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A case study of performance-based pavement maintenance and rehabilitation needs assessment in Pennsylvania

Zheng Yubin[1] Bai Qiang[2] Chen Lin[2] Bismark Agbelie[3]

([1]Key Laboratory of Road and Traffic Engineering of Ministry of Education, Tongji University, Shanghai 201804, China)
([2]School of Highway Engineering, Chang'an University, Xi'an 710064, China)
([3]Department of Civil and Environmental Engineering, The Catholic University of America, Washington, DC 20064, USA)

Abstract: This paper presents the theory, method, and application of performance-based pavement needs assessment at a state level, using the Pennsylvania Interstate System as an example. First, a general framework is presented for the pavement asset management and a general optimization model is established for the pavement maintenance and rehabilitation needs assessment. Also, the bundling of pavement segments for the project implementation is discussed. Using the examples of Statewide Transportation Improvement Plan and Long Range Transportation Plan for Pennsylvania Interstate System, the application of performance-based pavement needs assessment is demonstrated. It is shown that unconstrained analysis can help decision-makers investigate the real maintenance and rehabilitation needs; financially-constrained analysis can help decision-makers select projects for implementation and examine the corresponding future pavement conditions. Trade-off analysis can help decision-makers investigate the outcomes of different investment levels on pavement maintenance and rehabilitation and make the final decision on the investment level. The proposed case study provides a good example of performance-based pavement needs assessment for developing countries.

Key words: pavement; maintenance and rehabilitation; needs assessment; performance-based; performance modeling

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While most developing countries are still focusing on adding more highways to their transportation system[1], many developed countries, including the United States, are significantly allocating financial resources to highway infrastructure maintenance and rehabilitation (M&R) activities. In the United States, the moving ahead of progress in the 21st Century Act (MAP-21) and the Fixing America's Surface Transportation (FAST) Act established a performance-based approach for state DOTs to efficiently manage and improve the highway infrastructure system[2]. Therefore, state DOTs need to develop and integrate statewide goals, objectives, and performance measures for highway investment decision-making. In relation to pavement system management under the FAST Act, there is a need to conduct a detailed pavement needs analysis, for both short-term and long-term interstate planning and programming, and to effectively link the pavement investment with the system pavement performance. Most existing pavement management systems predominately focus on a short-term approach, and most often do not provide a long-term needs assessment or connect the investment with the system performance[3-6]. Therefore, there is a need to adopt optimization methods when conducting a performance-based pavement needs analysis for short-term planning, state transportation improvement programs (STIPs), and long-term planning, long range transportation plans (LRTPs), to meet the FAST Act requirements.

Pavement investment needs assessment in transportation planning is basically to investigate pavement M&R needs at the network level during a planning period. Different from project-level pavement M&R needs analysis which selects appropriate M&R activities and develops the optimal M&R schedule for a specific pavement, network-level pavement M&R needs analysis either evaluates the total cost to maintain all pavements in the network above a certain condition level or conducts prioritization/optimization to select pavement segments to implement most cost-effective M&R treatments under budget constraints so that the limited budget can be optimally allocated[7].

Much research has been conducted on pavement M&R needs/planning at the network level. One of the earliest attempts was made by Abelson and Flowerdew[8] who used dynamic programming to estimate the least required investment needs to maintain a road network in Jamaica. In the 1980s, the Arizona DOT used optimization techniques for its pavement M&R management, which was based on linear programming and focused on minimizing

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Biographies: Zheng Yubin (1983—), male, Ph. D. candidate; Bismark Agbelie (corresponding author), male, doctor, assistant professor, agbelie@ cua. edu.

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cost[9-10]. Starting from 1989, the FHWA (Federal Highway Administration) required each state highway agency to have a pavement management system to manage their pavements[11]. In the 1990s, several transportation agencies started to use geographic information systems (GIS) in pavement management for the purposes of data management and the demonstration of analysis results. For instance, a prototype pavement management system was developed for Fountain Hills based on the GIS platform[12]. In the 2000s, optimization techniques were applied in the research of pavement management. For instance, Fwa et al. [13] adopted multiobjective optimization for pavement maintenance programming at the network level. Wang et al. [14] formulated the M&R scheduling problem as a bi-objective integer programming model which maximized the effectiveness of pavement maintenance treatments and minimized the maintenance-incurred user disturbance. In the last ten years, advanced and sophisticated optimization methods have been widely used for network-level pavement M&R decision-making. For instance, Gao et al. [15] used a parametric method for the bi-objective pavement maintenance and rehabilitation-scheduling problem by generating Pareto solutions. Peng et al. [16] developed an optimal funding allocation model for network-level asphalt pavement management systems. Zhang et al. [17] integrated life-cycle analysis and life-cycle optimization into the optimization model for network-level pavement M&R planning. Lee and Madanat[18] proposed a joint bottom-up solution methodology for network-level pavement rehabilitation and reconstruction decision making. Zhang et al. [19] developed a general iterative approach for network-level joint optimization of pavement M&R planning. Santos et al. [20] used an adaptive hybrid genetic algorithm for pavement management decision making. Wu et al. [21] incorporated risk in the decision-making and proposed a risk-based optimisation for pavement preventative maintenance with probabilistic LCCA. France-Mensah and O'Brien[22] conducted a comparative case study for the budget allocation models of pavement maintenance and rehabilitation at the network level. Chu and Huang[23] proposed a mathematical programming framework to model and quantitatively compare different maintenance strategies for network-level highway pavements using mixed-integer linear programming models. Khiavi and Mohammadi[24] used NSGA-Ⅱ to solve the multiobjective optimization in pavement M&R decision-making.

