

An Interactive Graphical Pavement Management System: Windows ILLINET

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How can a pavement management system (PMS) be presented to maximize its usefulness to pavement managers in making rehabilitation decisions? This research developed an interactive, graphical multimedia PMS called Windows ILLINET, which is a user-friendly, Windows-based software. It applies color graphics, text, and digitized video images to display current and historical pavement condition, rehabilitation information, and predicted pavement performance. It also offers multiple decision-making options. Moreover, users can be interactively involved in the decision-making procedure. The results from the research should be very valuable in the development of future PMS software.

The main purpose of developing a pavement management system (PMS) is to create a tool that will assist pavement engineers in making decisions concerning the management of pavement facilities. While any PMS can store vast amounts of data, it is imperative that data be transformed into useful information to aid in making rehabilitation decisions. This paper describes a robust tool called Windows ILLINET, a newly developed graphical, interactive PMS.

Windows ILLINET is a Windows-based system developed for the Illinois Department of Transportation (IDOT) by the Department of Civil Engineering at the University of Illinois at Urbana-Champaign. This system applies color graphics, text, and digitized motion video images to display current and historical pavement condition, rehabilitation information, and predicted pavement performance. It is coded in C++ 4.0 and runs in Microsoft Windows 3.1.

The supporting data base is the Illinois Pavement Feedback System (IPFS). This new PMS has several special features. First, the system can indicate graphically almost all of the information in the data base and the predicted pavement performance. Second, it offers a large number of combinations of network-level and project-level decision-making options. Third, the interactive decision-making option allows users to be involved and apply their own knowledge. If the results generated by the algorithms are not desirable, the users can modify either the parameters in the decision-making procedure or the rehabilitation decisions, based on their own experience. Fourth, this system has a user-friendly interface. Users can easily learn and master it. Many of the concepts were suggested by IDOT personnel. The previous work done by Mohseni was also very helpful (1-3).

GRAPHICAL DATA INTERPRETATION

Data must be formatted into understandable information to facilitate any necessary decisions. "Unexplained numbers are not information" (4) and cannot be used by decision makers unless the numbers are presented in a meaningful context. To make data more understandable, the numbers need to be analyzed and then interpreted in various formats, such as verbal explanations, tabular summaries, and visual representations, such as graphs.

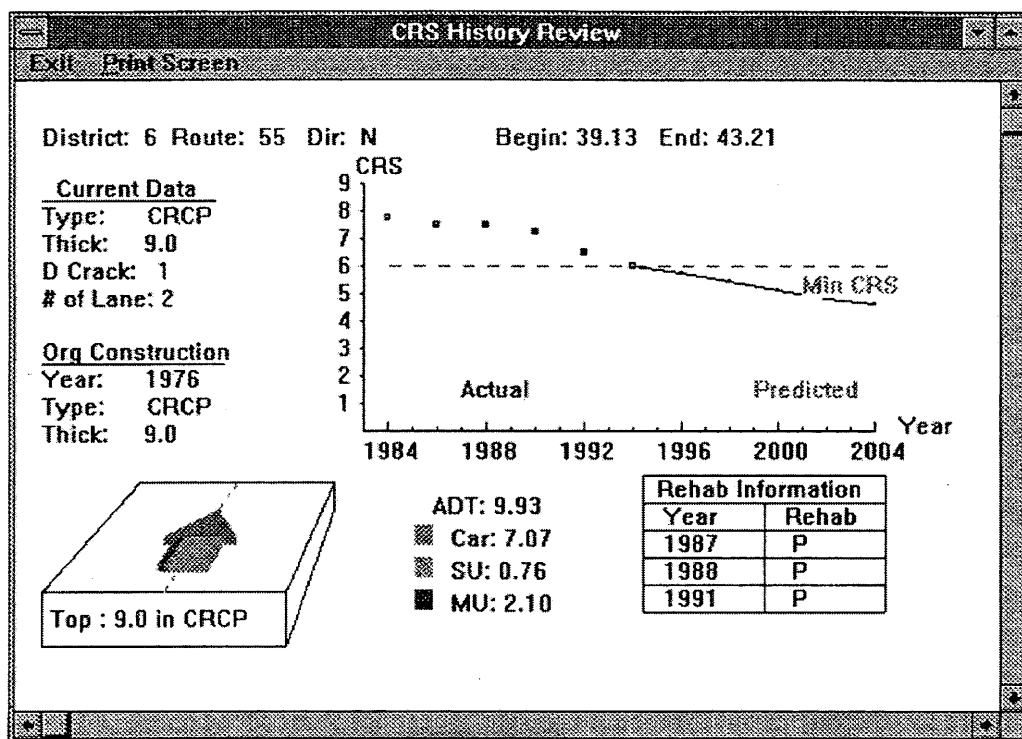
The key problem to successfully implement the data analysis and interpretation component is being able to quickly access an overwhelming amount of data. As Wildbur has pointed out, people often "mistakenly refer to the information explosion in the world today. In fact, there is no information explosion—it's a numbers explosion, and it falls to designers to turn the numbers into useful information" (4). The use of computer graphics can help quickly turn numbers into useful information. Colors, sounds, and motion videos can also be applied to sharpen the images and make the displayed information more easily understandable. All these technologies make "visual thinking" possible. Friedhoff and Benzon stress that visual thinking is "a legitimate and distinctive mode of thinking" and that the relatively effortless processing capabilities of the human visual system are properly exploited by the use of graphics (5,6).

Graphical Display of Source Information

The available data and information can be depicted on screen in graphics or digitized images. Audio information can be supplied if available. The pavement condition and traffic histories are displayed in graphics format upon users' request when these history data are available in IPFS. This greatly helps decision makers understand the data stored in the data base. The graphics include a historical pavement Condition Rating Survey (CRS), predicted future CRS, and rehabilitation information for each section. Traffic history data can also be provided on screen, including average daily traffic (ADT), single-unit and multiunit truck volumes, equivalent single axle loads, and growth rate histories of each.

