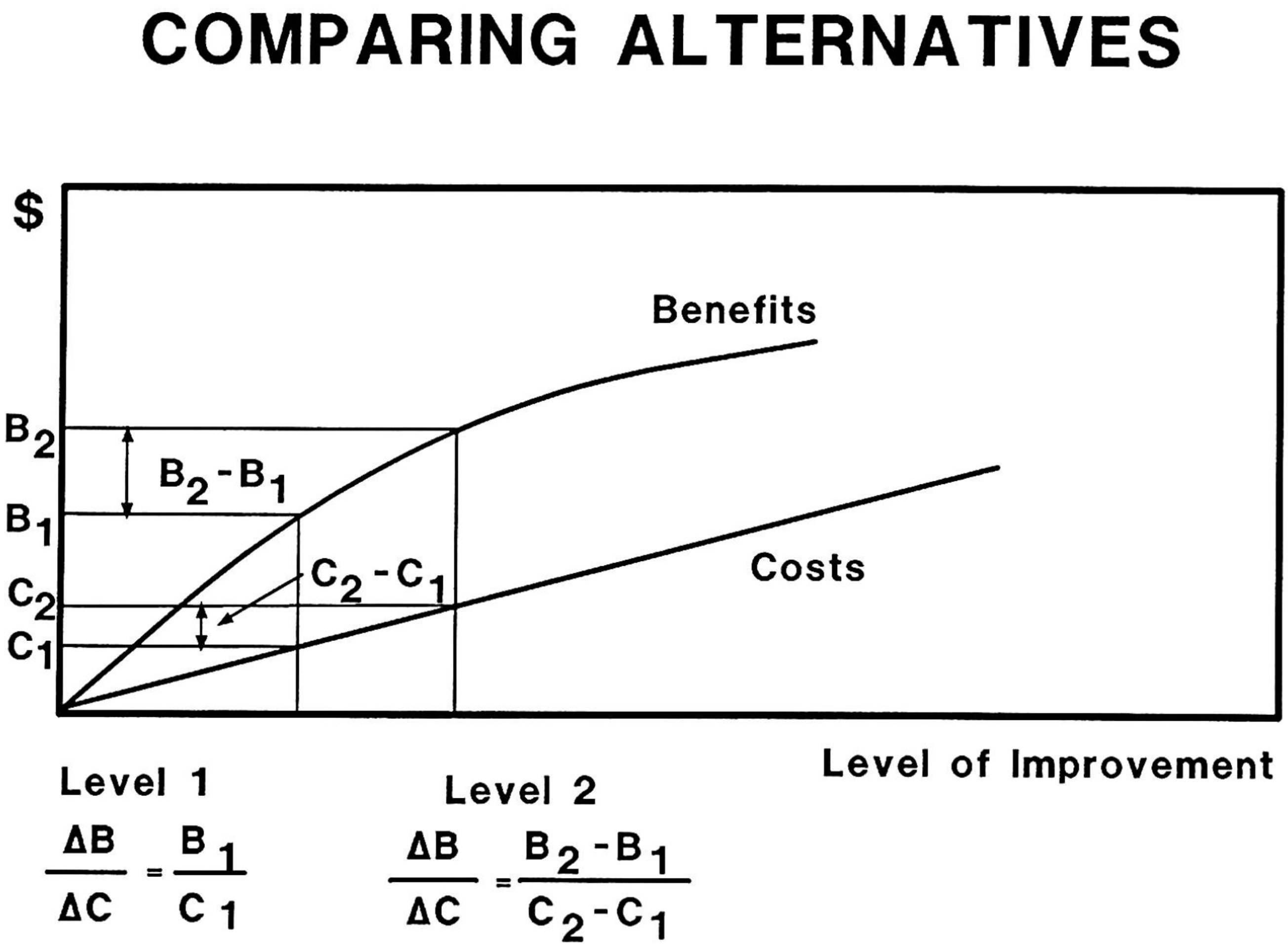

FIGURE 4

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