1-1-1993

Developing a network optimization model for pavement management using dynamic programming

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Developing a network optimization model

for pavement management using dynamic programming

by

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A Thesis Submitted to the

Graduate Faculty in Partial Fulfillment of the

Requirements for the Degree of

MASTER OF SCIENCE

Department: Civil and Construction Engineering
Major: Transportation Engineering

Signatures have been redacted for privacy

Iowa State University
Ames, Iowa
1993

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ACKNOWLEDGMENTS

I would like to acknowledge the great assistance, support, and patience by my major professor, Tom Maze, during all the time I was working on my thesis. My sincere thanks Dr. Kathleen Waggoner, Dr. Ed Kannel, and Dr. Howard Meeks, my other committee members for their assistance. A special thanks to Brian McWaters of the Iowa DOT for his help in providing the data. I would also like to thank the Iowa Transportation Center for providing me with the financial support to finish my research.

I would like to express my deep gratitude and thanks to my parents Ghaleb and Haya, and to the rest of the family, Ayman, Randa, Eyman, and Mohammad for their support, understanding, encouragement, and unconditional love at all times. Finally, a special thank you to **DOT** for the love, support, and encouragement during the past year. Thanks, I would not have done it without you!

ABSTRACT

Dynamic programming is used in conjunction with a deterministic pavement prediction model (Performance curves) to obtain optimal maintenance and rehabilitation strategies for pavement sections over a specified planning horizon. The output is determined in conjunction with a specified minimum performance standard and can be used for network and project level analysis.

Pavement sections are divided into four different types depending on the surface type: jointed reinforced concrete, continuous reinforced concrete, composite, and flexible. Prediction curves are determined using the Iowa Department of Transportation Pavement Condition Rating (PCR) equations. Inputs to the program include: available treatment or rehabilitation strategies and their associated costs, pavement performance curves, PCR transition functions, and pavement characteristics. Different planning horizons and performance standards can be used to run the program.

The dynamic program then takes these inputs and simultaneously outputs, for each pavement section for the entire planning horizon, the optimal maintenance strategy that will minimize the total cost and keep the pavement above a certain performance level. The dynamic program is guaranteed to give an optimal solution.

To validate the dynamic program, Iowa segments of Interstate Highway 80 were used as a case study. The results from the dynamic program were compared to the I-80 construction history for the years 1987 to 1992.

CHAPTER 1

INTRODUCTION

The Federal-Aid Highway Act of 1956 authorized the construction and completion of the 41,000 mile-National System of Interstate Highways. Between July 1, 1970 and June 30, 1990, the Federal government spent almost 110 billion dollars on highway capital expenditures (**1**, p. 30). Capital expenditures account for 47.4 percent of highway expenditures compared to 55.6 percent in 1970. Maintenance accounts for 26.3 percent in 1990 compared to 22.7 percent in 1970 (**1**, p.30). By 1992, nearly 99.7 percent of the system was completed. Most of the work that was done in the 1960's, 1970's, and an early part of the 1980's was mainly pavement design and construction. Today, after more than 30 years of Interstate construction, the era of constructing new highway systems is almost over. The emphasis now is toward maintaining and rehabilitating existing systems.

About 30 to 40 percent of the highway payments (**2**, p. 62) are spent on maintaining road networks. Sixty to eighty billion dollars have been spent maintaining all classes of pavements in the United States since 1956. Overall, the Federal Highway Administration (FHWA) has reported that actual maintenance expenditures increased 195 percent per year between 1972 and 1985 (Reference **3**). Due to the high cost of maintaining pavements in good condition, developing and implementing a comprehensive pavement management system has become an important task for state and local governments.

Adopting a pavement management system (PMS) may result in large savings and better use of funds and facilities. In the State of Arizona, for example, $40 million were saved between 1980 and 1985 following the development and implementation of their PMS (**4**, p. 6.22). Savings were calculated by comparing results from the Arizona DOT old practices with maintenance and restoration decisions made using the new PMS. Similar savings have been realized in other states following the implementation of their PMSs (Reference **5**). An efficient and effective PMS helps state and local governments in distributing their existing resources for pavement maintenance and rehabilitation.

There are different definitions for pavement management systems. A simple definition is that a "PMS is an integrated set of systematic procedures designed to help highway engineers or managers in making consistent, cost effective, and reasonable decisions related to pavement maintenance and rehabilitation" (**6**, p. 2-1). PMSs have been developed for several states. Most have been tailored for the needs of a particular state, enhancing its availability of information and improving pavement maintenance and the distribution of restoration funds. The level of sophistication incorporated into a pavement management system depends upon state or local highway agency needs. The PMSs developed have ranged from simple step-wise procedures based on decision trees, to large scale deterministic or stochastic mathematical programming models.

The objective of this research is to determine the feasibility of using deterministic dynamic programming to develop an optimization model for the resource allocation problem in a pavement management system. Dynamic programming, as it will be discussed in detail later, brings added flexibility and efficiency to the pavement management problem. To evaluate the application of deterministic dynamic programming to the pavement management model, Iowa sections of Interstate 80 are analyzed. The results from the analysis will be compared to Iowa Department of Transportation construction records for the past 5 years.

As mentioned earlier, the method used in this research is deterministic dynamic programming. The use of dynamic programming (DP) brings flexibility and adds to the effectiveness of a pavement management system. As it will be discussed later, the design characteristics of DP fit very well with the basic design principles of pavement management systems. Dynamic programming is a member of the family of mathematical programming techniques. It provides a systematic procedure for determining the decision or combination of decisions that increases the overall effectiveness of the system (7, p. 332). There is no general algorithm for a dynamic program. The equations used in the model must be developed to fit the individual situation that is considered.

Depending on the characteristics of a problem being solved by a dynamic program, each problem is divided into different segments. Those segments define the problem as a whole. In pavement management terms, these problem segments represent the number of years considered in the planning horizon and the pavement condition rating index. For more information and a traditional example of dynamic programming refer to reference (7, pp. 332-336).

Most pavement management systems include two models: the resource allocation model and the pavement performance prediction model. These two models form the basis of any PMS. The research performed in this thesis is related to the first component, which is, the resource allocation model. For a better understanding of the PMS process, pavement performance prediction must be defined.

Performance is defined as the "ability of a pavement to fulfill its purpose over time" (**8**). A prediction method is "a mathematical description of the expected values that a pavement attribute will take during a specified analysis period "(**8**). Prediction models can be deterministic or stochastic. Performance curves and survival rates are two of the most commonly used deterministic approaches in PMS. A Markov chain model is the most commonly used stochastic approach in PMS. It is the pavement prediction model used in the PMS that determines the nature of the PMS model.

The deterministic approach is utilized in this research due to the fact that the Iowa DOT uses the deterministic approach in predicting pavement condition. Prediction, or performance curves, define the variations of pavement attributes over time. Different performance curves are used for different pavement types depending on the characteristics of the pavement. Performance curves normally calculate the expected serviceability and age or traffic relationship (**9**). Other attributes or indices can also be used.

The primary component of any resource allocation model are the decision variables. They are the type and timing of pavement treatment or rehabilitation strategy to be used in improving the condition of the pavements. The objective to be satisfied, resource limitations, and other system constraints are the remaining components of the model.

Objectives are expressed in terms of a mathematical equation (objective function). The dynamic program is then designed to optimize the value of the objective function. The objectives for any agency usually take the form of minimizing total cost, including user and/or agency costs, maximizing benefits, or a combination of both. Common constraints include funding, labor supply, available time to perform maintenance, and physical characteristics of the pavement system.

The solution procedure for dynamic programming problems begins with the last stage and ends with the first. This means the optimal decision for the last stage will be determined first, then the mathematical programming algorithm works backward to reach the first stage. The stage that the mathematical program begins with represents the last year in the planning period considered. The last stage to be solved will represent the first year in that period.

There are advantages to using dynamic programming to solve pavement management problems. Dynamic programming provides an efficient and easy way of developing a PMS model. Dynamic programming problems can include any type of equations, whether linear or non-linear, and can handle a large set of variables and constraints without limitations in data entry.

Thesis Organization

The thesis will be organized as follows:

CHAPTER 1. Introduction: research goals and a summary of the method used are discussed.

CHAPTER 2. Literature Review: discussion of former methods and models used in different states to solve pavement maintenance management problems.

CHAPTER 3. Problem Statement: the inputs to the system, the model formulation, constraints and limitations. The system's characteristics and the expected results are also included..

CHAPTER 4. Methodology: consists of a detailed description of the solution procedure, its design, application, and validation.

CHAPTER 5. Program Formulation: the computer program written to solve the problem using Fortran 77. The program is then applied to an example problem and results of this application are analyzed.

CHAPTER 6. Conclusion: comments on the research findings and comparisons of the results from this model with those of the Iowa Department of Transportation practices.

CHAPTER 2

LITERATURE REVIEW

Not all highway agencies use the same pavement management system (PMS). Different PMSs have been developed for different highway agencies. Whether it is for states or local governments, cities, or counties, the primary objective of any pavement management system is the same: to manage a pavement network in the best manner possible, taking into consideration the pavement treatment or restoration funds available. Depending on the transportation agency's needs, the systems developed range from models using mathematical programming techniques, such as linear programming, to simple decision trees or what is referred to as rule-based systems. This chapter will review systems ranging in complexity from decision trees to dynamic programming. The discussion identifies how each system is functioning and compares the different systems in terms of their advantages and disadvantages.

The discussion is divided into two parts. The first part covers three different PMSs developed for states and highway agencies. The first two were developed for state highway agencies. The third system is a widely used general purpose PMS package predominately marketed to local agencies. The second part provides a conclusion for these systems, identifies the limitations of existing PMS research, and explains the importance of the proposed research in filling the gap in the state of the art.

Examples from the literature on PMS

Pennsylvania Pavement Management System (STAMPP)

The Pennsylvania DOT is responsible for a highway system of about 44,000 miles (**10**, p. 8.8). The highway system ranges from an aging Interstate system to a large system of low volume local roads. In 1983, Pennsylvania's Secretary of Transportation formed an eight member pavement management task force, to evaluate the feasibility of a pavement management system for Pennsylvania. The task force began to develop the PMS first for the Interstate and then the Priority Commercial Network.

The model

The first step in developing the pavement management system, which was called **STAMPP** (**S**ystematic **T**echnique to **A**nalyze and **M**anage **P**ennsylvania's **P**avements) was to build a complete data base containing detailed information about the pavement. The formulation of the data base is an important step in the development of a pavement management system. The data base was referenced to designated permanent segments of the pavement network. These segments were established using criteria such as physical features. Segments were defined based on pavement surface type, age, and traffic volume.

The second step was to develop a pavement condition survey form which would provide the information needed to manage each of the pavement segments. Appendix 1 contains a survey form for rigid pavements developed for STAMPP.

The final step in the development of the pavement management system consisted of developing a computer program. The program, which runs on a personal computer (PC), enables the input of the condition survey information into the data base and produces reports useful for maintenance programming or project planning.

The condition survey information is entered into a personal computer. Output is in the form of treatment strategies using a matrix designed for each pavement and shoulder type. See Appendix 2 for rigid pavement treatment strategies developed for STAMPP.

Discussion

STAMPP provides an example of a simple PMS model. The model itself is based on a decision tree. The decision tree was developed using the judgment and experience of personnel who worked directly with pavement maintenance. It does not use mathematical programming techniques to find treatment strategies or in the scheduling of projects. Since the model does not provide prediction capabilities for future pavement conditions, recommended treatment strategies are not scheduled in advance, but rather are incorporated on a year to year basis. Without pavement condition prediction capabilities in the PMS model, network level analysis and planning (5, 10, or 20 years in the future) can not be accomplished.

Conclusion

The three steps discussed in developing STAMPP are essential to the development of a pavement management system. As seen from the development of STAMPP, the data base is a very important part of the pavement management system. The amount of data needed for the PMS largely depends upon the complexity of the pavement management model and also on the needs of the agency. To collect the necessary data, a survey form should be designed and used by individuals doing the actual survey. The survey form is an essential part of the data collection process. It promotes consistent pavement condition evaluations. Consistent condition data is of utmost importance to an efficient pavement management process. The last step is model development. The output from the model should contain information necessary to make decisions regarding the selected pavement treatment or restoration strategies to improve a pavement section. This, of course, will lead to the management of the entire pavement network as one system.

In summary, the most important advantages of STAMPP are that

1) it is easy to use; and

2) it does not require a large data set to operate the program.

The disadvantages of the system are that

1) the system does not schedule projects and define project priorities; and

2) cost minimization or benefit maximization is based on human judgement. The analysis does not consider the whole planning period, but is done on a year to year basis.

Arizona Pavement Management System

This system is a good example of the application of mathematical programming techniques to pavement management. Linear programming and Markov decision processes are used within Arizona's pavement management system to develop desirable allocations of resources to individual projects.

Arizona's highway system consists of a wide range of pavements that represent an investment of $10 billion (**4**, p. 6.18). Due to the complexity of the system and the large amount of money invested in it, the need to develop a comprehensive system to manage a wide ranging and varied highway network emerges.

A team of management scientists, highway engineers, and computer specialists was formed to study Arizona's pavement management system needs. The main goal was to develop a decision making tool to maintain the Arizona DOT's road network in the most desirable condition within budget limitations. The Arizona Department of Transportation (DOT) is required by the Legislature to prepare a 5-year construction plan (**4**, p. 6.18). Therefore, one objective of the system was to serve as the basis for developing the 5-year plan.

<u>The model</u>

To achieve the required system needs, two separate objectives for the mathematical programming approach were considered. These were to select pavement maintenance and restoration activities which maximize benefits and another which minimize costs. Both objectives used a Markov decision process to predict pavement condition and linear programming to find the optimal solution for the pavement network. The two models were analyzed, because of the following advantages of Markov chain and linear programming when applied to the minimization model, the Arizona Department of Transportation implemented the minimization approach (**4**, p. 6.19).

1) The model will determine the budget required to maintain the roads at selected standards. This will help in determining the needed budget for maintaining the highway network.

2) The results are easy to understand.

3) The effect of budget cuts on road conditions is easily estimated.

4) The program makes it possible to divide the entire highway system into small sections that belong to a particular category.

A principal part of the Arizona PMS is a mathematical optimization model, a linear program, termed the Network Optimization System (NOS) (**4**, p. 6.19). The model recommends treatment strategies that will achieve long-term and short-term standards for road conditions. It also determines the minimum budget requirements needed to maintain these standards.

The Markov decision process provides data needed and makes pavement condition predictions. The key elements in the process are states and transition probabilities. A state defines a set of specific levels of the measures used to evaluate pavement performance. The Arizona DOT considers four pavement performance measures including (**4**, p. 6.20): (1) present roughness, (2) present amount of cracking, (3) change in amount of cracking during the previous year, and (4) index to the first crack. Index to the first crack is a number that is linked to the last non-routine maintenance action taken on the road (**4**, p. 6.20).

Transition probabilities are defined as the likelihood one mile of pavement in a certain state will remain in that state or move to another state during one year. Transitional probabilities represent both predicted future performance and the uncertainty associated with the prediction (**4**, p. 6.20).

To determine the transition probabilities, a large historical data base set was used. Applying statistical regression techniques to the historical database, the transition probabilities were determined. The transition probabilities were then adjusted several times, based on current data, before being used in the pavement management model. After adjustments to the transition probabilities were completed, the results were verified by comparing the predicted performance, using the Markov chain model, to the actual performance of a random sample of road segments selected from the Arizona DOT's highway network.

In addition to the transition probabilities other inputs were needed, including maintenance and rehabilitation costs, feasible rehabilitation actions for each state, and performance standards. Performance standards include

1) minimum performance levels,
2) maximum number of miles below certain performance levels, and
3) overall pavement condition.