The relationship between the traffic volume and the highway capacity for a specified pavement section can be displayed as well, as indicated by the pavement diagram in the lower left corner of Figure 1. The width of the tail of the arrow shown on the pavement is proportional to the ADT. If the arrow width exceeds the pavement width, the traffic volume exceeds the assumed capacity of 2,000 passenger cars per lane per hour. This occurs for some highway sections in the Chicago area and indicates that the traffic is congested and cannot travel at the speed or with the ease of movement that the

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Note: 1 in = 2.54 cm, 1 mile = 1.61 km

FIGURE 1 View history information.

drivers would like. The graphical display of this relationship is easier for IDOT managers to quickly understand than a mere presentation of the traffic volume numbers would be.

Figure 1 also illustrates a graphical display of the past and predicted future condition of the pavement section. The information at the top of the screen identifies the pavement section. Key information about the current and original pavement section is shown at the left. The CRS history and predicted CRS for the specified section over a period of 20 years appear in the graph at the upper right of the screen. To help the user relate the CRS at any time to the CRS level at which rehabilitation is needed, a broken line that represents the CRS value identified by the user as a rehabilitation trigger value is indicated as Min CRS. Traffic information is also provided on this screen, as described above.

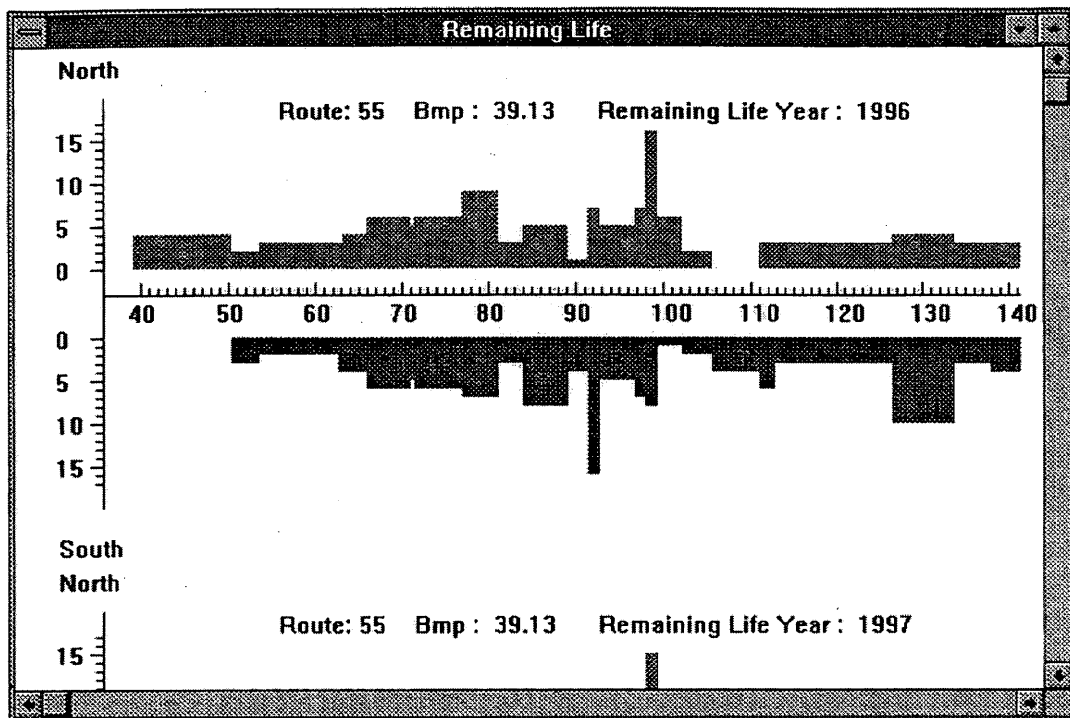
The rehabilitation history information is tabulated at the bottom right corner of the screen. This information helps the user interpret the CRS history curve. More detailed pavement rehabilitation history and construction information are provided on other screens.

Video images have been taken during pavement inspections of Illinois highways and are stored by IDOT. Those images, along with sound, are converted into digitized files that can then be provided on the computer when requested by the user. These digitized video images give decision makers an appreciation for the current pavement condition. It makes users feel as though they are driving along the highway and inspecting the condition. To display PMS video images, an analog/digital capture board is used to digitize the images and sound, and the digitized files are indexed by route number and milepost. The digitized files are then written to CD-ROMs. A compact disc drive is used to search through the files and read the file for a user-specified highway number and milepost to the screen.

Graphical Results

A PMS needs to display the data collected and stored in the data base, as well as the analysis results and predicted pavement performance. Such displays will assist the decision makers who are eager to know the probable consequences of their rehabilitation decisions. The system can display graphically the network analysis results, including quantified benefits, average network CRS, remaining life, budget requirements, and so forth, as well as detailed section-by-section information on predicted pavement performance, remaining life, and rehabilitation plans. Bar graphs and line graphs are used to demonstrate the pavement conditions and rehabilitation plans. Colors are used to illustrate pavement attributes. Also, network rehabilitation strategies and performance can be depicted in map format to make the information vivid. This helps the user interpret the analysis results.

An example of graphically displaying network analysis results is the remaining life screen in Figure 2. The interstate route number and beginning milepost for a selected section in the selected IDOT district are located at the top of the screen. The horizontal axis indicates the mileposts for a length of highway that contains the selected section; the vertical axis indicates the remaining life in years. The upward bars represent the remaining lives of each section in one direction of the highway; the downward bars represent the remaining life of the sections in the other direction. A bar with zero height indicates no remaining life left for that section in that year (i.e., the current or predicted CRS in that year is already less than or equal to the minimum CRS). The user may scroll down this screen to see the remaining life chart for this length of highway for each year in the analysis period. From this graph, users can quickly see and appre-



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FIGURE 2 Display yearly predicted remaining life.

ciate the remaining life changes for the selected section and how they compare to the remaining lives of other sections along the route.

