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Forecasting Pavement Rehabilitation Needs for Illinois Interstate Highway System

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The Illinois Interstate highway network is deteriorating rapidly because of its age and heavy truck loadings. Unfortunately, the funds required for rehabilitation far exceed the available funds. The Illinois Department of Transportation (IDOT) faces many difficult decisions concerning ranking rehabilitation projects in order of priority and anticipating future pavement conditions and rehabilitation needs. To assist IDOT in making these decisions, three analyses were conducted by using the ILLINET pavement network rehabilitation management program. The first of these was an analysis of the accuracy of ILLINET's pavement condition prediction models. The second was an analysis of the remaining life of each of the more than 1,200 pavement sections in the Illinois Interstate network. The third was a comparison of the rehabilitation needs predicted by ILLINET with those in IDOT's latest multiyear program. The results of these analyses are of immediate practical use to IDOT in forecasting pavement rehabilitation needs for individual pavement sections, Interstate routes, and the entire Interstate network.

The Illinois Interstate highway system consists of about 1,750 two-directional miles of heavily trafficked multiple-lane pavements that were constructed largely between 1957 and 1980. About one-third of these pavements were originally constructed as 10-in. (25.4-cm) jointed reinforced concrete pavement (JRCP), and about two-thirds were originally constructed as continuously reinforced concrete pavement (CRCP) ranging in thickness from 7 to 10 in. (17.8 to 25.4 cm).

These pavements have performed well, despite Illinois' wet-freeze climate, poor subgrade soils, the prevalence of nondurable aggregates, and an unexpectedly high volume of heavy truck loadings. A recent survival analysis indicates that the mean life (years from construction to first major rehabilitation) of these pavements was about equal to the design life of 20 years, whereas the mean 18-kip (8.1-metric-ton) equivalent single axle loadings (ESALs) carried was three to four times higher than the design traffic (*1*).

The Illinois Interstate system is now deteriorating rapidly because of its age and the high volume of heavy truck loadings. As of 1991 about 60 percent of the system had been resurfaced, and much of the rest either is currently in need of rehabilitation or will be within the next 10 years. Unfortunately, the funds required for rehabilitation far exceed the available funds. The Illinois Department of Transportation (IDOT) faces many difficult decisions concerning ranking rehabilitation projects in priority order and anticipating future pavement conditions and rehabilitation needs.

In 1985 IDOT began working together with the University of Illinois to develop the Illinois Pavement Feedback System (IPFS). A major part of the IPFS project has been the development of the IPFS data base, which provides IDOT districts and central offices with data on design, construction, traffic, and condition of 1,263 Interstate highway sections. Although the IPFS data base is neither error-free nor complete, it is sufficiently developed for use in analyses that will provide useful answers to many of IDOT's questions. In addition to the survival analysis already mentioned, other analyses conducted with the IPFS data base include assessment of truck traffic growth rates and the development of performance prediction models.

Another major component of IPFS is the ILLINET pavement rehabilitation network management program. ILLINET uses data from the IPFS data base, decision trees, performance prediction models, and a variety of project-level and network-level management algorithms to generate feasible rehabilitation strategies (treatments and timing) for each pavement section in the Illinois Interstate network for a period of up to 10 years. The network management algorithm options available in ILLINET include analysis of needs (assuming an unconstrained budget), ranking, benefit-cost ratio, incremental benefit-cost ratio, and long-range optimization. The development of ILLINET and its capabilities have been described previously (*2,3*).

Because of the large mileage of Illinois Interstates that will need rehabilitation in the coming years and the expectation that funding for rehabilitation will be inadequate, IDOT is concerned about being able to anticipate the potential impact of insufficient rehabilitation funding on the overall condition of the network. Among the specific questions IDOT would like to answer are the following:

- How accurately can we predict the future condition of individual pavement sections and the future condition of the network as a whole?
- How uniform are the various Interstate routes in condition? Is it feasible to manage long corridors of Interstate as units, or must we continue piecemeal rehabilitation of more than a thousand short highway sections?
- How well are our rehabilitation needs met by the funds available? What will be the effect of the programmed funding level on the overall condition of the network?