Following the coding of all the data, the optimization problem is solved using a linear programming package. The solution procedure consists of (**11**, p. 12):

1) generating cost input data,
2) generating transition probabilities,
3) generating the input required for the linear program in its standard form, and
4) solving the linear program.

As an output, the value of the objective function (minimize the total cost) and selected treatment strategies for each state are obtained. Using separate runs for different states, a year to year budget for the highway network is formulated. From the yearly plan, a list of projects and their associated costs are derived using engineering judgment for all of the five years.

Discussion

The pavement management model consists of two parts, Markov transition probabilities and a linear Program. The Markov transition probabilities are used to predict future pavement conditions. Probability estimates are based on historical data and are estimated using regression techniques. Prediction of pavement condition using transition probabilities simplifies the process as a whole and helps in the reduction of the amount of information to be collected.

Linear programming is used to determine the optimal solution for either objectives, cost minimization or benefit maximization. The values of the decision variables define the optimum solution, which in turn determines the total cost and treatment strategies for pavement groups scheduled over the planning period (1, 5, or 10 years). Since pavement prediction is based on transition probabilities, the procedure is stochastic, as opposed to deterministic.

Conclusions

By using the Network Optimization System (NOS), the Arizona Department of Transportation has reported savings of about $40 million between 1980 and 1985 (**4**, p. 6.22). The savings were calculated by comparing the NOS solution and the traditional ranking method used in the past by the Arizona Department of Transportation.

Advantages of this system are as follows:

1) The ease of predicting pavement condition in the future using transition probabilities.

2) The flexibility of choosing the type of the objective function to be optimized (minimize total cost or maximize benefits).

3) Since pavement condition is predicted into the future, the system is capable of scheduling treatment strategies for future years. The resulting decisions will minimize the cost and keep pavement condition above the minimum standards set by the Arizona DOT.

The disadvantage of the system is in the method used to predict the pavement condition. Pavement sections that have the same physical characteristics are grouped together. Then, using transition probabilities, portions of the group will transform to different condition states. Since the system deals with pavements state wise, the individual pavement sections that belong to a certain state lose their identity. The loss of a section's identity makes the process of identifying needs for individual sections impossible. For example, take a pavement group that consists of 20 sections with a total length of 20 miles. Assume the following transition probabilities: 75% remain in the same state, 25% move to the next state. Applying the transition probabilities may result in 75% of the sections (15 miles) remaining in the same state and 25% (5 miles) transforming to the next state. It is estimated that 15 miles of the network will stay in the same state. The question to answer is: which individual sections stayed in that original state?

PAVER Pavement Management System

This example relates directly to the research methodology described in this thesis. Dynamic programming is used to determine the optimal solution to the pavement network. The pavement management system uses dynamic programming and Markov probabilities to allocate pavement management resources.

Introduction

Dynamic programming is used with a Markov-chain probability-based prediction model to obtain minimum cost maintenance strategies over a specific planning horizon (**12**, p. 90). Non-linear programming techniques are used in the pavement management model to determine the Markov probabilities for pavement condition prediction. The model is an improvement to the existing PAVER and Micro PAVER pavement management systems. This version of PAVER increases the prediction and optimization capabilities of the two systems. For more about PAVER refer to reference (**13**).

The pavement management model categorizes the pavement sections according to the Pavement Condition Index (PCI), which is a measure of pavement performance and ranges between 0 to 100. Each pavement category is represented by a bracket of 10 PCI points (**12**, p. 90). The categories are used as states in the development of the dynamic program used to solve the optimization system. Data taken from pavement sections at Army installations were used to build the prediction models. Each section of the pavement is identified by location, pavement type, pavement use, and pavement condition index (PCI). To reduce variations among individual pavement sections in the road network, pavement sections are grouped into families with common characteristics (i.e., pavement surface type and level of use). These pavement families are also be used in the development of the dynamic programming process.

Cost estimates for treatment strategies for pavements in specific PCI ranges are available from the results of an ongoing research on the relationship between PCI and cost to treat a pavement section. The assumption is pavement at lower PCI values will be more expensive to treat than a pavement in better condition. This research is being conducted by Purdue University for the U.S. Army Construction Engineering Research Laboratory (USA-CERL) (**14**). The results of the research provide costs of several maintenance alternatives for different surfaces as a function of the surface condition. This information will be used directly in the dynamic programming framework.

<u>The model</u>

The pavement management system considered consisted of two models, the optimization model using dynamic programming, and the prediction model using Markov Chains. The next two subsections provide a brief discussion of each model.

<u>Prediction model (Markov-chain)</u> All sections in a given network are divided into different families based upon common characteristics. The PCI range of 0 to 100 is divided into 10 states, with each state being 10 PCI points bracket. Each pavement section is affected by duty-cycles through its design life. The duty-cycle is defined as the effects of one year's weather and traffic on a pavement section (**12**, p. 91). A state vector defines the probability of a pavement section being in each of the 10 states in any given year. Figure 1 (**12**, p. 91) shows the schematic representation of state, state victor, and duty cycle.

To predict the way the pavement will deteriorate with time, the Markov probability matrix (transition matrix) is identified. An assumption was made that the pavement condition will not drop by more than one state in a single year (**12**, p. 90). This means the pavement will either stay in its previous condition or transfer to the next lowest state in one year. That assumption results in a matrix with a diagonal structure as shown in Figure 2 (**12**, p. 91).

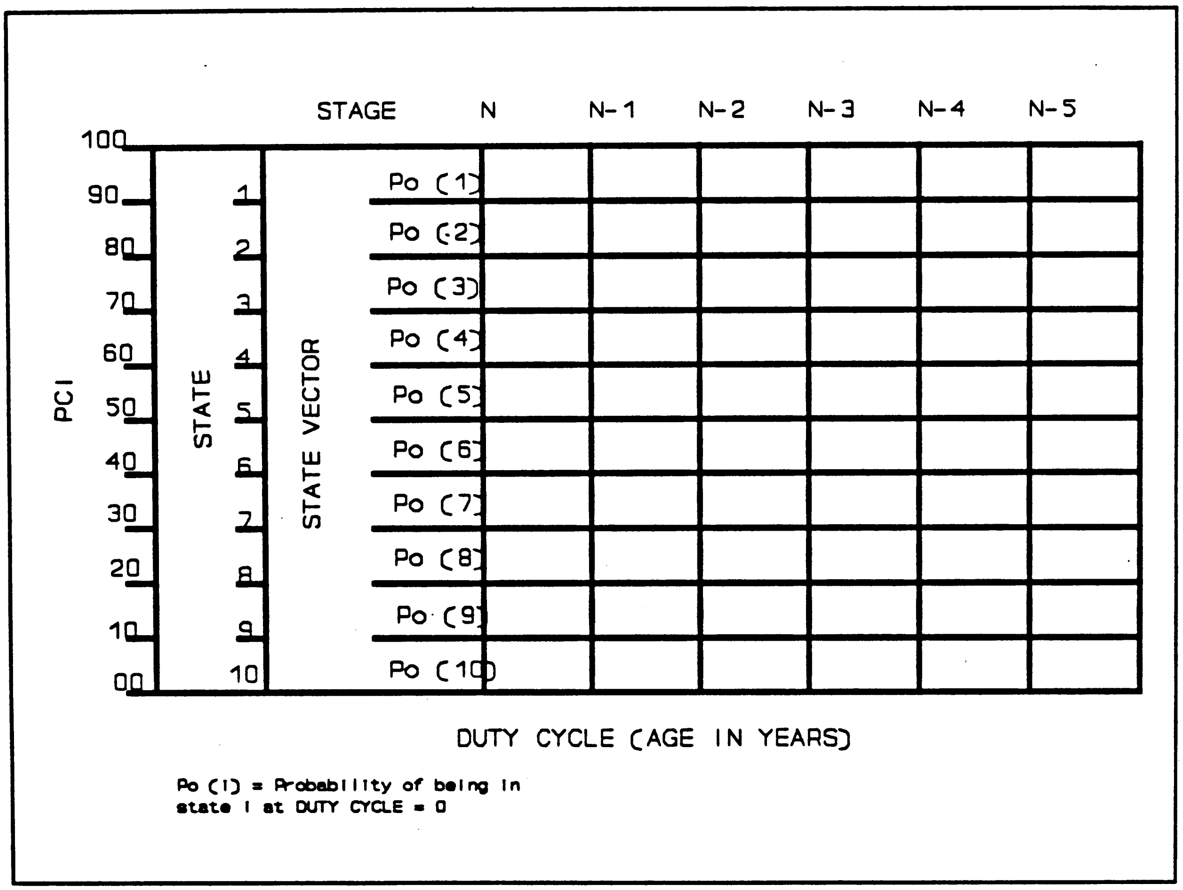

Figure 1. Diagram of state, state vector, and duty cycle (**12**, p.91)

$$
P = \begin{bmatrix}
p(1) & q(1) & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & p(2) & q(2) & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & p(3) & q(3) & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & p(4) & q(4) & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & p(5) & q(5) & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & p(6) & q(6) & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & p(7) & q(7) & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & p(8) & q(8) & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & p(9) & q(9) \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1
\end{bmatrix}
$$

$$q(I) = 1 - p(I)$$

Figure 2. Probability transition matrix structure (**12**, p.91)

The state vector for any duty cycle is obtained by multiplying the initial state vector by the transition probability for that duty cycle. The probabilities are predicted using a non-linear programming approach (Non-linear regression), with an objective function to minimize the absolute distance between actual and predicted conditions (**12**, p.92).

<u>Optimization model (Dynamic Programming)</u> The basic parts of any dynamic programming model are states, stages, decision variables, return, and transition functions (**12**, p. 92). Each stage is considered to be a duty-cycle (one year). Each state is a 10 PCI bracket for every pavement family. At each stage, for every possible state, there should be a set of feasible decisions. These decisions are the pavement maintenance and

repair alternatives. The final part of the dynamic program is the transition function. This determines to which state the pavement will transcend to (wear out) as it moves from one stage (year) to the next.

In general, dynamic programming transition functions can be deterministic or stochastic. In this case, the transition function is defined by a Markov transition matrix and is a stochastic process. The return is the expected cost of a particular decision in each state and at each stage. The required data for the dynamic programming model are (**12**, p. 92):

1) Markov transition probabilities.
2) Costs of applying a certain treatment strategy to each pavement family in a certain state.
3) Feasible treatments in each state for every pavement family.
4) Number of years in the planning horizon.
5) Interest rate, inflation rate, and rate of increase in funding.
6) The associated benefits over one year for being in a certain state. The benefits are calculated from the area under the PCI curve.
7) The minimum allowable state for each pavement family.
8) The transformations that define the new pavement family that the pavement section will belong to if a certain treatment is applied to a certain pavement family.

<u>Model procedure</u>

The dynamic programming process begins at the final year of the planning horizon. In dynamic programming terms, that is stage 0. The procedure arrives at the most effective solution using the steps below (**12**, p. 93):

1) Check to see if routine maintenance is feasible at the last year. If yes, calculate its cost for each state in every family. If not, a very large value is added to the cost to make sure that it will not be selected.

2) All other feasible treatment costs are calculated for all states in each family.

3) Find the total present worth of the cost for each treatment. This will consists of two parts. The first part is the immediate cost of the treatment, and the second is the total expected cost in the remaining years as a result of applying a certain treatment at a certain stage. The sum of the second part will be discounted using the effective interest rate. The effective interest rate is calculated using the interest rate, inflation rate, and rate of increase in funding.

4) The same procedure will be carried out for the remaining stages until stage N or year 0 is reached.

Model output

The output from the dynamic programming model consists of the following information (**12**, p. 94):

1) Optimal maintenance alternatives in every year for every family and state.

2) The present worth expected to accumulate during the life cycle if the optimal treatments selected are implemented.

3) The expected benefits of applying the recommended strategies.

4) The effectiveness/cost ratio calculated for every family and state.

Conclusion

From the discussion above, it can be seen that PAVER and Micro PAVER, provide an efficient way to solve the pavement management optimization problem. Dynamic programming combined with Markov chain probabilities enabled the developers of the PMS model to achieve their goals and objectives in a very efficient and straight forward manner.

As discussed earlier in the Arizona DOT PMS, the disadvantage of using the stochastic approach is that individual pavement sections lose their identities. The ease of predicting pavement condition in the future using Markov probabilities provides the system with one of its most important advantages.

Literature review conclusions

The three pavement management system applications discussed in this chapter show the wide range of different systems that can be used for the better management of pavement networks. The three systems discussed have different objectives, development methodologies, and produce different outputs. This is indicative of the nature of pavement management systems. Since each system is designed for a different highway agency, with different needs, resources, and capabilities, the resulting systems vary to fit the condition present at each highway agency.

The pavement management system models discussed ranged from decision trees to mathematical programming techniques. Since the research reported in this thesis focuses on network optimization, more emphasis is placed on the two systems that utilized mathematical programming techniques to achieve the optimal solution for the pavement management problem.

In an extensive literature search of pavement management systems for the years 1988 to 1992, no systems were found using dynamic programming and deterministic techniques to predict pavement condition. This thesis will apply deterministic dynamic programming to pavement management and demonstrate the model through its application to the Iowa interstate network. The major difference between the system used in PAVER and the methodology proposed for this thesis, is the model used to predict the pavement condition. While the PAVER pavement management system uses a **stochastic** approach, the proposed model for this thesis will use a **deterministic** approach. For predicting pavement condition, the Iowa Department of Transportation Pavement Condition Rating (PCR) equations are used (see Appendix 4). The deterministic approach can be used to simulate a stochastic model. To achieve the simulation, pavement prediction parameters used in the performance curves should be varied a large number of times, then for each change, the model will be solved, and optimal decisions will be determined. The optimal solution will result in the minimum cost for the whole system. The main reasons for using the deterministic dynamic programming approach are:

1) From the pavement management literature search conducted, it was found that there is a lot of demand by highway agencies for using deterministic approaches in pavement performance prediction.

2) The flexibility that dynamic programming has to offer in developing the optimization model for the PMS in terms of the model structure.

3) Dynamic programming structure fits the pavement management problem in terms of dividing it into stages and states.

4) When using deterministic dynamic programming, analysts are not limited to the use of linear equations as is the case in linear programming.

5) Dynamic programming reduces the size of the problem, which saves computation time.

CHAPTER 3

PROBLEM STATEMENT

The purpose of this research is to develop a mathematical tool using deterministic dynamic programming to effectively manage the maintenance and rehabilitation of Iowa's Interstate pavement network. The mathematical model (management model) optimally allocates the available resources for maintenance and rehabilitation of pavements among competing projects to achieve the greatest benefit from the pavement network.

Deterministic dynamic programming is used to allocate the resources within the pavement management system. Dynamic programming, used to solve a multi decision process, reduces the problem size and still guarantees an optimal or best solution.

All highway agencies are faced with making decisions every year regarding the selection of projects for maintenance and rehabilitation. Since funds are limited, making efficient allocation decisions is very important. To effectively manage the pavement network, a pavement decision model should be applied to complete the selection process. Using such a model will effectively and consistently assist agency management personnel in making cost effective decisions regrading the maintenance and rehabilitation of the entire pavement network.

The pavement management optimization model consists of four parts including the objective function, constraints or system limitations, input, and output.

Output

The expected results or output from the pavement management model include:

1) Type of treatment strategy to be applied to each pavement section.

2) Time in the future to implement the treatment strategy (stage).

3) The total cost of maintaining the pavement network within performance standards.

4) Total number of miles in each state at each stage.

