Integration of Ramps with Pavement Management System Mainline Network Database

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ABSTRACT

Ramps constitute an integral part of an agency highway network. Not only they provide access to the mainline highway network, but also some may be of sufficient length to be treated as a highway segment. However, the importance of ramps has not been widely recognized and addressed within the pavement management system (PMS). Ramps can deteriorate faster than mainline routes resulting in discomfort to the motorists. The New Jersey Department of Transportation (NJDOT) is responsible for the maintenance, rehabilitation, and reconstruction of more than 4000 ramp segments in their state highway system. In order to define the need for maintenance and rehabilitation (M&R) work, plan implementation in a timely fashion, and to establish annual budgets, NJDOT added their ramp network to the PMS in 1995. For this purpose, a PMS component to compile and analyze the ramp data was developed. Once the survey was complete, the data was loaded to the PMS. In 2001, NJDOT initiated development of a second generation of the PMS that included further ramp studies. Another ramp distress data collection cycle was initiated in 2002 and will be completed in 2003, which will follow the 1995 ramp survey approach.

This paper details a novel approach on the integration of ramps with the existing mainline network database that resulted from eight years of PMS development and enhancement efforts. The paper reports the scope and methodology for the ramp survey and analysis, development of ramp identification system, a condition-rating procedure for field-testing of ramp network, QA/QC procedure, loading procedure of the ramp data to the PMS and a ramp M&R and optimization analysis. The integration of ramps within the PMS mainline network database provides the ramp's condition and needs summaries after performing the M&R analysis. The analytical capabilities of the PMS are utilized for the management of ramps after performing several budget scenarios. Integrating ramp inventory and condition rating data with the PMS mainline network can lead to an effective ramp M&R decision-making.

1.0 INTRODUCTION

The accumulated investment of public funds expended to construct and maintain a pavement network generally amounts to a substantial figure. A pavement network is therefore a valuable asset to the population that it serves, and it should be managed such that the value of the asset is maintained at an optimal level over the long term. In this regard, experience has shown that, over time it is less expensive to invest in timely preventative maintenance and/or rehabilitation rather than in reconstruction on a sporadic basis. Ramps constitute an essential part of an agency highway network. Not only they provide access to the mainline highway network, some may be of sufficient length to be treated as a highway segment. Ramps can deteriorate faster than mainline routes resulting in discomfort to the public. Poor roads cost American motorists billion of dollars in wasted fuel, added tire wear and extra vehicle repair [1]. In order to implement preventative maintenance and/or rehabilitation for a ramp network, information concerning the condition of the network, its rate of deterioration, and the impact of rehabilitation efforts on its serviceability levels is required. It is therefore necessary to monitor the performance of each section of the ramp network on an ongoing basis. A PMS is a set of tools or methods that assists decision makers in finding optimum strategies for providing and maintaining pavements in a serviceable condition over a given period of time [2]. However, the importance of ramps has not been widely recognized and addressed within the PMS.

This paper describes the integration of ramps with the existing mainline network database that resulted from eight years of PMS development and enhancement efforts. The paper reports on the scope and approach for the ramp survey and analysis, development of ramp identification system, a condition-rating procedure for field testing of ramp network, QA/QC procedure, loading procedure of the ramp data to the PMS and a ramp Maintenance and Rehabilitation (M&R) and optimization analysis. Such network level ramp management system will take time to achieve full implementation and benefits in terms of improved overall ramp condition, reduced maintenance costs, user cost savings, etc. and which may not be realized for several years. Such benefits fall into the category of improved decision-making.

2.0 BACKGROUND

In 1980, New Jersey Department of Transportation (NJDOT) started the development of a PMS that addressed the ride quality, surface distress, rutting, and skid resistance of the 3,680 centerline Kilometers (2,300 centerline miles) of roadway. With the passage of the Intermodal Surface Transportation Efficiency Act (ISTEA), NJDOT had to expand its PMS to cover the entire Federal Aid System and to include additional analytical capabilities that would help the department to more cost-effectively manage its pavements. In 1994 a PMS enhancement project (NJDOT PMS-I) was initiated and a needs determination task was undertaken. The enhancements identified in the needs determination task were grouped into four major categories: PMS coverage, in terms of highway network components; PMS data collection and management, PMS analytical components; and access to PMS and its Interfaces with other systems [3].

An enhanced PMS that meets the agency requirements was developed. Several engineering models and economic analysis were implemented in the developed PMS. Some of these models were specifically developed for New Jersey, while others were calibrated to suit New Jersey conditions. Also, significant enhancements were made to the PMS analytical capabilities. The enhanced PMS is capable of running network level optimization analysis, which allows the user to select the most cost-effective, multi-year rehabilitation program for a specified budget or performance levels. Also, it is capable of running project level optimization analysis, which allows the user to compare different design alternatives and select the optimum one. The enhanced PMS has the following subsystems: Database Management, Network Analysis, Engineering Feedback and Project Design & Analysis [4].

