IMPLEMENTATION OF A SYSTEMS APPROACH TO PAVEMENT DESIGN

Robert L. Lytton and W. Frank McFarland, Texas Transportation Institute, Texas A&M University

ABRIDGMENT

A systems analysis model for pavements has been implemented in Florida, Kansas, and Louisiana. A computer program for the design of flexible pavements using the AASHO Interim Guide as a structural subsystem has been developed and can be implemented within any state. It incorporates most of the major variables involved in pavement design in a realistic way. Revisions required to accommodate the unique factors of each state can usually be made with a minimum of reprogramming effort. Collateral improvements such as construction cost simulation and pavement feedback data systems are required to provide reliable input data and, in the long run, to verify the assumptions made in design.

•NCHRP project 1-10, Translating AASHO Road Test Findings: Basic Properties of Pavement Components, commenced in 1966 and was completed in 1970 (1, 2). The work resulted in an increased interest and use of computerized systems approaches to pavement design, and NCHRP funded an additional project to determine whether the systems analysis model for pavements (SAMP5) could be implemented in states other than the one where it originated (3).

The main aims of the project were to test an overall system with a strategic approach to the pavement design process and to get an in-depth evaluation of the approach by the cooperating states. The state highway departments of Florida, Kansas, and Louisiana agreed to cooperate in the project. Major revisions made to the SAMP5 program to satisfy the design requirements of the states resulted in SAMP6, a new version of the program.

The major finding of this project was that SAMP6 is a working systems model for pavements. The states in which the computer program was tested expect to use it in their design system: Louisiana for design; Florida for design studies and as a building block for a future, more mechanistically oriented design system; and Kansas as a supplement to its current design system. States that currently use the AASHO Interim Guide as a design method can use the SAMP6 computer program directly. Other states that wish to use some other structural subsystem must use one that predicts the decrease of serviceability index (SI) with time and traffic. Then, their structural subsystem can be inserted directly into the SAMP6 computer program as it now stands. The effort required to implement the SAMP6 system within any state has been reduced to a minimum by providing the following:

1. SAMP6 in modular, distinct subsystems that can be replaced or reprogrammed with a minimum of effort;
2. A users' guide, 2 program documentation decks, and flow charts;
3. These programs on magnetic tape;
4. All equations used in SAMP6 assembled in the appendix to the final report of the project.

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The main problems encountered in implementation are the following:

1. Organization. How the state is organized to design pavements is important, i.e., whether it has a centralized or decentralized organization and whether a single person or section has primary responsibility for technical details of pavement design or whether a committee has this responsibility. The more dispersed the responsibility is, the more extensive are the required implementation efforts.
2. Confidence in the model. There is a greater tendency for pavement designers to use the program if they know what is in the program, if they trust and agree with the models used, if they believe that all or most of the pertinent factors are included, and if the predicted results on conventional pavements match what their experience indicates is a successful design.
3. Reliable data. Sometimes too much data are collected for some subsystems and not enough for others. The SAMP6 program provides a framework within which the right amount of data can be collected. As experience is gained, the reliability of the data can be improved.

Figure 1 shows the operation of the SAMP6 program. The present program includes all of the features shown except a consideration of seal coat and skidding accident costs for which few reliable data are currently available. The SAMP6 program can consider the costs of all materials in the cross section, including the shoulders, and can allow these costs to vary with the volume of material placed. Full cross-sectional design and variable costs have proved to have significant effects on optimum pavement strategy.

BENEFITS OF USING THE SYSTEMS APPROACH

The systems approach may be used to satisfy a variety of pavement design objectives, including the following:

1. Minimization of the total cost of the pavement during a given analysis period,
2. Minimization of construction costs,
3. Reconsideration of the optimal overlay strategy throughout the life of the pavement, and
4. Determination of optimum design strategies in periods of inflation and cost fluctuation such as those due to the energy crisis.

An example of this latter use is a typical run for Florida in 1973 when the asphalt cost was estimated to be 18 cents per gallon. SAMP6 was run again in 1974 with the same data except that the asphalt cost was estimated to be 36 cents per gallon. The results are given in Table 1.