5) The total benefits in terms of the average Pavement Condition Rating (PCR) of the total pavement network. For each pavement section, the PCR will be multiplied by the length of that section, then the average for the entire pavement network will be calculated.

The output from the program is used to develop a year to year plan for maintaining each pavement family of the road network. Also a long-range plan, for the planning horizon, is developed for the entire road network.

The first two output results are taken directly from the decision variables used in the pavement management model. The two items provide the most important information needed to develop the project level (short-range) and the network level (long-range) needs for the pavement network. The advantage of using deterministic dynamic programming is evident in the output. A deterministic model selects specific treatment strategies for specific pavement sections or projects. This type of information, specific treatment strategies for specific projects, is not available when a stochastic approach is used.

The remaining items in the output can be determined by analyzing the values of the decision variables. By adding the costs of treatment strategies of all the pavement sections, the total cost of the entire pavement network for the planning horizon is determined. Also, yearly costs can be calculated. The number of miles in each state (condition) is determined by comparing the PCR value with the different PCR ranges (states) and then adding the section lengths in each state. Finally, the pavement performance of the highway network is determined by finding the average PCR value for the whole pavement network.

Objective Function

The objective function can take different forms depending on the information available and also on the agency needs. The following is a summary of different objective function forms:

1) Minimization of user costs.
2) Minimization of maintenance and rehabilitation costs (Agency cost).
3) Minimization of total costs (User cost + Agency cost).
4) Maximization of benefits.
5) A combination of two or more objectives.

For purposes of this research, minimizing maintenance and rehabilitation costs is selected to form the objective function for the pavement management model. One of the main reasons for selecting this criterion for the objective function is the Iowa Department of Transportation does not have pavement performance prediction curves, which are related to calculating benefits. Since minimizing agency costs is selected, benefits are not considered. Rather, the model is limited by minimum performance standards (e.g., all pavement sections should have a PCR of not less than 70). As before, the decision variables are used to determine the total cost of maintaining the pavement network. The objective function is constrained by a set of system limitations, which are included in the next part of the model.

Constraints

The constraints or system limitations are those that include the system requirements and characteristics. They include:

1) Budget constraints (the amount of available funds every year for maintenance and rehabilitation).

2) Time limitations (the amount of time resources, days, in every year to conduct maintenance and rehabilitation activities).

3) Treatment strategies available at each state.

4) Terminal value for the Pavement Condition Rating (PCR) (the minimum allowable condition for any pavement section).

5) Maximum number of miles, or percent of total miles allowed to reach the terminal value.

6) Human resource limitations (labor hours available for maintenance and rehabilitation activities).

Input Parameters

To achieve the required results from the pavement management model, the following input parameters must be available for the analysis of the pavement system.

1) Performance curves to predict pavement condition at any point in the future.

2) Pavement section lengths.

3) 18 K Equivalent Single Axle Load (ESAL) information.
   - Predicted traffic in the future.
   - Yearly traffic for each section.

4) Pavement type (e.g., Rigid, Flexible).

5) Cost of applying available treatment strategies to a pavement section at each state.

6) Available funds to perform pavement maintenance each year.

7) Number of years in the planning horizon.

8) Terminal Pavement Condition Rating (PCR) value.

9) The resulting PCR value after applying a certain treatment strategy to a certain section at a certain state. These values are taken from the transition function for the dynamic program.

A complete description of the mathematical relationships among the decision variables in the objective function and the constraints are presented in Chapter 5. The data needed to model the pavement network are listed in Chapter 5 and Appendix 5.

CHAPTER 4

PROPOSED METHODOLOGY

Deterministic dynamic programming is used to develop the pavement management system for the Iowa Department of Transportation. For a better understanding of how dynamic programming works, the following characteristics are defined.

1. Each dynamic programming problem can be divided into different stages, with a policy decision required at each stage.

2. Each stage consists of a certain number of states depending on the characteristics of the problem.

3. The purpose of making a decision at each stage is to transform the current state into a state associated with the next stage.

4. The solution procedure is designed to find an optimal solution for the overall problem. This means to find an optimal decision at each stage for each of the possible states.

5. Given the current state, an optimal policy of the remaining stages is independent of the policy adopted in previous stages.

6. The solution procedure begins by finding an optimal policy for the last stage, and continues for other stages (7, p. 336).

The deterministic approach means that the state at the next stage is completely defined or determined by the state and decision at the current stage. In the probabilistic case, there is a probability distribution for the outcome (state) in the next stage (year).

The advantage of using dynamic programming is evident. It reduces the problem size, and still guarantees an optimal or best solution. To illustrate how dynamic programming reduces the problem size, consider the following example:

The decision process for selecting the best rehabilitation or treatment strategy and its timing for a particular pavement section, if considered on the network level (i.e., long-range plan) becomes an extensive decision tree. If only five (5) possible alternatives are considered, and only decisions every year for a period of 10 years, then the number of possible alternatives or combinations of decisions would be 5^{10}. Figure 3 shows this process for only 3 decision periods. From Figure 3, the complexity of the decision process becomes evident. On the other hand, when dynamic programming is used, the possible combinations of decisions over the 10 years will be reduced to **(5 X 5 X 10)** for the entire period. The reduction in the size of the problem is the result of how dynamic programming works. The problem is divided into stages, and the decision variables will determine the treatment strategy at each stage. Figure 4 shows the decision tree when dynamic programming is used.

For further understanding of how dynamic programming works, consider the following example. This example is designed to illustrate the features of dynamic programming when used in pavement management systems.

The example considers six (6) road sections in different conditions. The sections belong to the same pavement family (rigid pavements). The condition of the pavement is determined by calculating the Pavement Condition Rating (PCR) values through an assumed performance curve. The performance curve, in terms of PCR, is assumed to be a function of only the total number 18K ESAL the pavement has experienced. The traffic volume information covers 10 years and the PCR values for each section during the 10

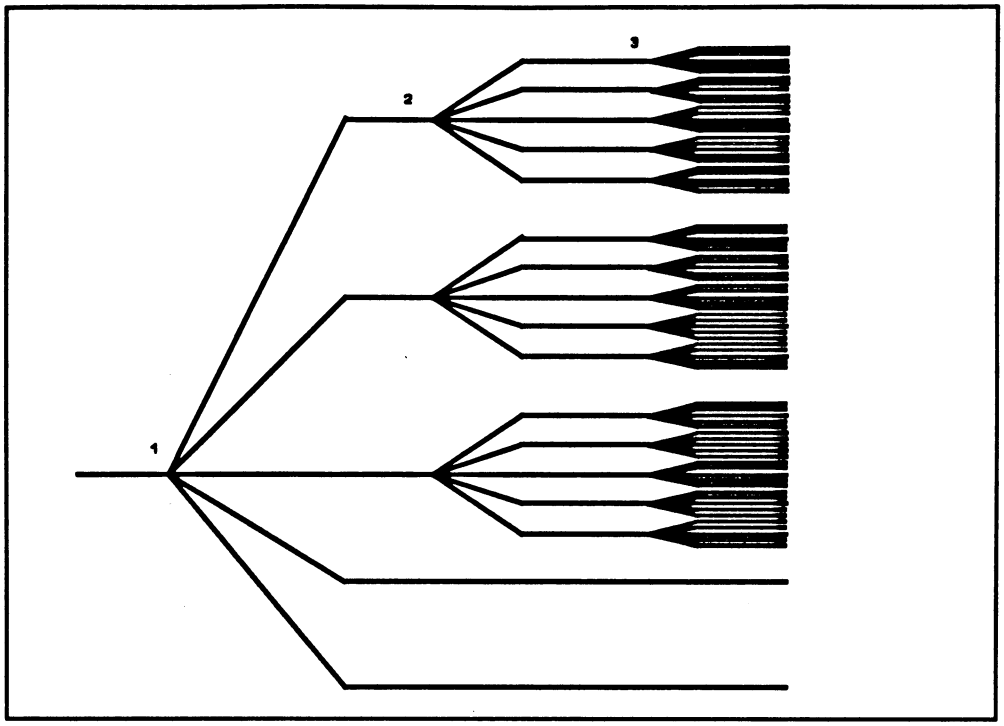

Figure 3. Decision tree of project decision process (15, p.3)

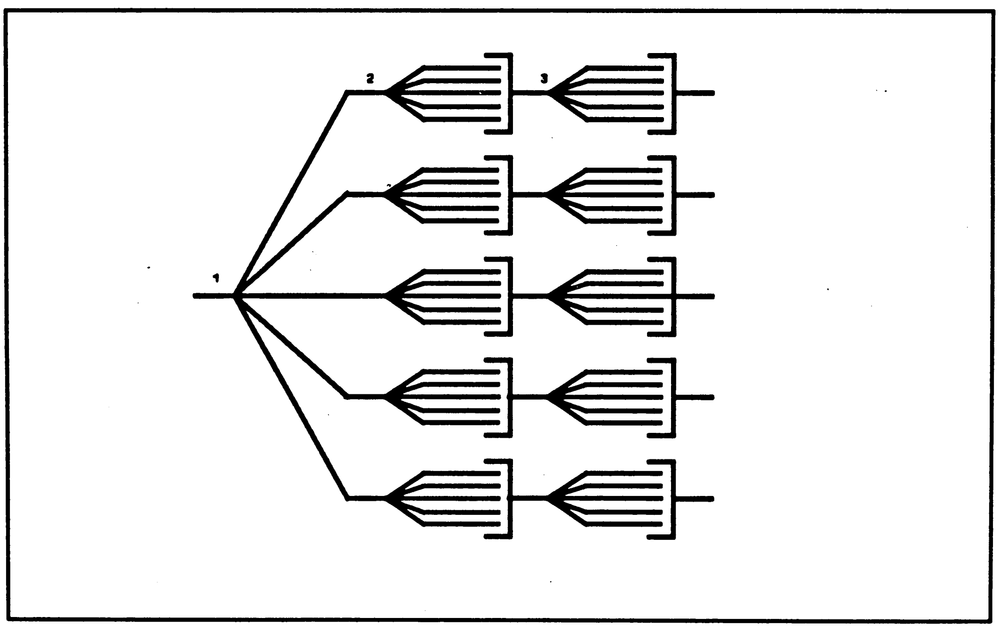

Figure 4. Dynamic programming method applied to the decision process (15, p.4)

year period are shown in Table 1. The performance curve in the example has the following form:

$$PCR = 100 - a\ (\text{Total 18K ESAL})$$

where; a = constant depending on surface type.

Pavement condition is divided into seven (7) states. The first six (6) states have a PCR range between 100 and 40, and the seventh state has a PCR value of less than 40. Table 2 shows pavement states and their associated PCR ranges. The additional information needed is related to the available treatment strategies and the cost of applying each alternative. Table 3 contains a list of the available treatment strategies and their associated costs. All cost numbers are assumed values and are based on two 12-ft lane miles. After dividing the pavement sections into different states based on their PCR value, the feasible treatment strategies for each state should be identified. Table 4 defines the feasible strategies for each state.

Table 1. PCR Information for 10 Years

Section Number	Section Length	PCR*									
		1	2	3	4	5	6	7	8	9	10
1	2.50	90	88	85	82	79	75	70	65	59	54
2	2.35	91	89	84	80	77	72	69	64	60	57
3	3.50	49	40	32	25	18	15	14	12	10	09
4	1.50	70	67	63	60	57	53	50	46	43	39
5	2.70	67	63	59	56	52	48	44	41	38	35
6	3.20	60	53	44	36	30	23	15	14	13	10

* PCR values are based on the following equation
PCR = 100 - (a * (Total 18K ESAL))

Table 2. Pavement States and PCR Ranges

Pavement State	PCR Range
State # 1	100 to 90
State # 2	89 to 80
State # 3	79 to 70
State # 4	69 to 60
State # 5	59 to 50
State # 6	49 to 40
State # 7	Less than 40

Table 3. Available Treatment Strategies

Treatment Strategy	Cost/Mile
1. Routine Maintenance	\$5,000
2. Surface Treatment	\$20,000
3. Overlay ≤ 4"	\$70,000
4. Overlay > 4"	\$80,000
5. Pavement Replacement	\$125,000

Table 4. Feasible Treatment Strategies

Pavement State	Feasible Treatment Strategies				
State # 1	1	2	3	4	5
State # 2	1	2	3	4	5
State # 3	2	3	4	5	
State # 4	3	4	5		
State # 5	3	4	5		
State # 6	4	5			
State # 7	5				
1. Routine Maintenance 2. Surface Treatment 3. Overlay ≤ 4" 4. Overlay > 4" 5. Pavement Replacement					

The objective to be achieved in this example is to minimize the total cost over a ten-year (10) period. There will be no consideration for interest or inflation rates. To make the example as simple as possible, only one constraint is considered. The constraint will deal with the minimum allowable state that any pavement section can reach before replacing the pavement. The constraint will be worded as follows:

THE MINIMUM ALLOWABLE STATE IS A PCR VALUE OF 40

The solution obtained for the example shown using dynamic programming is summarized as follows:

For rigid pavements and for the data given in the example the following treatment strategies were selected:

State 1	Routine maintenance.
State 2	Routine maintenance.
State 3	Surface treatment.
State 4	Surface treatment.
State 5	Surface treatment.
State 6	Overlay <= 4".
State 7	Pavement replacement.
State 8	Pavement replacement.
State 9	Pavement replacement.
State 10	Pavement replacement.

To determine the solution for each section, the following procedure is used:

1) Determine the condition (PCR value) for the section from the data given or the performance curve.

2) Determine the state of the pavement section depending on the PCR value.

3) When the state is defined, select the appropriate treatment strategy from the above list.

4) Increase the PCR value depending upon the type of treatment strategy selected for the pavement section.

5) Determine the cost for each year, and find the total cost for the planning horizon.

Usually the cost of applying each treatment strategy depends upon the state of the pavement section. To simplify the example, treatment costs are assumed constant regardless (See Table 3).

The following is an interpretation of the results for section # 1.

Based on the data given in Table 1, the decrease in the PCR values for section # 1 were 2, 3, 3, 3, 4, 5, 5, 6, 5 points, for the years 2 through 10, respectively. The resulting maintenance strategies according to the dynamic programming solution are:

- Year 1 Routine maintenance.
- Year 2 Routine maintenance.
- Year 3 Routine maintenance.
- Year 4 Routine maintenance.
- Year 5 Surface treatment.
- Year 6 Routine maintenance.

- Year 7 Routine maintenance.

- Year 8 Routine maintenance.

- Year 9 Surface treatment.

- Year 10 Routine maintenance.

Section number (1) is 2.5 miles in length and the total cost for section (1) is **$200,000**. For more detailed information about all the sections refer to Appendix 3. Figure 5 shows the network for the dynamic program structure.

After defining dynamic programming characteristics, the pavement management model will be set using dynamic programming characteristics. The terms used in the definition are the same as those used in defining dynamic programming. The difference is in using pavement characteristics in defining these terms.

1. Stages: Each stage in the model will represent one year in the planning horizon period. The planning horizon may be 5, 10, or 20 years.

2. States: These are ranges of the Pavement Condition Rating (PCR) value. The PCR values are between (0) to (100), and each range of (10) points represents a state. State **1**: PCR between 100 and 90, state **2**: PCR between 89 and 80, state **3**: PCR between 79 and 70, state **4**: PCR between 69 and 60, state **5**: PCR between 59 and 50, state **6**: PCR between 49 and 40, state **7**: PCR between 39 and 30, state **8**: PCR between 29 and 20, state **9**: PCR between 19 and 10, and state **10**: PCR between 9 and 0. Each pavement section is in one of the above states depending on its PCR value.

3. Decision Variables: These represent different types of maintenance treatments or policies to apply.

4. Objective Function: This may be to minimize total cost or maximize the benefits subjected to certain constraints or limitations that will be discussed later.