Three analyses recently conducted to assist IDOT in answering these questions are described in this paper. The first of these was an analysis of the accuracy of ILLINET's pavement condition prediction models. The second was an analysis of the remaining life of each of the 1,263 pavement sections in the Illinois Interstate network. The third was a comparison of the rehabilitation needs predicted by ILLINET with those in IDOT's latest multiyear rehabilitation program. The purpose of these analyses is to demon-

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strate the practical benefit that a network rehabilitation program with ILLINET's capabilities can provide a state highway agency in quantifying rehabilitation needs and ranking rehabilitation projects in priority order.

ACCURACY OF PAVEMENT CONDITION PREDICTION MODELS

DOT evaluates pavement condition by using condition rating survey (CRS) values, which are assigned by panels of expert raters in field inspections conducted in even-numbered years. CRS is the key pavement condition indicator that is used for planning, programming, and scheduling highway pavement improvement projects. Pavements are rated on a 1 to 9 scale on the basis of the distress observed. The best rating is 9, which is assigned to a newly constructed or resurfaced pavement. For guidance in assigning CRS ratings, panel members consult a manual that illustrates various pavement types and conditions with photographs accompanied by distress descriptions and CRS ratings.

In general, a pavement with a CRS value that falls below 6 would be programmed by IDOT for rehabilitation within the next 5 years. However, many sections have CRS ratings below 6 because their rehabilitation must be deferred because of a lack of funds. Some pavements require considerable maintenance to keep the CRS above 5; below this level ride quality is generally very poor, and maintenance needs become more extensive.

CRS Models

ILLINET contains models to predict CRS for the following pavement types:

- JRCP,
- CRCP, and
- Asphalt concrete (AC) overlay of JRCP (JROL) and CRCP (CROL).

Each predictive model was developed from in-service pavement condition data. After considerable evaluation of different possible model forms, the following functional form was selected for the CRS models:

$$\text{CRS} = 9 - 2 \cdot a \cdot \text{THICK}^{b} \cdot \text{AGE}^{c} \cdot \text{CESAL}^{d} \tag{1}$$

This nonlinear model form may also be expressed in the following linear form by logarithmic transformation:

$$\log_{10}(9 - \text{CRS}) = 0.301 + \log_{10} a + b \cdot \log_{10}\text{THICK} + c \cdot \log_{10}\text{AGE} + d \cdot \log_{10}\text{CESAL} \tag{2}$$

where

CRS = panel condition survey rating (1 to 9),
THICK = slab thickness for JRCP or CRCP and overlay thickness for AC overlay,
AGE = years since construction or overlay,
CESAL = accumulated million ESALs in outer lane since construction or overlay, and
a, b, c, d = constants for each pavement type (Table 1).

TABLE 1 Constants for CRS Model Prediction

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
JROL, CROL	-0.4185	-0.1458	0.5732	0.1431
JRCP	1.7241	-2.7359	0.3800	0.6212
CRCP	0.7900	-1.3121	0.1849	0.2634

CRS Model Calibration

Within a certain climatic range (i.e., Illinois conditions) pavements of a certain type and design can be expected to exhibit a general trend in condition as a function of time and traffic loadings. However, even pavements of a single type and design can exhibit highly variable performances. Therefore, the prediction model must be calibrated to the observed condition of a specific section to accurately predict the performance of that section.

In other words if the actual current condition of a given section differs from the CRS predicted by the model (as it almost certainly will, because the model describes the mean performance of all sections of that pavement type), then the prediction curve must be adjusted to match the actual value. If this calibration is not done future conditions predicted by the model for that section will not be reasonable.

Two different methods for prediction model calibration are available. The first method basically involves shifting the prediction curve upward or downward so that it passes through and extrapolates from the actual known pavement condition (e.g., CRS). The extrapolated curve is parallel to (and thus predicts the same rate of deterioration as) the mean curve. This approach inherently assumes that the data on age and past accumulated traffic are accurate but that the specific section's performance differs from the predicted mean performance.

