Sainteks: Jurnal Sain dan Teknik
E-ISSN: 2685-8304
Volume 8, Nomor 02, 2026
http://ejournal.uicm.ac.id/index.php/sainteks/

Flexible Pavement Design Using MDP 2024 and Asphalt Institute

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Abstract: *Accurate flexible pavement thickness design is essential for structural reliability, particularly under high heavy-vehicle traffic and Over Dimension Over Load (ODOL) conditions that may accelerate fatigue cracking and rutting. This study compares pavement thickness, structural responses, and estimated service life obtained using the 2024 Pavement Design Manual (MDP 2024) and the Asphalt Institute method, supported by Pavement-PastDean, under three planned traffic-load scenarios of 5, 15, and 60 million CESA. The analysis uses actual field subgrade CBR data from Jalan Simpang Maruyung, Kutamandiri, Tanjungsari, Sumedang Regency, with a design CBR of 9%, selected from the lowest of three field measurements. Both methods produced pavement structures that met the design criteria in all scenarios. At 5 million CESA, the total thicknesses were 300 mm for MDP 2024 and 450 mm for the Asphalt Institute; at 15 million CESA, they were 385 mm and 505 mm, respectively; and at 60 million CESA, both converged to 540 mm. At 5 million CESA, estimated service life was 6.41 million CESA for MDP 2024 and 7.17 million CESA for the Asphalt Institute, while at 15 million CESA the values were 20.43 and 18.48 million CESA, respectively. At 60 million CESA, MDP 2024 produced an extreme value of 980,184.82 million CESA versus 79.35 million CESA for the Asphalt Institute. This extreme value is attributed to the transfer-function formulation after the AC-Base tensile strain decreased to 7.499 microstrain due to the stiff cement-treated base (CTB, E = 3,000 MPa), and should not be interpreted as evidence of superior rutting performance because both methods produced the same subgrade compressive strain. Overall, the relative performance of the two methods varied with traffic level, indicating a nonlinear relationship between load level and predicted pavement performance.*

Keywords: *flexible pavement; MDP 2024; Asphalt Institute; Pavement-PastDean; CESA*

DOI: https://doi.org/10.37577/sainteks.v8i02.1185
Received: 08, 2026. Accepted: 09, 2026. Published: 09, 2026

INTRODUCTION

Road infrastructure development in Indonesia has increased rapidly in line with growing transportation and mobility needs. In flexible pavement design, determining pavement layer thickness is important because it directly affects road strength, durability, and service life. The problem is compounded by the high intensity of heavy-vehicle traffic and the continued occurrence of Over Dimension Over Load (ODOL) practices in the field. Actual loads exceeding pavement design capacity may trigger premature failures, including fatigue cracking in asphalt layers and rutting in the subgrade before the pavement reaches its intended design life.

Various flexible pavement thickness-design methods are currently used at national and international levels, including AASHTO 1993, the Asphalt Institute method, the Nottingham method, Austroads, and the 2024 Pavement Design Manual (MDP 2024) (Rochma Riyani et al., 2025; Wibawa et al., 2025). MDP 2024 is the latest national method developed to accommodate developments in traffic conditions, materials, pavement technology, and Indonesian road characteristics (Kementerian PUPR Direktorat Jenderal Bina Marga, 2024; Parianto, P., Sulandari, E., & Mukti, 2025). The Asphalt Institute method, documented in MS-1(Institute, 1983) is an international mechanistic-empirical approach that has been widely used for flexible pavement design (Kosasih, 2025). Internationally, mechanistic-empirical approaches such as the Mechanistic-Empirical Pavement Design Guide (MEPDG) NCHRP 1-37A have produced systematically different thickness and performance predictions from earlier empirical guides such as AASHTO 1993, particularly under high traffic and warm climates (Carvalho, R. L., & Schwartz, 2006; Thompson, 1996). Differences in the concepts and parameters of the two methods can therefore produce different pavement thicknesses, making comparative studies useful for identifying differences in design outputs, structural efficiency, and appropriate application conditions (Rafi Sugema & Robi Maulana, 2025).