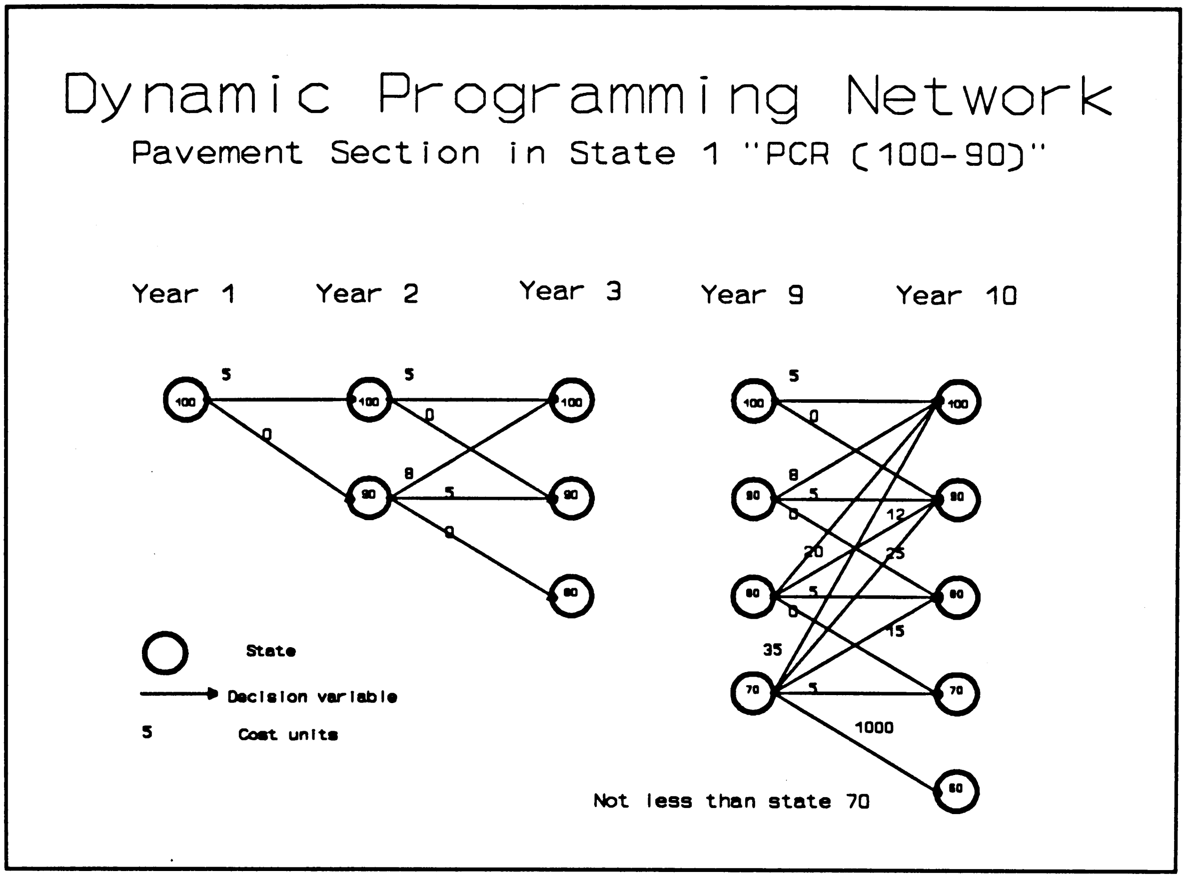

Figure 5. Dynamic program network

CHAPTER 5

MODEL METHODOLOGY

By definition, in deterministic dynamic programming the condition of each pavement section is completely defined. This means the state at the next stage is determined by the state and the decision at the current state. For each pavement section in any state at each stage, the model determines the feasible treatment strategies to be applied. The model will then select the series of strategies that result in an optimal objective function.

Determining the feasible treatment strategies requires the ability to predict the pavement condition at future stages. The Iowa Department of Transportation PCR equations are used to develop performance curves, which in turn, are used to predict pavement condition at each state in different stages in the future. The use of these performance curves to predict pavement condition in the future is described later in this chapter.

The objective function can have different alternatives. As discussed earlier, several approaches may be used to achieve the optimization for the whole pavement network. The following example represents one of the alternatives, "Minimizing Maintenance and Rehabilitation Cost (Agency Cost)", and also defines some of the constraints that will be used.

Minimizing Agency Cost

If minimizing the total cost is considered, the form of the objective function will be:

Minimize C, C = Total Cost

$$TotalCost = \sum_{y_1^p} \sum_{i_1^n} \sum_{j_1^o} \sum_{K_1^m} (L_{ijy}) * (T_k) * (A_k)$$

where;

n	=	number of pavement sections,
o	=	number of pavement states,
m	=	number of treatment strategies,
p	=	number of stages,
L_{ijy}	=	length of section i at condition j in stage y,
T_k	=	cost of applying treatment k to section i at state j per unit length, and
A_k	=	0, if treatment k can not be applied at condition j. And 1, if treatment k can be applied at condition j.

Constraints are:

a- Budget limitations.

b- Time limitations.

c- Treatment strategies available at each stage.

d- Terminal value for the pavement condition rating (PCR).

e- maximum number of miles that exist in a certain stage.

Tables 5 through 8 show the information needed for the dynamic programming model. The following information is included in each of the tables:

1) Available treatment strategies for flexible and rigid pavements. Tables 5 and 6.

2) The cost of applying different treatment strategies for flexible and rigid pavements. Tables 5 and 6.

3) Feasible treatment strategies for each state for flexible and rigid pavements. Tables 7 and 8.

4) The increase in the PCR value after applying a certain treatment strategy for both flexible and rigid pavements. Tables 9 and 10.

A very important part of the pavement management model is the pavement performance prediction. As mentioned earlier, the deterministic approach is used to predict the pavement condition in the future. The future pavement condition is forecasted using the Iowa Department of Transportation Pavement Condition Rating (PCR) equations (included in Appendix 4) which determines the value of PCR for different pavement types. The Iowa Department of Transportation did not have performance curves. Therefore, Iowa DOT PCR data are analyzed to develop an equation capable of predicting the condition of the pavement in the future depending on the pavement age. The following performance curve is used to predict the pavement condition (refer to Appendix 5 for an explanation):

$$PCR=(95.6)+(0.347X)-(0.221X^2)$$

Where; PCR = Pavement condition rating value (0-100), and
X = Pavement age in years since the last maintenance action.

The coefficient of determination, $R^2 = 0.975$

To develop the performance curve, all Iowa sections of Interstate 80 were analyzed at the same time. Sections were grouped using age in years, and the PCR values for each group were averaged. Using a non-linear regression computer package (Cricket Graph), a performance curve equation which is the best fit of the model through the average PCR of each group was determined.

The deterministic approach (performance curves) of predicting the future pavement condition, provides the decision makers with the ability to make decisions at both project and network level. Since the condition of any pavement section is determined using a performance curve, maintenance and rehabilitation actions can be determined through the PMS model for each individual section. This provides the deterministic dynamic programming approach with one of its major advantages. See Appendix 5 for the more information regarding the performance curve parameters.

Table 5. Flexible Pavement Available Treatment Strategies

Type of Treatment	Code	Cost
Routine Maintenance	00	$3,000
Crack Sealing	02	$5,000
Patching	20	$125,000
Resurfacing - 3"	43	$150,000
Resurfacing - 4.5"	44	$215,000
Resurfacing - 6"	45	$270,000
Pavement Replacement	70	$1,000,000

Table 6. Rigid Pavement Available Treatment Strategies

Type of Treatment	Code	Cost
Routine Maintenance	00	$5,000
Joint / Crack Sealing	03	$10,000
Full Depth Patching	10	$200,000
Partial ACC Patching	20	$125,00
Resurfacing - 4"	72	$275,000
Resurfacing - 6"	75	$470,000
Pavement Replacement	70	$1,000,000

Table 7. Feasible Treatment Strategies for Flexible Pavements

State #	PCR Range	Feasible Treatments
1	100 - 90	00, 02
2	89 - 80	00, 02, 20, 43
3	79 - 70	00, 02, 20, 43, 44
4	69 - 60	00, 02, 20, 43, 44, 45
5	59 - 50	00, 20, 44, 45, 70
6	49 - 40	00, 44, 45, 70
7,8,9,10	Less Than 40	70

Table 8. Feasible Treatment Strategies for Rigid Pavements

State #	PCR Range	Feasible Treatments
1	100 - 90	00, 03
2	89 - 80	00, 03, 20
3	79 - 70	00, 03, 20, 72
4	69 - 60	00, 03, 10, 72, 75
5	59 - 50	00, 10, 72, 75, 70
6	49 - 40	00, 10, 72, 75, 70
7,8,9,10	Less Than 40	70

Table 9. Resulting PCR Values After Applying Different Treatment Strategies at Each State - Flexible Pavements

Initial State	Feasible Codes	PCR Increase
1	00	Same
	02	5
2	00	Same
	02	5
	20	10
	43	15
3	00	Same
	02	5
	20	10
	43	15
	44	20
4	00	Same
	02	5
	20	10
	43	15
	44	20
	45	30
5	00	Same
	20	10
	44	20
	45	30
	70	90
6	00	Same
	44	20
	45	30
	70	90
7,8,9,10	70	90

'able 10. Resulting PCR Values After Applying Different Treatment Strategies at Each State - Rigid Pavements

Initial State	Feasible Codes	PCR Increase
1	00	Same
	03	5
2	00	Same
	03	5
	20	10
3	00	Same
	03	5
	20	10
	72	25
4	00	Same
	03	5
	10	10
	72	25
	75	35
5	00	Same
	10	10
	72	25
	75	35
	70	90
6	00	Same
	72	25
	75	35
	70	90
7,8,9,10	70	90

To better understand how the PMS model works, the following small scale example from Interstate 80 is considered. Consider a pavement section with the following set of information:

- Section #: 872500
- County: Pottawattamie
- Direction: East
- Pavement Type: Continuous Reinforced Concrete (CRC)
- Section Length: 7.41 miles
- Age since last rehabilitation action: 18 years
- Planning Horizon: 5 years
- Actual PCR value: 34
- Predicted PCR value: 31

The solution procedure for the PMS model consists of several steps. The following is a brief description of each:

- Determine the state of the pavement section depending on the PCR value. The PCR value is between 31 and 40 and therefore, the state is 7.

- Check to determine if pavement replacement is the only feasible alternative. Since the state of the pavement section is less than 6, pavement replacement is the only feasible alternative.

- Update the PCR value to reflect the treatment strategy applied. Pavement replacement increases the PCR value to 97.

- Using the performance curve, predict the future PCR values for the remaining years in the planning horizon.

Year 2:	96
Year 3:	94
year 4:	93
Year 5:	91

- Depending on the predicted PCR value, determine the state of the pavement section for each year.

Year 2:	1
Year 3:	1
Year 4:	1
Year 5:	1

- The dynamic program will determine the best feasible treatment strategies for each year.

Year 1:	Pavement Replacement ($1,000,000)
Year 2:	Routine Maintenance ($3,000)
Year 3:	Routine Maintenance ($3,000)
Year 4:	Routine Maintenance ($3,000)
Year 5:	Routine Maintenance ($3,000)

- The total cost for the pavement section.
  Total Cost = $7,500,000

- The average PCR value = 94

The complete results for all Iowa sections of Interstate 80 are in Appendix 6.

CHAPTER 6

CONCLUSIONS

Deterministic dynamic programming was used to develop the mathematical tool used in building the pavement management system model for this thesis. After selecting the objective function (i.e., minimize maintenance and rehabilitation costs), and defining the technical relationships between decision variables, objective function, and constraints, the computer program was written using Microsoft® FORTRAN (**16**). The software uses FORTRAN 77. Only data from Interstate 80 were used to run the computer program. The data included the following elements:

1) Section identification information:

   - Section identification number
   - County
   - Direction of travel
   - Pavement type

2) Section characteristics:

   - Section length (miles)
   - 18 K ESAL (yearly and total)
   - PCR values

3) Treatment strategies:

   - Feasible treatment strategies for each pavement type at different states
   - Cost of applying different treatment strategies
   - The increase in PCR value after applying a certain treatment strategy to a pavement section at a certain state.

After loading all the information into the computer program, the model was run using a Z-386/25 ZENITH personal computer with 4 Meg bytes of random Access Memory (RAM). The running time for I-80 sections was about 2 minutes. The planning horizon for the application was 5 years, so that results could be compared with the Iowa Department of Transportation construction history for I-80. The results were obtained in the following format (See Appendix 6 for all the results):

1) Section identification information and length.

2) Yearly program that includes:

   - Year
   - Type of treatment strategy recommended
   - Cost of applying the treatment strategy

3) Total cost for the entire pavement network for the planning horizon.

Furthermore, the data can be analyzed to arrive at such information as:

1) Number of miles in each state for every year.

2) Average PCR value for each pavement type.

3) Average PCR value for the entire pavement network.

4) PCR value for a certain section for every year in the planning horizon.

5) Maintenance and rehabilitation costs for each pavement type (by year or total).

By examining the available information from the PMS model results, the advantage of using the deterministic approach in predicting future pavement condition becomes evident. The managers can not only identify the long-range plan, but short-range (Project Level) analysis can also be performed.

To validate the results from the dynamic programming model, the results were compared with the Interstate 80 construction data for the years 1897-1992 (See Appendix 7). Interstate 80 consists of 121 sections with a total length of 611.2 2-lane miles (about 305 miles). When comparing the results with the historical data, the following conclusions were drawn:

1) Twenty eight (28) sections were found to match exactly with the historical construction data (i.e., type of treatment strategy selected and the implementation time).

2) Fifty four (54) sections matched the treatment strategy selected, but there were one or two years difference in implementation times.

3) The rest of the thirty nine (39) sections did not match with the historical construction data. There were incidents when the same treatment strategy was applied, but the timing was different.

4) By examining the results from the PMS dynamic program model, it was noticed that some of the pavement sections had undergone a major maintenance activity and were scheduled to be replaced or reconstructed in the next year or two. This is one of the primary reasons why pavement management optimization techniques should be used in PMS models.

5) No cost numbers were compared directly in the results because of the nature of the objective function selected. A comparison of the total cost from the dynamic program (**$299,607,000**) and the I-80 construction history (**$211,412,000**) indicates that the results from the dynamic program are close

to those from the Iowa Department of Transportation keeping in mind the difference in formulating each program. The dynamic program was formulated to minimize agency costs based on a performance standard (**PCR ≥ 70** for the given example). The Iowa Department of Transportation results are not based on the same performance standard.

6) To determine the difference in PCR values between the Iowa Department of Transportation program and the dynamic program, 20 random sections were selected and compared. The comparison showed that the resulting PCR values from the dynamic program at the end of the 5-year planning horizon were slightly higher than those from the Iowa Department of Transportation data.

These conclusions indicate that even though similarities exist between the new model and Iowa DOT practices, further calibration and investigation of the pavement management model should be carried out. If the Iowa DOT decides to adopt such an approach for its pavement management system, more work should be done to fit its needs. Areas that need more investigation are:

1) Pavement performance prediction (Performance curves), in terms of developing new equations and selecting new variables to predict the pavement condition

2) Treatment strategies in terms of:

- Costs of applying different treatment strategies at different states.
- The resulting PCR value after applying certain treatment strategies.
- The determining of the feasible treatment strategies for each state.

3) Validation and calibration of the model.