NJDOT is responsible for the maintenance, rehabilitation and reconstruction of a ramp network estimated to be more than 4000 ramps. In order to define the need for this work, plan its implementation in a timely fashion and establish annual budgets to finance completion of the work, NJDOT in 1995 decided to add the ramps to the enhanced PMS. In order to implement this component, a basic inventory of the ramps and their condition was required. As a first step in this task the ramp network was sectioned by the individual segments of the ramp, and ramp identities were defined so that the ramps could be integrated with NJDOT's mainline network database. Subsequently field ramp condition survey was performed and the results loaded to the PMS [4]. In 2001, NJDOT initiated the PMS-II project, which involved continued operation, development and enhancement of the PMS. One of the main tasks of the project was to review and update the ramp inventory and conduct an updated manual field survey of the New Jersey ramp network. This data collection task will be completed in 2003.

3.0 SCOPE AND METHODOLOGY OF THE RAMP SURVEY AND ANALYSIS

The scope of the ramp survey described in this paper includes all ramps maintained by NJDOT that are approximately 4000. The ramps that were included in the survey were:

1. Ramps entering or leaving a state owned route and connecting with a state owned route or lower route in the hierarchy.
2. Left-hand turn lanes, that are separated from the mainline by a physical barrier
3. Jughandles
4. State owned rest areas
5. Acceleration and deceleration lanes

This survey did not include ramps that were less than 25 feet in length

Figure 1 shows the overall approach used to integrate the ramps into the PMS. The first step of the approach was to define the ramp network and develop unique ramp identification numbers. The following step in the approach was to develop a data base that included both the field data (i.e.; inventory and condition rating) and office inventory data. After creating the ramp data base in the PMS, the M&R analysis was performed. In this analysis, the M&R needs were estimated and the feasible M&R treatments for each ramp in need were determined. Having performed the M&R analysis, the PMS budgeting optimization module was used to develop a prioritized M&R program for the next five years.

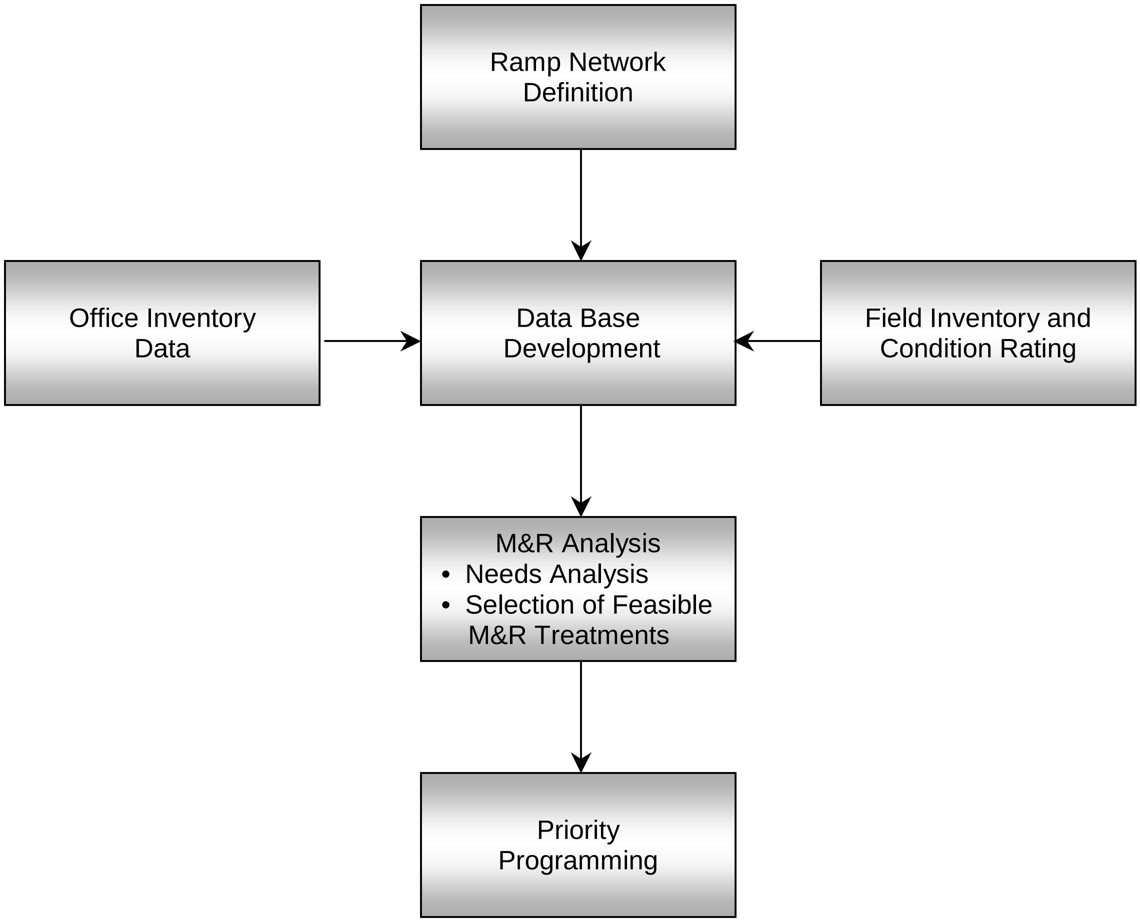


Figure 1: Ramp Survey and Analysis Framework

4.0 DEVELOPMENT OF RAMP IDENTIFICATION AND NAMING PROTOCOL

In this activity, a unique ramp identification convention was developed as shown in Figure 2 [4] and explained in detail in the following sub-section. The ramp identifier was used to uniquely and effectively identify individual ramps.