Previous studies have generally compared the two methods using representative design data rather than actual field data. Pasaribu et al. (2025) compared MDP 2024, the Asphalt Institute method, and AASHTO MEPDG using KENPAVE for four road classifications in Indonesia with representative design data. Their results indicated that MDP 2024 tended to produce higher and more optimistic allowable-load repetition predictions than the international methods and recommended local calibration using field data. This recommendation is consistent with findings from other developing-country contexts: Saudy et al., (2023), who implemented mechanistic-empirical pavement design and analysis in Egypt, and Li et al. (2011), who reviewed broader MEPDG implementation, both emphasized that transfer functions calibrated for one climate and material context may misestimate performance when applied elsewhere without local calibration or, at minimum, validation against local field data. This study follows that recommendation by using actual field CBR data and Pavement-PastDean to provide a more context-specific comparison of the two methods.

The novelty of this study lies in integrating actual field subgrade CBR data with mechanistic-empirical evaluation using Pavement-PastDean across three traffic-load levels. Thus, the comparison is not limited to layer thickness but also covers structural responses and estimated service life over different load levels. The research questions are: (1) how do flexible pavement thickness designs differ between MDP 2024 and the Asphalt Institute method under different traffic-load scenarios; (2) what structural responses—vertical compressive strain in the subgrade (εc) and horizontal tensile strain in asphalt layers (εt)—are generated by the two methods; and (3) how do the estimated service lives compare, and how consistently does Pavement-PastDean support the analysis of both methods? The objective is to obtain effective flexible pavement thickness designs using both methods and to evaluate the computational consistency of Pavement-PastDean in flexible pavement design analysis.

The contribution of the study is the integration of three elements: actual CBR data, three traffic-load levels, and a single analytical platform. Conceptually, the comparison is interpreted as follows: (1) a thinner design may be considered structurally efficient if it still satisfies the applicable distress criteria; (2) lower strain values indicate a relatively larger damage margin under the same criterion; and (3) higher service life indicates a greater load-repetition capacity according to the model used. These indicators should not be considered independently because an economical structure is not necessarily the most conservative, while a conservative structure is not necessarily the most economical.

THEORETICAL FOUNDATION AND ANALYTICAL FRAMEWORK

Comparative Research Framework

The analytical framework consists of three main outputs. First, the design output comprises pavement structure and layer thickness. Second, the response output comprises vertical compressive strain in the subgrade and horizontal tensile strain in asphalt layers. Third, the performance output comprises the estimated number of load repetitions until a specified distress criterion is reached. Computational consistency must be distinguished from field validation: if the software produces consistent outputs when inputs and design criteria are changed according to the prescribed procedure, this indicates consistency of the analytical process, but it does not demonstrate that the predicted service life will equal actual service life. Stronger validation requires comparison with measured pavement performance or an independent analytical method.

The two methods were compared under equivalent input conditions: the same location, subgrade data, and three planned traffic-load levels. This allows differences in results to be more directly attributed to characteristics of each method rather than differences in field conditions, while also allowing assessment of whether the relative behavior of each method remains consistent or changes as traffic loading increases.

Mechanistic-Empirical Approach and Pavement-PastDean

The mechanistic-empirical approach links mechanical pavement responses to empirical distress criteria. Flexible pavement is a layered system that receives wheel loads and transfers them through successive layers to the subgrade. Structural performance depends not only on total thickness but also on the combination of material types, layer stiffness, subgrade condition, traffic characteristics, and environmental factors. Pavement-PastDean is used as the analytical tool to evaluate structural responses and load-repetition capacity using multi-layer elastic theory, producing strain values that are used to interpret response differences between the two design methods.

Pavement-PastDean is managed and hosted by the Faculty of Civil and Environmental Engineering (FTSL), Institut Teknologi Bandung (ITB), as a collection of pavement-analysis programs comprising a Response Program Module and a Mechanistic Design Program Module. For structural-response evaluation, it applies distress criteria following the 1983 Asphalt Institute method (Bandung, 2026).