Detailed predicted pavement condition can be depicted in chart as well as map formats. Figure 3 charts the predicted pavement condition by milepost and year. In this chart, the horizontal axis represents time, and the vertical axis represents the milepost along the route. Four colors are used to identify the pavement conditions: "Excellent" in blue, "Good" in green, "Fair" in yellow, and "Poor" in red. (The CRS values that identify these condition categories are defined by IDOT.) These four color identifications are well known by the IDOT central office and district engineers. When the color chart appears on the screen, users can immediately understand the pavement condition situation at specified locations and years. Furthermore, in this chart, from left to right, users can understand the predicted changes in pavement condition through the years for a particular section. Also, from bottom to top, they can find out the pavement condition changes along the route for a specified year.

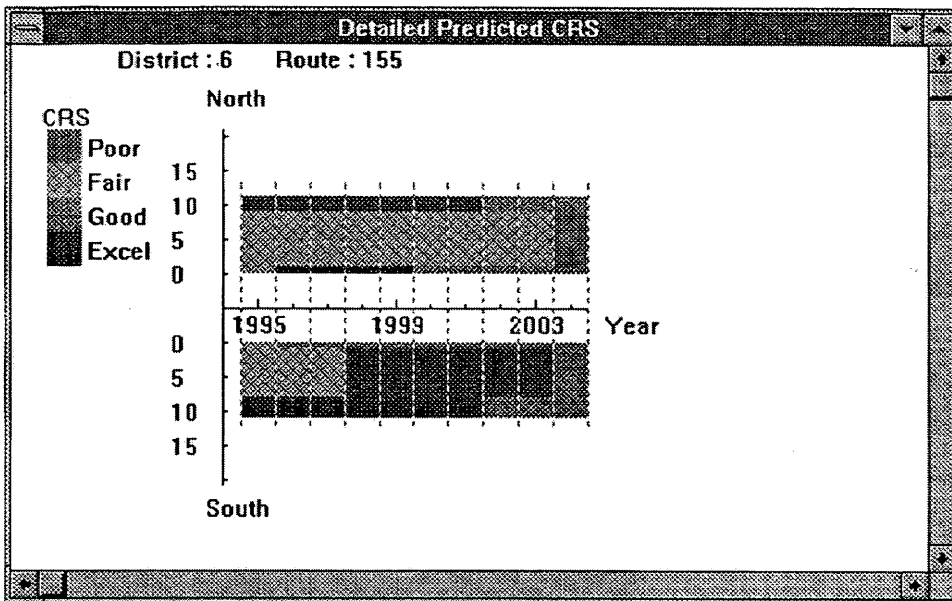
The yearly network rehabilitation strategy may also be depicted in a map format, as illustrated in Figure 4. The map contains the rehabilitation plan for District 6 in 1995. On this screen, the user can select a pavement section by identifying its route number, direction, and beginning and ending mileposts at the top left part of the screen. The user can also choose the year to be displayed. The middle left part contains the updated pavement information stored in the data base. The bottom left part displays the predicted CRS and rehabilitation plan for the selected section. The right part of the screen contains the network rehabilitation plan in the year selected at the "Year" box (which is 1995). Two red dots on the map indicate the beginning and ending mileposts of the specified section. Different colors are used to indicate different types of rehabilitation. This

graph can clearly indicate where, when, and what kind of rehabilitation is planned.

Network statistical analysis results are also depicted in graphs (see Figures 5 through 8). The network summaries are provided in four separate screens: (a) benefit and cost, (b) rehabilitation and cost, (c) condition (CRS), and (d) remaining life. Each screen indicates one or several network-level analysis values. For example, Graph A illustrates the total benefit and total cost of a multiyear rehabilitation plan for one district at a time or for all districts in the state. For the example in Figure 5, the total benefit is 40 091 000.94 veh*km (24,901,000.83 veh*mile) and the total multiyear cost is \$67.41 million. The yearly benefit and cost are depicted in two line graphs. To clearly indicate the relationships among benefits, expenditures, and available budget, a table is used.

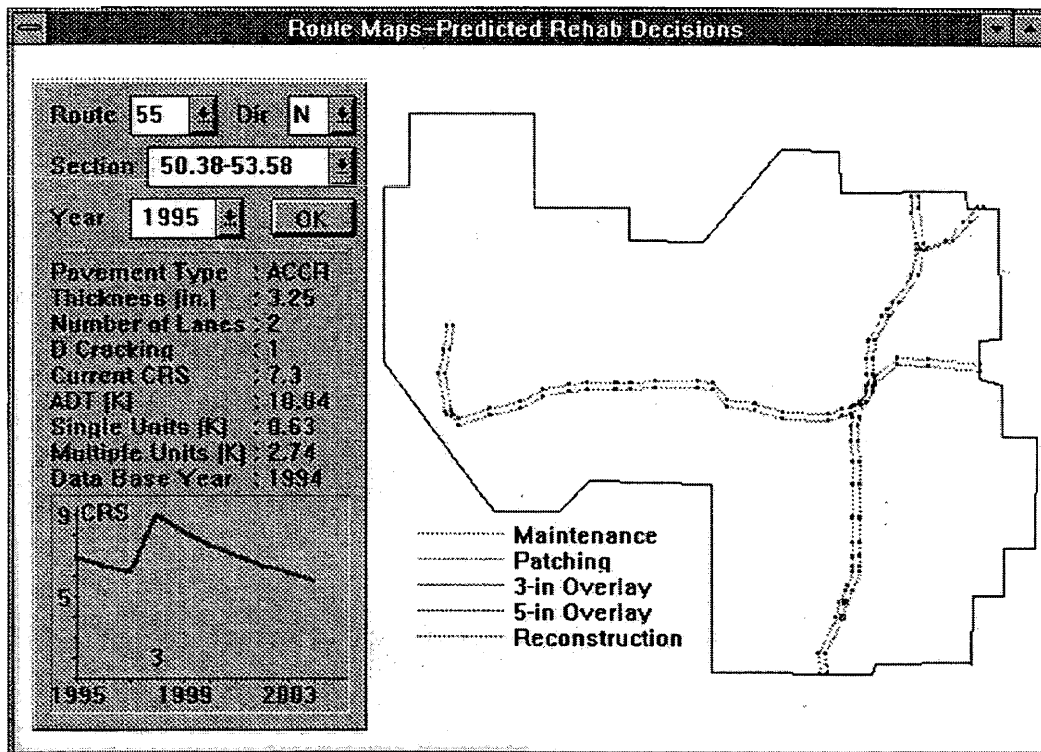
In Figure 6, the upper graph depicts the mileage percentages that should receive various types of rehabilitation (different colors are used to identify different rehabilitation types). The lower graph in Figure 6 presents the total rehabilitation cost each year in millions of dollars. The bars indicate the percentages of the total cost that are allocated for different kinds of rehabilitation in each year. For example, in 1999, approximately \$7 million will be spent, of which 12 percent will be used for patching, 66 percent for 7.6-cm (3-in.) overlays, 22 percent for 12.7-cm (5-in.) overlays, and none for reconstruction.

