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# Evaluation of Pavement Structure and Cost Based on the Road Pavement Design Manual and Component Analysis Method

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**Abstract: In transportation systems, two main elements are closely related: traffic and pavement. Pavement is a part of road construction designed with specific layers, thickness, strength, and stability to safely distribute vehicle loads to the subgrade. This study aims to determine the required pavement thickness for the Adam Malik Road using the Pavement Design Manual (MDP) 2017, MDP 2024, and the Component Analysis Method, as well as to compare the cost estimates (RAB) of flexible pavement obtained from these three approaches in order to evaluate their efficiency, accuracy, and relevance to project conditions. The analysis results indicate new pavement structure configurations for Adam Malik Road. Using MDP 2017, the structure consists of a 4 cm Wearing Course (AC-WC), a 6 cm Binder Course (AC-BC), and a 40 cm Upper Base Course (LPA). MDP 2024 produces a 6 cm Wearing Course (AC-WC), a 20 cm Upper Base Course (LPA), and a 15 cm Lower Base Course (LPB). Meanwhile, the Component Analysis Method results in a 5 cm Wearing Course (AC-WC), a 15 cm Upper Base Course (LPA), and a 15 cm Lower Base Course (LPB). In terms of cost, the AC-WC layer using MDP 2017 yields an estimated cost of Rp 7,739,010,060, MDP 2024 yields Rp 6,270,761,799, and the Component Analysis Method yields Rp 5,708,044,446. The lowest cost is obtained from the Component Analysis Method, which produces the thinnest pavement thickness compared to MDP 2017 and MDP 2024.**

***Keywords:*** *Pavement Structure, Cost Analysis, Pavement Design Manual, Component Method*

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## I. INTRODUCTION

Economic growth and the increasing mobility of populations have significantly intensified the demand for road infrastructure that is not only efficient but also durable in the long term. Roads serve as critical arteries of national development, facilitating the movement of goods, services, and people. In this context, the quality of road surfaces becomes a decisive factor in ensuring both performance and service life. A well-designed pavement structure can reduce maintenance costs, improve safety, and enhance user comfort, thereby contributing to sustainable infrastructure development.

One of the most crucial stages in highway design, particularly for toll roads, is the planning and evaluation of pavement thickness. This process requires high levels of technical accuracy to ensure that the pavement can withstand traffic loads and environmental conditions, while also maintaining cost efficiency. Inaccurate design may lead to premature deterioration, increased maintenance costs, and reduced service life, which ultimately undermine the economic benefits of infrastructure investment.

In Indonesia, the Manual Desain Perkerasan Jalan (MDP) functions as the primary technical guideline for pavement structure planning. The latest edition, MDP 2024, represents a comprehensive update from the 2017 version. Key improvements include the refinement of design methodologies, the integration of local environmental conditions such as tropical soil characteristics and high humidity, and the simplification of design formats to enhance long-term efficiency. These updates reflect the evolving challenges of infrastructure development in Indonesia and aim to provide more reliable and adaptable design solutions.

The relevance of pavement design becomes even more pronounced in post-disaster contexts. Following the September 28, 2018 earthquake in Palu, extensive damage occurred to road infrastructure, particularly in areas affected by liquefaction such as Petobo. In response, Adam Malik Road assumed a vital role as a replacement for H. M. Soeharto

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Road, serving as a key connector to Petobo and providing access to the local market and terminal. This transformation underscores the strategic importance of Adam Malik Road as a case study for evaluating pavement structure and cost efficiency in disaster-prone regions.

## II. LITERATURE REVIEW

### *A. The Function of Roads In The Transportation System*

Roads play a fundamental role in the transportation system, serving not only as channels of mobility but also as instruments of economic growth, social integration, and national strategy. Their functions can be categorized into several key aspects:

