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Determination of Optimum Timing of Pavement Maintenance in Local Roads using Effectiveness Index: A Case Study of Ramgram Municipality

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Abstract

Maintenance of road plays an important role in determining the total lifespan of a pavement which is often overlooked especially in a developing country. The reasons behind may be surging needs of construction of new road networks and insufficient fund allocation for road sector. Therefore, planning of road maintenance activities is crucial. In this study, an attempt is made to calculate the optimum timing of pavement maintenance in local roads. OPTime tool developed under NCHRP report 523, is used for calculating effectiveness index. The pavement condition trends over time are developed using the data collected during the field survey as well as records of pavement construction and maintenance. Costs for routine & periodic maintenance activities and trends of pavement condition changes are used as input in OPTime to obtain the effectiveness index and hence the optimum timing of pavement maintenance.

Keywords

Local Roads, Maintenance, Effectiveness Index, Optimal Timing, OPTime

1. Introduction

1.1 Background

Local Roads typically refer to roads that connect villages and small towns within a local administrative unit, such as a rural municipality or a village development committee. These roads are usually maintained by the local government and are intended to provide access to basic services, such as health centers, schools, markets, and administrative offices. After adopting federalism in 2008, Nepal now has three levels of governments. Federal Governments and two subnational governments: Province Government and Local Level Government. In the scope of the current study, the roads for the construction and maintenance of which local level governments are responsible are considered. Local road systems are crucial to a country's economic growth. In developing nations, rural roads are especially important as they provide transportation for agricultural goods, reduce poverty, and increase access to essential facilities like markets, schools, and healthcare services. To develop these roads, local governments and other organizations in developing countries invest a significant amount of money. Unfortunately, due to a lack of reliable and structured procedures, road development decisions are often made based on subjective judgement by public officials. This approach can lead to inefficient use of resources and neglect of fairness and long-term societal benefits [1]. A maintenance work applied at the optimal time results desired outcome whereas that at another time may be less effective or even counterproductive. Maintenance costs of roads in poorer condition can be many folds expensive than those maintained at good conditions [2, 3].

In present federal system of Nepal, decentralization policy is adopted and local government is now responsible for providing public services to local communities. A large length of roads within the country come under the jurisdiction of local government. It is therefore more important than ever to establish a well-defined methodology to maintain roads at local levels in a very efficient and cost-effective way.

1.2 Need of Research

The research aims at finding an objective way to determine the optimal timing for pavement maintenance works. The need of this research is felt due to the following situations that exist in local level.

- Lack of appropriate pavement management system to store records of historical pavement condition data
- Differences in approach for maintenance activities among different local levels. This is due to unavailability of an adequate document/guideline/standard for using in maintenance planning and works.

1.3 Research Objectives

The major objective of this research is to determine the optimal timing of maintenance work in local levels for the given maintenance works and local environment. The specific objective is to calculate the effectiveness index.

1.4 Limitations

The study uses OPTIME tool developed under NCHRP report 523 study. The tool uses historical pavement condition data to predict trend of pavement deterioration. These trendlines should be developed for each local level separately. Therefore, the relations developed for one local condition may not be applicable in places where traffic and weather/climatic conditions are different.

2. Literature Review

2.1 Previous Works

Change in pavement performance after treatment applications has been used by many researchers as objective function in optimization model. A comparison of methods of evaluating pavement performance along with a case study was conducted and importance of cost-effectiveness were highlighted [4]. Various measures of effectiveness of both short term and long-term performance were presented in the study. The study revealed that a treatment very effective in short term may not be effective in the long term. Maximization of long-term effectiveness as objective function to develop optimum maintenance programs is also widely used concept [5]. Three measures of effectiveness; treatment service life, increase in average pavement condition, and area bounded by the performance curve are used for determining long term effectiveness HMA overlay treatment [6].

2.2 Surface Distress Index

Surface Distress Index (SDI) is a quantitative measure of the condition of a pavement surface, which reflects the amount and severity of surface distresses, such as cracks, potholes, and rutting. It is used as an indicator of the overall pavement condition and helps in making decisions regarding the maintenance and rehabilitation of the pavement. Bina-Marg method is a commonly used method to determine the Surface Distress Index (SDI). The methodology of finding SDI using Bina-Marg method involves stages which is given in Table 1 .