4) The structure of the computer program:

- User friendly
- Operation manual
- Compatibility with the Iowa DOT data

In conclusion, the suggested approach (deterministic dynamic programming) used in developing the mathematical model for the pavement management system is beneficial and achieves the required goals of the system. Deterministic pavement condition prediction proves to be an advantage in any pavement management system, because it gives managers the flexibility of looking at long and short-range plans at the same time. The results from the developed model are promising, but more work needs to be done in this area.

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APPENDIX 1. CONDITION SURVEY INPUT FORM - RIGID PAVEMENTS

CONDITION SURVEY INPUT FORM - RIGID PAVEMENT

DIST. [ ] CTY. [ ] P/S [ ] APPL [ ] LEG.RTE. [ ] SPUR [ ] EQ. [ ] BEGIN STATION [ ] BEG. MILEPOST [ ] BEGIN DESCRIPTION [ ] TYPE SURF. [ ] 30/40/50 FLEXIBLE, 60/80/90 RIG.BASE, 70 RIGID DATE (M M D D Y Y) [ ]

ADT [ ] U/R [ ] TRAF.RTE. [ ] MFC [ ] LENGTH [ ] END STATION [ ] END MILEPOST [ ] END DESCRIPTION [ ] WIDTH [ ] DIR. [ ] OOS1 [ ] OOS2 [ ] OOS3 [ ]

CONDITION		EXTENT			SEVERITY
		<10%	10-30%	>30%	# JOINTS
JOINT SEAL FAILURE		7	8	9	> 50% MISSING
	NONE 4	4	5	6	> 1' SEALANT MISSING
	0	1	2	3	BOND LOSS >2'/JOINT
		<10%	10-30%	>30%	LENGTH
LONG. JOINT SPALLING		7	8	9	> 6"
	NONE	4	5	6	1"-6"
	0	1	2	3	< 1"
		<10%	10-30%	>30%	SLABS
TRANSVERSE CRACKING		7	8	9	> 1"
	NONE	4	5	6	1/4"-1"
	0	1	2	3	< 1/4"
		<10%	10-30%	>30%	# JOINTS
TRANS. JOINT SPALLING		7	8	9	CRUSHED JOINT
	NONE	4	5	6	ISOLATED SPALL >2"
	0	1	2	3	MINOR SPALL <2"
		<10%	10-30%	>30%	# JOINTS
FAULTING		7	8	9	> 1/2"
	NONE	4	5	6	1/4"-1/2"
	0	1	2	3	< 1/4"
		<5%	5-15%	>15%	SLABS
BROKEN SLAB		7	8	9	LOOSE PIECES
	NONE	4	5	6	INTERLOCKING PIECES
	0	1	2	3	HAIRLINE CRACKS
		<5%	5-15%	>15%	SLABS
BITUMINOUS PATCHING		7	8	9	POOR CONDITION
	NONE	4	5	6	FAIR CONDITION
	0	1	2	3	GOOD CONDITION
		<5%	5-15%	>15%	SLABS
SURFACE DEFECTS	NONE	4	5	6	5 OR MORE PER SLAB
	0	1	2	3	< 5 PER SLAB

RUTTING >1/2" OVER 50% SECTION LENGTH

NO	YES
0	1

SHOULDERS

LEFT AVERAGE TOTAL WIDTH	LEFT AVERAGE PAVED WIDTH	PAVED AND UNPAVED	RIGHT AVERAGE TOTAL WIDTH	RIGHT AVERAGE PAVED WIDTH
0-CURB [ ]	[ ] 0-CURB		0-CURB [ ]	[ ] 0-CURB
2' [ ]	[ ] 2'		2' [ ]	[ ] 2'
4' [ ]	[ ] 4'		4' [ ]	[ ] 4'
6' [ ]	[ ] 6'		6' [ ]	[ ] 6'
8' [ ]	[ ] 8'		8' [ ]	[ ] 8'
10' [ ]	[ ] 10'		10' [ ]	[ ] 10'

PAVED PORTION ONLY

CONDITION		LEFT EXTENT			SEVERITY		RIGHT EXTENT		
		<10%	10-30%	>30%	LENGTH		<10%	10-30%	>30%
LANE/SHOULDER SEPARATION		7	8	9	> 1"		7	8	9
	NONE	4	5	6	1/4"-1"	NONE	4	5	6
	0	1	2	3	< 1/4"	0	1	2	3
		<10%	10-30%	>30%	LENGTH		<10%	10-30%	>30%
DETERIORATION		7	8	9	HOLES/SEV.CRKING		7	8	9
	NONE	4	5	6	ENTIRE WDTH	NONE	4	5	6
	0	1	2	3	MINOR CRKING	0	1	2	3

PAVED AND UNPAVED

	DRAINS	<10%	10-30%	>30%	LENGTH	DRAINS	<10%	10-30%	>30%
SLOPE	0	1	2	3	DOES NOT DRN	0	1	2	3
	DRAINS	<10%	10-30%	>30%	LENGTH	DRAINS	<10%	10-30%	>30%
BUILDUP	0	1	2	3	DOES NOT DRN	0	1	2	3
		<10%	10-30%	>30%	LENGTH		<10%	10-30%	>30%
DROPOFF		7	8	9	> 4"		7	8	9
	NONE	4	5	6	>2"-4"	NONE	4	5	6
	0	1	2	3	1"-2"	0	1	2	3

REMARKS:

APPENDIX 2. RIGID PAVEMENT TREATMENT STRATEGIES

RIGID PAVEMENT TREATMENT STRATEGIES

		LOW			MEDIUM			HIGH		
		1	2	3	4	5	6	7	8	9
A	JOINT SEAL FAILURE	X	1	2	1	2	2	1	2	2
B	LONGITUDINAL JOINT SPALLING	1	2	3	4	4	4	4	4	4
C	TRANSVERSE CRACKING	X	X	X	2	3	3	9	(9)	9
D	TRANSVERSE JOINT SPALLING	X	1	3	4	4	4	5	5	5
E	FAULTING	X	6	6	7	8	8	9	9	10
F	BROKEN SLAB	6	6	6	9	9	9	9	9	9
G	BITUMINOUS PATCHING	9	9	9	9	9	9	9	9	9
H	SURFACE DEFECTS	6	6	6	9	9	9			
K	RUTTING	10								

(X) ROUTINE MAINTENANCE
(1) SPOT JOINT SEAL
(2) JOINT SEAL
(3) JOINT REHABILITATION
(4) JOINT SPALL REPAIR
(5) JOINT REPLACE
(6) SUBSEAL
(7) SUBSEAL & SLABJACK
(8) SUBSEAL & SLABJACK & GRIND
(9) SLAB REPLACE
(10) OVERLAY

COMBINATIONS FOR OVERLAY:

>30% PATCHING

OVERLAY REPAIR RECOMMENDATIONS:

ADTT	REPAIR
0 - 1000	3-1/2" BITUMINOUS
1001 - 2000	6" BITUMINOUS
2001 - 3000	CONCRETE OVERLAY
ABOVE 3000	RECONSTRUCT

EXPLANATION OF TREATMENT STRATEGIES

NUMBERS ACROSS THE TOP OF THE STRATEGY GRID (1 THRU 9) REFER TO MARKS ON THE CONDITION SURVEY INPUT FORM.-----------------------------------> LETTERS DOWN THE SIDE (A THRU K) REFER TO CORRESPONDING CONDITIONS. FOR EXAMPLE, A SECTION HAVING SEVERE TRANSVERSE CRACKING OVER 20% OF ITS SLABS IS CODED C8. C8 CONDITION ALONE INDICATES TREATMENT #9 - SLAB REPLACE.

NONE	EXTENT			SEVERITY
0	1	2	3	L
	4	5	6	M
	7	8	9	H

ANY COMBINATION OF CONDITIONS THAT REQUIRE >30% PATCHING WILL INDICATE TREATMENT #10 - OVERLAY.

APPENDIX 3. RESULTS PRINTOUT FOR EXAMPLE

SECTION # 2

Based on the data given in Table 1 (page 32), the decreases in the PCR values were 2, 5, 4, 3, 5, 3, 5, 4, and 3 points, for the years 2 through 10, respectively. The resulting maintenance strategies according to the dynamic programming solution are:

- Year 1	Routine maintenance.
- Year 2	Routine maintenance.
- Year 3	Routine maintenance.
- Year 4	Routine maintenance.
- Year 5	Surface treatment.
- Year 6	Routine maintenance.
- Year 7	Surface treatment.
- Year 8	Routine maintenance.
- Year 9	Surface treatment.
- Year 10	Routine maintenance.

SECTION # 3

Based on the data given in Table 1 (page 32), the decreases in the PCR values were 9, 8, 7, 7, 3, 1, 2, 2, and 1 points, for the years 2 through 10, respectively. The resulting maintenance strategies according to the dynamic programming solution are:

- Year 1 Overlay <= 4".
- Year 2 Surface treatment.
- Year 3 Surface treatment.
- Year 4 Surface treatment.
- Year 5 Surface treatment.
- Year 6 Routine maintenance.
- Year 7 Routine maintenance.
- Year 8 Surface treatment.
- Year 9 Routine maintenance.
- Year 10 Routine maintenance.

SECTION # 4

Based on the data given in Table 1 (page 32), the decreases in the PCR values were 3, 4, 3, 3, 4, 3, 4, 3, and 4 points, for the years 2 through 10, respectively. The resulting maintenance strategies according to the dynamic programming solution are:

- Year 1 Surface treatment.
- Year 2 Routine maintenance.
- Year 3 Surface treatment.
- Year 4 Routine maintenance.
- Year 5 Surface treatment.
- Year 6 Routine maintenance.
- Year 7 Surface treatment.
- Year 8 Routine maintenance.
- Year 9 Surface treatment.
- Year 10 Routine maintenance.

SECTION # 5

Based on the data given in Table 1 (page 32), the decreases in the PCR values were 4, 4, 3, 4, 4, 4, 3, 3, and 3 points, for the years 2 through 10, respectively. The resulting maintenance strategies according to the dynamic programming solution are:

- Year 1 Surface treatment.
- Year 2 Surface treatment.
- Year 3 Routine maintenance.
- Year 4 Surface treatment.
- Year 5 Routine maintenance.
- Year 6 Surface treatment.
- Year 7 Routine maintenance.
- Year 8 Surface treatment.
- Year 9 Routine maintenance.
- Year 10 Surface treatment.

SECTION # 6

Based on the data given in Table 1 (page 32), the decreases in the PCR values were 7, 9, 8, 6, 7, 8, 1, 1, and 3 points, for the years 2 through 10, respectively. The resulting maintenance strategies according to the dynamic programming solution are:

- Year 1	Surface treatment.
- Year 2	Surface treatment.
- Year 3	Surface treatment.
- Year 4	Surface treatment.
- Year 5	Surface treatment.
- Year 6	Surface treatment.
- Year 7	Surface treatment.
- Year 8	Routine maintenance.
- Year 9	Routine maintenance.
- Year 10	Surface treatment.

APPENDIX 4. INTERSTATE PCR-3 EQUATIONS

INTERSTATE PCR 3 EQUATIONS

TYPE	R^2	SIGN	COEFF.	VARIABLE
1 JOINTED	0.9609	+	0.31444	STRUCT. RATIO (NEW)
		+	0.24868	AGGREGATE-AGE RATING
		+	0.555061	PSI RATING
		-	10.4663	
2 CRC	0.8355	+	6.8476	ROAD RATER
		+	12.9271	PSI
		-	0.10871	% LIFE USED
		-	0.127973	AVERAGE K (SUBGRADE)
		+	5.5397	AGGREGATE CLASS
		+	4.1196	
3 COMPOSITE	0.9217	-	2.9x10^-6	TOTAL 18K ESAL
		+	0.65876	ASPHALT AGE RATING
		+	21.9046	AGGREGATE CLASS
		+	1.84355	AGE
		-	52.7501	
4 FLEXIBLE	0.7604	+	12.7505	PSI
		+	0.191146	ASPHALT AGE RATING
		+	1.3x10^-5	LAST 18K ESAL
		+	8.1818	

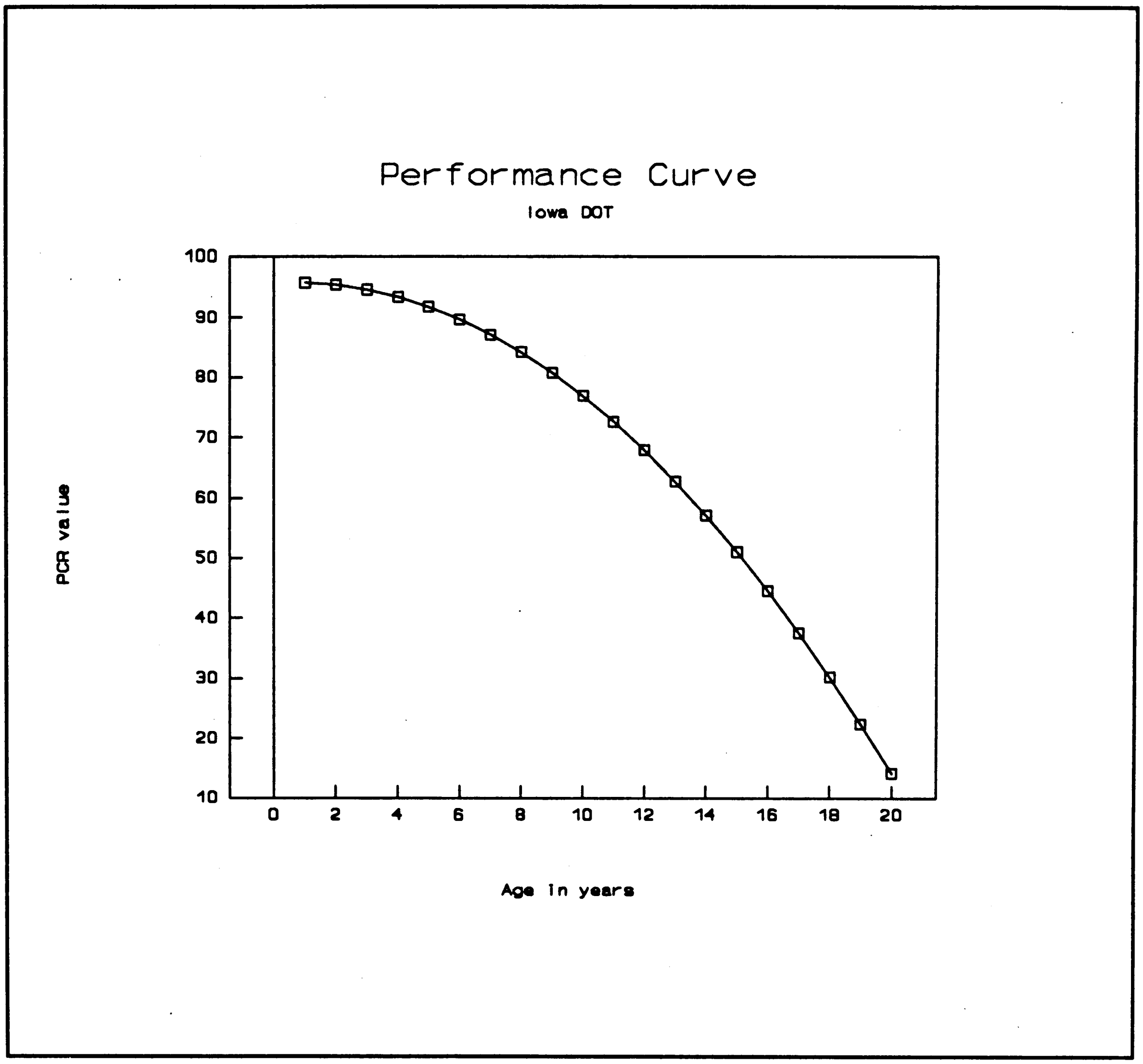
Source: Iowa Department Of Transportation

APPENDIX 5. PERFORMANCE CURVE PARAMETERS

PCR DATA:

Age in years	PCR value (0-100)
1	95.70
2	95.38
3	94.62
4	93.42
5	91.78
6	89.70
7	87.17
8	84.20
9	80.79
10	76.94
11	72.65
12	67.91
13	62.73
14	57.11
15	51.05
16	44.55
17	37.60
18	30.21
19	22.38
20	14.11

PERFORMANCE CURVE:



To develop the performance curve, all Iowa sections of Interstate 80 were considered at the same time. Sections were grouped together using age in years. Then PCR values for each group were averaged. Using a non-linear regression computer package (Cricket Graph), the performance curve equation was determined.