- Mobility and Accessibility: Roads enable the efficient movement of people and goods from one location to another. High levels of mobility contribute to increased productivity and accelerate economic growth. Accessibility to public service centers such as schools, hospitals, and markets is highly dependent on the quality and availability of road networks. Thus, adequate road infrastructure is a prerequisite for an inclusive and effective transportation system.
- Economic Function: From an economic perspective, roads act as the primary drivers of production and distribution activities. Integrated road systems facilitate logistics, interregional trade, and access to natural resources. As noted by Dediansyah et al. (2022), improvements in road quality can directly accelerate the flow of goods and services while reducing logistics costs. This demonstrates that investment in road development and maintenance has a direct impact on national economic efficiency.
- Social Function and Equitable Development: Roads also serve as instruments of social equity and regional development. By connecting remote areas to economic and social hubs, road networks enable communities in rural regions to access public services, education, and healthcare that were previously difficult to reach. Roads foster social interaction and strengthen integration among communities, thereby supporting social cohesion and reducing disparities between regions.
- Strategic and Defense Function: In the context of defense and security, roads have strategic importance as logistical routes and channels for troop mobilization. Well-developed and interconnected road infrastructure forms an integral part of national defense systems. Roads allow rapid responses to security threats, disaster relief distribution, and the mobilization of strategic resources. Consequently, road development is not only an economic investment but also a safeguard for national stability and sovereignty.
- Environmental and Aesthetic Function: Beyond technical and economic roles, roads also embody environmental and aesthetic dimensions. Roads designed with environmental considerations can mitigate negative impacts on ecosystems. The use of eco-friendly materials, effective drainage systems, and the incorporation of shade vegetation are integral to sustainable road design. From an aesthetic perspective, well-planned roads that harmonize with their surroundings enhance the quality of public spaces and improve user comfort.

### *B. Flexible Pavement*

Flexible pavement is a structural system composed of several layers with varying stiffness and bearing capacities. Generally, flexible pavement consists of three main layers: the surface course, the base course, and the subbase course, all of which rest upon the subgrade. The distribution of stresses within these layers decreases progressively with depth. Each surface layer must be capable of resisting vertical loads and vibrations generated by traffic. Consequently, the load-bearing capacity of flexible pavement depends on the characteristics of load distribution across its layered system.

The design of each pavement layer must meet specific requirements, as outlined below:

➢ *Surface Course*

The surface course is the uppermost layer of pavement, designed to provide comfort through a smooth and even surface. Its requirements include:

- High stability and durability to withstand wheel loads throughout the design life.
- Prevention of water infiltration into underlying pavement layers, which could cause structural deterioration.
- Effective distribution of wheel loads to the lower layers with lower bearing capacity.
- Functioning as a wearing course, directly exposed to friction and abrasion from vehicle braking.

➢ *Base Course*

The base course lies between the surface course and the subbase course, serving the following functions:

- Acting as a foundation for the surface course.
- Distributing traffic-induced stresses downward to prevent excessive pressure on the subgrade.
- Providing drainage for the subbase course.

Materials used for the base course must be sufficiently strong, typically crushed stone or gravel, capable of withstanding repeated traffic loads. Common specifications require a minimum California Bearing Ratio (CBR) of 50% and a plasticity index (PI) ≤ 4%.

➢ *Subbase Course*

The subbase course is positioned between the base course and the subgrade, with functions including:

- Protecting the subgrade from climatic influences.
- Distributing loads to the subgrade.
- Preventing subgrade material from migrating into the base course.
- Safeguarding the subgrade against heavy construction equipment during initial works.

Materials for the subbase course must meet design criteria, generally requiring a minimum CBR of 20% and PI ≤

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10%. The subbase is often relatively thick to ensure effective load distribution to the subgrade, while remaining cost-efficient. Its design may vary depending on initial planning requirements.

- *Subgrade*

The subgrade is the lowest layer in pavement construction. Its bearing capacity typically ranges between 0.5–1.5 kg/cm². Therefore, pavement structures must be designed to distribute wheel loads evenly so that stresses remain within the subgrade's capacity. The subgrade may consist of native soil compacted to meet standards, or imported soil if local conditions are inadequate.

Common problems encountered in subgrade construction, as noted by Sukirman (1999), include:

- Permanent deformation caused by repeated traffic loads.
- Swelling and shrinkage due to variations in soil moisture content.
- Settlement resulting from insufficient compaction, leading to suboptimal bearing capacity.

To minimize subgrade-related problems, stabilization must be ensured before constructing the upper pavement layers. The subgrade should maintain consistent moisture content and be compacted according to standards to achieve stability and prevent settlement under traffic loads. Key factors influencing subgrade performance include soil classification, CBR value, moisture content, particle characteristics, and soil plasticity.

