Prioritization for rehabilitation and preventive maintenance of pavement projects in Texas

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ABSTRACT

State highway agencies make decisions on prioritizing rehabilitation (RH) and preventive maintenance (PM) projects based on data extracted from the Pavement Management Information System (PMIS). The Texas department of Transportation (TxDOT) uses a combination of approaches that rely significantly on judgment for identifying PM and RH projects. Due to finite resources and an extensive road network to maintain, maintenance engineers must make optimal and cost-effective decisions to prioritize projects to receive appropriate treatments. Currently, prioritization methods implemented by TxDOT range from a simple ranking of projects based on judgment to comprehensive optimization by mathematical programming models. A state-wide survey was developed to obtain the methods and key factors used by the districts to make project selection decisions. The survey responses suggested that the major key factors for project selections are; condition score and distress score, surface age, average daily traffic, number of failures, skid number, ride score and maintenance expenditures. The survey also suggested that PMIS data combined with visual inspection are the main tools use to prioritize projects.

Keywords: Asphalt, Maintenance, Repair method

INTRODUCTION

A Pavement Management Information System (PMIS) is a process for cost-effectively managing roadways networks. This process includes a systematic, consistent approach of gathering and analyzing pavement data and generating recommendations for making informed pavement investment decisions. One of the major outcomes of the PMIS is to identify the pavement sections in need for repair, select the best treatment applications for those sections and decide on the timing of this treatment.

One of the key components of the PMIS is the rating systems. These systems involve calculating a numerical score or index based on the pavement distress and surface condition to make a comparison between roadway segments and identify the sections in need for repair (Peng and Ouyang, 2010). The most commonly used pavement condition indices include distress, rutting, and roughness. The indices for distress depend on the pavement conditions; such as Condition Rating Survey (Illinois), Pavement Distress Index (Arizona), and Pavement Structural Condition (Washington). Nebraska uses surface condition and rutting or faulting measurements to provide a single value termed the Nebraska Serviceability Index (NSI). Minnesota uses the Ride Quality Index (RQI), a measure of pavement smoothness, and the Remaining Service Life (RSL), an estimate of the pavement's remaining life. New Mexico uses the RQI as a rating method for surface roughness and the pavement serviceability index (PSI) to account for distresses such as cracking, rutting, and faulting. Full details on the pavement condition indices adopted by each state are documented by Papagiannakis et al. (2009).

Due to the limited financial resources and the aged roadways networks, the identified projects are incorporated in a cycle of prioritization to rank the pavement sections that need serious attention in a given fiscal year. Less prioritized sections can be identified for subsequent years when funding is available. By fixing priorities, the available budget can be directed to the sections that need to be rehabilitated/maintained first. Prioritization of needs is based on the policy and resources of agency and it depends on many factors such as; condition index, functional class, traffic level, subgrade conditions, drainage condition, etc. Prioritization methods range from a simple ranking of projects based on judgment to comprehensive optimization by mathematical programming models. Tighe et al., (2004) remarked that effective prioritization methods should be able to identify critical sections in a given network, identify the type of treatment, determine the best timing and determine the treatment cost. Four categories of methods can be used to prioritize alternative strategies and candidate sections namely; simple ranking, heuristic method, optimization method, and weight factor method.

The Texas Department of Transportation (TxDOT) are required to identify candidate projects that are in need for repair on annual basis. Although TxDOT has the *Needs Assessment tool* in their PMIS, it is not used exclusively by their twenty five districts. The main reason appears to be its lack of user-friendliness and its inability to capture local experience with the applicability of various treatments (Dessouky et al. 2011). The lack of simple prioritization methodology automated within PMIS, has forced many TxDOT districts to develop informal protocols to select and prioritize PM and RH projects. Most of these protocols rely on engineering experience and judgment. The objective of this study is to present the current practice of how TxDOT districts prioritize pavement projects in need of repair and select the appropriate treatment applications. A state-wide survey response was established to review the current practices and guidelines used by TxDOT districts in making PM and RH decisions.