Predicted pavement conditions and remaining lives are illustrated in Figures 7 and 8, respectively. The bar graph in the upper part of Figure 7 depicts the percentages of pavement length that will fall in the Backlog, Accruing, and Adequate categories. The bottom part of the screen indicates the average CRS in each year and the CRS values that encompass 90 percent and 100 percent of the sections. For example, in 1997, 41 percent of the mileage will be in Adequate



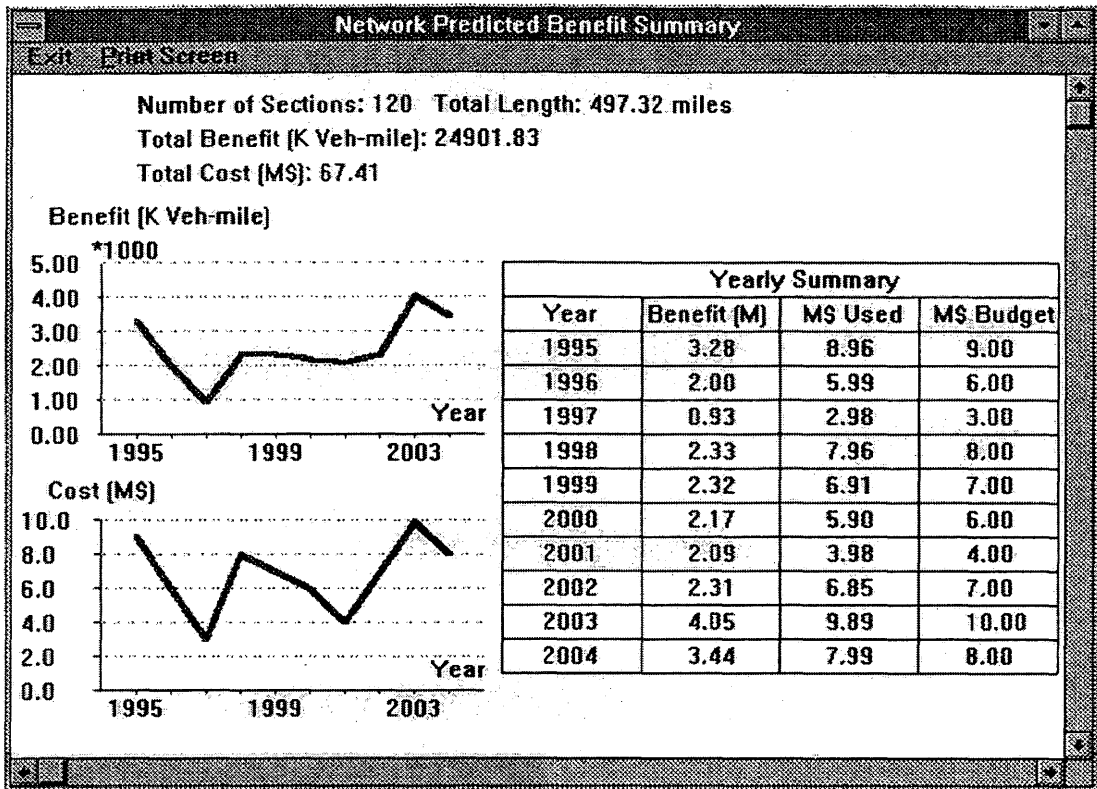
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FIGURE 3 Detailed predicted pavement condition chart.



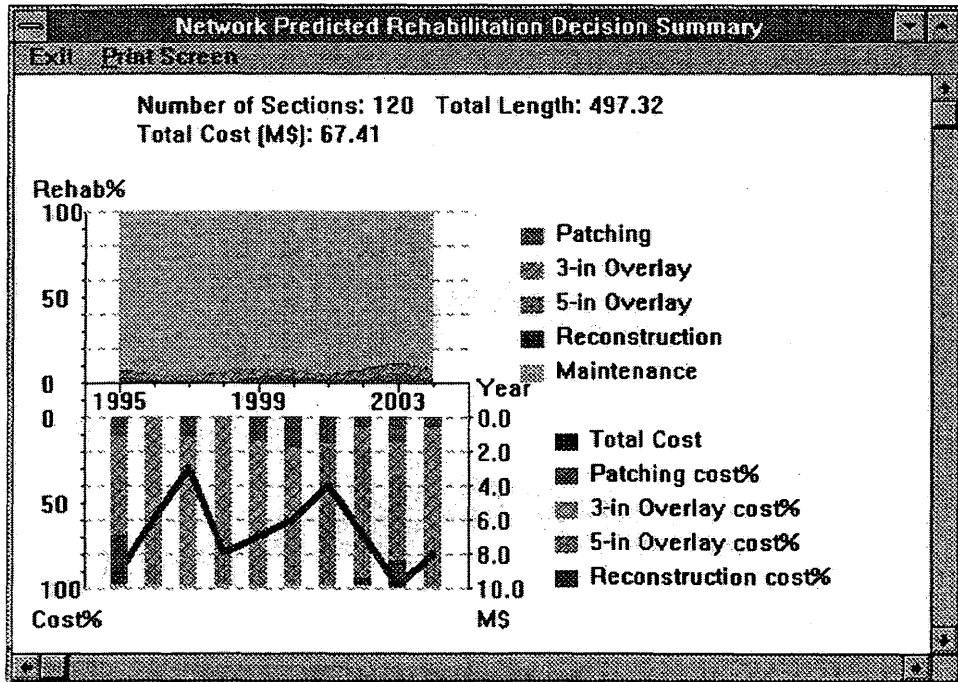
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FIGURE 4 Display rehabilitation plan in map format.