There are still many other studies on network-level pavement M&R decision-making which cannot all be reviewed and listed here due to paper length limit. Even though these studies have adopted advanced and sophisticated methods, there remain gaps between these studies and application in practice. First, most of these studies focus on short-term pavement M&R planning, and cannot be applied to long-term case, e. g., 20 or more years. Secondly, most of the advanced and sophisticated pavement management methods developed in research have not been adopted in practice. In 2012, the MAP-21 Act was signed for implementation in the United States. It established a performance-based framework to manage the transportation infrastructure. In 2015, the FAST Act was enacted as a further enhancement of MAP-21 to support the long-term development of the transportation infrastructure. Both acts require long-term planning for transportation infrastructure asset management, which is different from the practice of pavement management systems. Therefore, in the present study, a practical usable optimization model is adopted to conduct a performance-based pavement investment needs assessment for planning using a case study of the PennDOT interstate system. Even though the purpose is not to propose an advanced methodology, the real application experience will help practitioners know how to conduct a performance-based pavement investment needs assessment for long-term planning.

1 Performance-Based Pavement Needs Assessment

1.1 General framework

Typically, the framework of transportation asset management (TAM) can be used to conduct a performance-based pavement needs assessment. Fig. 1 presents a general transportation asset management (TAM) framework to support identifying and programming transportation projects. The TAM framework has the following primary components:

1) Goals & objectives: The goals and objectives of the TAM framework are to identify the most cost-effective activity profile for the highway asset to achieve asset state-of-good repair (SGR) over time.

2) Performance measures: Establish SGR thresholds for the pavement asset.

3) Performance modeling: Using historical pavement condition data, deterioration models are developed for the transportation asset. The models are used to predict asset deterioration over time and the remaining service life.

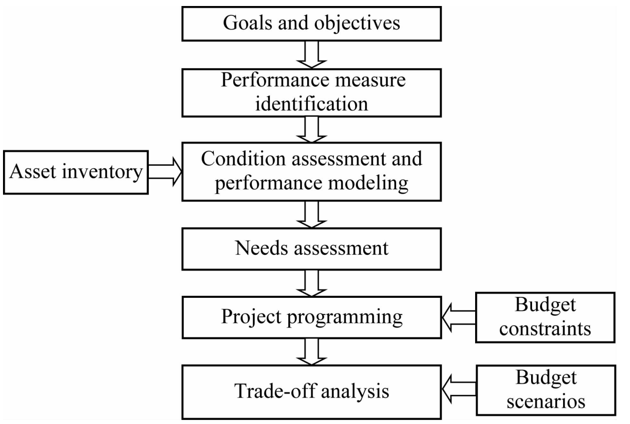

Fig. 1 TAM framework

4) Needs assessment: Evaluate the budgetary needs to achieve the performance goals. These results provide a base for DOTs to check what and where the M&R needs are.

5) Project programming: Recommend M&R projects through the optimization technique in a financially constrained environment and estimate the corresponding impacts on asset performance.

6) Trade-off analysis: Summarize performance tradeoffs under various investment levels.

Based on the general framework in Fig. 1, a more detailed methodology for pavement asset management is shown in Fig. 2. In needs assessment, the objective is to identify projects that can maximize system performance within budget constraints, while advancing the state's goals and objectives. In order to achieve this, the following methodology is recommended:

1) Use the results of the unconstrained analysis to recommend the most cost-effective asset repairs based on inspection condition data;

2) Bundle asset M&R activities into programmable projects by analyzing suggested repair, timings and geographic locations for potential mobilization/economy of scale savings;

3) Incorporate the decision-maker's preferences by assigning weights to each performance measure and a scale to score projects based on performance values;

4) Optimize the project selection process so as to maximize the program benefit under a budget constraint.

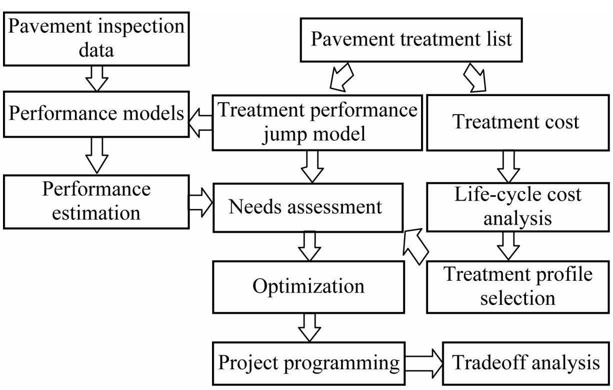

Fig. 2 The methodology for pavement needs analysis

1.2 Unconstrained needs assessment

1.2.1 Pavement treatments

Planning-level analysis is not intended to provide detailed project-level treatment recommendations. Instead, recommendations made at the planning level will identify what level/category of pavement treatments ought to be applied. Thereafter, the specific decision in relation to the exact treatment to be applied will be finalized at the local offices based on field observations of various indices. Also, planning-level analysis at the statewide level must account for the variety of treatments applied at the district level that have similar costs and performance benefits. Therefore, grouping together treatments with similar costs and performance benefits will provide each district with flexibility to choose preferred treatments, such as routine maintenance, minor rehabilitation, rehabilitation, and replacement.