The second calibration method uses the actual current condition (e.g., CRS) and the current annual traffic level to "backcast" values for the age or past accumulated traffic inputs, which will predict a condition level matching the actual value. This method, which shifts the mean curve horizontally forward or backward until it passes through the actual known condition level, is particularly appropriate when the accuracy of the age or past traffic data are questionable.

This latter calibration method is currently used in ILLINET because of the uncertainty associated with estimating accumulated ESALs. The current annual ESALs in the outer traffic lane may be estimated more reliably from current or recent counts of the average daily traffic, single-unit trucks, and multiple-unit trucks. A direct relationship is assumed to exist between pavement age, annual ESALs (ESALPYR), and cumulative ESALs:

$$\text{CESAL} = \text{AGE} \cdot \text{ESALPYR} \tag{3}$$

The CRS model for a given pavement type may be calibrated to the current condition of any given section of that type in any year by calculating the following two calibration constants:

$$C_1 = \left(\frac{9 - \text{CRS}}{2 \cdot a \cdot \text{THICK}^{b} \cdot \text{ESALPYR}^{d}} \right)^{\frac{1}{c+d}} \tag{4}$$

$$C_2 = C_1 \cdot \mathrm{ESALPYR} \tag{5}$$

Once the model has been calibrated to the current condition of the section, the condition of the section in any future year may be predicted as a function of the change in the age of the pavement in years (ΔYEAR) and the change in millions of accumulated ESALs (ΔCESAL) over that time period:

$$\mathrm{CRS}_{\mathrm{future}} = 9 - 2 \cdot a \cdot \mathrm{THICK}^b \cdot (C_1 + \Delta\mathrm{YEAR})^c \cdot (C_2 + \Delta\mathrm{CESAL})^d \tag{6}$$

The increase in millions of accumulated ESALs over some future time period is computed by using the current annual ESALs (ESALPYR), the length of time (ΔYEAR), and an assumed annual ESAL growth rate. A compound growth rate of 6 percent is used as a default in ILLINET, although this value may be changed at the user's discretion.

Accuracy of CRS Prediction for Pavements Without D-Cracking

The first step in assessing the accuracy of the CRS prediction models was a comparison of the 1992 CRS values predicted by the models with the actual 1992 CRS values assigned by the expert rating panels. This was done by using CRS history, pavement design, and traffic information retrieved for each of the 1,263 Interstate sections in the IPFS data base.

For each section the appropriate model for the pavement type was calibrated to the actual 1990 CRS, and the CRS was projected from that point assuming a 6 percent compound growth rate in ESALs. This comparison showed that the models predicted CRS well from 1990 to 1992 for bare CRCP, bare JRCP, AC-overlaid CRCP, and AC-overlaid JRCP without D-cracking. The results are shown in Figures 1, 2, 3, and 4, respectively.

To assess how many years into the future the CRS models could provide accurate predictions, the comparison of predicted and actual 1992 CRS values was repeated with models calibrated to 1988 CRS data and then to 1986 CRS data. Sections that were rehabilitated between the starting year and 1992 were excluded from the analysis. The results for pavements without D-cracking indicate that the models' predictive accuracies are good even for 6 years into the future. Analysis of the models' accuracies for longer time periods could be done, but there is a limitation: the predicted and actual CRS values can be compared only for sections that do not receive any rehabilitation during the time period considered. For periods of 8 years or more the number of sections available for use in the analysis becomes considerably smaller.

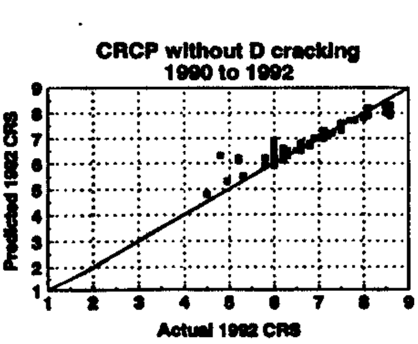

FIGURE 1 Predicted versus actual 1992 CRS for CRCP without D-cracking.

