CHAPTER 2

PAVEMENT MANAGEMENT SYSTEM

2.1. INTRODUCTION TO PAVEMENT MANAGEMENT

The ability of a pavement system to serve a society is largely a function of planning. Planning is the intersection between engineering and politics. Pavement managers respond to the needs of society by planning the growth of the pavement system within the constraints of financing, public policy, environment, and technology. The pavement manager's first responsibility is to make the best possible use of public funds. The manager must expand the pavement system to serve society's needs while maintaining the system in a safe and serviceable condition. This task would be easy if pavements did not deteriorate, but the serviceability of all pavements begins to decrease the day they are placed in service, if not sooner. Cracks and ruts form under traffic load, utility companies trench and patch across roadways, and asphalt binder becomes brittle and cracks from exposure to the environment. As the pavement deteriorates, action must be taken to restore or prevent the loss of pavement serviceability. When adequate funds are not available to meet demands, the manager must decide which needs are most important. Pavement management is an important tool in the decision process.

Pavement management is a systematic method to assess pavement condition, to identify M&R needs, and to plan pavement maintenance and rehabilitation (M&R) activities. A pavement management system (PMS) is a tool to track pavement inventory and condition, estimate future condition, determine M&R requirements and costs, and develop and prioritize M&R projects.

Figure 2.1 illustrates the typical deterioration relationship for most pavements, and highlights when different types of maintenance should be applied Preventive Maintenance includes such activities as crack sealing, rejuvenators, sealers, etc.

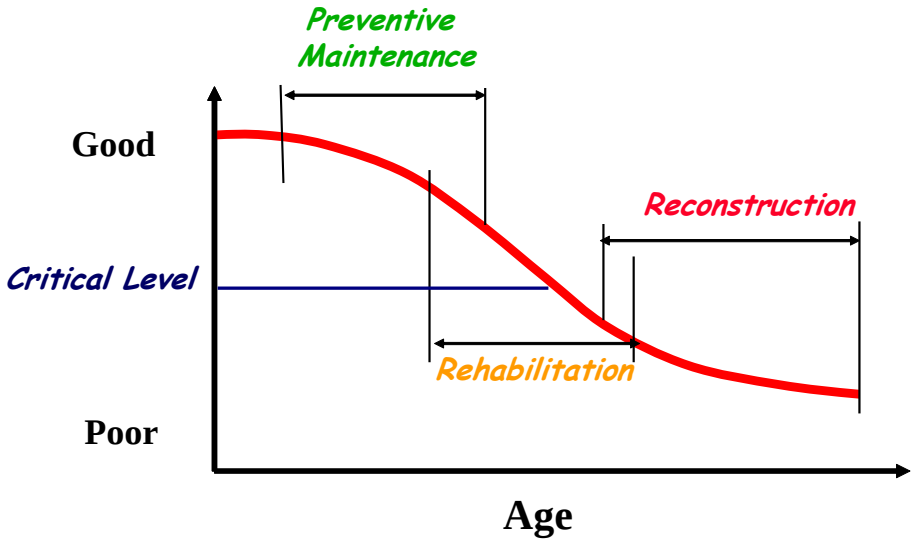

Figure 2.1. Illustration of pavement deterioration and M&R costs.

Resurfacing is selected for badly deteriorated pavements that can no longer provide service and must be replaced with a new pavement. Reconstruction typically entails the placement of large patches and/or asphalt concrete overlays. Unit costs are much lower for preventive maintenance if applied before major distress occurs as compared to rehabilitation costs for a badly deteriorated pavement.

The first step in pavement management is to determine the state of the pavement system. This is accomplished by a comprehensive inspection of all pavements in the road network. The network of pavements is first divided into logical components, such as a single street, called a *route*. Each route is then divided into pieces small enough to efficiently manage, known as *segments*. Each segment is evaluated for surface condition and assigned a level of importance. Condition evaluation requires at minimum a visual inspection (using automated digital imaging) with independent measurement of roughness, rutting, and raveling. The level of detail of the visual survey is selected to complement the other data collected during the evaluation process: a condition rating in accordance with ASTM D6433 Pavement Condition Index (PCI) survey with 38 distress types and multiple severity levels. The importance of a segment is determined by the pavement manager, and is typically a function of street use, location, traffic type, and traffic volume.

After the condition of the pavement network has been determined, the pavement manager must select treatment options that are appropriate to address the maintenance and rehabilitation (M&R) needs of the pavement system. The selection of treatment options is based on applicability, availability, and cost of treatments that have been proven effective in field tests along Nashville streets. Treatments should address or prevent deficiencies in the pavement without causing additional problems. A treatment that requires materials or skills not readily available should not be selected. The total cost of a treatment process throughout its life cycle should be considered, because often a treatment with a low initial cost will not have the greatest cost-to-benefit ratio. Once the treatment options have been selected, the guidelines for use and application of each option must be established. The combination of treatment options and guidelines for selecting the appropriate option for a project are collectively known as a *maintenance policy*.

By standardizing the available treatments and the treatment selection process, a maintenance policy allows reasonably accurate estimation of maintenance needs several years into the future based on current pavement conditions. The estimated M&R needs can be used to develop paving plans and M&R projects. Historical and bid cost data can be used to calculate the cost of the required M&R projects, which is then compared to anticipated budget levels to determine the most effective way to allocate funding. PMS cost data can also provide support for additional funding requests, and justify planned or previous expenditures.

2.2. PMS SOFTWARE SELECTION PROCESS

PMS software packages vary in scope, sophistication, ease-of-use, and capability, and no one package will satisfy the needs of the many different state and local PMS users. The proper software must be chosen, or the PMS will fall into disuse.