1.2.2 Pavement performance modeling

Pavements deteriorate with age due to accumulated traffic loads, weather, application of de-icing chemicals, and other factors. Pavement deterioration models can simulate the deterioration trend and forecast future conditions[25-26]. Fig. 3 presents an example of pavement performance changes after pavement treatment. From the figure, it can be observed that pavements deteriorate with time and there is a performance jump immediately after pavement treatment.

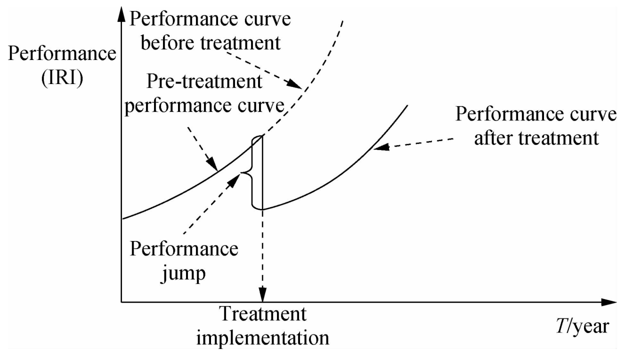

Fig. 3 Pavement performance international roughness index (IRI) change after pavement treatment

1.2.3 Pavement treatment recommendations

Using life-cycle cost analysis and existing pavement conditions, treatments are recommended for the pavement segment. The recommended treatments should be able to minimize the life-cycle cost of the pavement segment while keeping the pavement in an acceptable state-of-good repair during service life.

1.3 Constrained needs assessment

1.3.1 Pavement project optimization

In the constrained needs assessment, optimization can be used to find the optimal solution that maximizes the benefit under the limited budget. Even though many advanced and complex optimization techniques have been developed for pavement M&R decision-making, most of them have not been applied in real practice due to difficulties in the applications of complex optimization techniques to real applications, especially in relation to a large pavement network. To achieve the needs of pavement M&R planning at network level, while not making the model too complex, the following optimization model is used:

$$\max Z = \sum_{i=1}^{I} \sum_{j=1}^{J} \sum_{k=1}^{K} x_{ijk} s_{ijk} \tag{1}$$

s. t.

$$\sum_{i=1}^{I}\sum_{k=1}^{K} x_{ijk} d_{ijk} \leqslant b_j \qquad \text{for all } j \tag{2}$$

$$\sum_{j=1}^{J}\sum_{k=1}^{K} x_{ijk} \leqslant 1 \qquad \text{for all } i \tag{3}$$

$$P_{ij}(x_{ijk}) \geqslant P_{\min} \quad \text{or} \quad P_{ij}(x_{ijk}) \leqslant P_{\max} \qquad \text{for all } i, j \tag{4}$$

where i is the pavement segment index; j is the year index; k is the treatment index; I is the total number of pavement segments; J is the total number of years in the planning horizon; K is the total number of pavement treatments; x_{ijk} equals 1(implement treatment k in the j-th year on pavement segment i) or 0 (do not implement treatment k in the j-th year on pavement segment i); s_{ijk} is the general benefit to implement treatment k to pavement segment i in the j-th year; d_{ijk} is the cost to implement treatment k to pavement segment i in the j-th year; b_j is the budget limit in the j-th year; P_{ij} is the value of performance measures for pavement segment i in the j-th year; $P_{\min}$ is the minimum allowed values of the performance measure (the higher the better performance measures); $P_{\max}$ is the maximum allowed values of the performance measure (the lower the better performance measures, e. g. IRI).

Using this model, different types of treatment combinations can be automatically investigated for each pavement segment and this helps to choose the optimal one, as well as to reach the optimal decision at network level.

1.3.2 Pavement project bundling

In most states, the pavement system is divided into segments for the convenience of pavement management. Each segment is a unit for condition data collection/reporting and treatment recommendation. A pavement segment is typically around 0. 5 miles (1 mile = 1. 169 km) long[27]. Usually, pavement inventory, condition, and treatment history are typically recorded based on each pavement segment. In the process of pavement needs assessment, pavement activity recommendations are provided for each pavement segment based on its condition and treatment history. However, for the convenience of pavement project programming and delivery, it is better to bundle several pavement segments (with proposed treatment activities) together. Bundling segments are expected to yield cost savings by reducing mobilization efforts, minimizing material costs due to economies of scale, and encouraging competition from contractors bidding on rehabilitation and replacement projects. The basic method for bundling projects and incorporating them into a budget-constrained programming process is as follows:

1) Bundling rules setting: Identifying a minimum project length (e. g., 2 miles); identifying a preferred project length (e. g., 5 miles); identifying a synchronization timeframe for advancing/delaying activity implementation; a poor condition state should be avoided as the result of any bundle being implemented.

2) Bundling eligibility checking: Pavement segments must be on the same route and direction for bundling; segments must be of the same pavement type (asphalt/composite or concrete); a common activity must be recommended for the majority of the bundled length; and the timing of all activities within a bundle must be within the specified timeframe.