X X X X X X X X X X	**X**	**X**	**X X X X X**
SRI	Ramp Description	Multiple Ramps	Mainline M.P. Reference

Figure 2: Ramp Identification and Naming Protocol

The naming convention was based on NJDOT's Standard Route Identifier (SRI) procedure defined by the Transportation Data Development Bureau and represented in Figure 3.

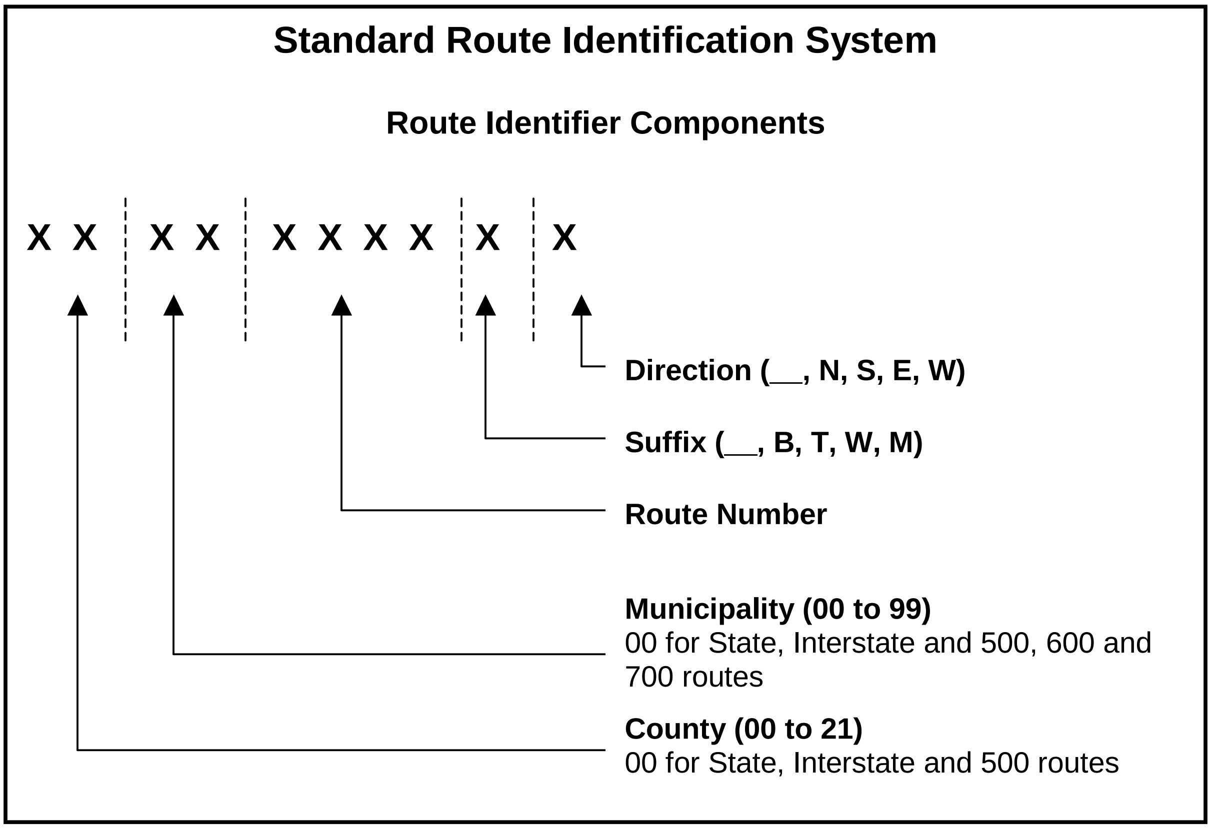


Figure 3: NJDOT Standard Route Identification (SRI) System

4.1 Standard Route Identifier

The ramp information was attached to the predominate route. The first ten characters represent the predominant route Standard Route Identifier (SRI) number already defined. The NJDOT PMS defines the routes within the mainline network database as Interstate (I), New Jersey (NJ), United State (US), Toll Authority (TA), County (CO) and Local / Municipal (LO) routes.

The following is the SRI route hierarchy.

1. Interstate routes have priority over U.S. numbered routes.
2. U.S. numbered routes has priority over New Jersey numbered routes.
3. New Jersey numbered routes has priority over all remaining routes.

4.2 Ramp Description

The next character is reserved for the ramp description. The following is a summary of the possible descriptions.

A - Off ramp exiting the predominate route in the increasing direction of the predominate route.

B - On ramp entering the predominate route in the increasing direction of the predominate route.

C - Collector lanes in the increasing direction of the predominate route.

X - Off ramp exiting the predominate route in the decreasing direction of the predominate route.

Y - On ramp entering the predominate route in the decreasing direction of the predominate route.

Z - Collector lanes in the decreasing direction of the predominate route.