2.3 OPTime Tool

The NCHRP report 523 introduced a technique to evaluate the most cost-effective timing for preventive maintenance treatments.[2] This technique uses an Excel VBA-based software called OPTime which can be obtained from NCHRP website. The report defines the benefit area as the disparity between the computed areas linked to the post-treatment performance curve and the do-nothing curve. This approach is the most accurate method for evaluating treatment efficacy because it considers treatment service life, overall pavement condition, and directly demonstrates the improvement in pavement performance. This concept is illustrated in Figure 1[7].

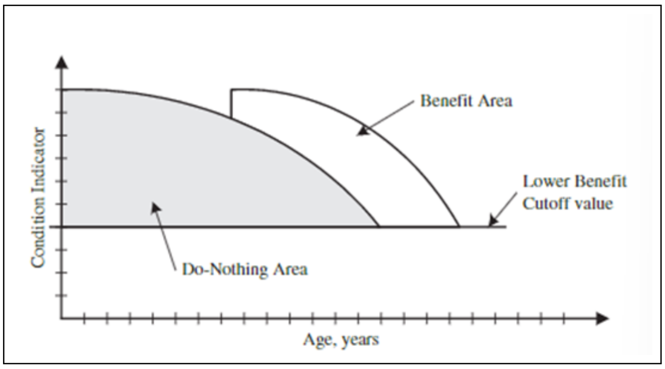

Figure 1: Conceptual Illustration of Do-nothing and Benefit Areas [2]

3. Methodology

The study starts with selection of road sections in the study area. An overview of the methodology used in the research study is presented in figure 2.

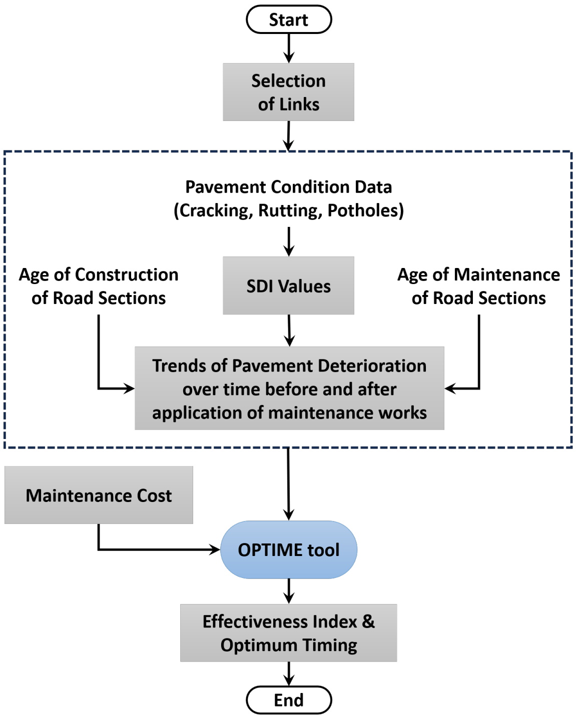

Figure 2: Flowchart of Methodology

3.1 Study Area

Ramgram Municipality is selected for study location. Ramgram municipality is the district headquarter of Nawalparasi