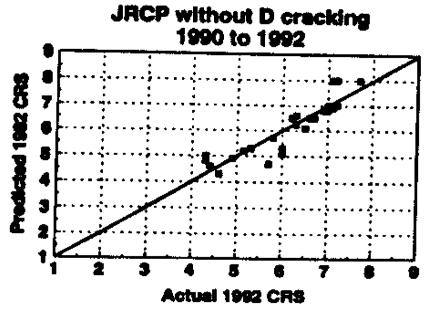

FIGURE 2 Predicted versus actual 1992 CRS for JRCP without D-cracking.

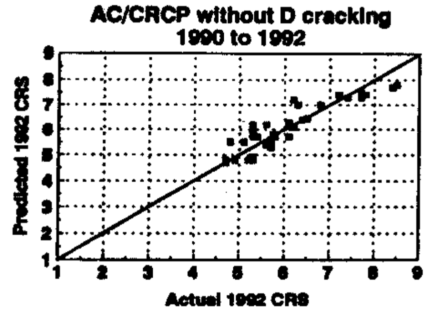

FIGURE 3 Predicted versus actual 1992 CRS for AC-overlaid CRCP without D-cracking.

Accuracy of CRS Prediction for Pavements with D-Cracking

The drop in CRS from 1990 to 1992 was generally greater for D-cracked pavements than the models predicted. When the CRS models were developed in 1986 a D-cracking variable was not in-

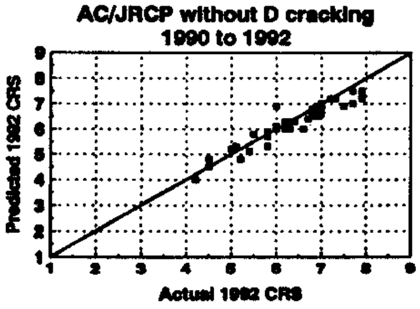

FIGURE 4 Predicted versus actual 1992 CRS for AC-overlaid JRCP without D-cracking.

cluded, primarily because the D-cracking data contained in the IPFS data base at that time were not considered sufficiently reliable.

In 1991 a thorough review of the D-cracking data in the data base was conducted by using distress survey results, materials records, and previous research results. That review was done to conduct survival analyses of bare and resurfaced concrete pavements in Illinois with and without D-cracking (*4*). One finding of the survival analysis was that both bare and overlaid pavements without D-cracking lasted longer and carried more truck traffic than D-cracked pavements of the same type and thickness. The mean life (age and accumulated ESALs) was 20 to 50 percent higher for non-D-cracked pavements than for D-cracked pavements of the same type and thickness.

To account for the more rapid deterioration of D-cracked pavements, an analysis was conducted to determine an appropriate adjustment that could be applied to the predicted rate of loss in CRS. This was done for four pavement categories (bare JRCP, bare CRCP, AC-overlaid JRCP, and AC-overlaid CRCP, all with D cracking) by comparing the predicted with the actual 1992 CRS by using CRS data sets from 1990, 1988, and 1986. The following adjustment factors were found to give the best fit over the time ranges considered:

Adjustment Factor	*Pavement Category*
1.2	Bare JRCP
1.2	AC-overlaid JRCP
1.2	AC-overlaid CRCP
1.5	Bare CRCP

An alternative to applying these adjustment factors to the rate of CRS loss for D-cracked pavements would be to repeat the regression of the CRS models with an additional term for D-cracking. However, the use of adjustment factors may be preferable because IDOT personnel will be able to modify the factors as needed in future years to maintain a good fit of predicted to actual CRS without having to conduct nonlinear regression analyses to modify the CRS models themselves.

REMAINING LIFE ANALYSIS

ILLINET was also used to predict the remaining life of each section of the Illinois Interstate network. The purposes of this analysis were to assess the overall health of the network and to examine the variabilities in the remaining lives of pavements along the various Interstate routes. This knowledge would be useful to IDOT in assessing the feasibility of identifying corridors of multiple sections that could be brought up to uniform condition and subsequently managed as units in terms of future rehabilitation decisions.