APPENDIX 6. DYNAMIC PROGRAM RESULTS

SECTION: 872420 COUNTY: POTTAWATTAMIE DIR: E TYPE: 3 LENGTH = 2.81MILES
YEAR = 1 ROUTINE MAINTENANCE COST= 3000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 CRACK SEALING COST= 5000
SECTION: 872430 COUNTY: POTTAWATTAMIE DIR: W TYPE: 3 LENGTH = 2.81MILES
YEAR = 1 ROUTINE MAINTENANCE COST= 3000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 CRACK SEALING COST= 5000
SECTION: 872440 COUNTY: POTTAWATTAMIE DIR: E TYPE: 3 LENGTH = 2.14MILES
YEAR = 1 ROUTINE MAINTENANCE COST= 3000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 CRACK SEALING COST= 5000
SECTION: 872450 COUNTY: POTTAWATTAMIE DIR: W TYPE: 3 LENGTH = 2.14MILES
YEAR = 1 ROUTINE MAINTENANCE COST= 3000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 CRACK SEALING COST= 5000
SECTION: 872460 COUNTY: POTTAWATTAMIE DIR: E TYPE: 3 LENGTH = 1.66MILES
YEAR = 1 ROUTINE MAINTENANCE COST= 3000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 CRACK SEALING COST= 5000
SECTION: 872470 COUNTY: POTTAWATTAMIE DIR: W TYPE: 3 LENGTH = 1.66MILES
YEAR = 1 ROUTINE MAINTENANCE COST= 3000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 CRACK SEALING COST= 5000
SECTION: 872480 COUNTY: POTTAWATTAMIE DIR: E TYPE: 3 LENGTH = 4.91MILES
YEAR = 1 ROUTINE MAINTENANCE COST= 3000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 CRACK SEALING COST= 5000
SECTION: 872490 COUNTY: POTTAWATTAMIE DIR: W TYPE: 3 LENGTH = 4.91MILES
YEAR = 1 ROUTINE MAINTENANCE COST= 3000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 CRACK SEALING COST= 5000
SECTION: 872500 COUNTY: POTTAWATTAMIE DIR: E TYPE: 2 LENGTH = 7.41MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 872510 COUNTY: POTTAWATTAMIE DIR: W TYPE: 2 LENGTH = 7.41MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 872520 COUNTY: POTTAWATTAMIE DIR: E TYPE: 3 LENGTH = 8.44MILES
YEAR = 1 ROUTINE MAINTENANCE COST= 3000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 CRACK SEALING COST= 5000
SECTION: 872530 COUNTY: POTTAWATTAMIE DIR: W TYPE: 3 LENGTH = 8.44MILES
YEAR = 1 ROUTINE MAINTENANCE COST= 3000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 CRACK SEALING COST= 5000

SECTION: 872540 COUNTY: POTTAWATTAMIE DIR: E TYPE: 1 LENGTH = 7.78MILES
YEAR = 1 ROUTINE MAINTENANCE COST= 3000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 872550 COUNTY: POTTAWATTAMIE DIR: W TYPE: 1 LENGTH = 7.78MILES
YEAR = 1 ROUTINE MAINTENANCE COST= 3000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 872560 COUNTY: POTTAWATTAMIE DIR: E TYPE: 2 LENGTH = 4.08MILES
YEAR = 1 CRACK SEALING COST= 5000
YEAR = 2 CRACK SEALING COST= 5000
YEAR = 3 CRACK SEALING COST= 5000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 872570 COUNTY: POTTAWATTAMIE DIR: W TYPE: 2 LENGTH = 4.08MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 872580 COUNTY: POTTAWATTAMIE DIR: E TYPE: 3 LENGTH = 5.71MILES
YEAR = 1 CRACK SEALING COST= 5000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 872600 COUNTY: POTTAWATTAMIE DIR: W TYPE: 3 LENGTH = 5.71MILES
YEAR = 1 CRACK SEALING COST= 5000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 872610 COUNTY: POTTAWATTAMIE DIR: E TYPE: 3 LENGTH = 4.77MILES
YEAR = 1 CRACK SEALING COST= 5000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 872620 COUNTY: POTTAWATTAMIE DIR: W TYPE: 3 LENGTH = 4.77MILES
YEAR = 1 CRACK SEALING COST= 5000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 872630 COUNTY: CASS DIR: E TYPE: 3 LENGTH = 2.66MILES
YEAR = 1 CRACK SEALING COST= 5000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 872640 COUNTY: CASS DIR: W TYPE: 3 LENGTH = 2.66MILES
YEAR = 1 CRACK SEALING COST= 5000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 872650 COUNTY: CASS DIR: E TYPE: 3 LENGTH = 7.53MILES
YEAR = 1 CRACK SEALING COST= 5000
YEAR = 2 CRACK SEALING COST= 5000
YEAR = 3 CRACK SEALING COST= 5000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 872660 COUNTY: CASS DIR: W TYPE: 3 LENGTH = 7.53MILES
YEAR = 1 CRACK SEALING COST= 5000
YEAR = 2 CRACK SEALING COST= 5000
YEAR = 3 CRACK SEALING COST= 5000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000

SECTION: 872690 COUNTY: CASS DIR: E TYPE: 3 LENGTH = 7.48MILES
YEAR = 1 CRACK SEALING COST= 5000
YEAR = 2 CRACK SEALING COST= 5000
YEAR = 3 CRACK SEALING COST= 5000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 872700 COUNTY: CASS DIR: W TYPE: 3 LENGTH = 7.48MILES
YEAR = 1 CRACK SEALING COST= 5000
YEAR = 2 CRACK SEALING COST= 5000
YEAR = 3 CRACK SEALING COST= 5000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 872710 COUNTY: CASS DIR: E TYPE: 3 LENGTH = 5.92MILES
YEAR = 1 CRACK SEALING COST= 5000
YEAR = 2 CRACK SEALING COST= 5000
YEAR = 3 CRACK SEALING COST= 5000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 872720 COUNTY: CASS DIR: W TYPE: 3 LENGTH = 5.92MILES
YEAR = 1 RESURFACING 6" COST= 270000
YEAR = 2 CRACK SEALING COST= 5000
YEAR = 3 PATCHING COST= 125000
YEAR = 4 ROUTINE MAINTENANCE COST= 5000
SECTION: 872730 COUNTY: ADAIR DIR: E TYPE: 4 LENGTH = 6.00MILES
YEAR = 1 RESURFACING 6" COST= 270000
YEAR = 2 CRACK SEALING COST= 5000
YEAR = 3 PATCHING COST= 125000
YEAR = 4 ROUTINE MAINTENANCE COST= 5000
SECTION: 872740 COUNTY: ADAIR DIR: W TYPE: 4 LENGTH = 6.00MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 872750 COUNTY: ADAIR DIR: E TYPE: 4 LENGTH = 6.50MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 872760 COUNTY: ADAIR DIR: W TYPE: 4 LENGTH = 6.50MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 872770 COUNTY: ADAIR DIR: E TYPE: 4 LENGTH = 11.45MILES
YEAR = 1 ROUTINE MAINTENANCE COST= 3000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 872780 COUNTY: ADAIR DIR: W TYPE: 1 LENGTH = 8.07MILES
YEAR = 1 CRACK SEALING COST= 5000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 872790 COUNTY: ADAIR DIR: W TYPE: 1 LENGTH = 3.38MILES
YEAR = 1 CRACK SEALING COST= 5000
YEAR = 2 CRACK SEALING COST= 5000
YEAR = 3 CRACK SEALING COST= 5000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 872800 COUNTY: MADISON DIR: E TYPE: 4 LENGTH = 1.96MILES
YEAR = 1 ROUTINE MAINTENANCE COST= 3000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000

SECTION: 872810 COUNTY: MADISON DIR: W TYPE: 1 LENGTH = 1.96MILES
YEAR = 1 CRACK SEALING COST= 5000
YEAR = 2 CRACK SEALING COST= 5000
YEAR = 3 CRACK SEALING COST= 5000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 872820 COUNTY: DALLAS DIR: E TYPE: 1 LENGTH = 1.59MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 872830 COUNTY: DALLAS DIR: W TYPE: 1 LENGTH = 1.59MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 872840 COUNTY: DALLAS DIR: E TYPE: 3 LENGTH = 5.36MILES
YEAR = 1 RESURFACING 6" COST= 270000
YEAR = 2 CRACK SEALING COST= 5000
YEAR = 3 PATCHING COST= 125000
YEAR = 4 ROUTINE MAINTENANCE COST= 5000
SECTION: 872850 COUNTY: DALLAS DIR: W TYPE: 1 LENGTH = 5.36MILES
YEAR = 1 RESURFACING 6" COST= 270000
YEAR = 2 CRACK SEALING COST= 5000
YEAR = 3 PATCHING COST= 125000
YEAR = 4 ROUTINE MAINTENANCE COST= 5000
SECTION: 872860 COUNTY: DALLAS DIR: E TYPE: 2 LENGTH = 4.98MILES
YEAR = 1 RESURFACING 6" COST= 270000
YEAR = 2 CRACK SEALING COST= 5000
YEAR = 3 PATCHING COST= 125000
YEAR = 4 ROUTINE MAINTENANCE COST= 5000
SECTION: 872870 COUNTY: DALLAS DIR: W TYPE: 2 LENGTH = 4.98MILES
YEAR = 1 RESURFACING 6" COST= 270000
YEAR = 2 CRACK SEALING COST= 5000
YEAR = 3 PATCHING COST= 125000
YEAR = 4 ROUTINE MAINTENANCE COST= 5000
SECTION: 872880 COUNTY: DALLAS DIR: E TYPE: 2 LENGTH = 6.86MILES
YEAR = 1 RESURFACING 6" COST= 270000
YEAR = 2 CRACK SEALING COST= 5000
YEAR = 3 PATCHING COST= 125000
YEAR = 4 ROUTINE MAINTENANCE COST= 5000
SECTION: 872890 COUNTY: DALLAS DIR: W TYPE: 2 LENGTH = 6.86MILES
YEAR = 1 RESURFACING 6" COST= 270000
YEAR = 2 CRACK SEALING COST= 5000
YEAR = 3 PATCHING COST= 125000
YEAR = 4 ROUTINE MAINTENANCE COST= 5000
SECTION: 872900 COUNTY: DALLAS DIR: E TYPE: 2 LENGTH = 4.40MILES
YEAR = 1 RESURFACING 6" COST= 270000
YEAR = 2 CRACK SEALING COST= 5000
YEAR = 3 PATCHING COST= 125000
YEAR = 4 ROUTINE MAINTENANCE COST= 5000
SECTION: 872910 COUNTY: DALLAS DIR: W TYPE: 2 LENGTH = 4.40MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 872920 COUNTY: POLK DIR: E TYPE: 1 LENGTH = 3.64MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000

SECTION: 872930 COUNTY: POLK DIR: W TYPE: 1 LENGTH = 3.64MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 872960 COUNTY: POLK DIR: E TYPE: 1 LENGTH = 10.64MILES
YEAR = 1 RESURFACING 6" COST= 270000
YEAR = 2 CRACK SEALING COST= 5000
YEAR = 3 PATCHING COST= 125000
YEAR = 4 ROUTINE MAINTENANCE COST= 5000
SECTION: 872970 COUNTY: POLK DIR: W TYPE: 1 LENGTH = 10.64MILES
YEAR = 1 RESURFACING 6" COST= 270000
YEAR = 2 CRACK SEALING COST= 5000
YEAR = 3 PATCHING COST= 125000
YEAR = 4 ROUTINE MAINTENANCE COST= 5000
SECTION: 872980 COUNTY: POLK DIR: E TYPE: 1 LENGTH = 4.29MILES
YEAR = 1 RESURFACING 6" COST= 270000
YEAR = 2 CRACK SEALING COST= 5000
YEAR = 3 PATCHING COST= 125000
YEAR = 4 ROUTINE MAINTENANCE COST= 5000
SECTION: 872990 COUNTY: POLK DIR: W TYPE: 1 LENGTH = 4.29MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 873000 COUNTY: POLK DIR: E TYPE: 1 LENGTH = 1.64MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 873010 COUNTY: POLK DIR: W TYPE: 1 LENGTH = 1.64MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 873020 COUNTY: POLK DIR: E TYPE: 1 LENGTH = 6.14MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 873030 COUNTY: POLK DIR: W TYPE: 1 LENGTH = 6.14MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 873040 COUNTY: JASPER DIR: E TYPE: 1 LENGTH = 3.00MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 873050 COUNTY: JASPER DIR: W TYPE: 1 LENGTH = 3.00MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 873070 COUNTY: JASPER DIR: E TYPE: 1 LENGTH = 6.03MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000

SECTION: 873080 COUNTY: JASPER DIR: W TYPE: 1 LENGTH = 6.03MILES
YEAR = 1 RESURFACING 6" COST= 270000
YEAR = 2 CRACK SEALING COST= 5000
YEAR = 3 PATCHING COST= 125000
YEAR = 4 ROUTINE MAINTENANCE COST= 5000
SECTION: 873090 COUNTY: JASPER DIR: E TYPE: 1 LENGTH = 5.44MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 873100 COUNTY: JASPER DIR: W TYPE: 1 LENGTH = 5.44MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 873110 COUNTY: JASPER DIR: E TYPE: 1 LENGTH = 6.54MILES
YEAR = 1 RESURFACING 6" COST= 270000
YEAR = 2 CRACK SEALING COST= 5000
YEAR = 3 PATCHING COST= 125000
YEAR = 4 ROUTINE MAINTENANCE COST= 5000
SECTION: 873120 COUNTY: JASPER DIR: W TYPE: 1 LENGTH = 6.54MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 873130 COUNTY: JASPER DIR: E TYPE: 1 LENGTH = 3.51MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 873140 COUNTY: JASPER DIR: W TYPE: 1 LENGTH = 3.51MILES
YEAR = 1 RESURFACING 6" COST= 270000
YEAR = 2 CRACK SEALING COST= 5000
YEAR = 3 PATCHING COST= 125000
YEAR = 4 ROUTINE MAINTENANCE COST= 5000
SECTION: 873150 COUNTY: JASPER DIR: E TYPE: 4 LENGTH = 6.21MILES
YEAR = 1 ROUTINE MAINTENANCE COST= 3000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 CRACK SEALING COST= 5000
SECTION: 873160 COUNTY: JASPER DIR: W TYPE: 4 LENGTH = 6.21MILES
YEAR = 1 ROUTINE MAINTENANCE COST= 3000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 CRACK SEALING COST= 5000
SECTION: 873170 COUNTY: POWESHIEK DIR: E TYPE: 4 LENGTH = 3.13MILES
YEAR = 1 ROUTINE MAINTENANCE COST= 3000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 CRACK SEALING COST= 5000
SECTION: 873180 COUNTY: POWESHIEK DIR: W TYPE: 4 LENGTH = 3.13MILES
YEAR = 1 ROUTINE MAINTENANCE COST= 3000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 CRACK SEALING COST= 5000
SECTION: 873190 COUNTY: POWESHIEK DIR: E TYPE: 1 LENGTH = 9.17MILES
YEAR = 1 ROUTINE MAINTENANCE COST= 3000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000