3) Updating bundles: Every year a recommendation will be made for every segment; and the bundling rules will be used to produce a project set based on condition segment recommendations.

2 PennDOT Interstate Pavement Needs Assessment and Pavement TAM Tool

PennDOT has a large interstate system with more than 2 600 segment miles (around 5 600 lane miles) of pavements, which are divided into more than 5 000 segments. Based on the framework and methodology presented earlier, a pavement TAM tool was developed to conduct needs assessment for planning purposes.

2.1 Performance measures

In PennDOT, the overall pavement index (OPI) and international roughness index (IRI) are used as the performance measures to evaluate the interstate pavement conditions. The OPI is a Pennsylvania pavement index that looks at both roughness as well as pavement distress. It is on a scale from 0 to 100 with 100 being in excellent condition. When a pavement experiences distress, that distress is quantified into a number and deducted from the excellent score of 100. The IRI is a measure of pavement roughness, and it was considered in the OPI. At the time of developing the pavement TAM tool, MAP-21 used the IRI as the performance measure, thus, IRI was used as a secondary performance measure in the PennDOT pavement needs assessment.

2.2 Pavement performance models

There are several types of pavement deterioration models in the literature. In the PennDOT pavement TAM tool, the empirical-based Markov model was used. A Markov model predicts the probability of being in any discrete condition state at any point in time based on pavement age and current condition state. Performance models for different geographical areas and different pavement types are different. A pavement deterioration model was developed for each pavement type in each geographical area. For planning purposes, pavement treatments were grouped into four categories: routine preservation, minor rehabilitation, major rehabilitation, and replacement. The average performance jumps after a treatment from historical data were used to measure the effectiveness of each category of pavement treatment.

2.3 PennDOT pavement TAM tool modules

The PennDOT pavement TAM tool was developed using the Macro/VBA in Microsoft Excel. The tool has user-friendly interfaces to help decision-makers conduct PennDOT Interstate pavement needs assessment. Fig. 4 is the "Home" interface of the pavement TAM tool.

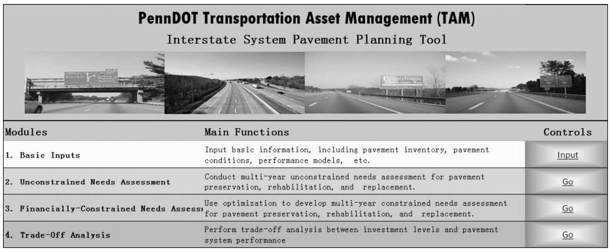

Fig. 4 Pavement TAM tool "Home" interface

From Fig. 4, it can be observed that PennDOT pavement TAM tool has four functional modules:

Module 1 (basic inputs module) This module guides users to input basic information into the tool to conduct various analyses, including pavement inventory, pavement conditions, and performance models. After the inputs, the summary of the existing pavement condition can be generated.

Module 2 (unconstrained needs assessment module) This module conducts multi-year unconstrained needs assessment. It can generate pavement treatment and timing, as well as the predicted conditions. Unconstrained needs assessment means there is no budget limit for pavement treatment. In the assessment process, pavement treatments are proposed based on the actual M&R needs. The tool uses life-cycle cost analysis to recommend the most cost-effective M&R activity based on inspection condition data. The results are: 1) Overall output summary, including unconstrained needs each year, pavement conditions under unconstrained needs assessment using excellent, good, fair and poor categories; 2) Treatment summary by year and by treatment type; 3) Cost summary by year and by treatment type; 4) A detailed list of treatments, costs, and conditions for each pavement segment; 5) A detailed list of projects with rankings; 6) Summary by district, county and route.

Module 3 (financially-constrained needs assessment module) This module applies optimization to develop multi-year constrained needs assessment for pavement treatments. It generates similar types of results as the unconstrained analysis, but with budget constraints.

Module 4 (trade-off analysis module) It performs trade-off analysis between investment levels and pavement system performance and can help decision makers investigate the best investment levels.

3 Performance-Based Pavement Needs Assessment for PennDOT Interstate System

This section presents two case studies to demonstrate the application of performance-based pavement needs assessment. The first case study is the needs assessment for a STIP; the second one is the needs assessment for a long-range plan.

3.1 Statewide transportation improvement plan

PennDOT needs to develop the STIP for years 2018—2021. Assume that the budget plan for interstate pavement is 2×10^8 US dollars for 2018 and 2.5×10^8 US dollars annual budget from 2019 to 2021. There are some confirmed projects from 2018 to 2021. The pavement TAM tool was used to conduct the analysis. The inputs include a pavement inventory, analysis period, pavement treatment cost, economic factors, confirmed projects, performance models, and budget information.

Using the pavement TAM tool, the unconstrained needs assessment was conducted. Fig. 5 presents the overall summary. From Fig. 5(a), it can be observed that under the unconstrained needs analysis, the first year requires more than 1.5×10^9 US dollars to fix the existing problem in the pavement system. It can be observed in Fig. 5(e) that no pavement segment during the life-cycle will be in poor condition under the unconstrained needs analysis. Tab. 1 presents the needs summary by lane miles and by cost for each treatment category and each pavement type.