Selection of Critical CRS

The "remaining life" of each Interstate section, defined as the number of years from 1993 until the section reached a CRS of 6.0, was predicted by using the CRS models, calibrated to the 1992 CRS and adjusted for D-cracking as described before, and assuming a 6 percent compound ESAL growth rate. This analysis was then repeated by using a CRS of 5.1, which IDOT personnel believed might represent more realistically the level at which a pavement was likely to be rehabilitated (considering the typical budget limitations), even though a CRS of 6.0 was the level at which rehabilitation would be desirable. Of course, the estimate of remaining life depends on the critical CRS selected.

Effect of Maintenance on CRS Prediction

The prediction of the number of years remaining to a CRS of 6.0 is reasonable in most cases; however, the prediction to lower CRS levels for any given section is highly dependent on the level of maintenance applied. Many sections of Interstate highway receive extensive maintenance to keep the pavement in service until rehabilitation can be done. The CRS histories of such sections fluctuate between about 5 and 6 for several years, despite a previous steady decline from 9 to about 6. Of course it is difficult to predict accurately the rate of deterioration for such sections.

Remaining Life of Interstate Routes

The results of the remaining life analysis were plotted by Interstate route and direction. The results for portions of I-55 and I-70 are shown in Figures 5 and 6, respectively, as examples. The heights of the bars indicate the remaining life in years. The numbers on the horizontal axis are mileposts, rounded to the nearest mile, given for reference.

Some Interstate routes show reasonable uniformity in remaining life, whereas others show large variations. I-55 is an example of a route with large variations in remaining life. The nonoverlaid pave-

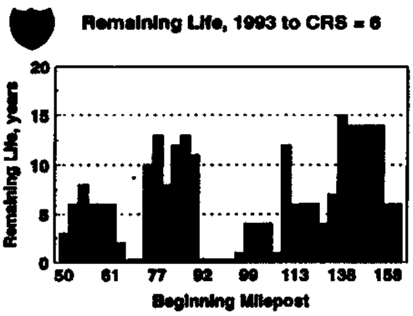

FIGURE 5 Remaining life of pavement sections along portion of Interstate 55.

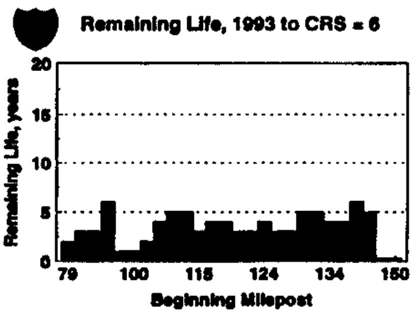

FIGURE 6 Remaining life of pavement sections along portion of Interstate 70.

ment sections represented in Figure 5 range in age from about 15 to 30 years, and the overlays on some sections range in age from about 3 to 12 years. About half of the sections have D-cracking, and thus have shorter predicted remaining lives than sections of similar design and traffic that do not have D-cracking. Some large differences in remaining life by direction are also evident for some sections.

Among the routes with more uniform remaining lives, some have fairly long and others have fairly short remaining lives. I-70 is an example of a route with a uniformly short remaining life: the sections illustrated by Figure 6 are primarily 8-in. (20.3-cm) CRCP with some 10-in. (25.4-cm) JRCP, constructed between 1960 and 1972. Nearly all of these pavements have D-cracking, which, combined with the heavy truck traffic on I-70, has resulted in considerable deterioration of the concrete. All of these sections have been overlaid at least once since 1980, and some have been overlaid three times. It is understandably discouraging to IDOT planners and district engineers to contemplate the future rehabilitation needs of such a long stretch of a heavily trafficked Interstate that, despite frequent rehabilitation and nearly constant maintenance, has only a few more years of remaining life.