TxDOT PMIS

The TxDOT has a *Needs Assessment t*ool as part of its PMIS. This tool assists districts in identifying roadway sections that are candidates for RH and/or PM. Moreover, the PMIS uses a comprehensive decision tree to differentiate between the conditions that warrant RH and PM treatments. However, PMIS does not optimize these candidate projects, given the available budget scenario in which TxDOT operates. The TxDOT districts choose specific maintenance treatments for various reasons. For instance, Figure 1 shows the most common treatment options for PM and RH utilized by TxDOT. In each case, most districts use only two to three of these treatments following their past experience and the availability of local materials and contractors. In terms of frequency of use, treatment options were classified as frequent (more than five projects per fiscal year), infrequent (less than five projects) and never used. Figure 1 indicated that seal coats and joint sealing are the most common PM treatments for flexible pavements. On the other hand, spot repair and seal coats with thin hot-mix asphalt (HMA) overlays are the most common RH for flexible pavements. More details on rigid pavements can be found elsewhere (Dessouky et al. 2011).

a) PM treatments b) RH treatments

Figure 1. Example of most common treatments identified by percentage used in districts for a) PM and b) RH projects.

To analyze the most commonly used treatments as a function of climatic and environmental conditions, the TxDOT districts were grouped into five zones as shown in Table 1 and Figure 2. The source of this climatic data is the weather maps of the State of Texas. The frequent use of PM/Rehab treatments in each district zone is listed in Tables 2 and 3. Distribution of treatments in urban and rural districts is also studied.

Table 1. Climatic Information on the District Zones.

	Geographic location	Average annual Temperature (F)	Average annual precipitation
Zone 1	South	>75	18–34 in
Zone 2	West	60–65	<18 in
Zone 3	North	50–60	18–26 in
Zone 4	North-East	60–65	26–50 in
Zone 5	East	60–70	>50 in

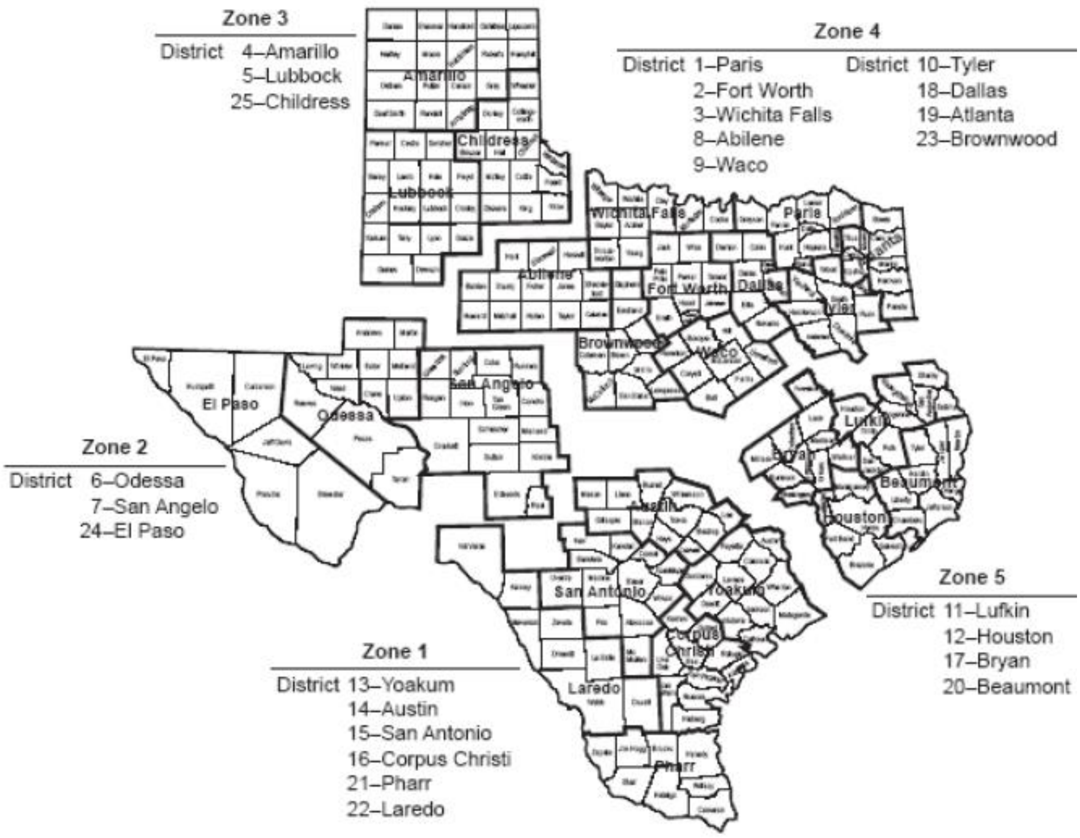


Figure 2. TxDOT Districts Distributed in Various Climatic Zones.