Metro Paving Department personnel evaluated several candidate software packages before selecting PMS software for use. Most of the software programs selected as candidates by Metro were listed in the Pavement Management Catalog produced by the U.S. Department of Transportation and Federal Highway Administration Office of Asset Management. Other

software programs evaluated were chosen based on their presence in the pavement management industry.

The software selection approach taken by Metro was to define the major components of PMS software and then determine the needs of Metro with respect to each component. Rating forms and criteria were developed prior to reviewing the candidate software packages. Each component of each candidate package was then rated on a scale of 1 (low) to 10 (high) against Metro's needs. Each software package was scored in the following 24 areas based on the criteria listed below.

- **Segment Identification Scheme:** *Ease of use, flexibility, ability to fit in with other systems.*

  The method used to identify a particular pavement segment should be easy to understand. Data about the route name, roadway location from segment start to segment end, address, and block-to-block segments should be readily accessible.

- **Segmentation:** *Adequate segment descriptors, dynamic segmentation.*

  The method used by the software to divide the pavement network into manageable segments should be logical and easy to follow. The segmentation method should complement the segment identification scheme.

- **Pavement Data:** *Supports pavement data with ease and flexibility.*

  The program should store physical pavement inventory data from the field such as geometrics, construction date, layer thickness, layer properties, and subgrade.

- **Pavement Condition:** *Supports pavement condition data with ease and flexibility.*

  The software should provide tools to manage and report pavement condition data such as distress, roughness, and rutting, and to correlate the data into pavement condition indices for reporting the overall condition of the roadway.

- **History:** *Supports pavement construction and condition history.*

  The program should store, manage, and analyze a wide range of historical data needed to produce future rehabilitation and maintenance projects.

- **Other Inventory:** *Ability to support other roadway assets in the PMS.*

  The program should store, manage, and analyze other right-of-way assets (sidewalks, utilities, etc.) in conjunction with pavement data, or integrate with software for managing other assets.

- **Flexibility:** *Allows the user to make changes in screens, reports, fields, and indices.*

  The software allows the user to customize the input, analysis, output, and presentation systems. The more flexible a system is, the less training and the fewer changes in current pavement management procedures need to occur.

- **Distress Analysis:** *Process used to calculate surface distress index.*

  The software should have the ability to calculate the selected condition index from distress data.

- **Condition Modeling Tools:** *Mathematical model used to predict future road condition.*

  The system should allow the user to easily estimate future pavement condition based on historical pavement condition data.

- **Treatment Selection:** *The right treatment at the right place at the right time.*

  The software should select the right preventive maintenance or rehabilitation treatment based on the condition of the road is critical to a successful pavement management system. The treatment selection system must also be easy for Metro to understand and change.

- **Prioritization:** *Prioritize a maintenance & rehabilitation schedule.*

  The software requires the ability to take pavement condition data of the roadway network and generate an M&R list based on other variables within the pavement management system such as functional class, planned utility projects, etc.

- **Economics:** *Budget analysis.*

  The software must simulate various budget scenarios, estimating future pavement condition of the network based on current pavement condition and various funding levels. Like treatment selection, the budgets in the software must be easy to understand and change.

- **Reports:** *Software is flexible enough to generate various types of reports.*

  The software should allow the end user to easily generate custom reports using tools similar to existing products (MS Access, Crystal Reports, etc.)

- **Graphs:** *Software is flexible enough to generate various types of graphs.*

  The software should have the ability to produce various types of charts and graphs. The software should allow the end user to create or modify custom graphs.

- **GIS:** *Software supports a "live link" to update and view pavement data through a GIS.*

  The software should be designed to easily work with GIS software applications. Data from the system can be used to automatically update GIS maps at the agency. Two-way data sharing at the database level is the preferred method of GIS interaction.

- **Web:** *The ability to report data and access data through the web.*

  The software should be designed to allow data access and reporting through a Web based application.

- **Interaction with other software:** *The ability to interact with other software applications.*

  The software should use an open data standard to allow data sharing with current and future Metro applications.

- **Data:** *Supports the inclusion of various types of data in the system easily.*

The software supports and manages other data elements such as images, GPS, traffic and other data issues within the pavement management system.

- **Network:** *Operates on the network with ease and flexibility.*

  The software requires capability to operate in a network environment with ease and flexibility. The software should support multiple simultaneous users.

- **Security:** *Data must be safe from malicious or accidental corruption.*

  The software requires capability to serve several users and still provide data protection. The software should support user-, field-, and record-level locking to allow interaction with non Paving Department employees.

- **Ease of use:** *Software is easy to use.*

  Users should be able to update and query the system with a minimum of difficulty.

- **Ease of training:** *Software is easy to learn to use.*

  New users should be able to use the software after a minimal training period.

- **Cost:** *Software cost must be reasonably priced.*

  The software cost should be competitive, and allow for per-seat and expandable licenses.

2.3. REVIEW OF CANDIDATE PMS SOFTWARE

Interviews were conducted with PMS software providers to review and evaluate candidate pavement management systems for the Metro Nashville and Davidson County Long Range Strategic Paving Plan. Many candidate systems were rejected early in the process for reasons of cost or scope. Systems with a software cost of more than $50,000 were rejected. Other packages were rejected because the vendor required the client to purchase pavement management services in order to receive the (often proprietary) software. Still other packages were rejected as insufficient for the size and scope of the Metro road network. Once all of the candidate PMS providers were evaluated, CartêGraph's Pavement View Plus was selected for implementation at Nashville and Davidson County. Items such as ease of use, learning curve, and cost were key factors.

2.4. CARTÊGRAPH PAVEMENTVIEW PLUS

PAVEMENTview Plus is divided into two modules. The "Segments" module contains inventory data for the network, including current conditions and physical attribute data. The other module, "Segment Analysis Models", contains the analysis routines and information required to produce a paving plan for Metro's pavement network.