Future Analyses of Remaining Life by IDOT

The remaining life analysis capability was added to the ILLINET program so that in future years this analysis can be repeated easily by IDOT personnel for the entire network or specific routes. The user needs only to select an ESAL growth rate and a critical CRS. The standard keyboard "page up" and "page down" keys are used to move through the Interstate route graphs displayed on the computer screen, and once a printer has been selected, the "shift" and "print screen" keys are used to print the displayed graph.

ANALYSIS OF REHABILITATION NEEDS VERSUS IDOT PROGRAMMING

The third analysis conducted was a comparison of the rehabilitation needs predicted by ILLINET and IDOT's proposed multiyear rehabilitation program. This analysis has actually been conducted four times: first with IDOT's improvement program for fiscal years 1991 to 1995 and then for 1992 to 1996, 1993 to 1997, and most recently with the 1994 to 1998 program.

Proposed Highway Improvement Program

The multiyear program itemizes IDOT's proposed expenditures for Interstate highways, state highways, and other facilities in several areas, including pavement rehabilitation, bridge rehabilitation or replacement, major highway construction, and safety improvements. The programmed expenditures considered in this analysis were those for resurfacing and reconstruction of Interstate pavement sections. Programmed expenditures for patching, interchange reconstruction, and bridge reconstruction were excluded.

Rehabilitation Needs Analysis with ILLINET

One of several pavement network management algorithms programmed in ILLINET is the needs algorithm, which estimates the rehabilitation needs for up to 10 years into the future, assuming no yearly budget constraint. Every section in the network whose condition falls below a user-defined minimum CRS is a candidate for rehabilitation. The type of rehabilitation is determined by selection of one of several available options for project-level rehabilitation (2). For this analysis the needs algorithm was run by using a single thickness of asphalt resurfacing as the sole rehabilitation strategy. In fact the rehabilitation type is not significant to this analysis, the purpose of which is to predict the timing of rehabilitation, not the cost. The analysis was run for three critical CRS levels: 6.0, 5.5, and 5.1.

Comparison of Rehabilitation Needs with Program by Route

The sections with rehabilitation needs identified by ILLINET and the sections programmed for rehabilitation by IDOT were graphically displayed by Interstate route and direction. A comparison for portions of I-74 and I-80 are shown in Figures 7 and 8, respectively, as examples. For each direction the sections needing rehabilitation according to ILLINET are represented by the bars above the line representing the route, and the sections actually programmed by IDOT for rehabilitation are represented by the bars below the line. The numbers next to the bars indicate beginning and ending mileposts; these are followed in parentheses by the year that rehabilitation is needed or programmed.

A summary of the mileage of rehabilitation needs identified by ILLINET and the programmed rehabilitation mileage is provided in Table 2. This summary indicates that the rehabilitation work pro-

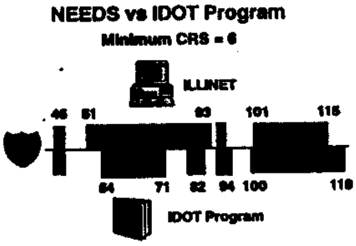

FIGURE 7 Rehabilitation needs (from ILLINET) versus rehabilitation programmed (from IDOT 1994–1998 program) for portion of Interstate 74.

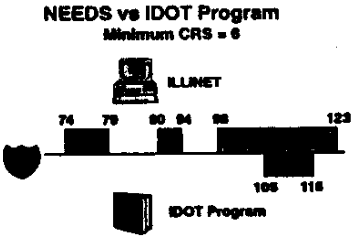

FIGURE 8 Rehabilitation needs (from ILLINET) versus rehabilitation programmed (from IDOT 1994–1998 program) for portion of Interstate 80.