Table 2 shows that seal and fog seal, joints sealing, microsurfacing and planning and texturing in flexible pavement are among the most common PM treatments in all zones. On the other hand, slurry seal and rigid pavements texturing are among the least common PM treatments in 21 percent to 42 percent of the districts, respectively. Although multiple course microsurfacing is the third least common treatment (54 percent), it is mostly used in northern districts (zones 3 and 4) with moderate to cold temperatures. Overall, there is no significant difference noticed between treatments among zones 1, 2, and 5 and among zones 3 and 4. As expected, due to the higher precipitation in the eastern districts, permeable friction course overlays are commonly used (e.g., zone 3).

The urban districts are Austin, Houston, Dallas, Fort Worth, and San Antonio while all others are considered rural districts. The PM treatment is identical in urban and rural districts. However, rural districts tend to use seal coat, multiple microsurfacing, and texturing more often than urban districts. On the other hand, due to the high percentage of rigid pavements in urban districts, the PM/rehab treatments are more frequently used compared to rural districts. Moreover, the urban districts have more rehab applications compared to the rural districts, such as fabric under-seal with thin overlays, hot in-place recycling, and full depth repair of concrete pavement.

Table 2. PM Treatments Distributed in Different Climatic Zones, and Urban and Rural Districts.

PM Pavement Treatments	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Urban	Rural
Fog seal	√√	√	√√	√√	√√	√√	√√
Cleaning and sealing joints & cracks	√√	√√	√√	√√	√√	√√	√√
Seal coat/chip seal	√√	√√	√√	√√	√√	√√	√√
Multiple course seal coat	√√	√			√√	√	√
Asphalt rubber seal coat	√	√	√√	√	√	√	√√
Permeable friction course overlay	√	√	√		√√	√	√
Paver-laid surface treatment (Novachip)	√		√√	√		√	√
Wheel path microsurfacing			√	√√	√	√	√
Full-width microsurfacing	√√	√√	√√	√	√√	√√	√√
Multiple course microsurfacing			√√	√			√
Slurry seal							
Planning and texturing (flexible pavement)	√√	√√	√	√√	√√	√	√√
Planning and texturing (rigid pavement)						√	

Table 3. Rehab Treatments Distributed in Different Climatic Zones, and Urban and Rural Districts.

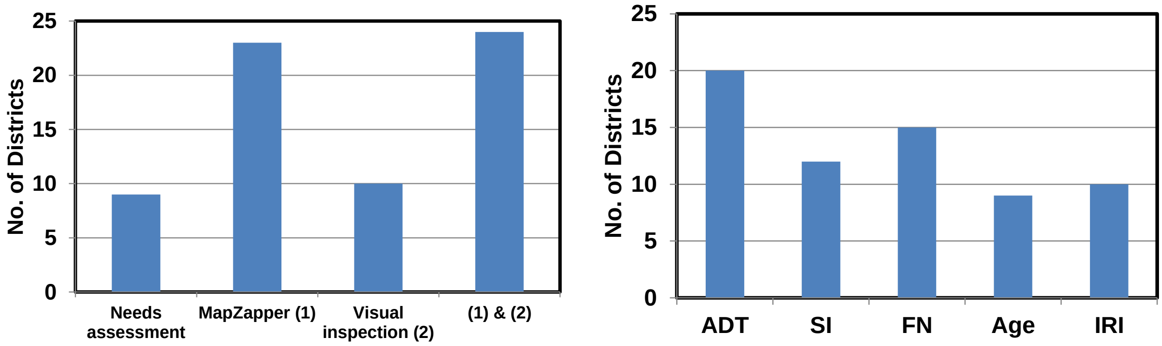
Rehab Pavement Treatments	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Urban	Rural
Fabric underseal & thin HMA overlay		√	√	√		√	
Seal coat & thin HMA overlay (< 2")	√√	√√	√√	√√	√√	√√	√√
Thin HMA overlay (< 2")	√√	√√	√	√√	√√	√√	√√
Ultra-thin bituminous overlay (< ¾")			√		√		
Hot in-place recycling & thin overlay	√						
Hot in-place recycling	√					√	
Cold in-place recycling & seal coat					√		
Cold milling & overlay (< 1 ½")	√√		√√	√√	√	√	√
Repair of localized sections	√√	√	√√	√√	√√	√√	√√
Full-depth repair of concrete pavement			√√	√	√√	√√	√
Bituminous shoulder (remove & replace)		√√	√√	√√		√	√