Using the planned budget, a financially constrained analysis can be conducted. Fig. 6 presents the overall summary of the constrained needs analysis. Fig. 6(e) indicates that, although the budget is used up each year, approximately 4.5% of pavement segments are in poor condition at the end of the analysis period. The result indicates that the budget is insufficient to cover total pavement needs. This is consistent with the expectation since the budget is much lower than the unconstrained needs generated in Fig. 5(a). Tab. 2 presents the needs summary by lane miles and by cost for each treatment category and each pavement type.

From this case study, it can be seen that the proposed methodology and the developed TAM tool can be well used for short-term pavement M&R planning, which is comparable to most pavement management systems.

3.2 Long-range transportation plan (LRTP)

The analysis period for PennDOT LRTP is 2018—2040. Similar to the STIP analysis, after finishing all related inputs, the unconstrained and constrained needs assessment can be conducted. Fig. 7 presents the overall summary for the unconstrained needs analysis. The result from year 2024 to 2027 shows that an increasing trend of investment is needed to maintain the interstate pavement system in an acceptable condition (no "poor" condition). The total unconstrained needs from 2018 to 2040 were confirmed as 2.3838×10^{10} US dollars.

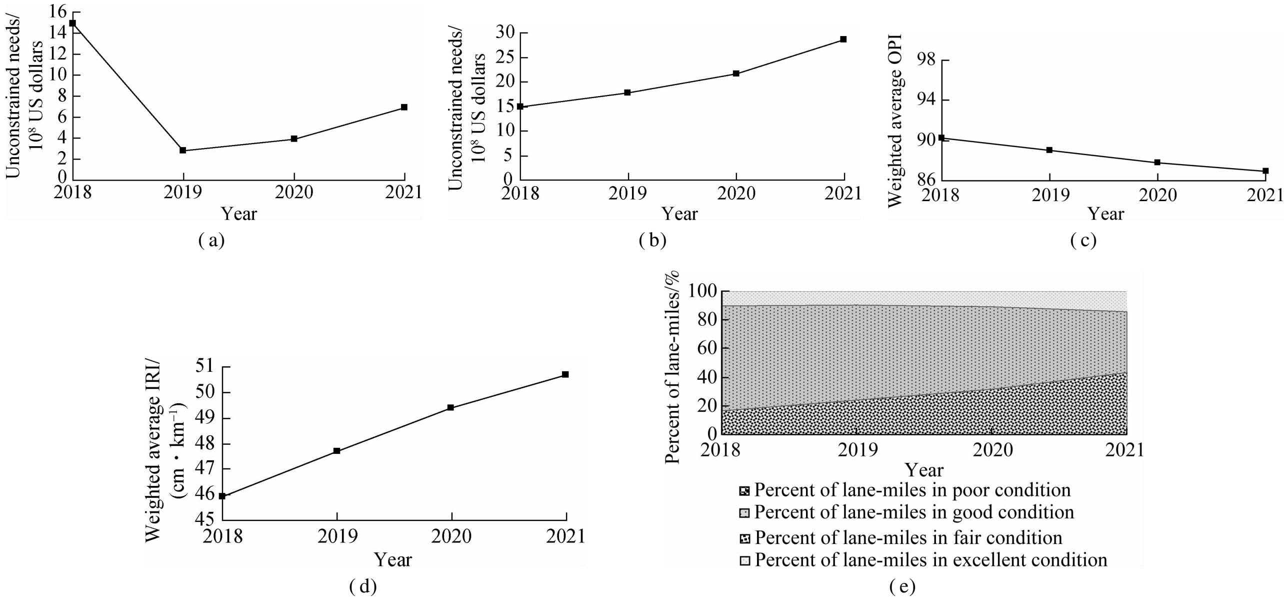

Fig. 5 STIP unconstrained needs assessment results. (a) Annual needs trend; (b) Cumulative needs trends; (c) Average OPT trend; (d) Average IRI trend; (e) Sate-of-repair trend

Tab. 1 Treatment and cost summary (unconstrained needs)

Summary		Summary of activities (in lane-miles)				Summary of costs (in thousands of YOE dollars)			
		2018	2019	2020	2021	2018	2019	2020	2021
Asphalt pavements	Minor rehabilitation	0	0	0	0	0	0	0	0
	Rehabilitation	0	0	0	0	0	0	0	0
	Replacement	30.49	7.06	9.48	11.81	145 943	24 827	29 465	41 297
Composite pavements	Minor rehabilitation	0	5.00	0	1.39	0	611	0	228
	Rehabilitation	16.51	3.06	21.30	2.01	8 297	1 071	6 823	745
	Replacement	195.53	54.88	87.93	133.86	898 721	177 458	265 085	443 483
Concrete pavements	Minor rehabilitation	34.17	31.22	24.32	38.84	7 431	7 010	5 784	9 514
	Rehabilitation	18.43	1.01	0	1.43	29 306	890	0	1 332
	Replacement	84.37	24.50	25.47	55.81	399 275	71 675	85 007	189 363
Total(all pavement types)	Minor rehabilitation	34.17	36.21	24.32	40.23	7 431	7 621	5 784	9 743
	Rehabilitation	34.94	4.07	21.30	3.44	37 602	1 961	6 823	2 077
	Replacement	310.39	86.44	122.89	201.48	1 443 938	273 959	379 557	674 143