TABLE 2 Summary of Rehabilitation Needs Versus Rehabilitation Program

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	237.17	170.31	153.14	153.81	412.99
2	160.10	114.71	51.58	95.46	320.10
3	196.55	123.85	93.73	117.73	476.63
4	122.83	91.09	72.90	107.27	207.26
5	256.03	146.81	112.98	172.49	510.82
6	106.01	43.57	32.78	62.54	246.56
7	263.95	143.98	113.28	131.63	405.93
8	117.78	86.77	37.62	37.62	352.16
9	110.17	53.82	7.91	7.91	229.88
Total	1570.59	974.91	675.81	939.23	3161.93

Notes:

1. All miles are one-directional.
2. Ratio of miles programmed by miles needed (for critical CRS = 6.0) is 939.23 / 1570.59 = 0.60, or 60 percent.
3. District 2 has one resurfacing project programmed on I-180 (mileposts 5.43 to 9.76, both directions), which was not included in this comparison because I-180 is not currently in the IPFS database.
4. Only resurfacing and reconstruction projects programmed for 1994-1998 were considered in this comparison. Patching, interchange reconstruction, bridge reconstruction, etc. were excluded. Some projects let for bids recently may not be included. The latest bid letting information available was December 1992.

grammed by IDOT with the anticipated available funds is only about 60 percent [939 versus 1,570 mi (1502 versus 2512 km)] of the needs identified by ILLINET to keep all sections of the Interstate above a CRS of 6.

If additional funding is not available a large percentage of Interstate sections are predicted to fall below a CRS of 6.0 over the next 5 years. If the funds available for rehabilitation continue to fall short of the amount required to keep the pavements in acceptable condition the backlog of deficient pavements will continue to grow. This will result in substantial maintenance expenditures and probably more costly rehabilitations as well. Of course what constitutes an acceptable pavement or a deficient pavement depends on the target CRS level selected.

At a critical CRS of 5.5 the ratio is about 96 percent [939 versus 975 mi (1502 versus 1560 km)], and at a critical CRS of 5.1 the programmed mileage exceeds the needs indicated by ILLINET by about 39 percent [(939 versus 676 mi (1502 versus 1082 km)]. These results suggest that the rehabilitation funds programmed over the next 5 years should be sufficient to keep nearly all sections of the Interstate network above a CRS of 5.5 over that time period.

Limitations of Needs Algorithm

ILLINET's needs algorithm was used in the present analysis to identify projects that will reach the selected critical CRS and determine the total mileage of these projects. This algorithm was run by using resurfacing as the single rehabilitation strategy. Hypothetically the budget for rehabilitation is unlimited, so a section is resurfaced as soon as it reaches the critical CRS. This algorithm, particularly when it is run with a single rehabilitation strategy, does not necessarily develop the optimum rehabilitation plan for the network.

Indeed, what is an "optimum" plan depends on what benefit one chooses to maximize or what cost one chooses to minimize. The needs algorithm seeks to eliminate the mileage of deficient pavements. It may do this in a way that is not the most cost-effective for particular sections or for the network as a whole. For example, a severely deteriorated pavement that continues to deteriorate rapidly probably should not be resurfaced every few years; some longer-lasting rehabilitation strategy would be more cost-effective. Other analyses conducted for this research study and described in a separate paper indicate that very different network rehabilitation programs may be developed depending on the network-level management algorithm selected (5). For example, in another analysis conducted by using ILLINET, the incremental benefit-cost ratio algorithm produced a network rehabilitation program with the same total cost (in millions of dollars) as the needs algorithm, but with a 50 percent improvement over the needs analysis in vehicle-miles traveled on good pavements. This is because the incremental benefit-cost algorithm may pick more costly rehabilitation strategies for some sections if they are more cost-effective for the network as a whole and also will favor rehabilitation of higher-volume routes, because the benefit that it seeks to maximize is vehicle-miles traveled on good roads.

Future Program-Versus-Needs Analyses by IDOT

The capability of comparing IDOT's multiyear improvement program with the results of the needs analysis was added to the ILLINET program so that in future years this analysis can be repeated easily by IDOT personnel for the entire network or for specific routes. The multiyear program of pavement rehabilitation and reconstruction projects simply needs to be entered into an ASCII input file with route, direction, and beginning and ending milepost data. The user has only to select an ESAL growth rate and a critical CRS.