SECTION: 873200 COUNTY: POWESHIEK DIR: W TYPE: 1 LENGTH = 9.17MILES
YEAR = 1 ROUTINE MAINTENANCE COST= 3000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 CRACK SEALING COST= 5000
SECTION: 873210 COUNTY: POWESHIEK DIR: E TYPE: 1 LENGTH = 4.35MILES
YEAR = 1 RESURFACING 6" COST= 270000
YEAR = 2 CRACK SEALING COST= 5000
YEAR = 3 PATCHING COST= 125000
YEAR = 4 ROUTINE MAINTENANCE COST= 5000
SECTION: 873220 COUNTY: POWESHIEK DIR: W TYPE: 1 LENGTH = 4.35MILES
YEAR = 1 RESURFACING 6" COST= 270000
YEAR = 2 CRACK SEALING COST= 5000
YEAR = 3 PATCHING COST= 125000
YEAR = 4 ROUTINE MAINTENANCE COST= 5000
SECTION: 873230 COUNTY: POWESHIEK DIR: E TYPE: 1 LENGTH = 6.23MILES
YEAR = 1 RESURFACING 6" COST= 270000
YEAR = 2 CRACK SEALING COST= 5000
YEAR = 3 PATCHING COST= 125000
YEAR = 4 ROUTINE MAINTENANCE COST= 5000
SECTION: 873240 COUNTY: POWESHIEK DIR: W TYPE: 1 LENGTH = 6.23MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 873250 COUNTY: POWESHIEK DIR: E TYPE: 1 LENGTH = 1.29MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 873260 COUNTY: POWESHIEK DIR: W TYPE: 1 LENGTH = 1.29MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 873270 COUNTY: IOWA DIR: E TYPE: 1 LENGTH = 5.04MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 873280 COUNTY: IOWA DIR: W TYPE: 1 LENGTH = 5.04MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 873290 COUNTY: IOWA DIR: E TYPE: 1 LENGTH = 4.49MILES
YEAR = 1 RESURFACING 6" COST= 270000
YEAR = 2 CRACK SEALING COST= 5000
YEAR = 3 PATCHING COST= 125000
YEAR = 4 ROUTINE MAINTENANCE COST= 5000
SECTION: 873300 COUNTY: IOWA DIR: W TYPE: 1 LENGTH = 4.49MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 873310 COUNTY: IOWA DIR: E TYPE: 1 LENGTH = 5.60MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000

SECTION: 873320 COUNTY: IOWA DIR: W TYPE: 1 LENGTH = 5.60MILES
YEAR = 1 RESURFACING 6" COST= 270000
YEAR = 2 CRACK SEALING COST= 5000
YEAR = 3 PATCHING COST= 125000
YEAR = 4 ROUTINE MAINTENANCE COST= 5000
SECTION: 873330 COUNTY: IOWA DIR: E TYPE: 1 LENGTH = 6.39MILES
YEAR = 1 RESURFACING 6" COST= 270000
YEAR = 2 CRACK SEALING COST= 5000
YEAR = 3 PATCHING COST= 125000
YEAR = 4 ROUTINE MAINTENANCE COST= 5000
SECTION: 873340 COUNTY: IOWA DIR: W TYPE: 1 LENGTH = 6.39MILES
YEAR = 1 RESURFACING 6" COST= 270000
YEAR = 2 CRACK SEALING COST= 5000
YEAR = 3 PATCHING COST= 125000
YEAR = 4 ROUTINE MAINTENANCE COST= 5000
SECTION: 873350 COUNTY: IOWA DIR: E TYPE: 4 LENGTH = 2.62MILES
YEAR = 1 CRACK SEALING COST= 5000
YEAR = 2 CRACK SEALING COST= 5000
YEAR = 3 CRACK SEALING COST= 5000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 873360 COUNTY: IOWA DIR: W TYPE: 4 LENGTH = 2.62MILES
YEAR = 1 CRACK SEALING COST= 5000
YEAR = 2 CRACK SEALING COST= 5000
YEAR = 3 CRACK SEALING COST= 5000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 873370 COUNTY: JOHNSON DIR: E TYPE: 4 LENGTH = 11.30MILES
YEAR = 1 CRACK SEALING COST= 5000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 873380 COUNTY: JOHNSON DIR: W TYPE: 4 LENGTH = 11.30MILES
YEAR = 1 RESURFACING 6" COST= 270000
YEAR = 2 CRACK SEALING COST= 5000
YEAR = 3 PATCHING COST= 125000
YEAR = 4 ROUTINE MAINTENANCE COST= 5000
SECTION: 873390 COUNTY: JOHNSON DIR: E TYPE: 1 LENGTH = 4.09MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 873400 COUNTY: JOHNSON DIR: W TYPE: 1 LENGTH = 4.09MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 873410 COUNTY: JOHNSON DIR: E TYPE: 1 LENGTH = 2.05MILES
YEAR = 1 RESURFACING 6" COST= 270000
YEAR = 2 CRACK SEALING COST= 5000
YEAR = 3 PATCHING COST= 125000
YEAR = 4 ROUTINE MAINTENANCE COST= 5000
SECTION: 873420 COUNTY: JOHNSON DIR: W TYPE: 1 LENGTH = 2.05MILES
YEAR = 1 RESURFACING 6" COST= 270000
YEAR = 2 CRACK SEALING COST= 5000
YEAR = 3 PATCHING COST= 125000
YEAR = 4 ROUTINE MAINTENANCE COST= 5000
SECTION: 873430 COUNTY: JOHNSON DIR: E TYPE: 1 LENGTH = 3.06MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000

SECTION: 873440 COUNTY: JOHNSON DIR: W TYPE: 1 LENGTH = 3.06MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 873450 COUNTY: JOHNSON DIR: E TYPE: 1 LENGTH = 4.18MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 873460 COUNTY: JOHNSON DIR: W TYPE: 1 LENGTH = 4.18MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 873470 COUNTY: CEDAR DIR: E TYPE: 1 LENGTH = 3.99MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 873480 COUNTY: CEDAR DIR: W TYPE: 1 LENGTH = 3.99MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 873490 COUNTY: CEDAR DIR: E TYPE: 4 LENGTH = 8.09MILES
YEAR = 1 CRACK SEALING COST= 5000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 873500 COUNTY: CEDAR DIR: W TYPE: 4 LENGTH = 8.09MILES
YEAR = 1 CRACK SEALING COST= 5000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 873510 COUNTY: CEDAR DIR: E TYPE: 1 LENGTH = 2.46MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 873520 COUNTY: CEDAR DIR: W TYPE: 1 LENGTH = 2.46MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 873530 COUNTY: CEDAR DIR: E TYPE: 1 LENGTH = 2.86MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 873540 COUNTY: CEDAR DIR: W TYPE: 1 LENGTH = 2.86MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 873550 COUNTY: CEDAR DIR: E TYPE: 1 LENGTH = 7.08MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000

SECTION: 873560 COUNTY: CEDAR DIR: W TYPE: 1 LENGTH = 7.08MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 873570 COUNTY: SCOTT DIR: E TYPE: 1 LENGTH = 10.92MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 873580 COUNTY: SCOTT DIR: W TYPE: 1 LENGTH = 10.92MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 873590 COUNTY: SCOTT DIR: E TYPE: 1 LENGTH = 6.55MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 873600 COUNTY: SCOTT DIR: W TYPE: 1 LENGTH = 6.55MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000
SECTION: 873610 COUNTY: SCOTT DIR: E TYPE: 1 LENGTH = .99MILES
YEAR = 1 RESURFACING 6" COST= 270000
YEAR = 2 CRACK SEALING COST= 5000
YEAR = 3 PATCHING COST= 125000
YEAR = 4 ROUTINE MAINTENANCE COST= 5000
SECTION: 873620 COUNTY: SCOTT DIR: W TYPE: 1 LENGTH = .99MILES
YEAR = 1 RESURFACING 6" COST= 270000
YEAR = 2 CRACK SEALING COST= 5000
YEAR = 3 PATCHING COST= 125000
YEAR = 4 ROUTINE MAINTENANCE COST= 5000
SECTION: 873630 COUNTY: SCOTT DIR: E TYPE: 1 LENGTH = 4.23MILES
YEAR = 1 RESURFACING 6" COST= 270000
YEAR = 2 CRACK SEALING COST= 5000
YEAR = 3 PATCHING COST= 125000
YEAR = 4 ROUTINE MAINTENANCE COST= 5000
SECTION: 873640 COUNTY: SCOTT DIR: W TYPE: 1 LENGTH = 4.23MILES
YEAR = 1 RESURFACING 6" COST= 270000
YEAR = 2 CRACK SEALING COST= 5000
YEAR = 3 PATCHING COST= 125000
YEAR = 4 ROUTINE MAINTENANCE COST= 5000
SECTION: 873650 COUNTY: SCOTT DIR: E TYPE: 1 LENGTH = 4.70MILES
YEAR = 1 RESURFACING 6" COST= 270000
YEAR = 2 CRACK SEALING COST= 5000
YEAR = 3 PATCHING COST= 125000
YEAR = 4 ROUTINE MAINTENANCE COST= 5000
SECTION: 873660 COUNTY: SCOTT DIR: W TYPE: 1 LENGTH = 4.70MILES
YEAR = 1 RESURFACING 6" COST= 270000
YEAR = 2 CRACK SEALING COST= 5000
YEAR = 3 PATCHING COST= 125000
YEAR = 4 ROUTINE MAINTENANCE COST= 5000
SECTION: 873680 COUNTY: SCOTT DIR: E TYPE: 1 LENGTH = 1.26MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000

SECTION: 873690 COUNTY: SCOTT DIR: W TYPE: 1 LENGTH = 1.26MILES
YEAR = 1 PAVEMENT REPLACEMENT COST= 1000000
YEAR = 2 ROUTINE MAINTENANCE COST= 3000
YEAR = 3 ROUTINE MAINTENANCE COST= 3000
YEAR = 4 ROUTINE MAINTENANCE COST= 3000

TOTAL COST = $299,607,000

APPENDIX 7. INTERSTATE 80 REHABILITATION HISTORY (87-92)

CONSTRUCTION AND MAINTENANCE WORK ON INTERSTATE 80 - 1987 TO 1992

OBS	LET DATE/BID ORDER	PROJECT NUMBER	WORKTYPE	COUNTY	PROJECT LIMITS FROM	TO	AWARDED AMOUNT
142	032790/063	IR-80-1(174)40--12-15	ASPH CEMENT CONC PAVEMENT	CASS	39.29	55.33	$7,962,355.48
158	050190/139	IR-80-1(174)40--12-15	ASPH CEMENT CONC PAVEMENT	CASS	39.29	55.33	$7,147,956.06
54	051088/098	IR-80-3(59)100--12-25	ASPH CEMENT CONC RESURFACING	DALLAS	100.9	106.81	$1,458,098.49
183	021291/059	IR-80-6(137)229--12-52	ASPH CEMENT CONC RESURFACING	JOHNSON	225.9	239.4	$4,290,568.50
88	122088/057	IR-80-8(127)302--12-82	ASPH CEMENT CONC RESURFACING	SCOTT	302.8	305.4	$687,725.32
153	050190/051	IN-80-2(129)86--15-01	ASPH CEMENT CONC RESURFACING	ADAIR	TO		$160,321.96
165	060590/088	IR-80-6(137)229--12-52	ASPH CEMENT CONC RESURFACING	JOHNSON	226.9	239.99	$2,360,755.06
41	022388/038	IR-80-1(168)3--12-78	ASPH CEMENT CONC RESURFACING	POTTAWATTAMIE	3.35	7.53	$1,080,705.61
148	032790/138	IR-80-6(137)229--12-52	ASPH CEMENT CONC RESURFACING	JOHNSON	226.9	239.99	$2,715,281.92
129	021390/055	IR-80-6(137)229--12-52	ASPH CEMENT CONC RESURFACING	JOHNSON	226.9	239.99	$2,695,235.42
82	083088/038	IR-80-1(170)6--12-78	ASPH CEMENT CONC RESURFACING	POTTAWATTAMIE	4.38	6.84	$1,987,060.83
15	060987/063	IR-80-3(52)99--12-25	ASPH CEMENT CONC RESURFACING	DALLAS	100.82	122.39	$1,190,776.76
154	050190/066	IR-80-3(67)99--12-25	ASPH CEMENT CONC RESURFACING	DALLAS	100.93	106.91	$716,791.11
49	032988/515	MP-80-1(3)125--76-77	ASPH CEMENT CONC RESURFACING	POLK	TO		$188,605.00
143	032790/06	4IR-80-7(58)256--12-16	ASPH CEMENT CONC RESURFACING	CEDAR	257.65	265.69	$2,717,937.74
3	033187/061	IR-80-2(114)73--12-01	ASPH CEMENT CONC RESURFACING	ADAIR	73.4	85.75	$1,782,731.99
13	050687/512	MP-80-4(1)107--76-25	BITUMINOUS SURFACING	DALLAS	TO		$150,066.25
103	040489/520	MP-80-6(2)215--76-48	BITUMINOUS SURFACING	IOWA	TO		$134,039.92
109	051689/511	MP-80-4(3)73--76-01	BITUMINOUS SURFACING	ADAIR	73.31	93.43	$19,954.44
12	050687/183	IR-80-5(113)148--12-77	BUILDING REMODEL	POLK	TO		$290,578.70
11	050687/182	IR-80-6(120)235--12-52	BUILDING REMODEL	JOHNSON	TO		$462,316.70
40	022388/028	IR-80-8(120)278--12-82	CONCRETE PAVEMENT REPAIR	SCOTT	278.09	306.74	$1,678,805.50
172	082890/037	IN-80-7(62)266--15-16	CONCRETE PAVEMENT REPAIR	CEDAR	266.1	280.58	$287,145.00
188	032691/034	IN-80-6(153)240--15-52	CONCRETE PAVEMENT REPAIR	JOHNSON	240.22	257.59	$240,765.96
141	032790/050	IN-80-8(131)278--15-82	CONCRETE PAVEMENT REPAIR	SCOTT	278.06	302.75	$132,938.48
48	032988/501	MP-80-4(2)86--76-01	CONCRETE PAVEMENT REPAIR	ADAIR	85.8	93.27	$19,617.65
151	050190/037	IN-80-5(137)152--15-50	CONCRETE PAVEMENT REPAIR	JASPER	152.88	174.4	$740,723.68
152	050190/042	IN-80-1(177)34--15-78	CONCRETE PAVEMENT REPAIR	POTTAWATTAMIE	35.15	39.23	$56,437.60
39	022388/027	IN-80-6(127)191--15-79	CONCRETE PAVEMENT REPAIR	POWESHIEK	192.91	209.82	$143,537.50
187	032691/033	IN-80-6(152)215--15-48	CONCRETE PAVEMENT REPAIR	IOWA	217.1	226.3	$226,660.50
38	022388/024	IR-80-5(123)151--12-50	CONCRETE PAVEMENT REPAIR	JASPER	151.39	174.4	$1,487,560.92
191	032691/039	IN-80-8(139)280--15-82	CONCRETE PAVEMENT REPAIR	SCOTT	280.58	306.73	$447,723.60
36	022388/018	IR-80-7(52)265--12-16	CONCRETE PAVEMENT REPAIR	CEDAR	266	278.09	$828,328.54
90	012089/039	IN-80-5(128)82--15-79	CONCRETE PAVEMENT REPAIR	POWESHIEK	183.7	192.9	$38,254.00
136	032790/038	IN-80-6(140)215--15-48	CONCRETE PAVEMENT REPAIR	IOWA	215	226	$66,658.91
241	042892/130	IM-80-2(133)73--13-01	CONCRETE PAVEMENT REPIR	ADAIR	TO		$73,115.00
242	042892/131	IM-80-8(145)278--13-82	CONCRETE PAVEMENT REPAIR	SCOTT	278.08	306.73	$370,311.00
233	032792/031	IM-80-6(166)240--13-52	CONCRETE PAVEMENT REPAIR	JOHNSON	240.22	257.59	$298,852.00
232	032792/030	IM-80-5(158)152--13-50	CONCRETE PAVEMENT REPAIR	JASPER	152.88	174.4	$138,805.00
118	080889/049	IN-80-5(135)152--15-50	CONCRETE PAVEMENT REPAIR	JASPER	152.88	174.4	$46,952.37
204	043091/051	IN-80-5(143)152--15-50	CONCRETE PAVEMENT REPAIR	JASPER	152.88	174	$155,390.50
117	080889/046	IN-80-3(65)100--15-25	CONCRETE PAVEMENT REPAIR	DALLAS	100	106	$75,929.53
205	043091/054	IN-80-5(144)183--15-79	CONCRETE PAVEMENT REPAIR	POWESHIEK	173.74	192.91	$28,696.00
110	062789/060	IN-80-6(133)204--15-48	CONCRETE PAVEMENT REPAIR	IOWA	215.1	306	$733,113.69
139	032790/047	IN-80-5(136)182--15-79	CONCRETE PAVEMENT REPAIR	POWESHIEK	TO		$36,760.66
120	080889/054	IN-80-1(176)34--15-78	CONCRETE PAVEMENT REPAIR	POTTAWATTAMIE	35	39	$34,778.75
182	021291/038	IN-80-1(185)00--15-78	CONCRETE PAVEMENT REPAIR	POTTAWATTAMIE	0	3	$76,435.00
231	032792/029	IM-80-6(165)216--13-48	CONCRETE PAVEMENT REPAIR	IOWA	215.1	226.3	$128,064.00
226	012292/078	IR-80-6(160)241--12-52	GRADE & ACC PAVEMENT	JOHNSON	239.6	240.45	$1,034,130.86
192	032691/076	IR-80-5(138)137--12-77	GRADE & ACC PAVEMENT	POLK	138.32	141.67	$1,948,525.68
71	072688/028	IR-80-2(71)78--12-01	GRADE & ACC PAVEMENT	ADAIR	TO		$663,840.14
206	043091/056	IR-80-8(140)284--12-82	GRADE & PCC PAVEMENT	SCOTT	284.35		$2,599,185.39
209	071691/122	IR-80-5(152)137--12-77	GRADE & PCC PAVEMENT	POLK	142.1		$321,781.99
119	080889/050	IR-80-7(56)246--12-52	GRADE & PCC PAVEMENT	JOHNSON	TO		$1,045,317.86
186	032691/030	IR-80-3(62)115--12-25	GRADE & PCC PAVEMENT	DALLAS	115 TO		$2,277,459.37
140	032790/048	IR-80-8(110)284--12-82	GRADE & PCC PAVEMENT	SCOTT	TO		$6,765,231.36
208	060491/063	IR-80-5(152)137--12-77	GRADE & PCC PAVEMENT	POLK	142.1		$334,628.64
121	080889/057	IR-80-8(128)284--12-82	GRADE & PCC PAVEMENT	SCOTT	TO		$585,679.50
224	012292/063	IR-80-5(132)151--12-50	GRADE & PCC PAVEMENT	JASPER	149.89	151.27	$2,758,427.64
46	032988/083	IR-80-1(162)27--12-78	GRADE & PCC PAVEMENT	POTTAWATTAMIE	27.02	28.01	$1,562,924.10
137	032790/044	IR-80-5(130)143--12-77	GRADE & PCC PAVEMENT	POLK	142.52	151.45	$7,769,360.41
83	083088/040	IR-80-2(115)79--12-01	GRADING	ADAIR	TO		$205,704.65
60	051088/528	MM-6439--69-16	MISCELLANEOUS	CEDAR	TO		$6,177.32
20	060987/120	IR-80-6(121)192--12-79	MISCELLANEOUS	POWESHIEK	192.8	209.8	$668,376.40
123	080889/502	MM-6537--69-16	MISCELLANEOUS	CEDAR	TO		$5,855.82
171	071790/098	IR-80-7(61)265--12-16	MISCELLANEOUS	CEDAR	265.53	278.47	$450,550.00
80	072688/511	MM-6437--69-48	MISCELLANEOUS	IOWA	TO		$5,215.83
63	051088/542	MM-1077--69-77	MISCELLANEOUS	POLK	TO		$14,770.80
247	090392/001	IM-80-3(64)115--13-25	MISCELLANEOUS	DALLAS	TO		$830,107.00
21	060987/122	IR-80-8(114)280--12-82	MISCELLANEOUS	SCOTT	278.09	306.74	$1,153,619.15