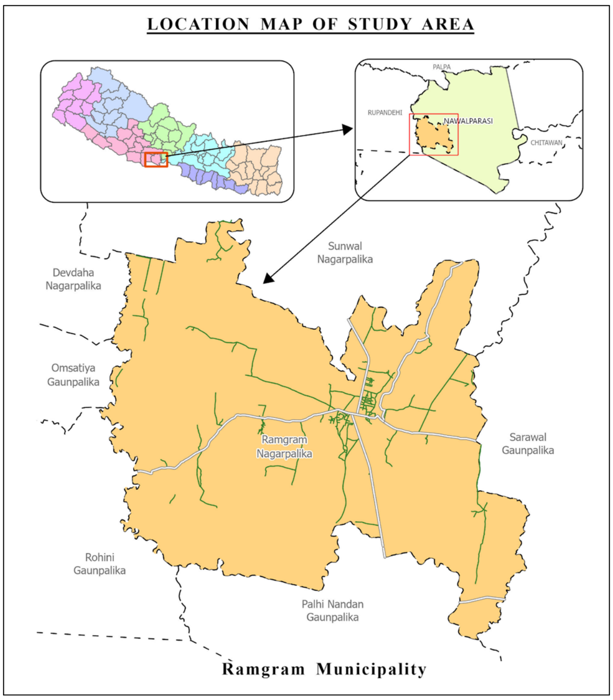

Figure 3: Study Area

Table 1: Stages of SDI Calculation

Stage 1 (Cracking Area)		Stage 2 (Avg Crack Width)	
No Cracking	$SDI_1 = 0$	No Cracking	$SDI_1 = 0$
$Area \leq 10\%$	$SDI_1 = 5$	$Width \leq 1mm$	$SDI_2 = SDI_1$
10% <Area <30%	$SDI_1 = 20$	1mm <Width <3mm	$SDI_2 = SDI_1$
$Area \geq 30\%$	$SDI_1 = 40$	$Width \geq 3mm$	$SDI_2 = SDI_1*2$
Stage 3 (No of Potholes)		**Stage 2 (Rutting Depth)**	
No Potholes	$SDI_3 = 0$	No Rutting	$SDI_4 = 0$
$Potholes \leq 10/km$	$SDI_3 = SDI_2+5$	$Rutting \leq 1cm$	$SDI_4 = SDI_3+2.5$
10/km <Potholes <50/km	$SDI_3 = SDI_2+75$	1cm <Rutting <3cm	$SDI_4 = SDI_3+10$
$Potholes \geq 50/km$	$SDI_1 = SDI_2+225$	$Rutting \geq 3cm$	$SDI_2 = SDI_3+20$

(Bardaghat Susta Paschim) district. It was established in the year of 2053 Chaitra 14, and restructured on 2073 Falgun 27 merging the previous Ramgram Municipality and 5 VDCs (Amraut, Sukrauli, Hakui, Banjariya and Devgaon) covering a total area of 93.91 sq.km.

The municipality is about 9 km south of Mahendra Highway and surrounded by Sunwal Municipality in the north, Sarawal Municipality in the east, Palhinandan and Rohini Rural Municipality in the south and Rohini Rural Municipality, Omsatiya Rural Municipality and Devdaha Municipality in the west.

3.2 Data Collection

A total of 120 road sections were selected for the study. A survey was conducted along these road sections for collection of pavement distress data. The distress data collected include crack area, average crack width, number of potholes and rut depth. The construction age and age of last maintenance activity were also recorded.

3.3 Data Preparation

A summary of construction age and maintenance ages of all road sections surveyed is presented in figure 4. To determine how the pavement condition is changing over time; the calculated SDI of different road sections are filtered. For example, there are 12 road sections that were constructed eight years ago. Their age of last maintenance and respective SDI values are presented in the table below. This data is then used to determine the trend of pavement condition changes over time.

Table 2: Maintenance age Vs SDI for Construction Age 8 years

Road Code	Age of Maintenance	SDI
B23	3	45
B53	2	97.5
B57	4	97.5
C100	3	37.5
C246	5	165
C295	2	37.5
C297	2	37.5
C304	2	37.5
C311	4	105
C357	3	97.5
C393	6	175
C414	3	45

Using Table 2, the following relation of pavement condition over time (*for construction age 8 years*) is obtained:

$$y = 5.6938x^2 - 9.9088x + 44.926$$

where;
y = pavement condition (SDI)
x = age (years)

In the similar way, the trends of pavement condition changes over time were developed for roads of different construction ages are determined. A relation of do-nothing condition is developed using the pavement conditions of those road sections where maintenance work is not applied after construction. Due to insufficient data for age of construction of one year and two years, the relation developed for do-nothing condition is used which is logically correct.

3.4 Maintenance Works

Department of Roads (DoR) has specified seven types of maintenance activities regarding roads. a) Routine/Regular maintenance works are those required continually on every road because of environmental degradation. Activities involved in this type are mostly related to cleaning and minor repairs. b) Reactive/Recurrent maintenance are required as per road condition when condition reaches critical threshold level. Activities involved are mostly patch repair, crack sealing and drain/parapet repair works carried out after appearance of damage. c) Cyclic/Periodic maintenance are required at interval of few years. Activities involved are fog seal, slurry seal, surface dressing, thin overlay, ottaseal etc. d) Responsive maintenance works related to correction of present defects as well as maintaining certain level of service. e) Road Side Maintenance works are activities related to stabilizing slopes, scaling off rock faces, masonry walls, revetments, road safety works etc. f) Emergency Maintenance works are required to deal with emergencies and problems calling for immediate action when services are threatened to be closed. g) Bridge Maintenance works are required for ensuring safe and uninterrupted passage of people and vehicles over streams, rivers and irrigation crossings.