CONCLUSIONS

The Illinois Interstate highway network is deteriorating rapidly because of its age and heavy truck loadings. Unfortunately, the funds required for rehabilitation far exceed the available funds. IDOT faces many difficult decisions concerning the ranking of rehabilitation projects in priority order and anticipating future pavement conditions and rehabilitation needs.

To assist IDOT in making these decisions three analyses were conducted by using the ILLINET pavement network rehabilitation management program. The first of these was an analysis of the accuracy of ILLINET's pavement condition prediction models. The second was an analysis of the remaining life of each of the more than 1,200 pavement sections in the Illinois Interstate network. The third was a comparison of the rehabilitation needs predicted by ILLINET with those in IDOT's multiyear program.

The analysis of the CRS prediction models showed that future pavement conditions could be predicted with acceptable accuracy for several years into the future. The rate of deterioration for bare and overlaid concrete pavements with D-cracking, which is more rapid than for pavements without D-cracking, could be more accurately predicted by using the adjustment factors determined in the present analysis. However, the effect of maintenance on pavement condition is difficult to predict.

The analysis of the remaining life of the Interstate routes demonstrated considerable variability along some routes and more uniform remaining life along others. This type of information is needed to assess the feasibility of identifying corridors of entire routes or major components of routes that could be brought up to uniform condition and subsequently managed as units in terms of future rehabilitation decisions.

The comparison of rehabilitation needs indicated by the ILLINET software with those in IDOT's multiyear improvement program demonstrated that for any selected critical CRS level a section-by-section and route-by-route comparison of rehabilitation needs and rehabilitation funding could be made. In that analysis the IDOT program met only about 60 percent of the indicated needs when the critical CRS was set at a level below which IDOT personnel generally consider rehabilitation desirable. What constitutes an acceptable or a deficient pavement depends on the critical CRS selected. However, even when rehabilitation costs are deferred because of budget limitations, maintenance costs continue to accrue and increase greatly as the pavement deteriorates.

The purpose of these analyses is to demonstrate the practical benefit that a network rehabilitation program with ILLINET's capabilities can provide a state highway agency in quantifying rehabilitation needs and ranking rehabilitation projects. The graphical displays and graphical printed outputs are useful in communicating the analysis results to the central office and district personnel responsible for rehabilitation planning and programming.

The ILLINET software has also been modified to facilitate these analyses being repeated in the future by IDOT personnel. This represents another step in development of IPFS: after development of the data base, after the retrieval of data for specific analysis demonstrations, and after demonstrating the practical value of the analysis results, user-friendly tools to do those analyses should be put into the hands of the IDOT planners and engineers responsible for pavement rehabilitation decision making. A reliable and accessible data base, reliable performance prediction models, and the tools required to do the analyses needed to support decisions are the essential elements of a dynamic feedback system for continuously improved pavement performance and efficient, cost-effective pavement network management.

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REFERENCES

1. Hall, K. T., M. I. Darter, and W. M. Rexroad. *Performance of Bare and Resurfaced JRCP and CRCP on the Illinois Interstate Highway System—1991 Update.* Illinois Highway Research Report 532-1. University of Illinois and Illinois Department of Transportation, July 1993.
2. Mohseni, A., M. I. Darter, and J. P. Hall. Illinois Pavement Rehabilitation Network Management Program (ILLINET). In *Transportation Research Record 1272,* TRB, National Research Council, Washington, D.C., 1990, pp. 85–95.
3. Mohseni, A. *Alternative Methods for Pavement Network Rehabilitation Management.* Ph.D. thesis. University of Illinois at Urbana-Champaign, 1991.
4. Hall, K. T., M. I. Darter, and W. M. Rexroad. *Performance of Bare and Resurfaced JRCP and CRCP on the Illinois Interstate Highway System—1991 Update.* Illinois Highway Research Report 532-1, FHWA Report FHWA-IL-UI-244. University of Illinois and Illinois Department of Transportation, July 1993.
5. Mohseni, A., and J. P. Hall. Effect of Selecting Different Rehabilitation Alternatives and Timing on Network Performance. STP 1121: *Pavement Management Implementation,* ASTM, Philadelphia, April 1992.