Both modules allow users to create custom forms, or data access screens. For example, the default inventory form has several fields (data items, such as pavement type or street name) but can be modified to omit fields that are not needed or to add new fields. This form has been modified to display only the information of interest to Metro Paving and added fields to the inventory database to store total route lengths and a flag (yes or no) for routes where state funds are used in maintenance. The network inventory forms have been modified to display the digital

images used in distress data collection. Multiple forms may be open at the same time in the software.

The entire system was linked to Metro's Geographic Information System (GIS) using CartêGraph's MAPdirector for ArcGIS software. Because the data from the system is stored in the Microsoft SQL Server database operated by Metro's IT department, it is also possible to get information directly from the database for use in the GIS or other related applications. Using SQL Server to store the PMS data also improves the integrity of the system and insures that the data is backed up appropriately in the processes used by the IT department.

The process of customizing PAVEMENTview Plus for Metro Public works consisted of four parts:

- *Schema* modification (a schema is the definition of the fields in the database and how they are related to each other) – This process involves deciding which fields to add to the PAVEMENTview database.
- Form modification – the creation of appropriate forms that make the data easy to get to and read while still showing all the required information in a minimum of space.
- Data modification – adding the required data to the pick lists (drop-down menus) in the inventory and the parameters of the pavement management engine.
- Report modification – adding and editing the default reports provided with the software to retrieve the required information from the system in a printable format. This includes creating custom charts.

Each part of the process is described in more detail below.

2.4.1. Schema Modification

Only a few data fields were added to the software to accommodate the data that was either available in the systems currently maintained by Metro or collected as a part of this effort. Most data could be accommodated by existing fields in PAVEMENTview Plus. Fields and record-sets had to be added to store the links to the photographs collected during the survey. There are four additional record-sets, one for each camera on the digital survey vehicle (forward, sign, rear, and downward). Each record-set contains fields for the name of the file (digital picture) and station recorded by the survey vehicle's DMI. All of these record-sets were added under the root record-set for inventories: Segments.

Several fields were also added to the Segments record-set itself:

- Is State Aid – a yes or no field that marks a road as eligible for state assistance when improvements are performed. These streets are still maintained by Metro. This information was obtained from Metro's GIS system.
- Paving Group – A list of districts for each paving group was stored in the Zone field (a default PAVEMENTview field), and a new field was created to store the paving group data. The new field is a text field as opposed to a numerical field to allow expansion of the system.
- Sequence ID – A numeric field used to put the segments of a route in order when viewing pictures or browsing the database.

A length field was also added to the Route record-set that, like Segments, is a root record-set. This length field stores the total length of all the segments on a route as provided by the GIS. This field should not be confused with the length field under the Segments record-set. The latter is a measurement of the length of an individual segment.

2.4.2. Form Modifications

Default forms were used whenever possible. Figure 2.2 shows the modified Segment Information screen from the CartêGraph PMS software. This is the most commonly used form in the PMS. Segment identification elements including route name, segment start, segment end, start address, end address, route length, and pavement length and width are found here. Also displayed are the current condition and the latest survey image of the current segment. This form is also used to access other forms showing construction history, distress details, and other camera views.

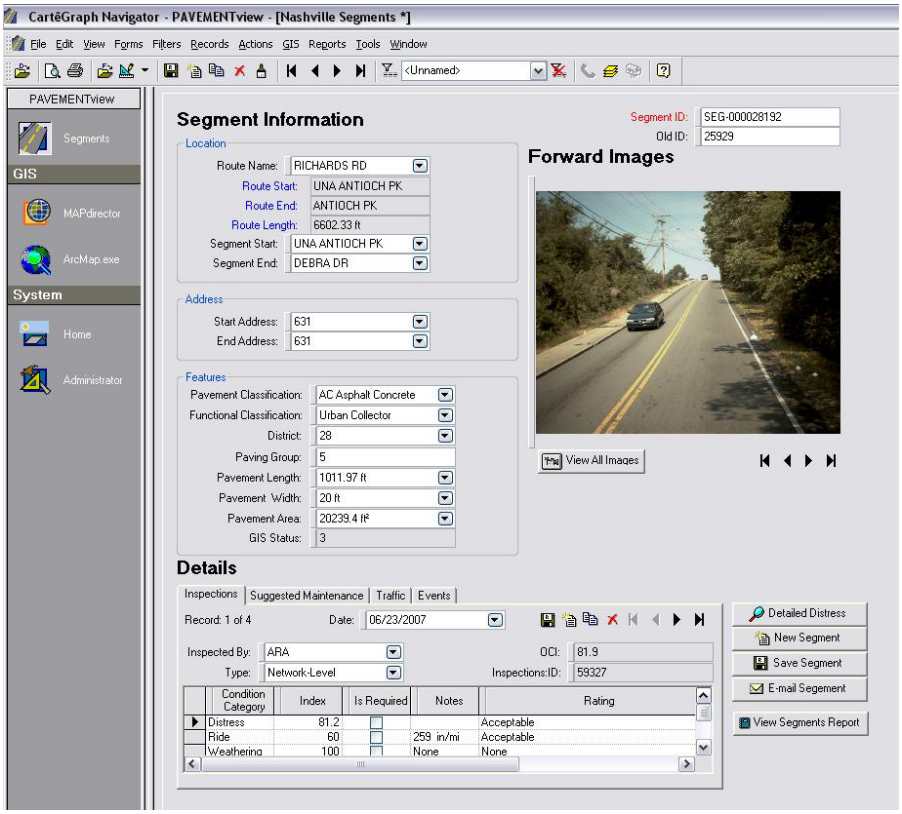

Figure 2.2. Example of pavement Segment data with forward view roadway image.