After the survey and discussion with related authorities, following maintenance works were found being carried out in the study area:

1. Routine Maintenance Works
2. Recurrent Maintenance Works
3. Periodic Maintenance Works

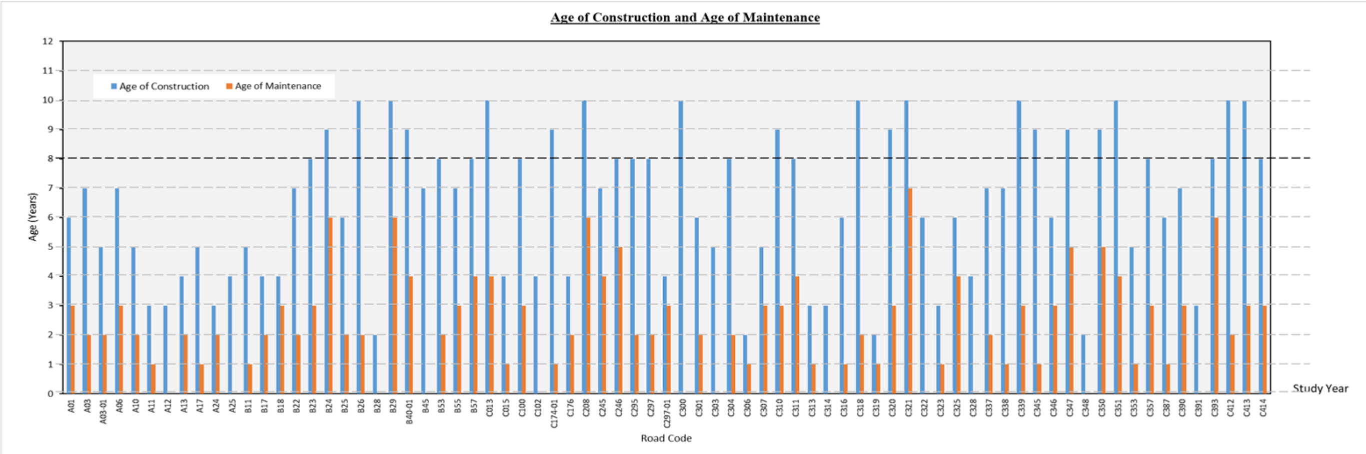

Figure 4: Summary of Age of Construction and Age of Maintenance

The maintenance activities under routine and recurrent works were carried out yearly. These activities include cleaning, minor repairs and patching works. The periodic maintenance work applicable for the studied sections is thin overlay. Therefore, the costs of these activities are estimated and used in the analysis. The optimum timing is then determined for periodic maintenance work.

3.5 Calculation of Effectiveness Index

Effectiveness indices are calculated for different years at which maintenance works are carried out. Benefits over do-nothing area are divided by the cost incurred for maintenance works carried out in respective years. These values are then changed proportionately considering the maximum as a 100 percent. The resulting percentages are effectiveness indices of maintenance work for the respective years. The higher the value of effectiveness index the higher is cost-effectiveness of maintenance work.

4. Results and Discussion

4.1 Pavement Condition Change Over Time

For determining the pavement condition changes of do-nothing case, the road sections which have no maintenance history are selected. The relation so obtained is presented in figure 5.

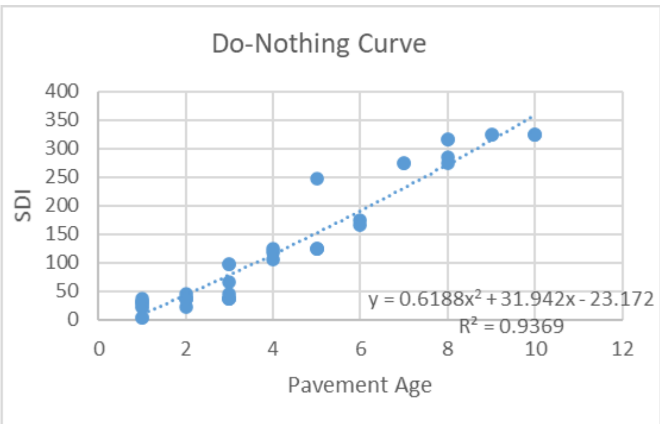

Figure 5: Pavement Condition vs Age in Do-Nothing Condition

In the similar way, trends of pavement condition changes are determined for various age of construction following the method described in section 3.3. The results of the analysis are presented in figure 6.

4.2 Effectiveness Index

Effectiveness indices are calculated for different maintenance work application years using the trends of pavement condition and maintenance records of the road sections. The results are shown in Table 3.