4.3 Multiple Ramp Identifier

This character identifies multiple ramps within the same one tenth of a mile. ‘1’ is assigned to the first ramp in the direction of travel. ‘2’ is assigned to the next ramp. The numbering starts with the ramp to the right where two ramps exit or enter at the same location. The origin of the ramp determines which side of the predominant route the ramp is located.

4.4 Mainline Mile Point Reference

The last five characters are reserved for the mainline reference post. The reference post is identified as the location where the gore area meets the linear reference point. The reference post is rounded to the nearest one hundredth of a mile. ‘00240’ represents 2.40 miles from the start of the route.

An example of this convention is shown in Figure 4 for the ramps of the intersection of routes I-195 and US 130.

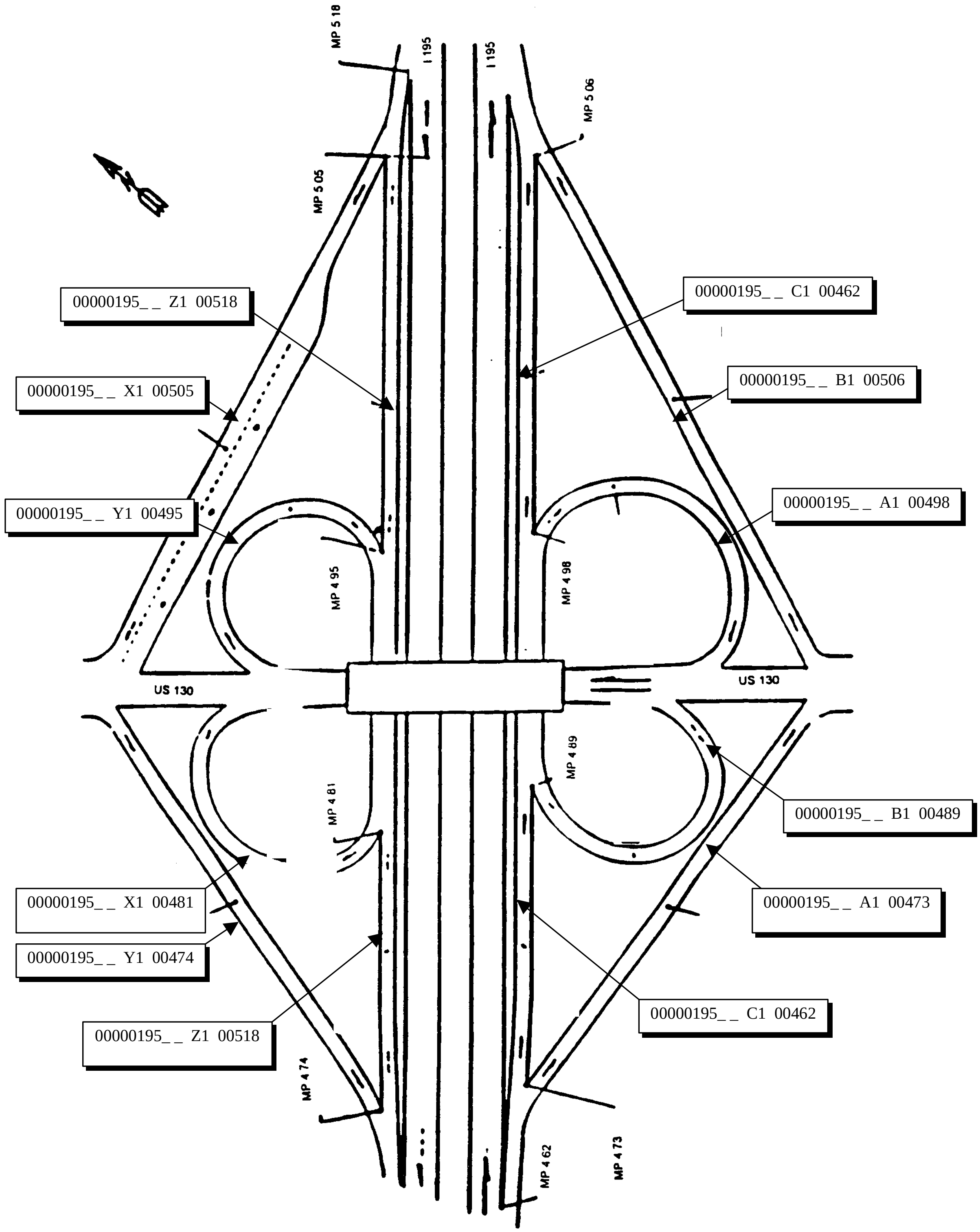


Figure 4: Pictorial Depiction of Ramp Identification and Naming Protocol

5.0 PAPER BASED OFFICE INVENTORY

This activity involved the gathering of basic inventory and attribute data. Most of the data was available from NJDOT's straight-line diagrams (SLD) and orthos photos [5]. The SLD was used to generate the following information.

1. Identifying the predominate route based on the guidelines previously established.
2. Indicating the type of ramp with limit description.
3. Locating mainline reference post.
4. Establishing the ramp identification number.
5. Identifying the county in which the ramp enters or exists the mainline.
6. Identifying the municipality in which the ramp enters or exits the mainline.

This data was gathered from the SLD and entered onto data entry sheets, as represented in the first section of Figure 5.