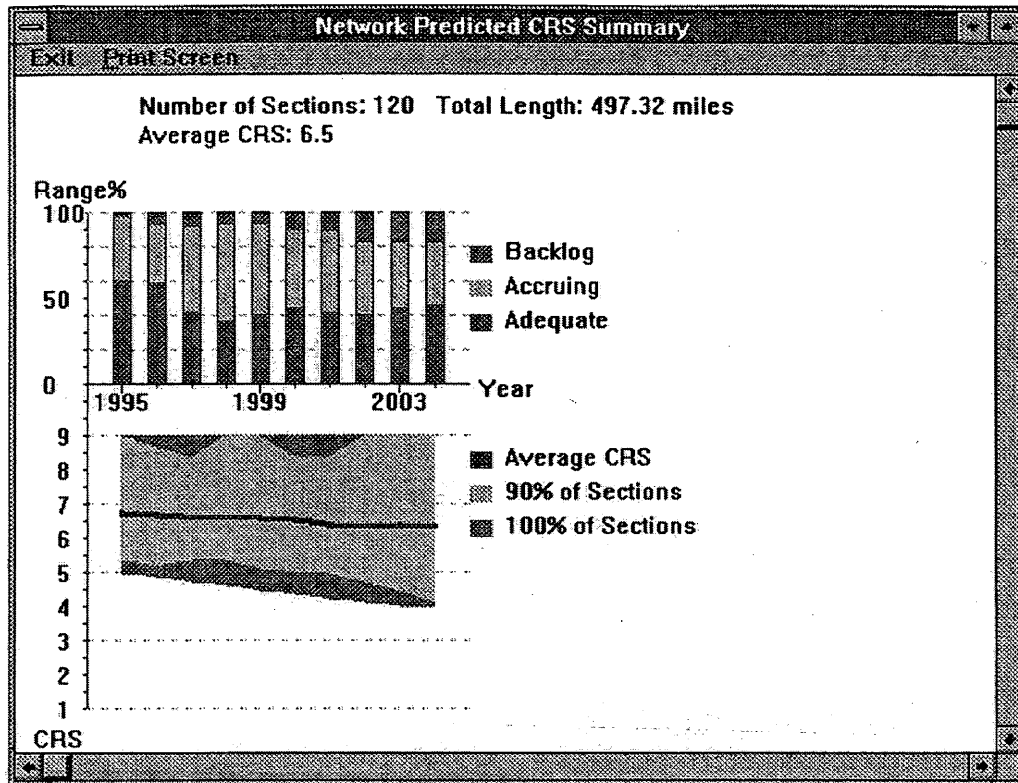
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FIGURE 5 Network benefit and cost analysis summary.



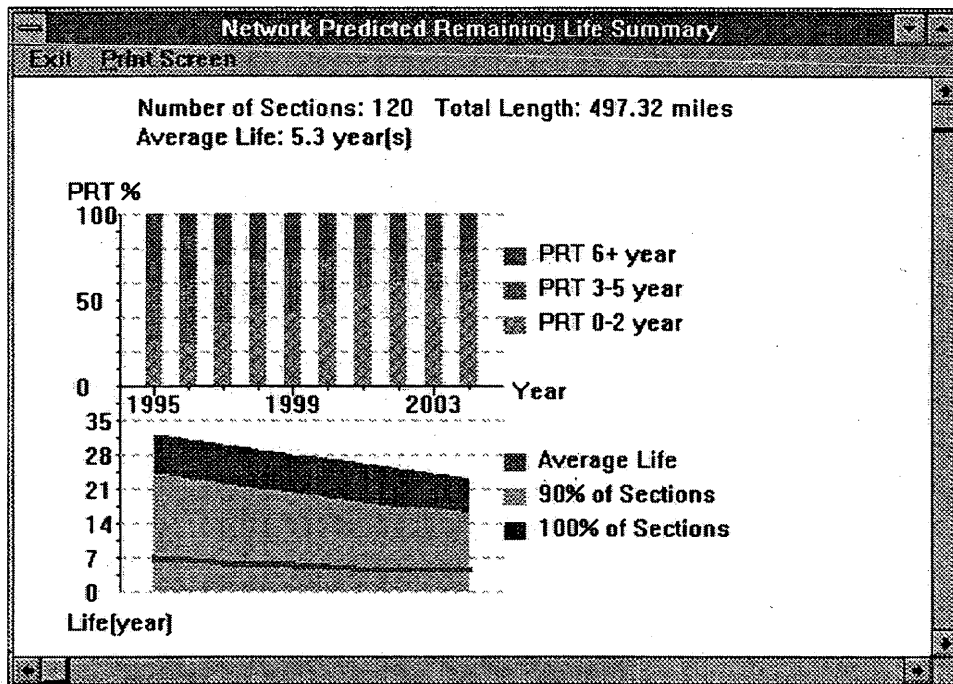
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FIGURE 6 Rehabilitation and cost allocation summary.



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FIGURE 7 Pavement condition summary.



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FIGURE 8 Pavement remaining life summary.

condition, 9 percent will be in Backlog condition, and the rest will be in Accruing condition. The average CRS will be 6.6 in 1997; the CRS for 90 percent of the sections will be between 5.4 and 8.4; the highest CRS will be 9; and the lowest CRS will be about 4.7. Figure 8 indicates that in 1997, 40 percent of the mileage will be in need of rehabilitation within 0 to 2 years; 30 percent will need rehabilitation in 3 to 5 years; and the remaining 30 percent will need no rehabilitation for at least 6 years. The average remaining life will be about 5.5 and will range from 0 to 30 years for various sections in the district. Ninety percent of the sections will have a remaining life of 21 years or less.