Asphalt Institute Method

The Asphalt Institute method is an analytical layered-system design approach documented in MS-1 (Institute, 1983). It determines pavement thickness using multi-layer elastic systems and enables structural responses to be analyzed based on layer configuration and material characteristics. In this study, it serves as the international comparison method for MDP 2024. Differences in results do not necessarily indicate that one method is incorrect; they may reflect differences in assumptions, parameters, distress criteria, and conservatism embedded in each design framework.

MDP 2024 and the Indonesian Context

The 2024 Pavement Design Manual (MDP 2024) was issued by the Directorate General of Highways as a replacement for the previous MDP and the 2017 MDP Supplement. It provides a reference for pavement structural design in Indonesia and considers structural selection, traffic conditions, environmental conditions, drainage, and construction requirements. Local characteristics are one reason for using actual field CBR data in this study: CBR is an indicator of subgrade bearing capacity that affects the structural requirements of overlying layers, and field data reduce dependence on example or typical values that may not represent actual site conditions. Two pavement distress mechanisms are the focus of this study: fatigue cracking, associated with repeated tensile strain in asphalt layers, and rutting, associated with permanent deformation in pavement layers including the subgrade. Because these mechanisms differ, a structure may have a favorable margin against one criterion while being closer to another; therefore, design evaluation should not be limited to layer-thickness comparison.

METHOD

This study uses a quantitative comparative design. Primary data were obtained through direct measurement of road geometry at Jalan Simpang Maruyung, Kutamandiri, Tanjungsari, Sumedang Regency, with a planned road length of 980 m and width of 6 m. Secondary data consisted of subgrade CBR values obtained from a previous geotechnical investigation by CV. Berkah Adi Laksana.

Pavement structures were analyzed under three planned traffic-load scenarios: 5, 15, and 60 million CESA, representing low, medium, and high traffic classes rather than measured traffic counts because the study road is a new road without observed traffic data. Each scenario was analyzed separately using MDP 2024 and the Asphalt Institute method with Pavement-PastDean. The design was iterated until the controlling criteria were satisfied (OK): fatigue cracking in asphalt layers, represented by horizontal tensile strain (εt), and rutting at the subgrade surface, represented by vertical compressive strain (εc). Wheel loading was represented by a single axle with dual wheels, 20 kN per wheel, tire pressure of 750 kPa, contact radius of 92.132 mm, wheel spacing of 330 mm, and axle width of 1,800 mm. These inputs were applied identically to both methods and all scenarios.

Research Location

The study was conducted on Jalan Simpang Maruyung, Kutamandiri, Tanjungsari, Sumedang Regency. Field subgrade CBR was measured at three test points on natural soil (Table 1). The design CBR used in the analysis was 9%, selected from the lowest field value and rounded from 8.9%. This conservative selection reflects the fact that field subgrade bearing capacity can vary and is sensitive to changes in moisture content, particularly during the rainy season. Using the lowest measured CBR limits the influence of localized reductions in bearing capacity, while sections with higher CBR values retain additional structural margin.

Table 1. Field Subgrade CBR Values

Test Point	Date	Station	Layer	Depth	CBR (%)
CBR-1	16 Jul 2026	STA 1	Natural soil	Surface	11.4
CBR-2	16 Jul 2026	STA 2	Natural soil	Surface	8.9
CBR-3	16 Jul 2026	STA 3	Natural soil	Surface	16.4

Source: Geotechnical investigation by CV. Berkah Adi Laksana.

Loading Scenarios and Research Variables

Three loading scenarios were analyzed: 5 million CESA (low traffic, for example a collector or local road), 15 million CESA (medium traffic, for example a secondary arterial), and 60 million CESA (high traffic, for example a toll road or major logistics corridor). For each scenario, the design process was conducted using both methods, resulting in six design combinations evaluated in terms of structural thickness, response, and service-life output. The main comparison variables were total structural thickness, vertical compressive strain in the subgrade (εc), horizontal tensile strain at each asphalt layer (εt), and the number of load repetitions sustained until a distress criterion was reached.