Figure 2.3 shows the distress detail form, accessed from the "Detailed Distresses" button of the main form. This form is used to review, modify, and update distress inspection data. These distresses are then used to calculate the distress condition index, discussed in Chapter 3. A reference area, showing a typical photo and standards for identifying each distress, is included on this form.

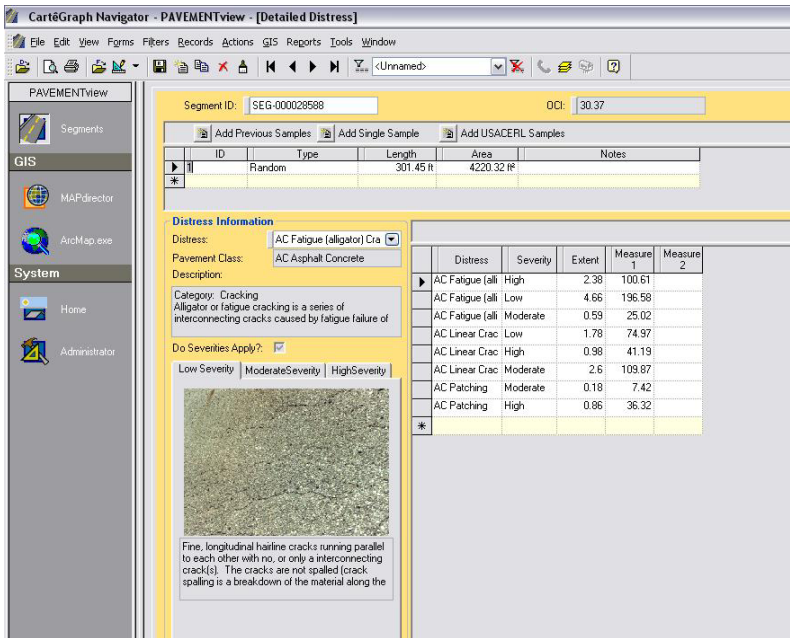

Figure 2.3. Example of distress data and associated digital images

Construction history information is accessed from the "Events" tab of the main form, as shown in Figure 2.4. Information about M&R performed on this segment of roadway is displayed in place of the condition information. The road shown in the figure received a mill and 1.5-inch asphalt overlay in June of 2005.

Figure 2.5 shows the analysis screen, where the parameters are combined to create a work plan. When analyzed together, the combination of parameters generate a specific work plan and future condition assessment of the network. This is the work engine of the pavement management system

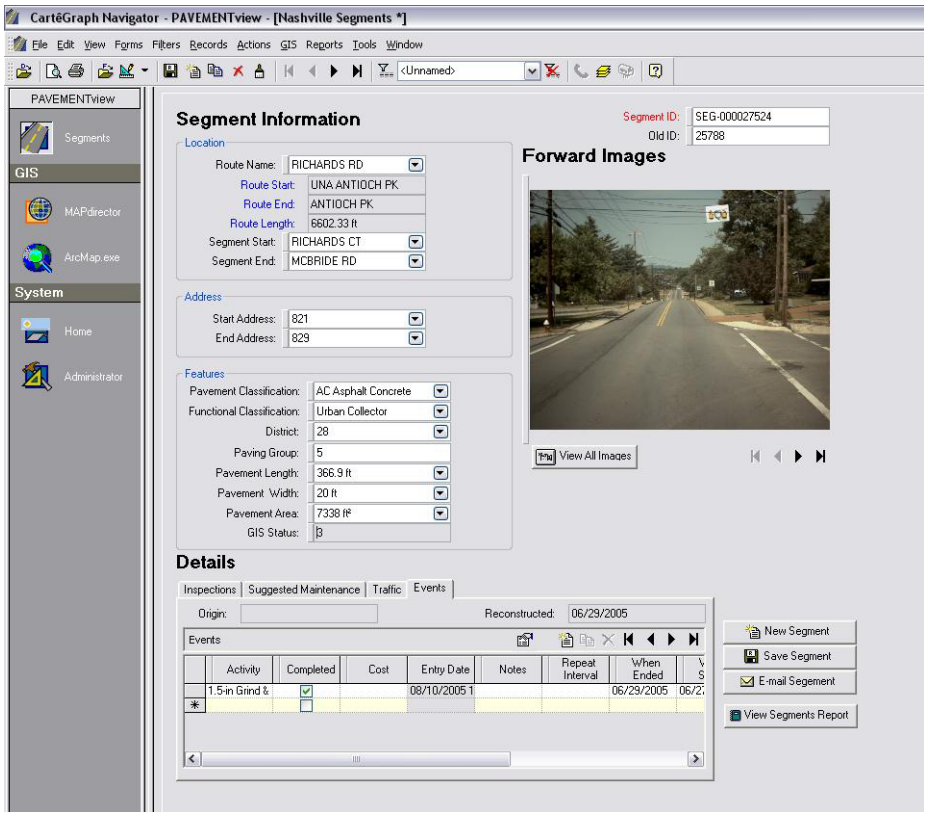

Figure 2.4. Example screen showing construction.