ALTERNATIVE DECISION-MAKING ALGORITHMS

A PMS should help managers select the "best" or most nearly "optimal" strategies after evaluating the costs and benefits with regard to various constraints. In recent years, many ranking and optimization algorithms and theories have been developed to help in making rehabilitation decisions (2,7-10). Each algorithm has advantages and disadvantages, and satisfies different requirements. However, none can meet all the desired decision-making needs. For example, if someone wants to repair the worst pavement sections first, he or she may choose the ranking algorithm, which will prioritize projects in worst-first order regardless of the rehabilitation type or life-cycle costs. Another person may want to consider both network-level prioritization and project-level rehabilitation type selection. He or she may choose the incremental benefit-cost ratio algorithm. A PMS that provides options for network-level and project-level decision making is more useful to a wider range of users in the agency who have a range of different concerns, priorities, and goals.

Windows ILLINET offers a total of 60 different decision-making options: 5 network-level algorithms, 6 project-level rehabilitation selection algorithms, and 3 different types of benefits. The system can run the algorithms only or can combine the algorithms with a user-defined committed rehabilitation plan, in which the user identifies specific rehabilitation projects that must be done at specific times.

Figure 9 contains all of the algorithm alternatives offered by Windows ILLINET. Committed Rehab Only, Needs, Ranking, B/C Ratio (Benefit/Cost), and Incremental B/C (Incremental Benefit Cost) are the five network algorithms. Committed Rehab Only means the system will do the analysis based only on the user-specified committed plan, without selecting any other rehabilitation projects or employing any other optimization algorithm. The other four algorithms can be run either alone or in combination with the committed rehabilitation plan. Decision Tree, Life-Cycle Cost, and Single Rehab options of Patching, 7.6-cm (3-in.) Overlay, 12.7-cm (5-in.) Overlay, or Reconstruction are the six project-level alternatives. The Decision Tree method uses decision tree cutoffs to determine which rehabilitation type should be selected for a given project. The critical CRS (Min CRS) is used in the Single Rehab method to select projects for rehabilitation. The ratio of predicted pavement life after rehabilitation to rehabilitation cost is the selection criterion used in the Life-Cycle Cost method. The three benefits the user can select are (a) Vehicle-Miles traveled on adequate pavements, a benefit measure that considers both pavement condition and traffic volume; (b) Average CRS over the multiyear analysis period, which is related to the area under the CRS performance curve; and (c) User

Cost, which puts a dollar amount per person per mile on operational costs as a function of pavement condition.

INTERACTIVE SYSTEM

Once the decision maker understands the pavement conditions and related information, he or she can make decisions by applying his or her own experience to evaluating the rehabilitation recommendations generated by the optimization algorithms supplied by the PMS. The decisions made by the PMS include alternative maintenance or rehabilitation strategies for given roadway sections based on the functional, structural, and material deficiencies found. It is true that several optimization algorithms exist in the system that can generate network rehabilitation strategies based on predicted pavement performance and can be accomplished by a computer without involving the pavement engineers or decision makers to a great extent. However, in this case, decision makers have no way of being involved in the decision-making process. The whole procedure follows a predetermined path until it generates the output. This is why a PMS is often called a "black box." Moreover, the outputs of the optimization algorithms are often not trusted or accepted. Therefore, there is a great need to involve decision makers to a greater degree in the process.

Windows ILLINET allows users to input their own policies and constraints. The decision-making policies may be different for each district and agency. For example, how many times can the highway be patched between two overlays? What conditions must be met to warrant reconstruction? What is the maximum pavement life that should be considered in calculating benefit? Windows ILLINET provides defaults for policy issues such as these; however, users can modify the defaults to reflect their own policies and constraints. Users can also specify any time period for the multiyear rehabilitation planning.

The procedure for using the interactive capability of Windows ILLINET to make the best rehabilitation decisions is as follows. The initial plan can be input by the user or generated automatically by the optimization algorithms supplied in the system, or a combination of the two. After prediction and analysis, the user can save and modify the rehabilitation plan generated by the system based on experience and then, evaluate the plan again. This procedure can be repeated until a satisfactory plan is obtained.

The screen that allows users to modify and create rehabilitation plans is depicted in Figure 10. A user can modify the rehabilitation plan (rehabilitation year, type, and cost) for any section using the Edit Plan option. He or she can also view the total cost spent each year and save the edited plan or cancel it.

USER-FRIENDLY INTERFACE

A user-friendly interface is applied in this interactive PMS. The interface's purpose is to make the system easy to learn, use, and control. "Easy to learn" means users can master this system in a shorter time compared to other pavement management systems. To do this, the system offers pull-down menus on the screen. Users can manipulate a mouse to pick up many items rather than using the keyboard. Ease of use is greatly enhanced by the on-line help function, available at any time, which provides detailed guidance that is relevant to the screen at which the user requested help. The system allows users to