Analysis Procedure

The analysis consisted of five stages: (1) preparation of site data and material parameters; (2) determination of pavement structure for each method at each CESA level; (3) execution of Pavement-PastDean to obtain mechanical responses and estimated load repetitions; (4) checking the OK criterion for each scenario, with structural adjustment and repeated analysis if a criterion was not satisfied; and (5) comparison of results between the two methods.

Interpretation Criterion

To avoid conclusions based only on absolute values, relative differences were also calculated. For two values X and Y, the relative difference with respect to reference value Y is:

$$\Delta(\%) = ((X - Y) / Y) \times 100\% \quad (1)$$

A positive value indicates that the first method has a higher value than the reference, whereas a negative value indicates the opposite. This measure was applied consistently throughout the Results and Discussion section to interpret differences in strain and service life proportionally.

Consistency Check

Lower εc values are interpreted as an indication of a larger safety margin against subgrade rutting, while the final interpretation remains subject to the distress criteria and models implemented in the software. Higher service-life values indicate greater load-repetition capacity according to the calculation model. Consistency was checked by comparing Pavement-PastDean outputs with the OK design criterion across all six scenarios. No inferential statistical test was performed because the unit of analysis consisted of only six deterministic design combinations and the objective was engineering comparison rather than statistical inference. Accordingly, the term “precision” is avoided and replaced by “computational consistency,” defined here as the ability of the software to return internally consistent OK/not-OK status when the same feasibility criteria are checked across the six design iterations.

RESULTS AND DISCUSSION

Pavement Structure and Layer Thickness

Table 2 presents the final layer thicknesses for the six design combinations (two methods × three CESA levels).

Table 2. Pavement Layer Thickness by Method and Loading Scenario (mm)

Layer	MDP 5M	MDP 15M	MDP 60M	AI 5M	AI 15M	AI 60M
AC-WC	40	40	40	40	40	40
AC-BC	60	65	–	60	65	–
AC-Base	100	130	150	150	200	150
CTB	–	150	150	–	200	150
Aggregate Base Class A	100	–	–	200	–	–
Aggregate Base Class C	–	–	200	–	–	200
Total thickness	**300**	**385**	**540**	**450**	**505**	**540**

Source: Pavement-PastDean output.

MDP 2024 produced thinner structures than the Asphalt Institute method at 5 and 15 million CESA (300 mm versus 450 mm, and 385 mm versus 505 mm), while at 60 million CESA the two methods converged to an identical 540 mm structure after the introduction of a cement-treated base (CTB, E = 3,000 MPa). This behavior is consistent with the local calibration embedded in MDP 2024 for Indonesian traffic and climate conditions and with the larger conservative margin associated with the Asphalt Institute method at lower traffic levels.