### C. *Pavement Design Manual Method (2017 Edition)*

The Pavement Design Manual (MDP) 2017 is the official technical guideline issued by the Directorate General of Highways, Ministry of Public Works and Housing (PUPR), through Decree No. 02/M/BM/2017. This document represents a revision of the previous 2013 edition and was developed to provide a standardized reference for pavement structure planning in Indonesia, applicable to both new road construction and rehabilitation of existing roads.

MDP 2017 was designed to address the need for a more systematic and consistent pavement design methodology that aligns with traffic conditions and soil characteristics specific to Indonesia. The guideline integrates both empirical and semi-mechanistic approaches in determining pavement layer thickness, taking into account critical factors such as traffic load, subgrade strength, design life, and material properties.

The primary objective of MDP 2017 is to provide technical guidance that enables road planners to determine optimal pavement structures from both technical and economic perspectives. Its scope includes:

- Design of flexible pavement and rigid pavement.
- Application to new roads as well as upgrading of existing roads.
- Coverage across national, provincial, district/city roads, and toll roads.
- Adaptation to tropical climate conditions and variations in subgrade characteristics in Indonesia.

The Cumulative Equivalent Single Axle Load (CESAL) represents the cumulative number of equivalent standard axle loads applied to the design lane throughout the pavement's design life. It is a fundamental parameter in pavement design, as it quantifies the cumulative traffic loading that the pavement must withstand.

- *CESAL is Determined Using the Following Parameters:*

$$ESA_{TH-1} = (\Sigma LHR_{JK} \times VDF_{JK}) \times 365 \times DD \times DL \times R$$

- ✓ ESATH-1 : Cumulative equivalent standard axle load (ESAL) in the first year.
- ✓ LHRJK : Average daily traffic volume for each type of commercial vehicle (vehicles/day).
- ✓ VDFJK : Vehicle Damage Factor, representing the load equivalency factor for each vehicle type.
- ✓ DD : Directional distribution factor, accounting for traffic distribution between directions.
- ✓ DL : Lane distribution factor, representing the proportion of traffic assigned to the design lane.
- ✓ CESAL : Total cumulative equivalent standard axle load over the design life.
- ✓ R : Traffic growth factor, representing cumulative traffic growth during the design period.

### D. *Pavement Design Manual Method (2024 Edition)*

The method applied in determining pavement thickness is based on the Pavement Design Manual No. 03/M/BM/2024, issued by the Directorate General of Highways, Ministry of Public Works and Housing (PUPR). The Pavement Design Manual (MDP) serves as the official technical guideline for designing pavement structures in Indonesia.

The latest edition, MDP 2024, replaces the previous version (MDP and Supplement 2017) and introduces several significant updates. These revisions were made to align pavement design practices with advancements in technology, evolving traffic conditions, and the characteristics of locally available materials. The updated manual emphasizes a more adaptive, efficient, and sustainable approach to pavement design, ensuring that infrastructure development remains responsive to national needs and environmental challenges.

In pavement design, traffic loads are converted into Equivalent Standard Axle Loads (ESA) using the Vehicle Damage Factor (VDF). The VDF of a particular vehicle represents the total ESA value derived from all axle groups of that vehicle.By applying VDF, traffic loads—comprising a mixture of vehicles from different classes with varying axle configurations and load magnitudes—can be standardized into a cumulative ESA value. This conversion enables the integration of heterogeneous traffic data into a single measure of pavement loading.

Structural pavement analysis is then conducted based on the cumulative ESA applied to the design lane throughout the

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pavement's design life. The ESA value obtained through VDF serves as the fundamental input for determining pavement thickness and evaluating structural performance under projected traffic conditions.

The basis of flexible pavement design using asphalt mixtures in this manual is founded on the mechanical properties of materials and the mechanistic analysis of pavement structures. This method establishes a direct relationship between input variables—such as wheel loads, pavement structure, and material properties—and output responses of the pavement to wheel loads, including stress, strain, and deflection.

The primary advantage of the mechanistic design method lies in its ability to analyze the effects of changes in design inputs, such as variations in materials or traffic loads, in a rapid and rational manner. Compared to purely empirical methods, the mechanistic approach offers several distinct benefits:

- It can be applied analytically to evaluate changes or variations in vehicle loads and their impact on pavement performance.
- Pavement performance with new or innovative materials can be assessed based on the mechanical properties of those materials.
- It enables analysis of the influence of environmental and climatic changes on material properties and, consequently, on pavement performance.
- It allows evaluation of pavement responses related to specific modes of distress, such as fatigue cracking and permanent deformation (rutting).