Table 3: Effectiveness Indices

Application Age, yrs	Effectiveness Index	Total Benefit
1	5.65	0.27
2	13.47	0.54
3	27.93	0.92
4	45.79	1.24
5	100.00	1.94
6	57.75	1.27
7	59.16	1.19
8	59.74	1.10
9	58.31	0.98

5. Conclusion

Effectiveness indices for various years are calculated. The thin overlay treatment applied in the studied area is most cost effective when applied at a five year interval in the studied area. Effectiveness indices values before as well as after fifth year are less than the value at fifth year suggesting there is an optimum timing for pavement maintenance works.

6. Recommendations

The quality of output of the study is heavily dependent on the number and accuracy of records used to determine the trends of condition indicator over time. The more the number of good records, the more fruitful will be the output.

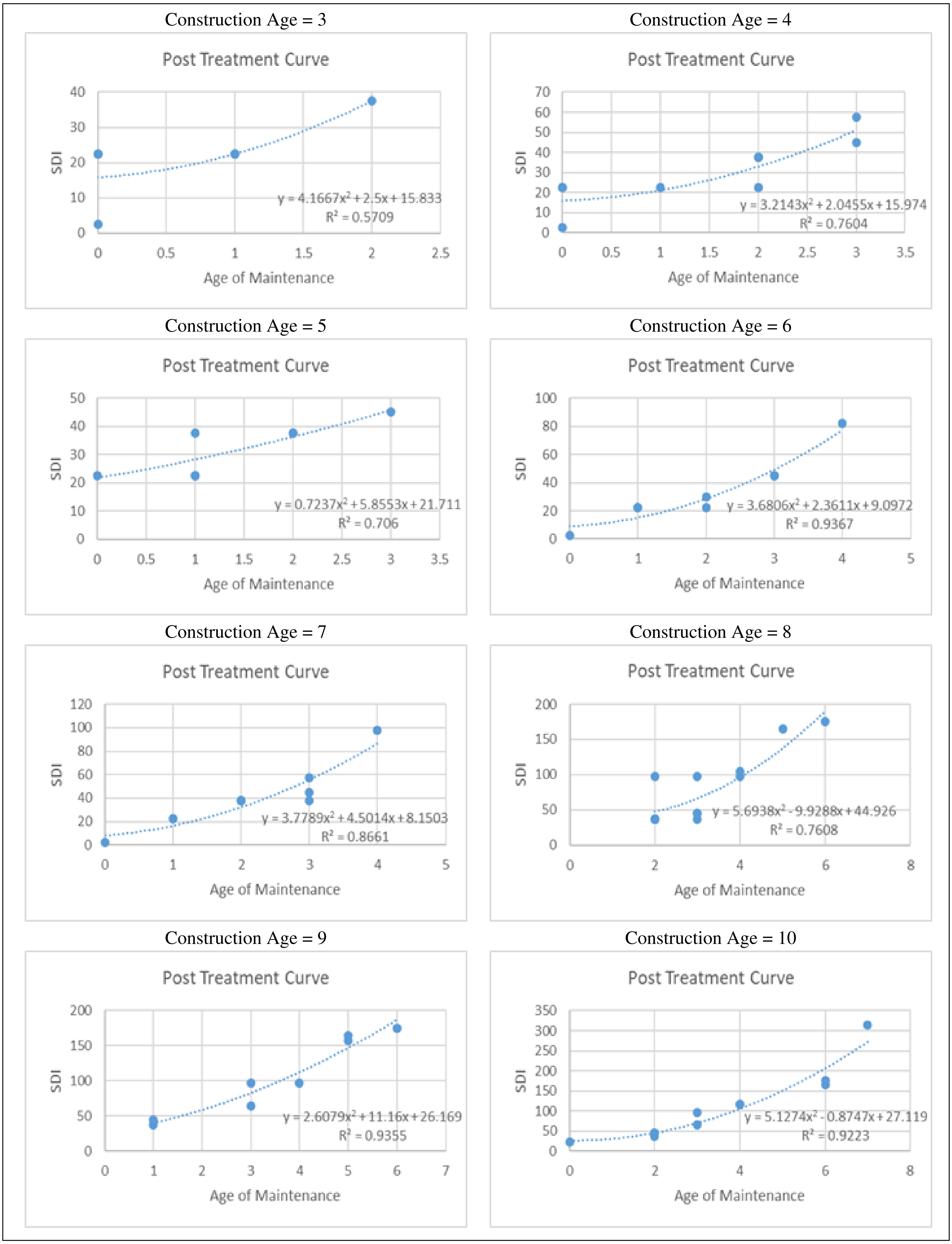

Figure 6: Pavement Condition Vs SDI at Different Construction Ages

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