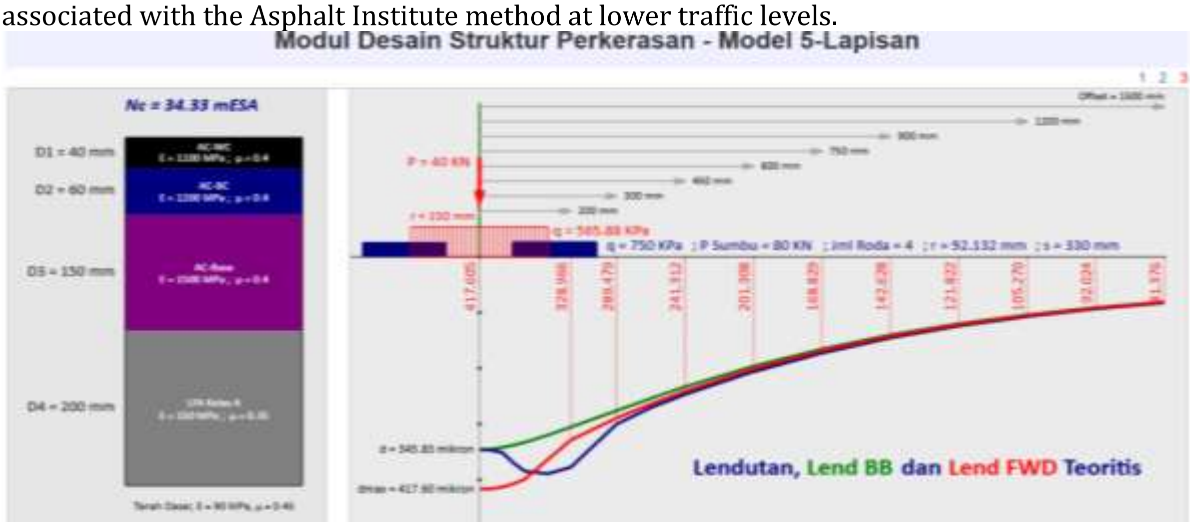

Figure 1. Pavement structure section and deflection response, MDP 2024, 5 million CESA (without CTB).

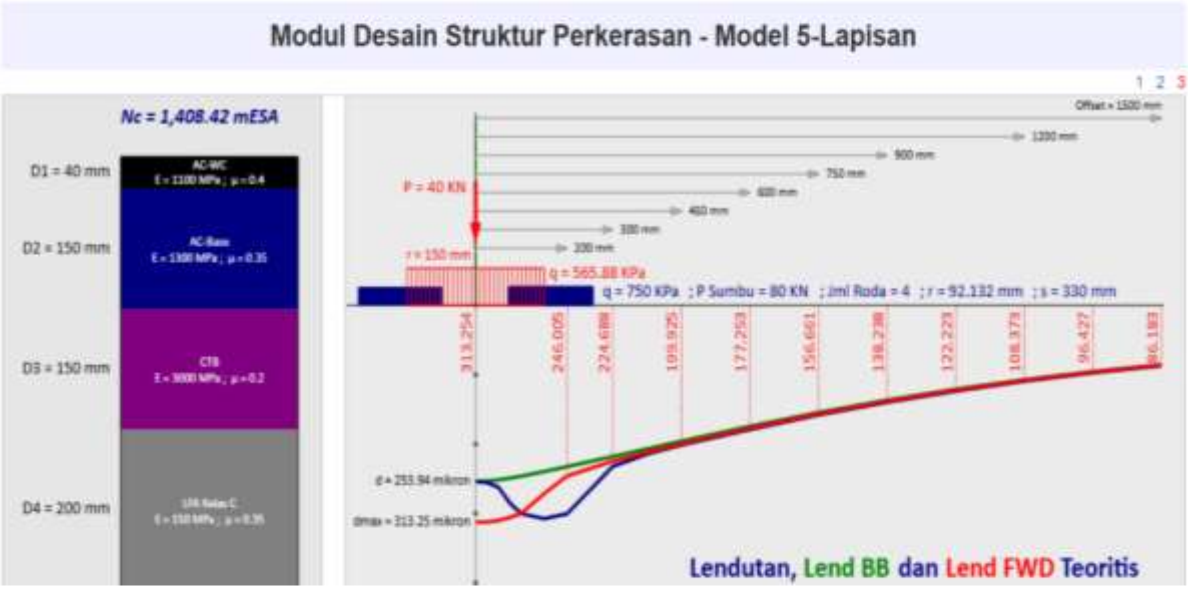

Figure 2. Pavement structure section and deflection response, MDP 2024, 60 million CESA (with 150 mm CTB, E = 3,000 MPa).

Structural Response: Vertical Compressive Strain of the Subgrade

Vertical compressive strain (εc) at the subgrade surface, a primary indicator of rutting risk, is presented in Table 3.

Table 3. Vertical Compressive Strain of the Subgrade (εc, microstrain)

Loading scenario	MDP 2024	Asphalt Institute	Difference (MDP higher)
5 million CESA	−490.913	−308.092	59.34%
15 million CESA	−368.216	−240.122	53.35%
60 million CESA	−180.069	−180.069	0.00%

Source: Pavement-PastDean output; relative difference calculated using the equation in Section 3.4.