Blank: 50% or less of the zone districts are implementing the treatment
√: >50% or more in the zone districts are implementing the treatment
√√: >80% or more in the zone districts are implementing the treatment

STATE-WIDE SURVEY

A survey of current practices in selecting and prioritizing PM and RH treatments was conducted to the twenty-five TxDOT districts. The survey targeted primary decision maker(s) who are engaged in project prioritization and treatment selection. Project selection refers to the treatment application category (i.e., PM or RH). Prioritization refers to ranking the projects in a particular order (usually from worst to better) and identify the worst ones for funding. Figure 3 summarizes the result of the methods TxDOT districts use to select pavement projects for treatment and the parameters used for the final prioritization. As described in the figure, the *Needs Assessment* report is developed using decision trees built into the PMIS. The *MapZapper* is a GIS-based software used to extract/display various condition indices/roughness from the PMIS database on district maps. The visual inspection is conducted by maintenance supervisors and engineers prior to and after finalizing the priority list of projects.

The survey responses suggested that the *MapZapper* combined with field visual inspection to verify the pavement condition vis-a-vis generated maps are the initial data used to identify the critical sites in need of repair. According to the survey, the *Needs Assessment* reports generated from the PMIS are slightly used. Moreover, the main parameters considered into project prioritization are the average daily traffic (ADT) and roadway functional class (e.g., Arterial, collector, local). Roadways with higher classification (e.g., interstate highways) and ADT are more likely to have higher priority. Survey responses also suggest that ADT is the main factor used as a tie-breaker when deciding between comparable project conditions. Other factors used by fewer than 50% of the TxDOT districts are pavement structural capacity as reflected by the Structure Index (SI), roughness in terms of International Roughness Index (IRI) and the pavement surface age. Other less priority factors considered in the selection of projects are accidents reports and public concerns.



(a) (b)

Figure 3. a) Management tools and b) pavement parameters used in final project prioritization (ADT: Average daily traffic, SI: Structural index, FN: Functional class number, IRI: International roughness index)

The final outcome of a pavement maintenance program is to identify the best treatment for the sections in need of repair. The best suited treatment is identified by the pavement distresses present as well as their severity. For flexible pavements, responses suggested that severe distresses due to structural deficiencies, such as deep rutting, failures and alligator cracking, are addressed with RH treatment as shown in Figure 4. Lesser severity surface distresses, such as surface cracking, roughness, weathering, raveling, and bleeding can be corrected with PM employed to preserve and extend the life of the original pavement. However, the majority of the responses suggested that the PM treatment is mostly used for all distresses. The survey also depicted that pavement type (rigid or flexible) has negligible influence in projects prioritization among districts. While, as previously noted, the traffic volume and functional class are the mostly considered factors.

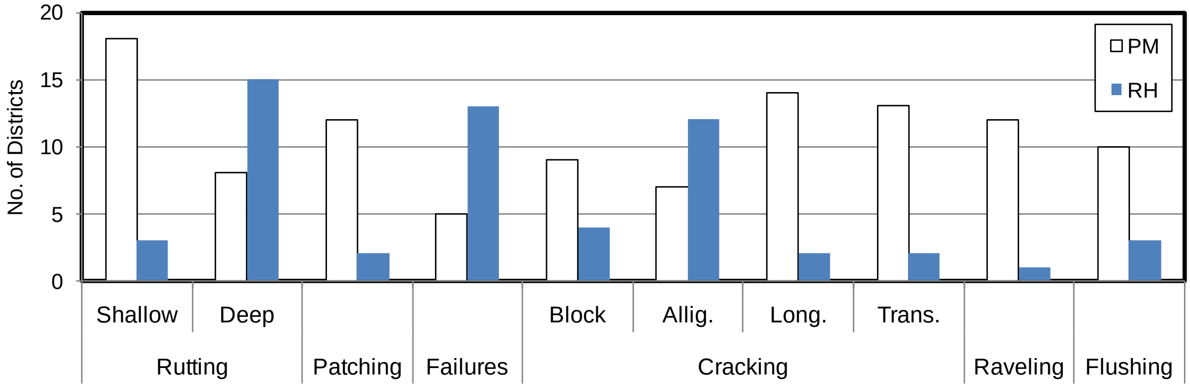
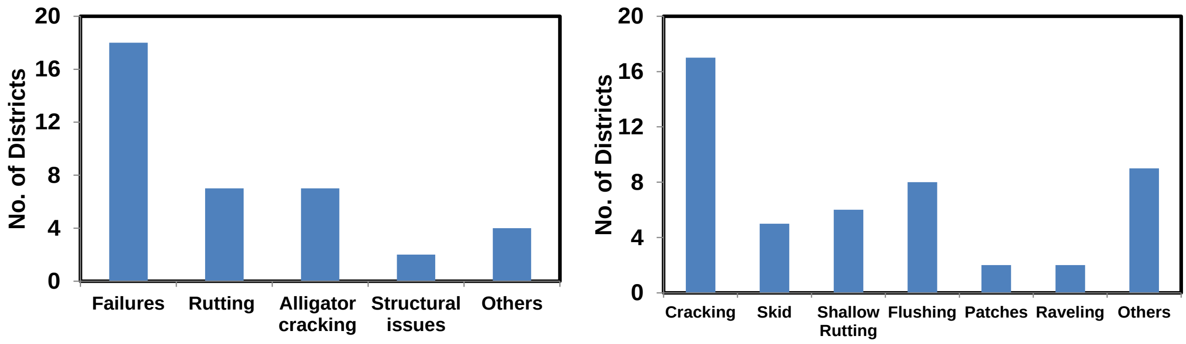