Algorithms Used In ILLINET

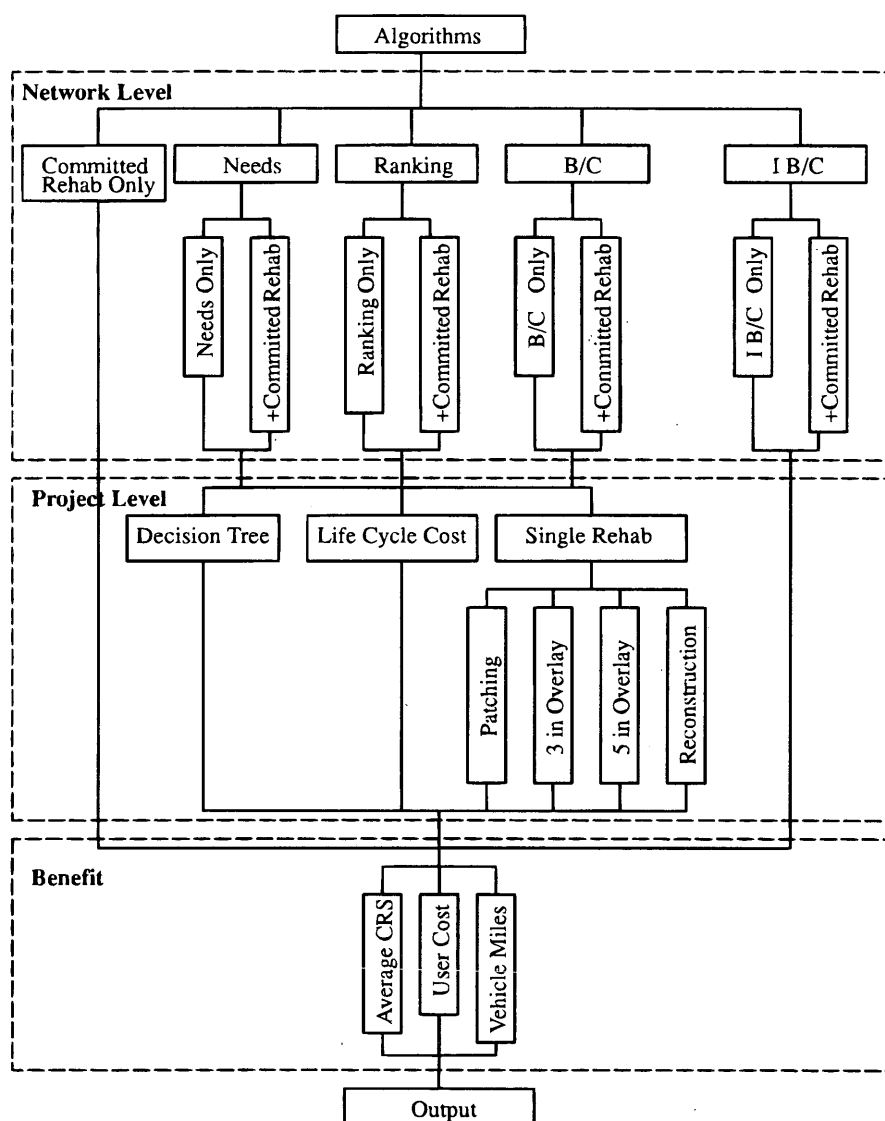


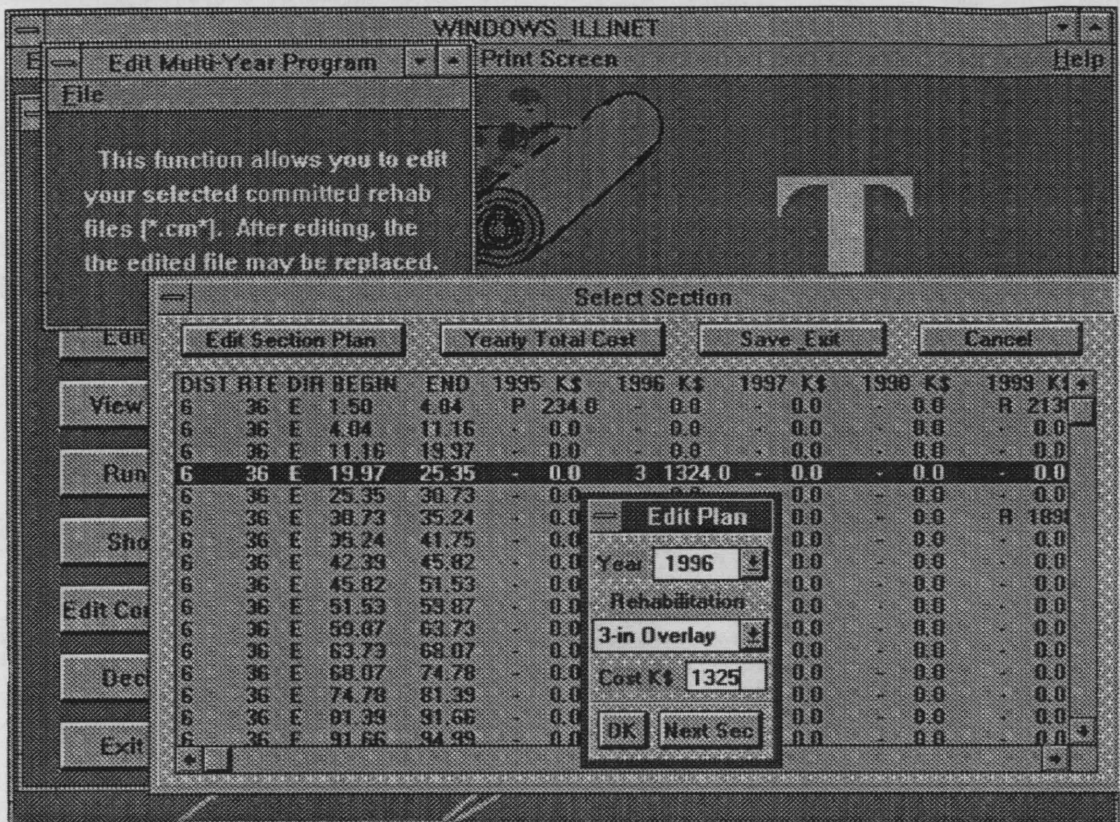
FIGURE 9 Algorithms used in Windows ILLINET.

easily start and cancel jobs whenever they want, which makes the system easy to control. Figure 11 illustrates all of Windows ILLINET's functions. Notice that almost all functions have more than one "entry" and "exit," which means the system is very flexible.