At low to medium traffic levels, MDP 2024 consistently produced higher εc than the Asphalt Institute method, indicating a relatively smaller safety margin against rutting. At 60 million CESA, both methods converged to the same εc because their designs converged to the same layer configuration. This pattern is consistent with Pasaribu et al. (2025), who also reported that MDP 2024 tended to produce more optimistic allowable-load repetition predictions than international methods.

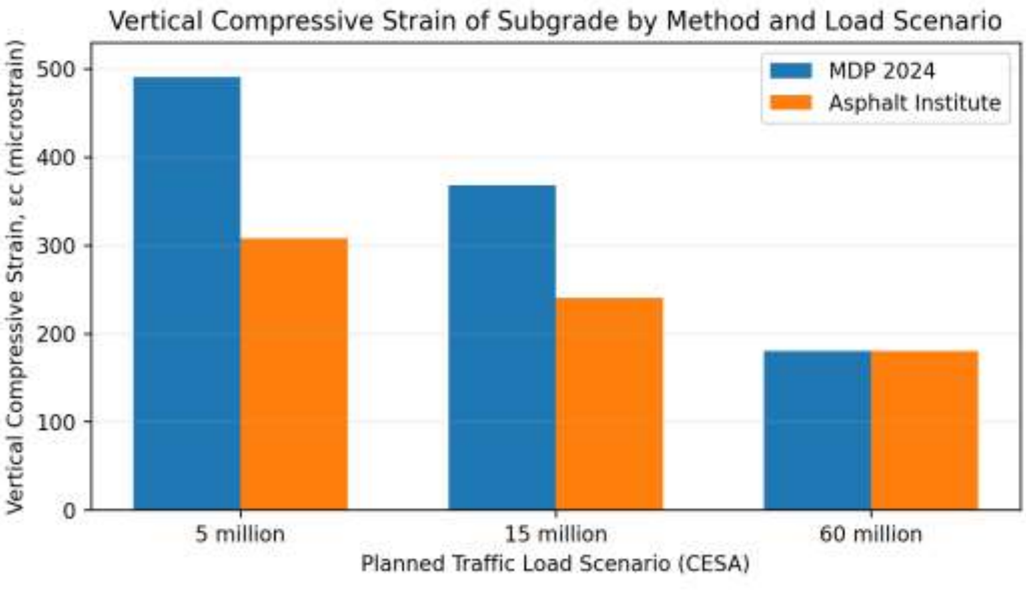

Figure 3. Vertical compressive strain of the subgrade (εc) by method and planned traffic-load scenario.

Structural Response: Horizontal Tensile Strain in Asphalt Layers

Table 4 presents horizontal tensile strain (εt) at the bottom of each asphalt layer, which is used as an indicator for fatigue-cracking criteria and directly addresses the second research question for the two structural-response variables.

Table 4. Horizontal Tensile Strain by Asphalt Layer (εt, microstrain)

Scenario	Layer	MDP 2024	Asphalt Institute
5 million	AC-WC	174.81	148.27
5 million	AC-BC	77.19	68.18
5 million	AC-Base	257.65	184.18
15 million	AC-WC	156.60	126.80
15 million	AC-BC	70.58	70.07
15 million	AC-Base	204.32	141.05
60 million	AC-WC	103.35	103.35
60 million	AC-Base	7.499	7.499

Source: Pavement-PastDean output.

At 5 and 15 million CESA, MDP 2024 produced higher εt values than the Asphalt Institute method at every asphalt layer, following the same pattern as εc and indicating a larger tensile-strain response at those load levels. At 60 million CESA, εt in the AC-Base decreased to 7.499 microstrain for both methods—approximately 25 to 35 times lower than at 5 and 15 million CESA—because the stiff CTB (E = 3,000 MPa) beneath the AC-Base substantially reduced tensile strain transmitted to that layer. This mechanism explains the extreme service-life value discussed below.

Estimated Service Life

Table 5. Estimated Pavement Service Life

Loading scenario	MDP 2024	Asphalt Institute	Controlling criterion
5 million CESA	6.41 million CESA	7.17 million CESA	Rutting (both methods)
15 million CESA	20.43 million CESA	18.48 million CESA	Rutting (MDP 2024); AC-Base fatigue cracking (AI)
60 million CESA	980,184.82 million CESA	79.35 million CESA	Rutting (both methods; different transfer functions)

Source: Pavement-PastDean output.