Figure 4. The distresses governing the treatment application for flexible pavement

To identify the distress type that governs the selection of treatment application for flexible pavements. Figure 5 suggests that pavement failure typically warrants a RH treatment, while surface cracking (e.g., longitudinal and transverse) typically warrants a PM treatment. Evaluation of pavement failure and structural deficiency issues are performed using non-destructive testing such as Ground penetrating Radar and Falling weight deflectometer. In some occasion trenches are considered for verification primarily in proposed heavy RH treatment.



a) RH b) PM

Figure 5. The distresses governing the selection of a) RH and b) PM projects for flexible pavements

CURRENT PRACTICE IN PROJECTS SELECTION/PRIORITIZATION

The following summarizes the factors and tools used to aid district personnel in project selections

- There are many engineers at all levels in each district engaged in the project selection process. In most cases, they tend to be the same personnel who makes the final selection for each treatment category (e.g., PM and RH) and pavement type. These engineers are identified as; area engineers, maintenance supervisors, pavement engineers, and directors of maintenance, operation and construction.
- Typical timing for starting the selection process initiated in late fall to early spring (from December to March) each year.
- Most districts use the "*MapZapper*" as their main tool to extract existing field site condition (e.g., condition score) combined with other tools such as PMIS and visual inspection to identify the candidate projects.
- The major factors considered into the projects' selection are annual daily traffic (ADT) and roadway functional class. Accidents reports and public concerns are among the factors considered in project selection. For projects with similar distress conditions, the ADT is

the main factor considered as the tie-breaker in deciding and selecting the project for treatment.

- There are no distress thresholds identified that warrant particular treatment in each decision category. However, major distresses such as rutting, failures, and alligator cracking are mostly treated through RH while PM is typically used for the surface-related distresses.

The following summarizes the methodology used by district personnel to select/prioritize projects (Dessouky et al. 2011):

1. Preliminary screening is performed to select project candidates for maintenance consideration. Area engineers conduct visual inspection in each district's roadway network and by *MapZapper* to allocate sections with low condition scores. Practically, sections not chosen in the previous fiscal year are included in the list, and most of the time they become strong candidates for the current fiscal year.
2. The preliminary list of projects is submitted to the district office along with a recommendation of the suggested treatments. Further information from the PMIS database using *MapZapper* is extracted for the proposed projects (e.g., previous year maintenance cost, ADT, condition score, distress score, skid resistance, etc.).
3. Area engineers combine the information from the visual inspection along with PMIS data, and classify sections into two treatment groups, PM and RH. The distress type is the main factor in selecting the treatment method. Suggested treatment is identified based on the distress severity. If the cause of the distress is unidentified, forensic analysis is proposed. Depending on the nature of distress and the size of the project, forensic analysis may be an option.
4. If a prioritization tool or formula is available in the district, a project can be ranked and a priority list can be identified. If no such tool is available, a combination between the condition score, the need assessment report, ADT, funding history, public concerns, and safety issues is considered to identify the priority list.
5. Each district office allocates the available funding for each treatment category until the available funds are exhausted. The remaining sections are reconsidered for treatment in the next fiscal year.
6. District office personnel conduct another in-field visual inspection of the projects on the priority list to validate the treatment selections and the priority assigned.