### *E. Component Analysis Method*

The Component Analysis Method is one of the traditional approaches employed in determining pavement thickness in Indonesia prior to the introduction of the more recent Pavement Design Manual. The fundamental principle of this method is that each pavement layer contributes a specific portion of strength to the overall structural capacity, and therefore the required thickness is determined by combining the contributions of all layers to withstand traffic loads throughout the design life. As noted by Sukirman (1999), the method primarily relies on the California Bearing Ratio (CBR) of the subgrade as the key parameter, which is then combined with cumulative traffic loading expressed in Equivalent Standard Axle Loads (ESA/CESAL) to establish the necessary pavement thickness. In this respect, the Component Analysis Method is considered semi-empirical, as it integrates field data from soil testing with standardized tables and charts for calculation.

In practice, the method is relatively simple and straightforward, making it widely applicable in road projects with light to medium traffic volumes. Its main advantage lies in the ease of obtaining CBR data and the simplicity of the design procedure. However, several studies have highlighted its limitations, particularly its lack of adaptability to modern traffic conditions characterized by heavier axle loads and more complex vehicle configurations. Moreover, the method does not account for the mechanistic properties of materials, which reduces its accuracy in predicting pavement distress such as fatigue cracking and rutting. Consequently, the design outcomes tend to be conservative, often resulting in pavement thicknesses greater than the actual requirement, which in turn increases construction costs.

Despite these limitations, the Component Analysis Method remains relevant as a comparative benchmark in pavement design research. By contrasting the results obtained from this method with those derived from the updated Pavement Design Manual, researchers and practitioners can better understand differences in accuracy, cost efficiency, and suitability under varying traffic and soil conditions in Indonesia. Thus, while it is considered outdated compared to mechanistic-empirical approaches, the Component Analysis Method continues to hold academic and practical value in evaluating pavement design alternatives.

## III. RESEARCH METHOD

### *A. Type of Research*

The type of research employed in this study is applied research, as the results are expected to provide practical solutions to technical problems in road planning, particularly in determining pavement structure and construction cost efficiency. In addition, the study adopts a descriptive-analytical approach, since it describes the existing conditions, performs technical calculations, and presents comparative analyses in a systematic manner.

### *B. Research Location*

This study was conducted on Adam Malik Road, located within the administrative area of Palu City, Central Sulawesi Province. The selection of this road segment as the research site was based on several considerations: it exhibits active traffic characteristics, possesses varied subgrade conditions, and forms part of a strategic road network that supports interregional connectivity within the urban area and its surroundings. These factors make Adam Malik Road a representative and significant location for evaluating pavement structure and construction efficiency in the context of urban infrastructure development.