Pavement designs using thick asphalt surface courses or sand-asphalt hot-mixed base courses generally remained in the top 30 designs but lost an average of 3.3 positions in the rankings. On the other hand, designs using water-bound limerock base moved up in the rankings by an average of 2.4 positions. The general trend is obviously to use less asphalt.

The ability to make routine studies of this sort can result in a fine-tuning of pavement design practice to the current market situation. The management and financial benefits to the highway department and the public are readily apparent.

REMOTE TERMINAL APPLICATIONS

The SAMP6 program and several others developed for the Texas Highway Department are available for use in an interactive mode in which a remote terminal can be acoustically coupled by telephone with the IBM 360/65 computer at Texas A&M University. A list of compatible terminals is available on request from the authors.

The interactive mode is a self-teaching arrangement that takes the person using the program through all of the steps of data input, piece by piece, explaining each step and giving typical values of input data. All of the data can then be stored in the user's data set. The user who wishes to run a similar problem sometime later can display the stored data set, make any desired changes, and rerun the problem. This capability

Figure 1. Operation of SAMP6.

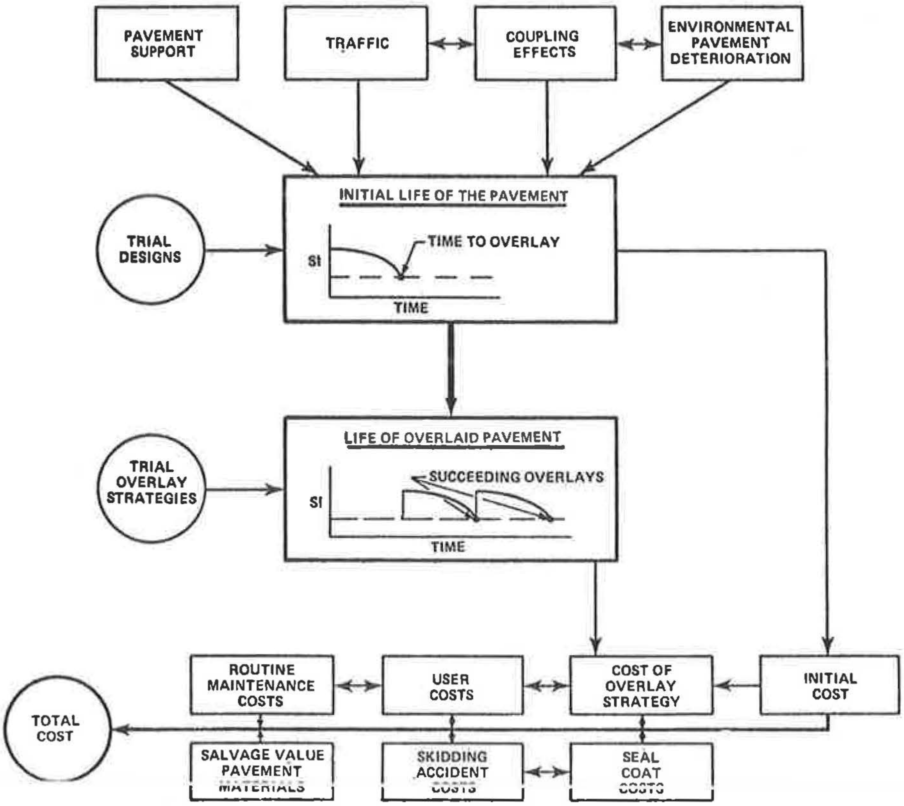

Table 1. Effect of energy crisis on optimum pavement strategy.

Category	Before Energy Crisis	After Energy Crisis
Optimum pavement thickness, in.		
Asphaltic-concrete surface course	4	1
Limerock base course	–	4
Type B stabilized subbase course	–	8
Number of overlays (40-year period)	9	4
Average thickness of best 30 designs, in.	10.5	11.6
Minimum total cost, dollars/yd^2	7.18	7.94
Increase of cost, percent	–	+10.6

makes a sensitivity analysis a simple matter. The system programs that are currently available on remote terminal in the interactive mode are as follows:

1. AASHO Interim Guide flexible pavement system (SAMP6),
2. Texas flexible pavement design system (3),
3. Texas flexible pavement design system using 3-layer elastic theory (4),
4. Texas rigid pavement system (5), and
5. Texas overlay design (6).