6.0 FIELD INVENTORY & CONDITION RATING

Once the office inventory was completed, the initial inventory database was used to generate field survey data forms. Figure 5 presents a typical form.

The field survey provided the following functions:

- Validation of information collected from the straight-line diagrams.
- Creation of new ramp records if a ramp was not found in existing records.
- Survey of each ramp from gore point to gore point. The gore is defined as the start of a physical barrier or end of pavement.
- Identify pavement type.
- Determine if the ramp was overhead or not.
- Record the relative milepost locations of the various attributes of the ramp. The attributes measured were the lane type, pavement width, number of lanes, and the presence of a structure.
- Locate and describe any structures within the ramp.
- Identify the presence of an overhead clearance sign if it exists for an overhead structure and record the signs.
- Indicate the general condition of the ramp.

The field survey data was collected using a vehicle equipped with a distance-measuring instrument (DMI). Two technicians were in the vehicle, one driving and the other recording all pertinent information. The vehicle traveled the ramps at the posted speed limit for safety. The ramp data collection form shown earlier in Figure 5 is broken into four sections.

1. Ramp Identifier
2. Sectional Data
3. Attributes
4. Distresses

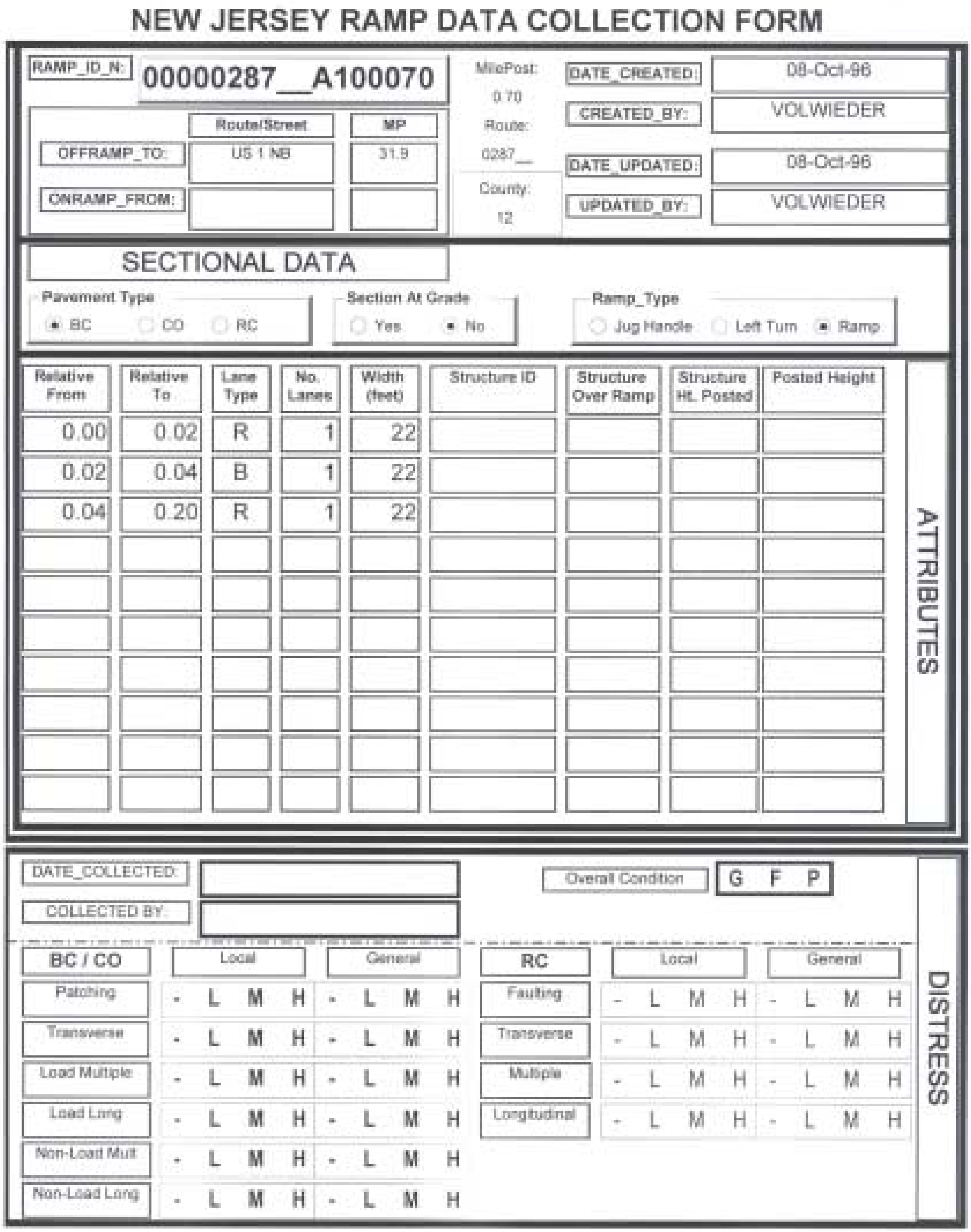
Ramp Identifier: This area of the form describes the location of the ramp. If a physical ramp was located based on the earlier section defining the scope of the ramp network but was not included in the inventory list, then the information for the ramp was collected so it can be added to the database. It was the passenger's responsibility to create a unique ramp ID (according to the definition of the ramp identifier characters) and enter information into all fields of a blank data collection form.