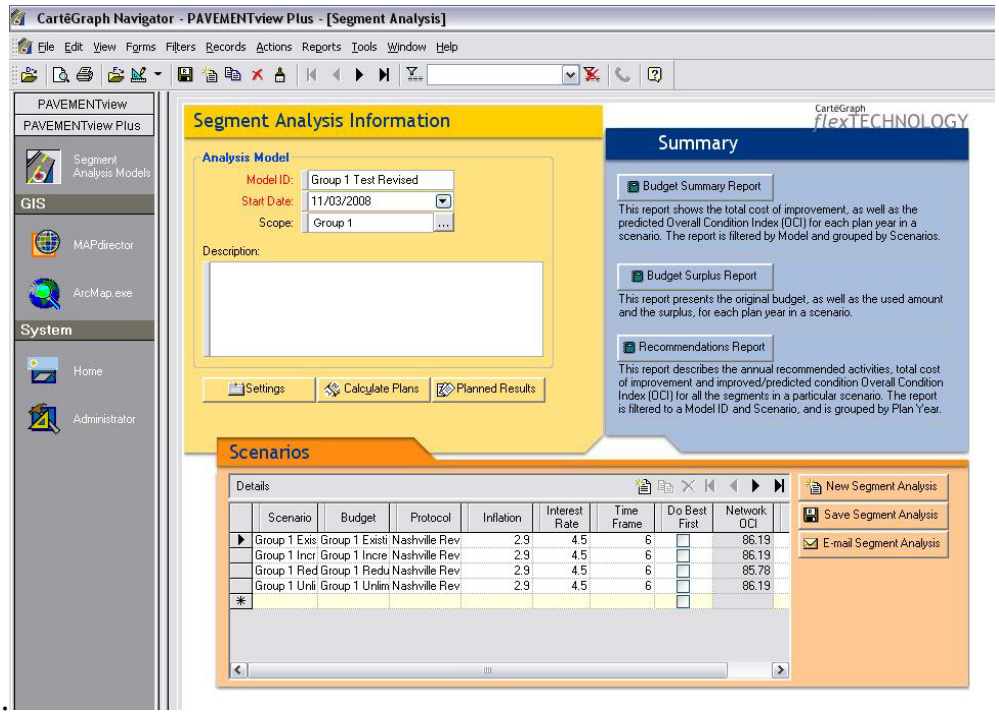

Figure 2.5. Segment Analysis screen used to generate work plans.

2.4.3. Data Modification

The data modification in the inventory module consisted primarily of modifying pick lists (drop-down menus) with the choices specified by Metro. For example, the pick list for "Jurisdiction" was modified to include "Metro Nashville", "Private", "State Highway", and "Unknown". Changes were also made to the condition calculation factors, discussed in Chapter 3.

The pavement management analysis module customizations were, by necessity, more complicated since they did not involve simply storing data. Due to the complexity, Chapters 3 and 4 are devoted to discussing the modifications to the pavement management analysis module. Chapter 3 discusses condition data and how the software stores and handles it. Chapter 4 is the decision making process used by the software to generate work plans. The "Settings" form shown in Figure 2.6 is where the various parameters required to generate these work plans are configured.

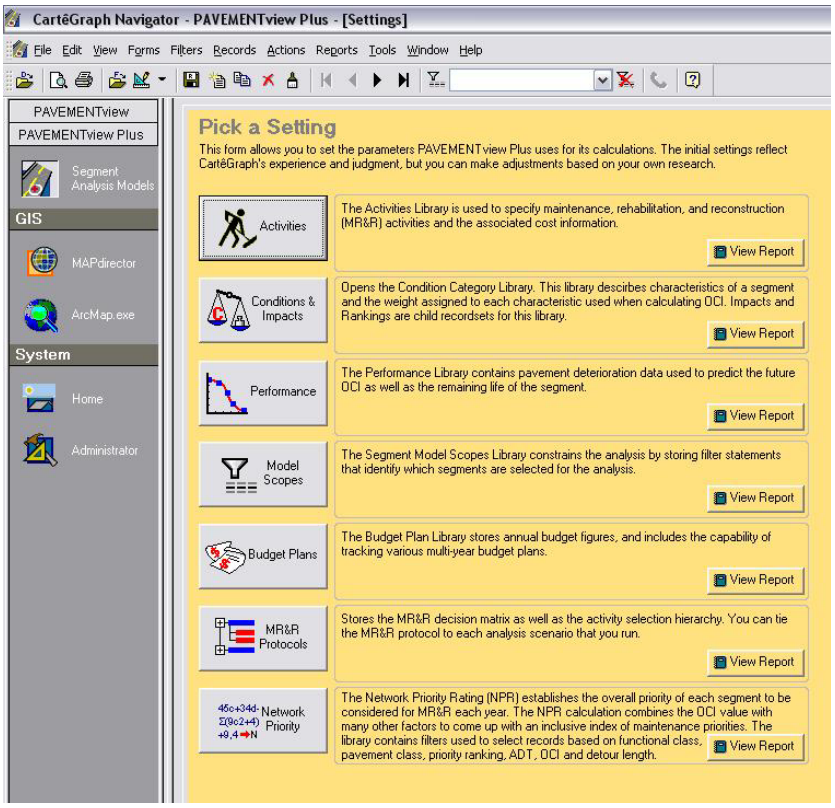

Figure 2.6. Pavement analysis settings form.

The parameters that can be customized from the "Settings" form are:

- Activities – A list of the maintenance, rehabilitation, and reconstruction (MR&R) activities used by Metro and the associated cost information as shown in Figure 2.7.
- MR&R Impact – The effects of performing an activity in a particular segment as shown in Figure 2.8. For example, reconstruction using HMA sets the PCI (Distress) rating to 100 and the Ride index to 100. On the other hand, a crack seal improves distress and ride by 10%. Also used to define the overall condition index (OCI).

- Model Scopes – Creates filters to limit the type of roadway for analysis. Roads may be included or excluded by any parameter found in the pavement inventory such as, state aid routes, routes maintained by other agencies, functional classifications, etc.
- Budget Plans – The list of different budgets that could be used for pavement rehabilitation as shown in Figure 2.9. Note that within each budget different money sources can exist. In Metro's case, there would be at least two different categories of funds: those used for state aid roads and others from the general fund.
- MR&R Protocol – The set of criteria that determines the treatment selection process as shown in Figure 2.10. This setting provides access to the MR&R decision matrix and the activity selection hierarchy.