All of these systems analysis programs have been implemented to some extent within a state highway department. One of these, the flexible pavement design system, is in common use in 10 of the 26 districts of the Texas Highway Department.

FUTURE IMPROVEMENTS

The following suggested improvements are based on evaluations by the cooperating states and the research team of the current capabilities and limitations of the SAMP6 computer program. System improvements to be recommended can be incorporated within the SAMP6 program itself. The collateral improvements to be suggested are entirely separate computer programs or data systems.

System Improvements

A systems program should be able to consider different designs along a single stretch of road. The designer is normally faced with variations in subgrade type as well as transitions from cut to fill along the length of a project. Although each of these sections could be considered separately by the current version of SAMP6, the separate design of pavement sections, which are built in series, may not be the optimum design. For example, the designer may wish to match depths and material of each of the pavement sections as well as possible. The use of such nearly standard details may result in an overall savings in construction cost. In addition, a systems program should be capable of considering pavement sections in parallel, such as is the case when the pavement width must be expanded to carry more traffic. The optimum material and layer combinations for a widened pavement to be built 10 or 15 years in the future may be different from those combinations that are optimum if the pavement is built now. A long-range improvement of SAMP6 is the development of a rigid pavement system similar to the flexible one so that both concrete and asphalt pavements can be considered side by side in the same program. In addition, there is a need to develop decision criteria on the weighting of various costs. Still unsettled is the question whether the following costs should be considered equally in determining the total cost of the system: initial construction; maintenance and rehabilitation; user costs such as traffic delay due to rehabilitation, roughness, and accidents; salvage value; and inflation and time value of money. Finally, there appears to be a need to develop another measure of system performance. A serviceability index measures riding quality, and perhaps a safety index is needed also.

Collateral Improvements

Three major developements will aid the operation and reliability of a pavement design and management system such as SAMP6. These are feedback data systems whether they are computerized or not, construction cost estimation by computer simulation, and maintenance rating systems. The pavement feedback data system is used most efficiently if it is part of an overall maintenance management system as is the case in Louisiana and Florida. Construction cost estimation by computer simulation can be done with existing programs (7) and can show areas where improved operations can save substantial costs. A maintenance rating system should be composed carefully so as to provide numerical values for various forms of pavement distress.

Subsystem Improvements

A number of improvements in the subsystems currently in SAMP6 fall into the areas of the structural subsystem, environmental serviceability loss subsystem, user cost and maintenance costs subsystems, and safety. In the structural subsystem, the models to be developed should be based on mechanics but should not be so complicated as to require extensive computer running time. Any new structural subsystem for SAMP6 should be capable of predicting pavement riding quality and safety deterioration due to traffic. Each of these is affected differently by distress mechanisms such as cracking, roughness, rutting, and polishing. These same kinds of distress can be caused by a hostile environment. Cracking can be caused by thermal cooling, thermal fatigue, and shrinkage. Roughness can be caused by cracking, frost heave, and expansive clay.

A currently funded Federal Highway Administration project is expected to produce results that will be applicable in the user cost subsystem. There is a continuing need to keep the unit costs within that subsystem up to date. The maintenance cost models within SAMP6 could be improved to include important variables such as traffic and temperature, which are not now included in a satisfactory way.

Many experienced engineers think that seal-coating extends the service life of a pavement and upgrades the skid resistance of the surface. This potentially beneficial effect of seal coats on the performance of a pavement needs to be considered.

SUMMARY

The SAMP6 program has been implemented in 3 states and has proved to be a practical, working systems model for pavements. Its implementation requires attention to numerous details of design technique and policy and its improvement, which is desirable in certain areas, will be a simple task. A variety of financial benefits can be derived in using it as an aid in making strategic pavement design and management decisions. It is readily available for use by all pavement designing organizations.

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