Neither method showed a uniform service-life advantage across all loading scenarios. The controlling criterion differed between methods at 15 and 60 million CESA; therefore, the service-life values should not be treated as a direct comparison of one identical distress model. The controlling-criterion column in Table 5 is provided to make this distinction explicit.

The extreme 60-million-CESA value—980,184.82 million CESA for MDP 2024 versus 79.35 million CESA for the Asphalt Institute—occurred even though both methods produced the same εc (−180.069 microstrain) at this load level and both remained controlled by rutting. This indicates that the extreme value is not evidence of a larger structural rutting margin. With identical εc, the difference arises from the different rutting transfer functions used by the two methods: MDP 2024, $N = (9300/\varepsilon c)$, and Asphalt Institute, $N = 1.365 \times 10^{-9} \times \varepsilon c^{-4.481}$. Because the two functions have very different sensitivity to the same strain value, the extreme result should be treated as an artifact of inter-method transfer-function differences rather than as a literal prediction of service life, and it is reported together with its mechanism rather than without diagnosis.

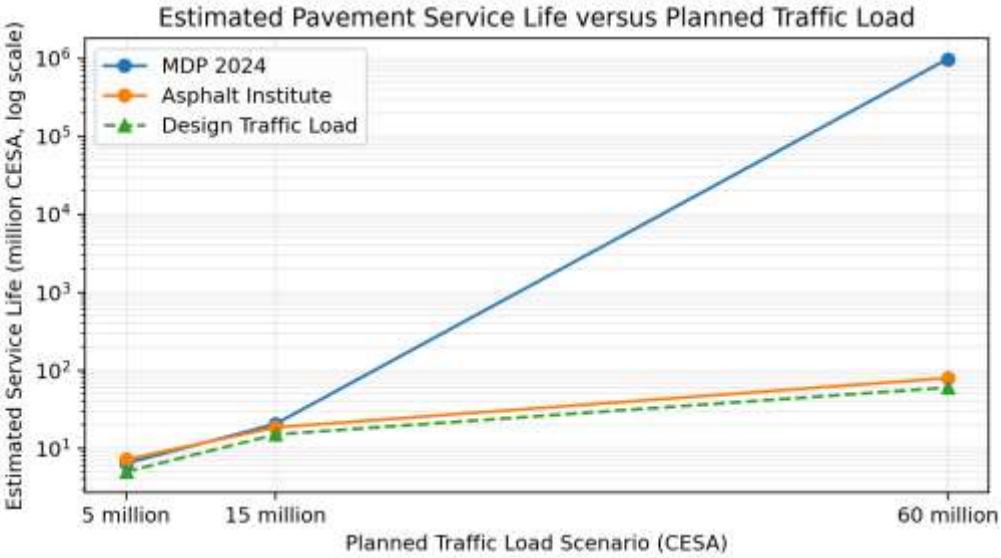

Figure 4. Estimated pavement service life versus planned traffic load (log scale).

Structural Efficiency and Design Conservatism

In terms of structural thickness, MDP 2024 produced relatively thinner pavement structures at low to medium traffic levels because it incorporates calibration factors for Indonesian traffic and climate conditions. This is consistent with Alya and Sulandari (2025) and Patiku et al., (2024), who reported that MDP 2024 provides structural alternatives that are more adaptive to traffic conditions and subgrade bearing capacity in Indonesia. From the perspective of structural response under potential overloading such as ODOL, the Asphalt Institute method produced consistently lower subgrade and asphalt-layer strains at low to medium traffic levels, indicating a more conservative response under uncertainty in actual field loading. The relative behavior of the two methods is therefore context dependent: MDP 2024 provides thinner structures under the tested conditions, while the Asphalt Institute provides a more conservative structural-response reference at 5 and 15 million CESA.