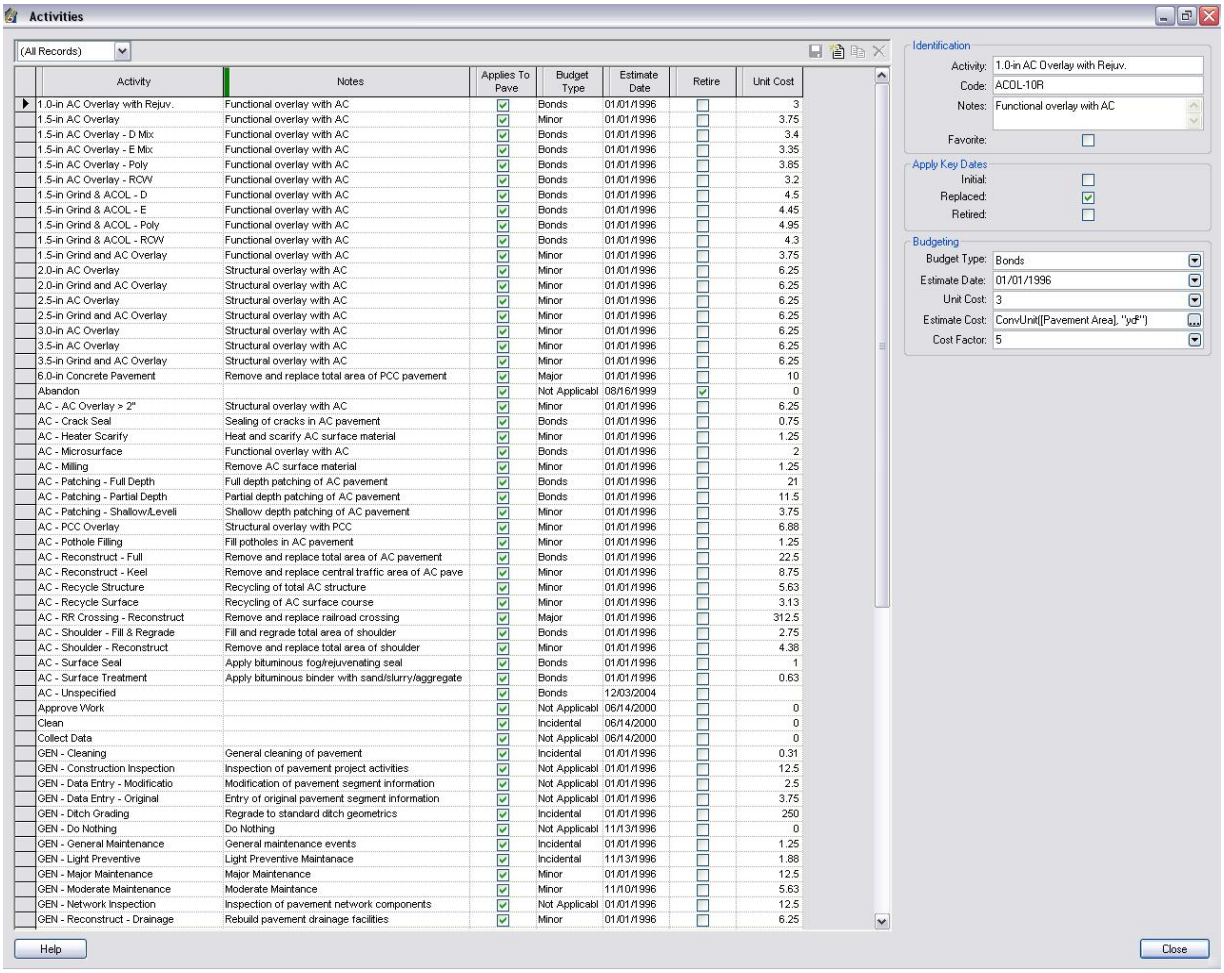

Figure 2.7. M&R activity set-up and costs.