Sectional Data: Following information was collected and verified.

Pavement Type	-	BC (bituminous), CO (composite), or RC (rigid concrete)
At Grade	-	Y or N
Type of Ramp	-	Jughandle, Left turn lane, Ramp

Attribute: This portion of the form allowed recording the from/to locations (in miles) of several attributes relative to the start of the ramp. These include:

- Lane Type
  - A - Acceleration Lane
  - C - Collector/Distributor
  - D - Deceleration Lane
  - R - Ramp
  - S - Ramp Split for left, right turns



NEW JERSEY RAMP DATA COLLECTION FORM

RAMP_ID_N: 00000287__A100070

MilePost: 0.70

Route: 0287__

County: 12

	Route/Street	MP
OFFRAMP_TO:	US 1 NB	31.9
ONRAMP_FROM:		

DATE_CREATED:	08-Oct-96
CREATED_BY:	VOLWIEDER
DATE_UPDATED:	08-Oct-96
UPDATED_BY:	VOLWIEDER

SECTIONAL DATA

Pavement Type: (•) BC ( ) CO ( ) RC

Section At Grade: ( ) Yes (•) No

Ramp_Type: ( ) Jug Handle ( ) Left Turn (•) Ramp

ATTRIBUTES

Relative From	Relative To	Lane Type	No. Lanes	Width (feet)	Structure ID	Structure Over Ramp	Structure Ht. Posted	Posted Height
0.00	0.02	R	1	22				
0.02	0.04	B	1	22				
0.04	0.20	R	1	22				

DISTRESS

DATE_COLLECTED:

COLLECTED BY:

Overall Condition: G F P

BC / CO	Local				General			
Patching	-	L	M	H	-	L	M	H
Transverse	-	L	M	H	-	L	M	H
Load Multiple	-	L	M	H	-	L	M	H
Load Long	-	L	M	H	-	L	M	H
Non-Load Mult	-	L	M	H	-	L	M	H
Non-Load Long	-	L	M	H	-	L	M	H

RC	Local				General			
Faulting	-	L	M	H	-	L	M	H
Transverse	-	L	M	H	-	L	M	H
Multiple	-	L	M	H	-	L	M	H
Longitudinal	-	L	M	H	-	L	M	H

Figure 5: Field Ramp Data Collection Form

- # Lanes
- Width (feet)
- Structure identifier. If there was a structure present, the following properties of the structure were surveyed:
  - If there was a structure, it was indicated if it was overhead in terms of ‘Y’ or ‘N’.
  - If the structure was overhead, it was indicated if a clearance sign was posted in terms of ‘Y’ or ‘N’

Distresses: The NJDOT for several years has employed the use of a semi-automated method for pavement surface distress rating successfully. The sophistication of the Automatic Road ANalyzer (ARAN) data collection tool and processing software has reduced the level of effort associated with visual surface distress data collection. NJDOT uses eight types of distresses for flexible/composite pavements and seven types of distresses for rigid pavements as shown in Table 1. These distresses types were recorded for each ramp during the field survey.

7.0 RAMP DATA QA/QC

Random selections of approximately 30% of the surveyed ramps were checked for the accuracy of data. This QA/QC involved rigorous field verification of the attribute, sectional and distress data. After satisfying these QA/QC requirements, the data was loaded to the PMS. During the data loading, the PMS applies QA/QC checks on the attribute and performance data and accepts only the correct data.

8.0 MAINTENANCE AND REHABILITATION ANALYSIS

The ramp data collected in the field was processed in a manner similar to that of normal highway segments. The beginning mileposts of all ramps were set to zero, while the ending mileposts were set equal to the ramp length. The field survey considered that occurrence of any distress covering up to and including 30% extent was local, while general occurrence corresponds to greater than 30% extent. A nominal value of 30% was entered into the PMS database for local occurrence and a value of 70% was entered for the general occurrence.

Table 1: NJDOT Distress Types by Pavement Types

DISTRESS TYPE	PAVEMENT TYPE
Non-Load Associated Multiple Cracks	Asphalt/Composite
Load Associated Multiple Cracks (Wheel Track)	Asphalt/Composite
Transverse Cracks	Asphalt/Composite
Non-Load Associated Longitudinal Cracks	Asphalt/Composite
Load Associated Longitudinal Cracks (Wheel Track)	Asphalt/Composite
Patching	Asphalt/Composite/Rigid
Shoulder - Condition	Asphalt/Composite/Rigid
Shoulder Drop Off	Asphalt/Composite/Rigid
Cracking	Rigid
Faulting	Rigid
Longitudinal Joint	Rigid
Transverse Joint	Rigid

Also, it was assumed that good, fair and poor conditions correspond to Surface Distress Index (SDI) values of 4.5, 3.5 and 2.5, respectively. New Jersey SDI ranges from 0 to 5, five being an excellent surface distress condition. The processed ramp data was loaded into the enhanced PMS. The ramp data stored in the “Ramp” sectional database of the PMS was analyzed and the average index representing the overall condition of each ramp was calculated. A simple M&R decision tree was developed using a trigger SDI value of 3. The structure of the decision tree is shown in Table 2.