CONCLUSIONS

This paper describes some important features of Windows ILLINET. This system is a user-friendly, graphical interactive PMS. As a robust pavement management tool, this system interprets numerical data in a graphical manner that can greatly assist pavement managers in understanding pavement situations quickly and

correctly. Multimedia applied in the system help demonstrate the pavement inspection motion video on the computer to vividly show pavement conditions. Furthermore, the interactive decision-making option allows users to use their own knowledge in the decision-making procedure, which helps avoid decisions that the users would not trust and would not consider acceptable. All in all, this system is a powerful PMS that has been enthusiastically welcomed by IDOT personnel, many of whom have been very involved in its development and testing. The results from the research shed light on important information-providing and decision-making capabilities of future PMS software. Implementation of Windows ILLINET is progressing and new ideas are being suggested as it is used more and more by IDOT engineers and managers.



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FIGURE 10 Interactive decision-making interface.

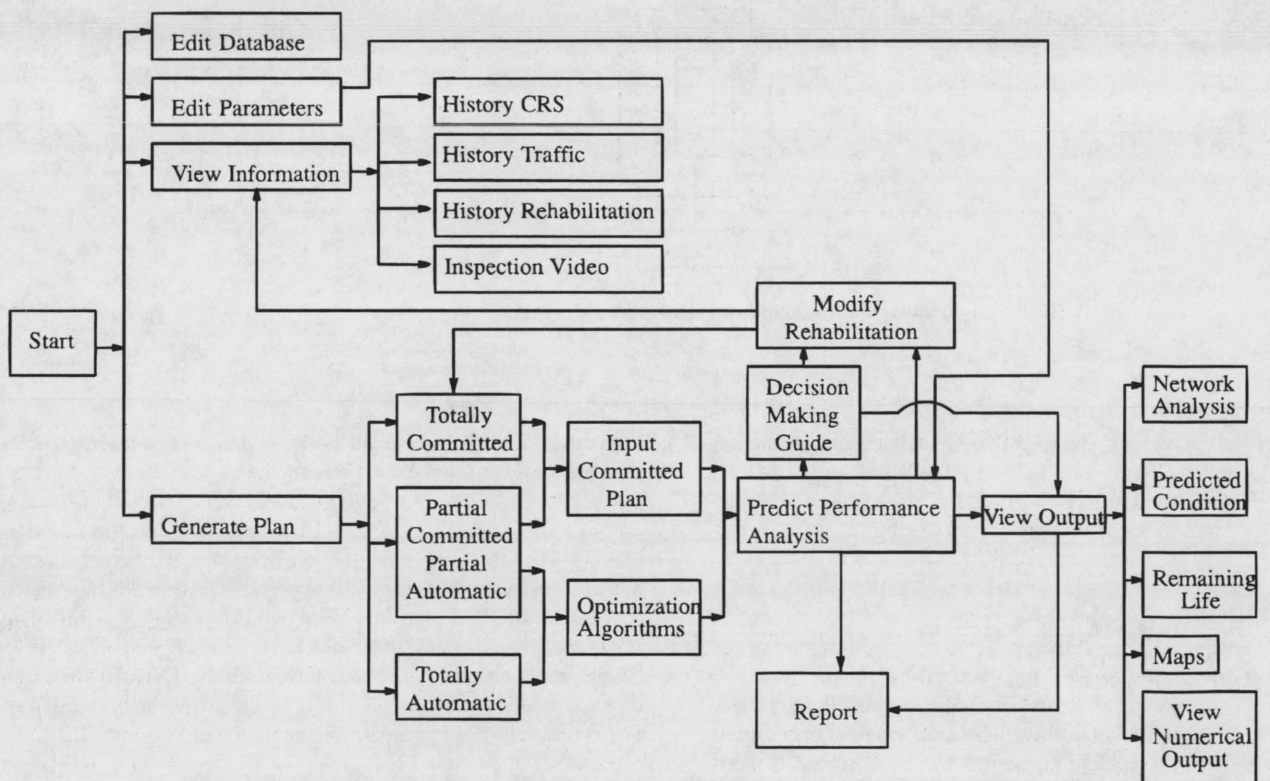


FIGURE 11 Function flow chart of Windows ILLINET.

REFERENCES

1. Darter, M. I., and J. P. Hall. *Illinois Pavement Feedback Data and Management System, Final Report*. Research Report 517-7F. Department of Civil Engineering, University of Illinois, Urbana-Champaign, 1990.
2. Mohseni, A., M. I. Darter, and J. P. Hall. *Alternative Methods for Pavement Network Rehabilitation Management*. Research Report 529-1, Department of Civil Engineering, University of Illinois, Urbana-Champaign, 1992.
3. Hall, K. T., Y. Lee, M. I. Darter, and D. L. Lippert. Forecasting Pavement Rehabilitation Needs for the Illinois Interstate Highway System. Presented at 73rd Annual Meeting of the Transportation Research Board, Washington, D.C., 1994.
4. Wildbur, P. *Information Graphics*. Van Nostrand Reinhold, New York, 1989.
5. Todd, S. *Scientific Visualization and Object Displays*. Master's thesis. University of Illinois at Urbana-Champaign, 1991.
6. Friedhoff, R., and W. Benzon. *The Second Computer Revolution: Visualization*. Harry N. Abrams, New York, 1989.
7. Haas, R., M. A. Karan, A. Cheetman, and S. Khalil. Pavement Rehabilitation Programming: A Range of Options. *Proc., North American Pavement Management Conference*, Vol. 2, 1985, pp. 6.41-6.66.
8. Shahin, M. Y., S. D. Kohn, R. L. Lytton, and W. F. McFarland. Pavement Budget Optimization Using the Incremental Benefit-Cost Technique. *Proc., North American Pavement Management Conference*, Vol. 2, 1985, pp. 6.96-6.107.
9. Cook, W. D., and R. L. Lytton. Recent Developments and Potential Future Directions in Ranking and Optimization Procedures for Pavement Management. *Proc., 2nd American Conference on Managing Pavements*, Vol. 2, 1987, pp. 2.183-2.194.
10. Haas, R., and W. R. Hudson. *Pavement Management Systems*. McGraw-Hill, New York, 1978.