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OBS	LET DATE/BID ORDER	PROJECT NUMBER	WORKTYPE	COUNTY	PROJECT LIMITS FROM	TO	AWARDED AMOUNT
108	051689/107	IR-80-6(131)239--12-52	MISCELLANEOUS	JOHNSON	239 TO		$214,519.60
62	051088/537	MM-6438--69-52	MISCELLANEOUS	JOHNSON	TO		$10,135.89
102	040489/121	IR-80-7(54)257--12-16	MISCELLANEOUS	CEDAR	257.6	267.19	$425,325.74
61	051088/536	MM-6437--69-48	MISCELLANEOUS	IOWA	TO		$10,889.00
113	062789/506	MM-4336--69-15	MISCELLANEOUS	CASS	TO		$7,161.05
22	072187/505	MM-4220--69-01	MISCELLANEOUS	ADAIR	TO		$6,660.25
17	060987/114	IR-80-7(48)258--12-16	MISCELLANEOUS	CEDAR	265.76	278.06	$448,857.33
23	072187/507	MM-4219--69-15	MISCELLANEOUS	CASS	TO		$7,316.72
160	050190/538	MM-1188--69-50	MISCELLANEOUS	JASPER	151.45	192.77	$10,115.32
115	062789/523	MM-1180--69-77	MISCELLANEOUS	POLK	TO		$13,696.56
162	050190/547	MM-4343--69-78	MISCELLANEOUS	POTTAWATTAMIE	TO		$8,034.83
59	051088/527	MM-4260--69-15	MISCELLANEOUS	CASS	TO		$6,694.02
18	060987/115	IR-80-6(122)214--12-48	MISCELLANEOUS	IOWA	214.43	257.66	$451,839.13
58	051088/524	MM-4261--69-01	MISCELLANEOUS	ADAIR	TO		$4,997.85
19	060987/119	IR-80-3(50)122--12-77	MISCELLANEOUS	POLK	122.4	173.85	$1,171,544.80
24	072187/508	MM-6369--69-16	MISCELLANEOUS	CEDAR	TO		$6,177.32
64	051088/546	MM-4259--69-78	MISCELLANEOUS	POTTAWATTAMIE	TO		$9,519.90
25	072187/517	MM-6367--69-48	MISCELLANEOUS	IOWA	TO		$5,662.28
249	090392/004	IM-80-5(160)151--13-50	MISCELLANEOUS	JASPER	TO		$568,231.43
26	072187/518	MM-6368--69-52	MISCELLANEOUS	JOHNSON	TO		$10,756.46
244	060292/098	IM-80-5(162)152--13-50	MISCELLANEOUS	JASPER	151.45	174.21	$708,184.40
116	062789/526	MM-4333--69-78	MISCELLANEOUS	POTTAWATTAMIE	TO		$8,155.14
112	062789/503	MM-4331--69-01	MISCELLANEOUS	ADAIR	TO		$3,172.00
122	080889/080	IR-80-6(135)193--12-79	MISCELLANEOUS	POWESHIEK	192.79	209.7	$367,247.19
159	050190/537	MM-6543--69-48	MISCELLANEOUS	IOWA	TO		$5,226.72
211	090591/002	IR-80-3(72)115--12-25	MISCELLANEOUS	DALLAS	TO		$748,518.00
163	050190/548	MM-6545--69-82	MISCELLANEOUS	SCOTT	TO		$14,896.64
210	090591/001	IR-80-3(64)115--12-25	MISCELLANEOUS	DALLAS	TO		$1,417,770.00
167	060590/130	IR-80-6(139)240--12-52	MISCELLANEOUS	JOHNSON	247.9	257.6	$578,306.01
27	072187/523	MM-1015--69-77	MISCELLANEOUS	POLK	TO		$14,367.96
248	090392/002	IM-80-3(72)115--13-25	MISCELLANEOUS	DALLAS	TO		$566,792.90
28	072187/527	MM-4218--69-78	MISCELLANEOUS	POTTAWATTAMIE	TO		$9,705.42
114	062789/516	MM-6535--69-48	MISCELLANEOUS	IOWA	TO		$5,117.83
29	072187/528	MM-6370--69-82	MISCELLANEOUS	SCOTT	TO		$18,038.72
65	051088/547	MM-6440--69-82	MISCELLANEOUS	SCOTT	TO		$20,891.43
42	022388/052	IR-80-5(124)137--12-77	MISCELLANEOUS	POLK	137.8	151.39	$1,455,231.40
10	050687/178	IR-80-8(112)280--12-82	MISCELLANEOUS	SCOTT	TO		$177,777.30
134	030690/505	MM-1183--69-77	MISCELLANEOUS	POLK	TO		$45,456.80
161	050190/539	MM-6544--69-52	MISCELLANEOUS	JOHNSON	TO		$14,425.00
194	032691/099	IR-80-3(64)115--12-25	MISCELLANEOUS	DALLAS	115 TO		$2,570,500.00
132	021390/533	MP-80-1(5)174--76-50	PAVEMENT REPAIR	JASPER	173.85	179.12	$36,978.62
237	032792/529	MP-80-6(5)258--76-16	PAVEMENT REPAIR	CEDAR	257.64	265.76	$26,113.48
57	051088/156	IN-80-1(166)39--15-78	PAVEMENT REPAIR	POTTAWATTAMIE	39.2	60.6	$189,669.46
177	010891/503	MP-80-4(1)107--76-25	PAVEMENT REPAIR	DALLAS	106.7 T	21.6	$101,909.00
245	082592/055	IM-80-6(179)215--13-48	PAVEMENT SURFACE REPAIR (PCC)	IOWA	215.12	225.88	$356,751.70
246	082592/056	IM-80-6(180)240--13-52	PAVEMENT SURFACE REPAIR (PCC)	JOHNSON	240.22	247.88	$279,221.80
164	060590/062	IR-80-1(183)34--12-78	RECONSTRUCTION	POTTAWATTAMIE	35.09	39.16	$2,426,838.96
203	043091/046	IR-80-7(57)265--12-16	RECONSTRUCTION	CEDAR	265.71	278.47	$21,928,979.1
214	111991/051	IR-80-6(157)205--12-48	RECONSTRUCTION	IOWA	204.44	209.61	$3,596,347.09
87	111588/032	IR-80-1(169)27--12-78	RECONSTRUCTION	POTTAWATTAMIE	TO		$274,071.50
190	032691/037	IR-80-6(145)191--12-79	RECONSTRUCTION	POWESHIEK	192.77	209.61	$7,088,943.28
31	121587/041	IR-80-2(117)61--12-15	RECONSTRUCTION	CASS	59.9	73.3	$6,348,589.98
9	050687/054	IR-80-5(113)148--12-77	RECONSTRUCTION	POLK	TO		$1,265,844.43
37	022388/023	IR-80-6(126)209--12-48	RECONSTRUCTION	IOWA	209.6	215.1	$2,495,384.98
52	041988/001	IR-80-3(57)106--12-25	RECONSTRUCTION	DALLAS	106.71	122.92	$23,074,431.0
106	042589/004	IR-80-5(127)143--12-77	RECONSTRUCTION	POLK	142.52	151.45	$5,143,066.86
7	050687/038	IR-80-6(119)209--12-48	RECONSTRUCTION	IOWA	209.6	215.1	$3,710,598.27
8	050687/043	IR-80-6(120)235--12-52	RECONSTRUCTION	JOHNSON	TO		$1,224,492.38
189	032691/036	IR-80-1(178)45--12-78	RECONSTRUCTION	POTTAWATTAMIE	45.143	59.917	$6,208,978.35
225	012292/074	IR-80-1(186)43--12-78	RECONSTRUCTION	POTTAWATTAMIE	45.14	59.91	$6,737,458.34
138	032790/046	IR-80-6(136)193--12-79	RECONSTRUCTION	POWESHIEK	192.77	209.61	$9,901,261.32
47	032988/084	IR-80-1(167)34--12-78	RECONSTRUCTION	POTTAWATTAMIE	35.11	39.29	$1,927,199.77
4	033187/115	IR-80-2(108)61--12-15	RECONSTRUCTION	CASS	59.9	73.3	$6,428,947.28
173	100290/043	IR-80-2(131)99--12-25	RECONSTRUCTION	DALLAS	100.92	106.86	$3,914,412.36
201	043091/007	IR-80-7(63)265--12-16	REINFORCED CONCRETE BOX CULVERT	CEDAR	TO		$641,779.00
185	032691/005	IR-80-3(71)115--12-25	REINFORCED CONCRETE BOX CULVERT	DALLAS	TO		$136,892.83
70	072688/001	IR-80-2(71)78--12-01	STRUCTURES	ADAIR	TO		$346,946.95
2	033187/030	IR-80-6(118)197--12-79	STRUCTURES	POWESHIEK	TO		$74,690.20

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OBS LET DATE/BID ORDER	PROJECT NUMBER	WORKTYPE	COUNTY	PROJECT LIMITS FROM	TO	AWARDED AMOUNT
89 012089/011	IR-80-5(126)166--12-50	STRUCTURES	JASPER	TO		$37,645.00
243 060292/039	IM-80-1(196)2--13-78	STRUCTURES	POTTAWATTAMIE	TO		$64,573.30
6 050687/008	IR-80-6(120)235--12-52	STRUCTURES	JOHNSON	TO		$37,267.58
86 111588/015	IR-80-1(169)27--12-78	STRUCTURES	POTTAWATTAMIE	TO		$354,868.18
92 022889/021	IR-80-7(53)244--12-52	STRUCTURES	JOHNSON	TO		$131,455.00
1 033187/018	IR-80-6(117)245--12-52	STRUCTURES	JOHNSON	TO		$59,687.10
69 061488/032	IN-80-8(122)295--15-82	STRUCTURES	SCOTT	TO		$53,009.30
53 051088/027	IR-80-6(128)211--12-48	STRUCTURES	IOWA	TO		$33,759.80
105 042589/003	IR-80-5(127)143--12-77	STRUCTURES	POLK	TO		$96,196.05
45 032988/048	IR-80-1(167)34--12-78	STRUCTURES	POTTAWATTAMIE	TO		$34,576.25
135 032790/021	IR-80-5(139)143--12-77	STRUCTURES	POLK	TO		$213,680.40
44 032988/047	IR-80-1(162)27--12-78	STRUCTURES	POTTAWATTAMIE	TO		$75,196.30
81 083088/001	IR-80-2(115)79--12-01	STRUCTURES	ADAIR	TO		$293,306.30
84 101188/007	IN-80-2(122)60--15-15	STRUCTURES	CASS	TO		$21,585.00
30 100687/001	IN-80-2(123)75--15-01	STRUCTURES	ADAIR	TO		$71,069.50

<u>The Total Cost from 87-92 = $211,411,684</u>