Examples of scheduled repair projects are shown in Figure 6. The farm-to-market (FM) 1472 in Laredo experienced deep rutting due to excessive truck loading and base failure. The district elected to perform a major base repair and apply concrete slab as final surface. The Interstate highway (IH) 20 in Abilene experienced fatigue cracking in the HMA surface layer and the district elected to remove the layer and apply seal coat with 1.25” porous fracture course to enhance draining and noise characteristics.

FM 1472: RH with base repair and rigid pavement due to severe rutting (High ADT)

IH 20: PM with porous layer over seal coat due to fatigue cracking (High ADT)

Figure 6. Examples of scheduled repair projects

Key Project Factors

One of the findings of the questionnaire is to identify the critical key factors that effectively contribute in selecting and prioritizing PM and rehab projects. Although it was suggested based on the site visits and questionnaire responses that districts have similarities in making prioritization decisions however, they were not exactly identical (Dessouky et al. 2011). This is attributed to the different climate conditions, district engineers' experience, availability of contractors and other factors. Nevertheless, one can highlight the critical key factors that are mostly used by the districts to assist in making decisions. They were not selected in this study solely on frequency of mention during district visits. Both frequency of mention, the logic expressed for using them, combined with the engineers experience resulted in the list of key factors shown in Table 4. Eight key project factors were identified for implementation in the tool. Six of these relate to rehab project selection and six relate to PM project selection.

Table 4. Key Project factors and Prioritization Applicability (Dessouky et al. 2011)

Project Factors	Rehab Project Prioritization Impact	PM Project Prioritization Impact
Condition Score	X	
Distress Score		X
Number of Failures per Mile	X	X
Ride Score	X	
Historical Maintenance Expenditure	X	X
Skid Number	X	X
Surface Age		X
Annual Daily Traffic (ADT)	X	X

The Condition Score (i.e., a composite index of distress and ride) and the Distress Score (a utility-based composite index of distresses) (Gharaibeh et al. 2011) are the most important key factors that are primarily used for identifying the critical projects in need for repair in a given network. Surface Age is considered as a major factor when deciding a PM treatment particularly when pavement reach certain age without treatment. Typically, pavement surface with 7-10 years old without treatment is considered a candidate for PM. The ADT is an indicator of total traffic volume and hence pavement deterioration rate. It is also used as a tie breaker between critical and non-critical projects. Number of Failures is an indication of the number of structurally failed spots in a given pavement and it is directly related to the need for RH treatment. Skid number is a major consideration for PM project particularly when it is combined with high crash records due to a surface-related safety concern. Ride score is a critical factor particularly on high speed roadways when driving comfort is in questions. Historical higher maintenance expenditures for a given section is indicative of the need adjusting the strategy for treatment selection (PM or Rehab) particularly if the previous treatment was not as effective as expected. Moreover, limited expenditure is also indicative of a pavement approaching the time for PM as a minimum.

SUMMARY AND CONCLUSIONS

The primary goal of this study was to present the current practices of selection and prioritization for PM and RH treatment projects in Texas. In TxDOT selection process required input of many engineering factors highlighting pavement conditions and traffic level. It also requires engineers input through visual inspections. Questionnaire responses implied that districts use GIS tool (namely *MapZapper*) as the main tool to access the PMIS database and extract pavement conditions. Visual inspection is also used as a screening tool for identifying preliminary selection and as a confirmation tool for validating final projects selection.

However, the lack of consistency among districts to establish a unified simple approach for project prioritization was the main observation from the districts questionnaire. The variation between districts takes place where priority and ranking tool may be used. The lack of documentation to report the selection process in the district offices has limited the resources to identify the best practice of project selection. The process acquires input of many factors including traffic level, truck traffic, ride score, skid number, crash analysis, structural index, treatment level, and cost. It also requires engineers and maintenance supervisors to submit their input and conduct visual inspections. Non-destructive testing are sometimes used for finalizing and identifying the best treatment methods.

Although there are numerous treatment applications for each project category (PM and Rehab) available to TxDOT. However, most districts use only two to three options in their pavement maintenance practice due to positive contractor experience, climate conditions and overall field performance. Seal coat and chip seal are the most common PM applications in the districts. Repair of localized sections (spot repair) and HMA overlay are the most used applications in rehab projects.

A set of eight key factors highlighting the combined experience of district engineers and logical thinking were introduced. These factors are: condition score, distress score, surface age, daily traffic, failure, skid number, ride score, and maintenance expenditures.

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