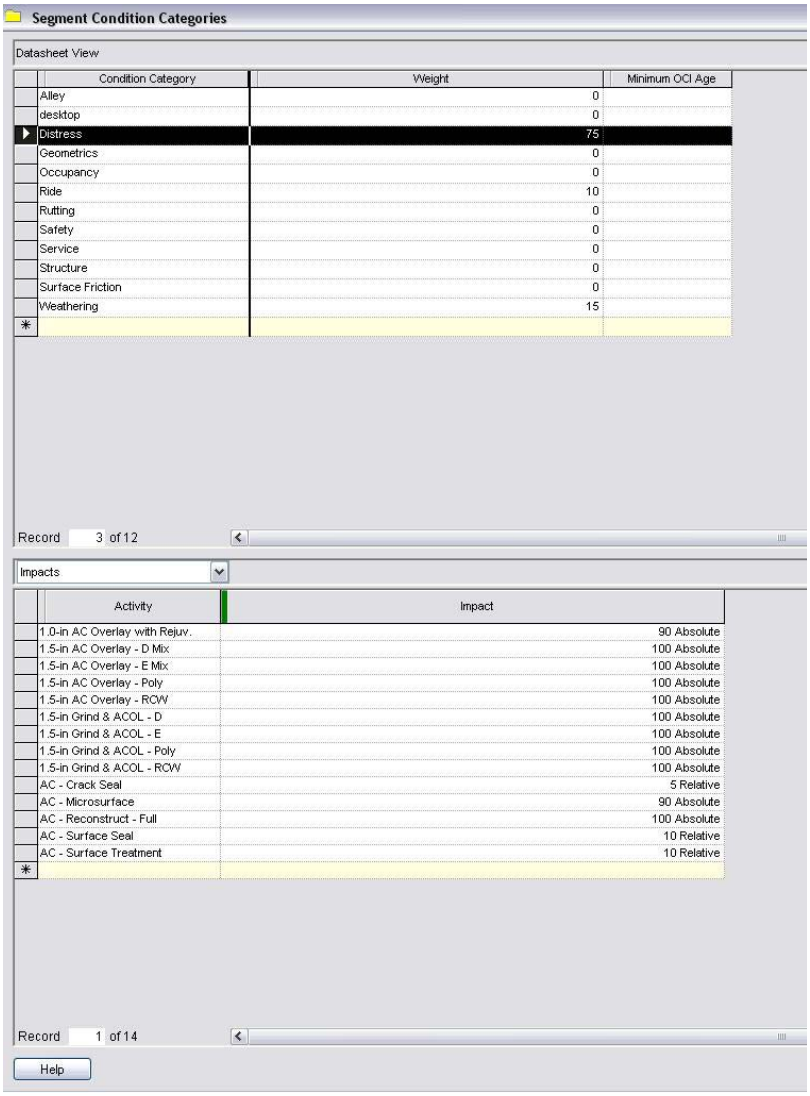

Figure 2.8. MR&R impact definition.

Figure 2.9. Typical budget setup.

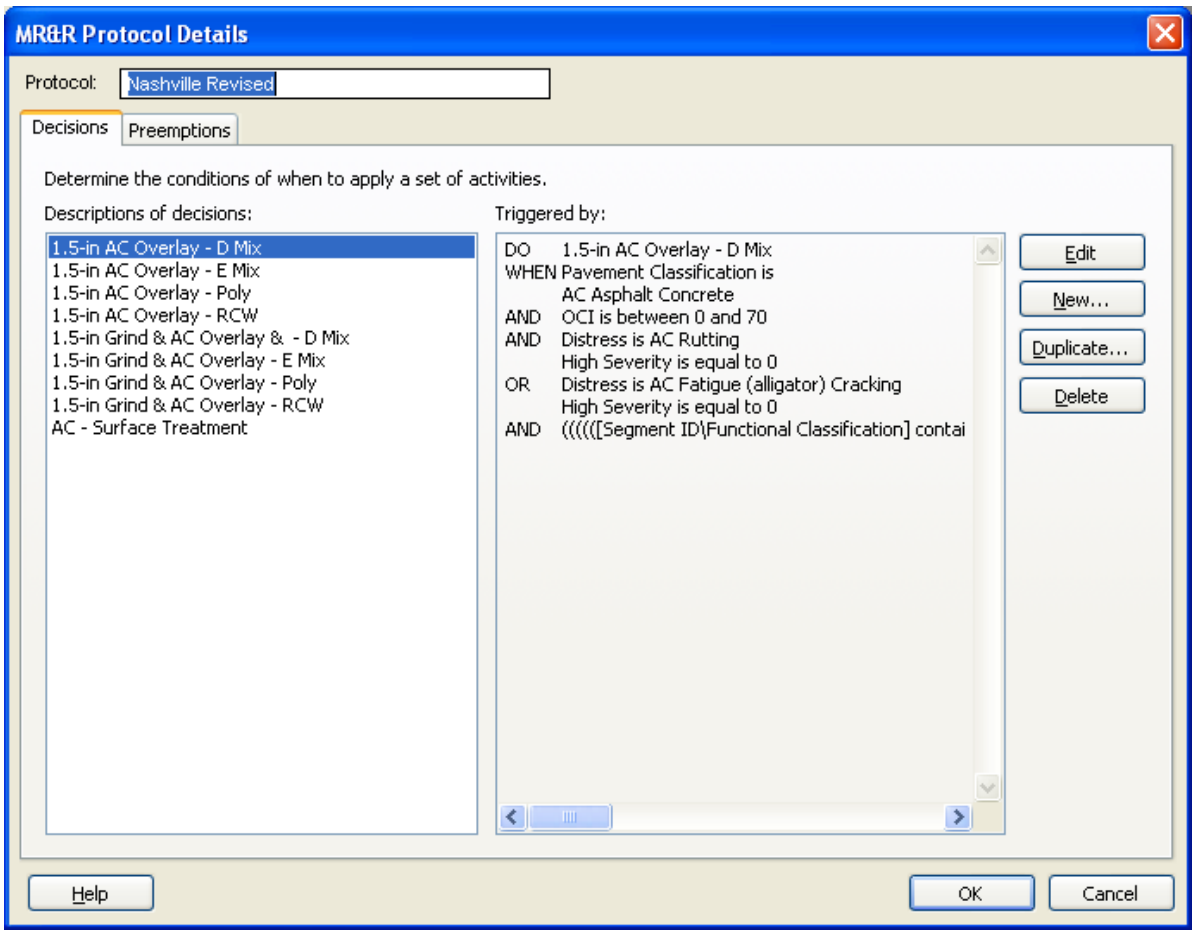

Figure 2.10. MR&R protocol definition.

- NPR Calculations – The equations used to rank streets in order of need using a prioritization analysis as shown in Figure 2.11. The Network Priority Rating (NPR) establishes the overall priority of each segment to be considered for MR&R each year. The NPR calculation combines the overall condition value with many other factors to come up with the inclusive index of maintenance priorities.