Table 2: Ramp M&R Decision Tree

Ramp Pavement Type	Surface Distress Index (SDI)	Type of Treatment
Flexible (BC)	Greater than or equal to three	No treatment required
	Less than three	Mill 2” and 4” AC overlay
Rigid (RC)	Greater than or equal to three	No Treatment required
	Less than three	Joint replacement and 4” AC overlay
Composite (CO)	Greater than or equal to three	No treatment required
	Less than three	Mill 2”+ joint replacement and 4” AC overlay

The ramp M&R and optimization analysis was performed using the PMS. The purpose of the PMS M&R analysis is to determine feasible treatments for each section within a programming period. If a section reaches the minimum acceptable performance criteria (i.e. trigger value) then the section is transferred to the decision trees for analysis of rehabilitation alternatives. The rehabilitation capital cost is calculated from the input unit costs and the maintenance costs predicted for the alternative. The cost-effectiveness of the alternative is then calculated by dividing the effectiveness by the present worth of the total costs [6].

The M&R analysis provided the rehabilitation needs of the ramp network. Figure 6 shows the need year distribution for the ramp network. It is seen that about half of the ramp network is in need in of rehabilitation in 2003. The figure also indicates that maximum percentage of total lane miles that will be in need of rehabilitation in any future year (i.e., between 2004 and 2007) is approximately below two percent indicating that other half of the ramp network is in better condition.

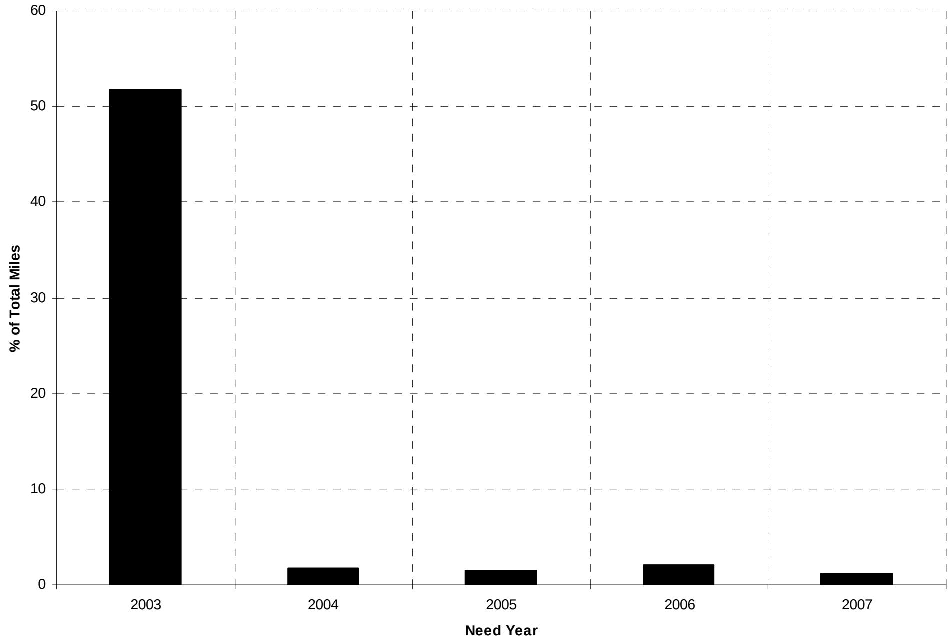


Figure 6: Rehabilitation Need Year Distribution of the Ramp Network

9.0 PRIORITY PROGRAMMING

The PMS M & R alternatives analysis provides input to the rehabilitation optimization. The PMS network optimization analysis involves determining optimal programs of rehabilitation for the network based on the input constraints. The constraints can include funding (budget) constraints, performance constraints and maximum advance/delay constraints or any combination of those constraints. The optimization can be executed in a cost-minimization or effectiveness-maximization mode including budget and performance constraints for either mode. The priority programming optimization procedure involves the marginal cost effectiveness analysis technique for selecting rehabilitation strategies. Marginal cost-effectiveness approach has been shown to give near-optimum results [7]. This marginal cost effectiveness method is the basis for priority programming adopted by Alberta, Prince Edward Island, New foundland, Idaho, Minnesota and South Carolina [8]. It is also the basis for comprehensive, integrated system developed for cities in Alberta [9,10]

These analytical capabilities of PMS were utilized for the ramp M&R and optimization analysis in which four budget scenarios were as follows.

1. A no-rehabilitation scenario, termed as "*Zero Budget*" scenario**,** was included in the analysis to show the change of the network condition in the case where no rehabilitation will be carried out.
2. A budget scenario in which the agency spends fifty million dollars each year to improve the deficient ramp network. This budget scenario was termed as "*50 m$/year*".
3. A budget scenario in which the agency spends twenty million dollars each year. This budget scenario was termed as "*20 m$/year*".
4. An open budget scenario, termed as "*Needs*", indicating funds required to bring the network to an acceptable level, meaning zero percent of ramps less than trigger.