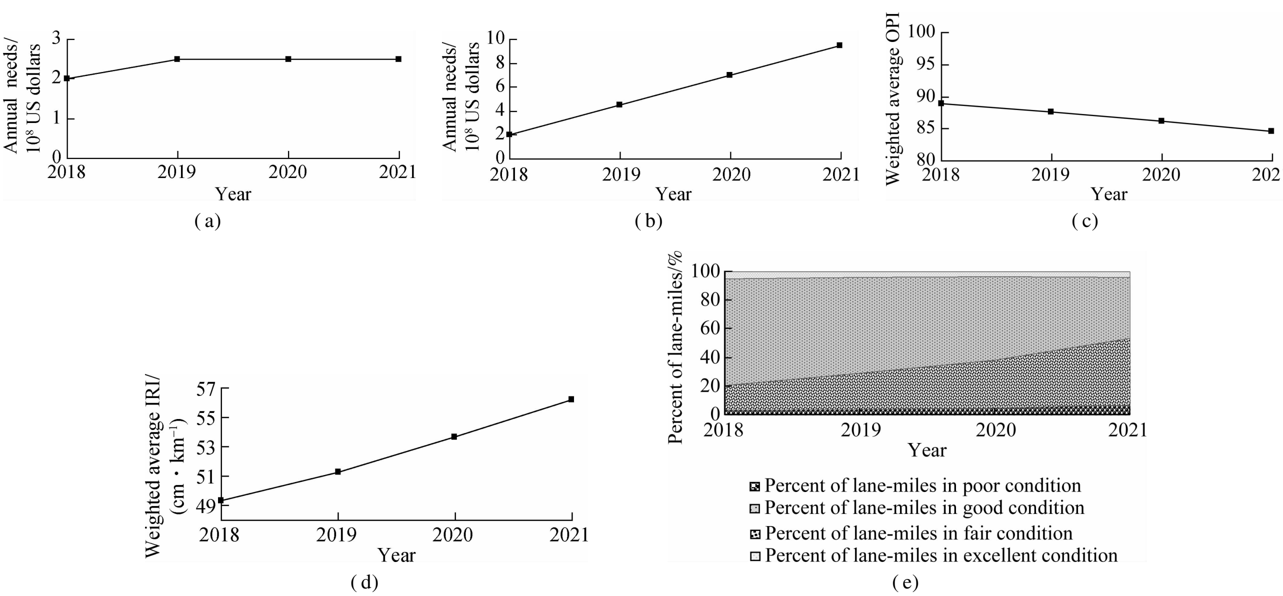

Fig. 6 STIP constrained needs assessment. (a) Annual needs trend; (b) Cumulative needs trend; (c) Average OPT trend; (d) Average IRI trend; (e) Sate-of-repair trend

Tab. 2 Treatment and cost summary (constrained needs)

Summary		Summary of activities (in lane-miles)				Summary of costs (in thousands of YOE dollars)			
		2018	2019	2020	2021	2018	2019	2020	2021
Asphalt pavements	Minor rehabilitation	0	0	0	0	0	0	0	0
	Rehabilitation	0	0	0	0	0	0	0	0
	Replacement	1.91	6.24	2.05	11.90	7 252	31 611	11 878	61 059
Composite pavements	Minor rehabilitation	0	5.00	0	0	0	611	0	0
	Rehabilitation	0	12.99	9.99	0	0	6 591	5 274	0
	Replacement	37.67	34.42	33.82	32.02	169 894	159 050	157 166	158 342
Concrete pavements	Minor rehabilitation	0	22.28	7.52	0	0	4 899	2 009	0
	Rehabilitation	0	0	0	0	0	0	0	0
	Replacement	4.04	10.42	15.25	6.12	22 666	47 407	73 697	29 842
Total (all pavement types)	Minor rehabilitation	0	27.27	7.52	0	0	5 511	2 009	0
	Rehabilitation	0	12.99	9.99	0	0	6 591	5 274	0
	Replacement	43.63	51.08	51.12	50.03	199 812	238 068	242 741	249 243