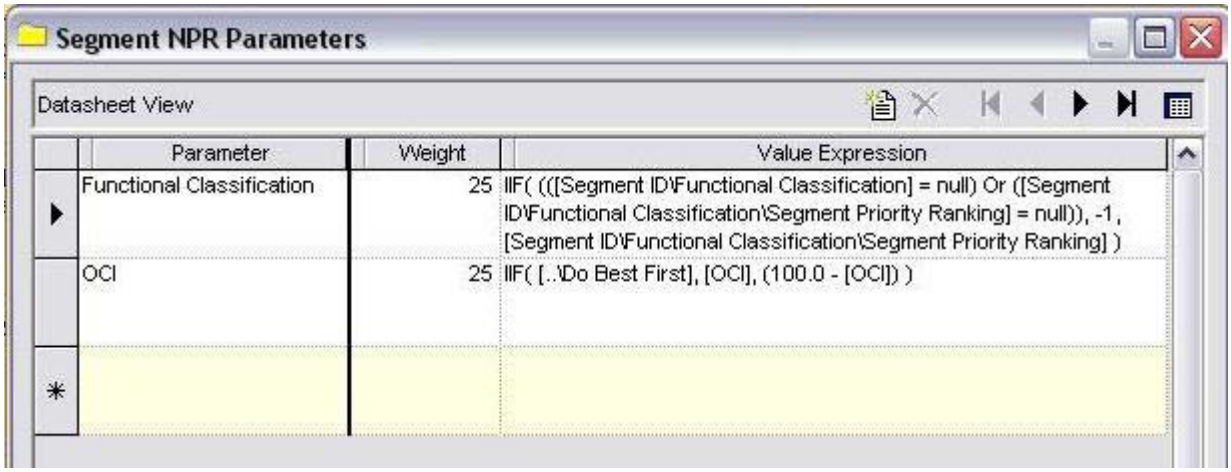

Figure 2.11. Typical NPR parameters in Metro PMS software.

- Performance – The age-versus-condition curves used to estimate the future condition of a pavement segment. Given a known current condition, the future condition can be determined by estimating the apparent age of the segment (note that this is different than the actual age) and then determining the condition for future years based on this. Performance curves can be accessed from either the inventory or management modules, but they are mainly used in the management module for the Metro Nashville implementation. Figure 2.12 shows a typical performance curve.

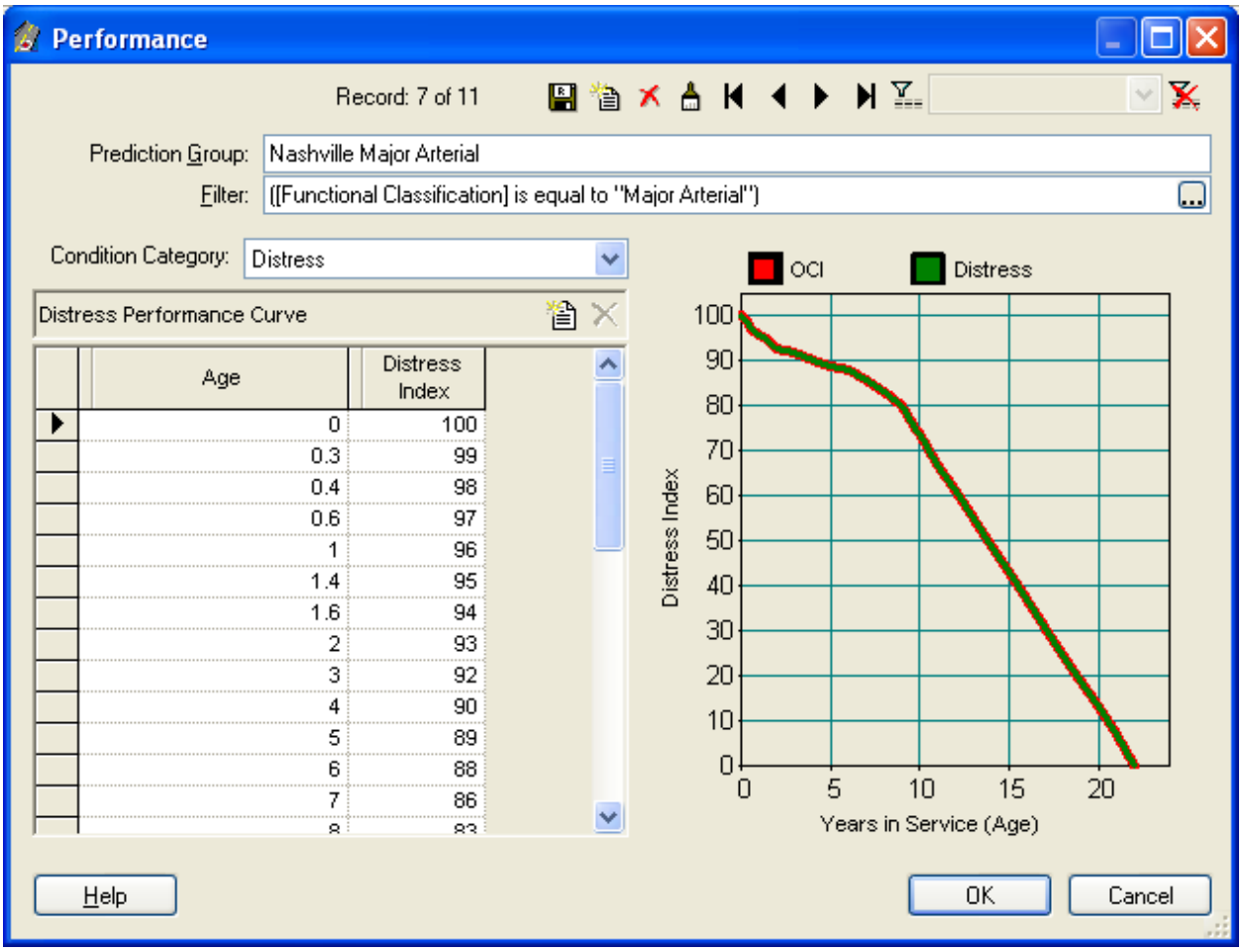

Figure 2.12. Typical CartêGraph deterioration curve.

2.4.4. Report Modification

The final part of the pavement management software that was customized was the report module. It was changed to match some of the existing reports in Metro's PavePro software and/or to address paving plan requirements. Two reports were created that list current condition (OCI) grouped into both district and paving group. ARA also modified a chart report to display the percentage of pavement (by area) within a certain condition category (excellent, good, fair, or poor). These data are displayed as a pie chart.