The result of this analysis is shown in Figure 7. The analysis shows that about half of the New Jersey ramp network is deficient using the 1995 distress data. With no spending on the rehabilitation of the ramps, the network annual rate of deterioration is about two percent. The ramp network performance greatly improves under the "*50 m$/year*" budget scenario. The network annual rate of improvement is about five and two percent under the "*50 m$/year*" and "*20 m$/year*" budget scenarios respectively. The "Needs" scenario is the budget required to implement the required rehabilitation strategy for each ramp exactly when it reaches a trigger value [11]. This is useful for performing cost-minimization optimizations. This analysis shows that the total budget required to keep the New Jersey ramp network below the trigger SDI value of three is 226 million dollars. It should be stressed that this was a preliminary analysis and uses PMS default parameters, such as unit cost, which may not be precise for ramps.

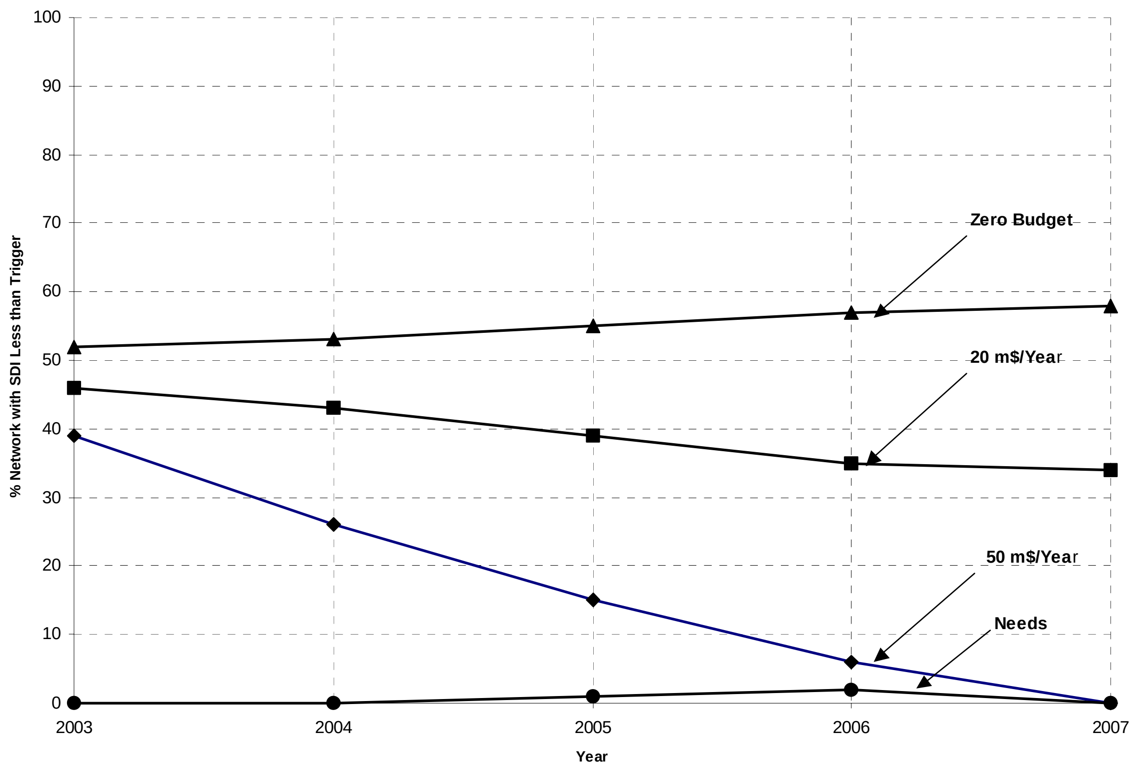


Figure 7: New Jersey Ramp Network Performance Prediction

Significance of the Ramp M&R and Optimization Analysis

This analysis is of great significance for M&R decision-making about the ramp network. The analysis not only identifies the deficient condition of the ramp network but also show the network improvement scenarios under different spending levels. Such analysis can provide an improved level of confidence for the agency decision makers for the network level spending and budget allocation. Therefore the ramp inventory and condition rating data can lead to an effective ramp M&R decision-making.

10.0 CONCLUSIONS AND RECOMMENDATIONS

This paper detailed a novel approach on the integration of ramps with the existing mainline network PMS database that resulted from eight years of PMS development and enhancement efforts. The paper reported on the scope and approach for the ramp survey and analysis, development of ramp identification system, a condition-rating procedure for field-testing of ramp network, QA/QC procedure, loading procedure of the ramp data to the PMS and a PMS ramp M&R and optimization analysis. Following conclusions and recommendations are made.

1. The integration of ramps within the PMS mainline network database can provide the ramp's condition and needs summaries.

2. Linkage of Straight-Line Diagrams (SLD) with the PMS will help in effective maintenance and rehabilitation decision-making about the ramp network

3. The analytical capabilities of the PMS can be utilized for the ramps' management after performing several budget scenarios.

4. The maintenance and rehabilitation unit costs for the ramp network can be different than the mainline network. The accurate ramp M&R analysis is dependent on the actual ramps unit costs.

5. Integrating ramp inventory and condition rating data with the PMS mainline network can lead to an effective ramp M&R decision-making.

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