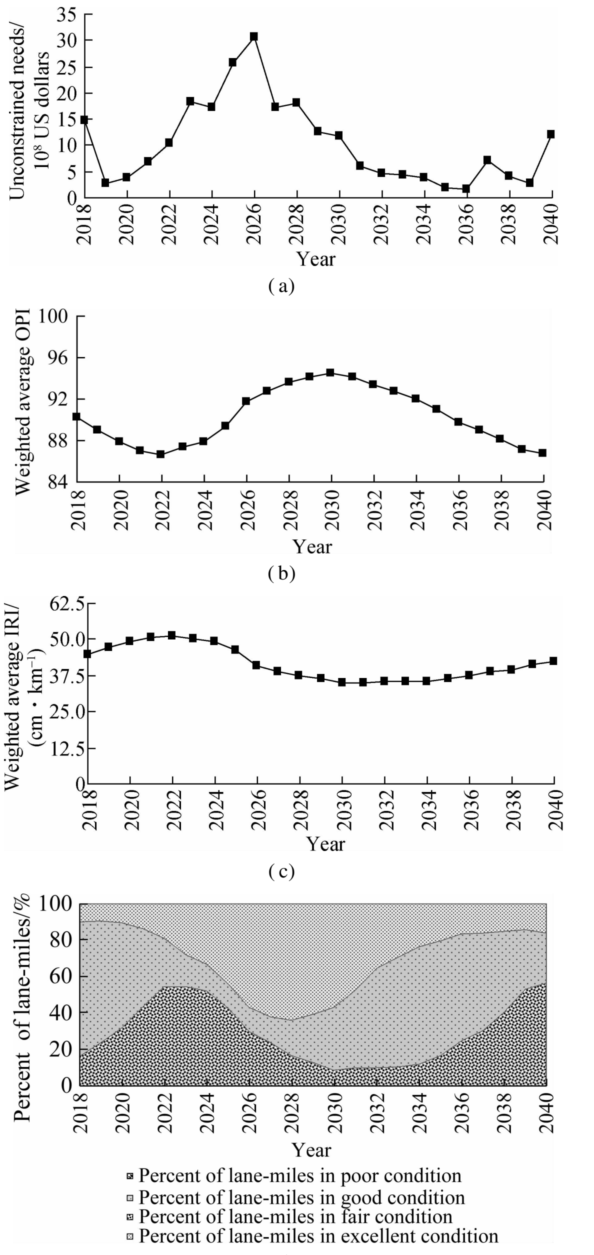

Fig. 7 LRTP unconstrained needs-overall output summary. (a) Annual needs trend; (b) Average OPT trend; (c) Average IRI trend; (d) Sate-of-repair trend

The information in Fig. 7 is very useful in pavement M&R planning and general long-term pavement planning. It can provide high-level decision-makers with the information about the anticipated needs in the long-term future so that they can plan beforehand at a high level if there is an unusually high needs in a certain period in the future.

Fig. 8 presents the financially-constrained results if the annual budget is set to be 5×10^8 US dollars (in year of expenditure dollars). Since the annual budget is much lower than the unconstrained needs as shown in Fig. 7(a), it is observed in Fig. 8 that, starting from 2022, the percent of pavement in poor condition increases sharply. The result can help decision-makers to ask for more funding for pavement M&R by informing those who allocate the funding that if they only provide 5×10^8 US dollars per year, the network-level pavement condition will become unacceptable.

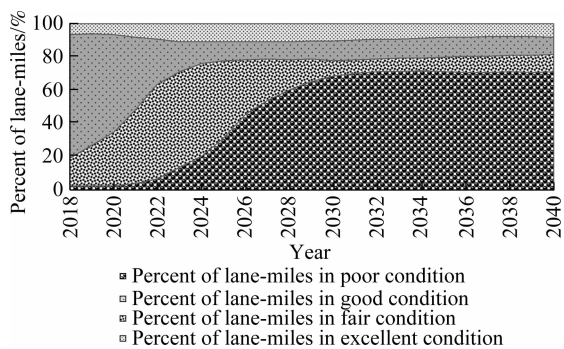

Fig. 8 LRTP constrained results (5×10^8 US dollars per year)

From this analysis, it is seen that the proposed methodology and the developed TAM tool can be used well for long-term pavement M&R planning, which is included in most existing pavement management systems.

Typically, the trade-off analysis is the favorite part for most decision makers; and it is also required by the performance-based approach. In the trade-off analysis, four investment levels were investigated: 3×10^8 US dollars per year (i. e., 300 million US dollars per year), 5×10^8 US dollars per year (i. e., 500 million US dollars per year), 6×10^8 US dollars per year (i. e., 600 million US dollars per year), and 7×10^8 US dollars per year (i. e., 700 million US dollars per year) in year of expenditure dollars. Fig. 9(a) and Fig. 9(b) present the system performance at different investment levels. Fig. 10 shows the system's state-of-good-repair at different investment levels. Based on the results, it is observed that in general, higher investment levels produce better system performance. The information in Fig. 10 can help decision makers inform their high-level officers about what level of performance the system can achieve if they provide a certain level of funding/investment, which can help them ask for more funding, with the exact amount of additional funding required. It also provides high-level officers the options of investment levels and the corresponding system performance to help them make a reasonable decision, which is the core of a performance-based pavement M&R needs assessment.

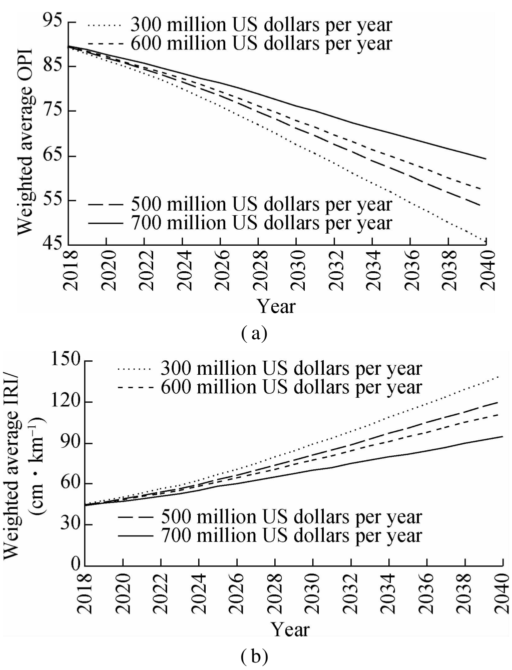

Fig. 9 Pavement system performance at different investment levels. (a) Pavement average OPI trend; (b) Pavement average IRI trend