Pavement-PastDean returned internally consistent OK status for both methods across all six tested scenarios. The evaluation remains limited to fatigue cracking in asphalt layers and subgrade rutting. Quantitative fatigue-cracking evaluation of the CTB itself, separate from the AC-Base above it, was not performed because strain output specifically for the CTB was not available from the software, representing one of the study limitations.

Study Limitations

This study has five main limitations. First, it covers only one road section, so the results cannot be directly generalized to different subgrade, traffic, or climate conditions. Second, the analysis does not include validation against actual pavement performance during service. Third, quantitative fatigue-cracking evaluation of the CTB was not conducted because layer-specific strain output was unavailable. Fourth, construction cost comparison was not performed because unit-price and work-volume data were not included in the research dataset; consequently, structural efficiency was compared in terms of layer thickness rather than cost. Fifth, Pavement-PastDean strain and service-life outputs were not cross-checked against an independent multi-layer elastic solver such as KENPAVE, BISAR, or ELSYM5. Such cross-validation would strengthen confidence in the reported absolute values and is recommended for future work.

Implications for Method Selection and Design Practice

For road sections with high uncertainty in actual loading, including the possibility of ODOL, the lower strain levels produced by the Asphalt Institute method at low to medium traffic levels warrant specific attention. For projects whose traffic parameters and field conditions are consistent with the assumptions of MDP 2024, the national method can produce thinner designs while retaining local calibration and distress-criterion checks. The purpose of this comparison is therefore not to replace MDP 2024 with the Asphalt Institute method, but to clarify the conservatism and sensitivity of each design framework. Under the tested conditions, MDP 2024 produced thinner structures, whereas the Asphalt Institute produced lower structural response values at 5 and 15 million CESA. Design decisions should consider traffic level, overloading risk, material quality, subgrade condition, climate, and maintenance-cost consequences together rather than selecting a method solely on the basis of the largest predicted service-life value. The 60-million-CESA result illustrates why extreme model outputs should be interpreted in light of transfer-function sensitivity rather than treated as direct evidence of structural superiority.

From a design-practice perspective, the findings support using the two methods as cross-checks. A structure designed using MDP 2024 can be examined using mechanistic criteria associated with the Asphalt Institute to verify that subgrade and asphalt-layer responses remain within acceptable limits, and the reverse comparison can also be made. Such cross-checking helps determine whether design differences arise from actual structural requirements or primarily from methodological assumptions and is particularly relevant where actual axle loads may exceed the assumed design loads.

Future research should expand the number of study locations, conduct sensitivity analyses of CBR and traffic, complete fatigue-cracking evaluation for CTB, calculate life-cycle costs for both structures, and validate model predictions against observed pavement distress data such as crack percentage, rut depth, or deflection measurements. These steps would transform the design comparison into predictive validation and provide a stronger basis for method-selection recommendations in the Indonesian context.

CONCLUSIONS

Based on the mechanistic-empirical analysis, MDP 2024 and the Asphalt Institute method both produced pavement structures that satisfied the design criteria under the three analyzed traffic-load scenarios. MDP 2024 produced thinner structures than the Asphalt Institute method at 5 and 15 million CESA (300 mm versus 450 mm, and 385 mm versus 505 mm), while both methods converged to an identical 540 mm structure at 60 million CESA. For subgrade response, the Asphalt Institute method produced lower vertical compressive strain than MDP 2024 at 5 and 15 million CESA, while both produced the same value at 60 million CESA. In terms of estimated service life, the Asphalt Institute value was higher at 5 million CESA, whereas the MDP 2024 value was higher at 15 million CESA. The extreme 60-million-CESA value was not caused by a change in the controlling distress mechanism but by different rutting transfer-function formulations applied to identical εc values; it should therefore not be interpreted as a literal prediction of actual service life without field validation. Pavement-PastDean produced internally consistent OK outputs for all six scenarios, but the study does not establish absolute predictive accuracy relative to actual field performance. Future research should expand the study locations, complete CTB fatigue-cracking evaluation, analyze CBR and traffic sensitivity, calculate life-cycle costs, and validate predictions against observed pavement distress.

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