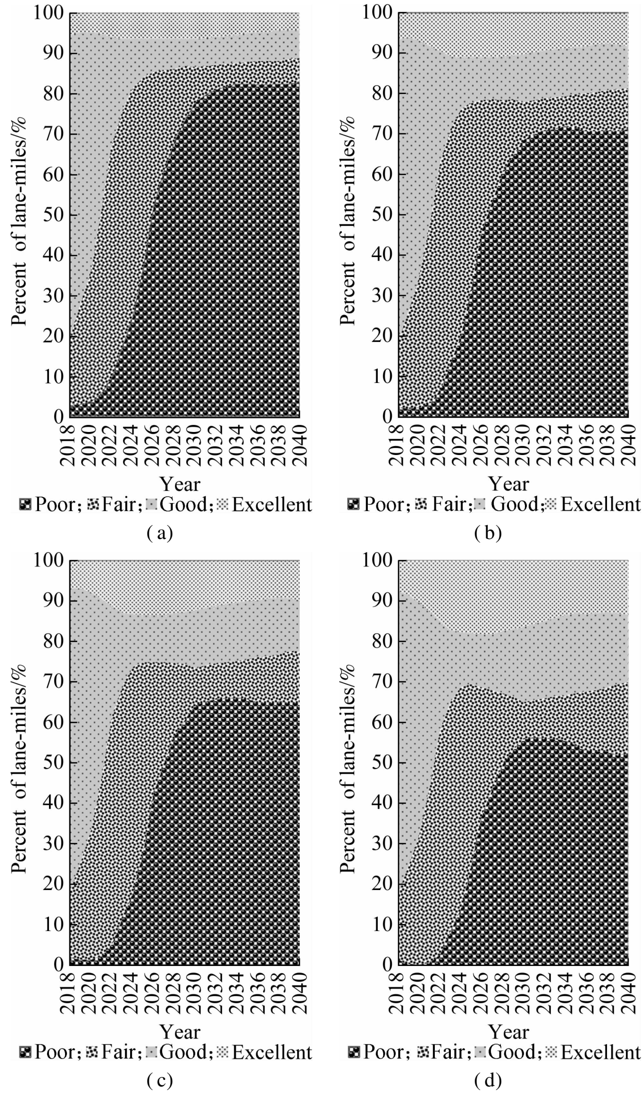

Fig. 10 Pavement state-of-good-repair comparison (in percent of lane miles) at different investment levels. (a) 300 million US dollars per year; (b) 500 million US dollars per year; (c) 600 million US dollars per year; (d) 700 million US dollars per year

4 Conclusions

1) This paper presented a case study of performance-based approach for short-term and long-term pavement needs assessment in transportation planning at state level. A general pavement asset management framework was developed, and the framework was applied to the pavement M&R needs assessment in transportation planning. The framework adequately connected pavement system performance and investment levels to meet the requirements of the FAST Act. Using two case study examples, a STIP and a LRTP, the performance-based pavement needs assessment for PennDOT was demonstrated.

2) The results from case studies show that the presented methodology and the developed TAM tool can be used in both short-term and long-term pavement needs assessment for transportation planning at a network level. It also demonstrates that unconstrained analysis and constrained analysis are essential parts of a performance-based approach for pavement M&R planning, and the trade-off analysis is the core part for a performance-based pavement M&R planning. The trade-off analysis presents decision makers with the options of investment levels and the corresponding system performance helps them make a reasonable decision. It is also a very good support for them to ask for more pavement M&R funding.

3) Even though the case study is from the US, it provides a good example for developing countries. Most developing countries are still focusing on highway construction and pay little attention to pavement M&R. Therefore, in their transportation planning, the most important focus is still planning new roads, not the M&R of the road. However, some developing countries, like China,

may soon shift from the construction stage to M&R stage. Through the tools adopted in the present study, developing countries can employ similar methods to develop their own TAM tools, resulting in time and financial resource savings.

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美国宾夕法尼亚州绩效式路面养护维修需求案例分析

郑育彬[1] 柏 强[2] 陈 琳[2] Bismark Agbelie[3]

([1] 同济大学道路与交通工程教育部重点实验室, 上海 201804)
([2] 长安大学公路学院, 西安 710064)
([3]Department of Civil and Environmental Engineering, The Catholic University of America, Washington, DC 20064, USA)

摘要:以美国宾夕法尼亚州(Pennsylvania)州际公路系统为例,介绍了绩效式路面养护维修需求分析的理论、方法与应用. 首先,介绍了路面资产管理的一般框架,建立了路面养护维修需求分析的一般模型,并充分考虑了在实际项目执行过程中的路段组合问题. 然后,以美国 Pennsylvania 州际公路交通改善规划(STIP)和中长期规划(LRTP)为例,详细介绍了绩效式路面投资需求分析. 案例结果显示,无资金约束分析可以帮助决策者了解路面养护维修规划的实际需求;有资金约束分析可以帮助决策者选择实际项目并清楚地了解未来路面的状况;均衡分析能够帮助决策者分析各种投资水平下的效果并作出正确投资水平决策. 该案例所采用的绩效式路面养护维修需求分析方法可为发展中国家所借鉴.

关键词:路面;养护维修;需求分析; 绩效式; 表现模型建模

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