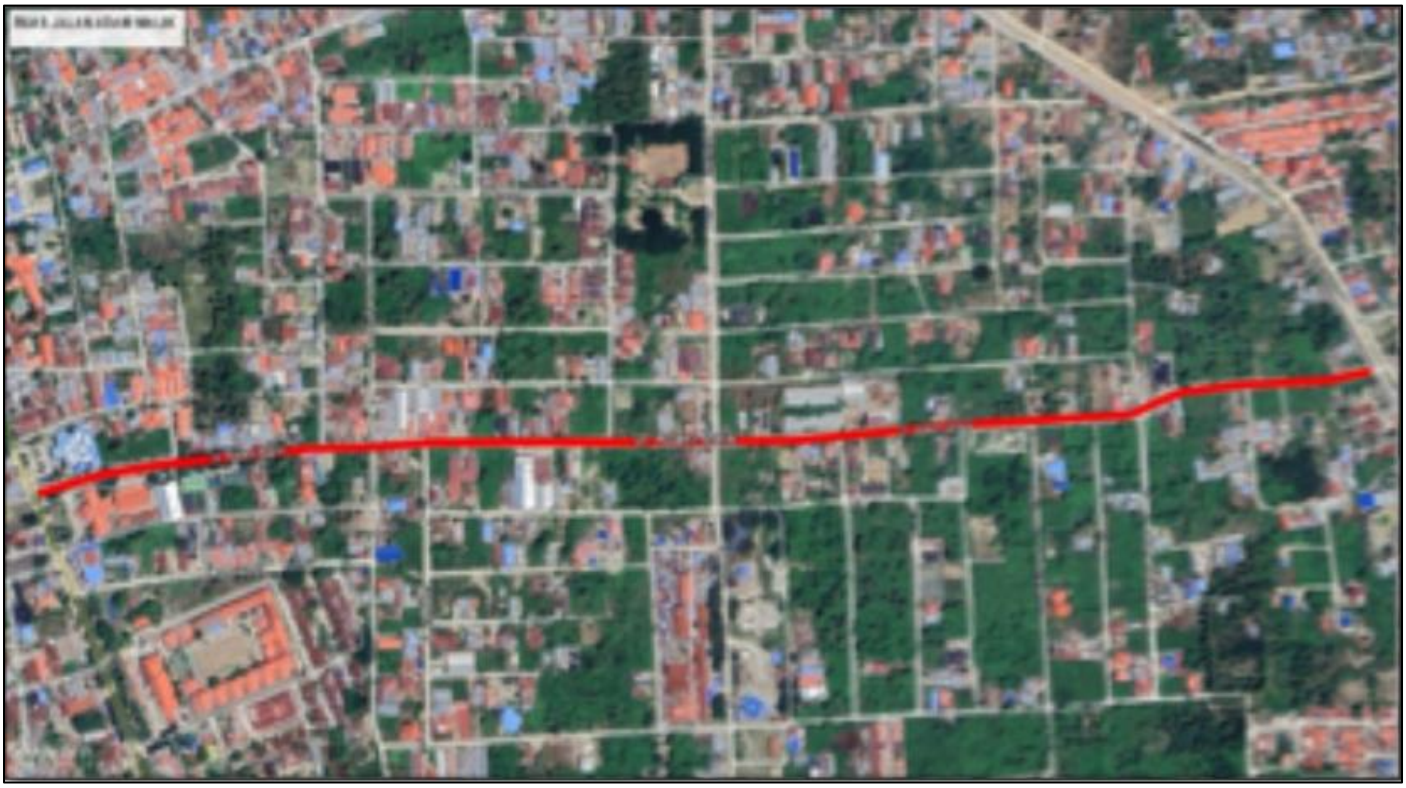
Fig 1 Research Location

*C. Data Collection Techniques*

Data collection is a critical stage in this research, as it forms the foundation for conducting technical analysis and cost evaluation of pavement structures. The techniques employed were adjusted to the type of data required, namely primary data and secondary data, within the framework of a quantitative comparative approach.

➢ *Primary Data Collection*

Primary data were obtained directly from the research site, namely Adam Malik Road, through field surveys and technical observations. The techniques included:

- Traffic Survey: Conducted to obtain Average Daily Traffic (ADT) data, which is used in traffic classification for pavement design methods. The survey was carried out by vehicle counting over a specified period (e.g., three consecutive days during peak and off-peak hours), after which the average values were calculated.
- Geometric Road Measurement: This involved measuring the width of the carriageway, shoulders, and the physical condition of the existing pavement. Measurements were taken using tools such as measuring tapes, roll meters, or total stations when necessary. These data were used to determine the pavement area and the volume of work required.
- Road Condition Survey: Conducted to obtain an actual overview of the physical condition of Adam Malik Road, including the type of pavement used, the level of damage, road width and geometry, and the existing service life. Observations focused on identifying cracks, deformations, patches, and wheel path rutting as indicators of current structural performance. The results served as a basis for validating new design proposals and estimating rehabilitation needs.

➢ *Secondary Data Collection*

Secondary data were obtained from relevant technical agencies and official documents related to road planning. The techniques included:

- Document Review: This involved collecting the Pavement Design Manual (MDP) editions of 2017 and 2024, project technical documents, and regulatory references such as Indonesian National Standards (SNI), Ministerial Regulations of PUPR, and unit price data from Bina Marga.
- Data Requests from Agencies: Data were formally requested through official letters submitted to relevant institutions, such as the Public Works Department of Palu City. The requested data included CBR values, geometric data, existing project records, and unit price information for construction works.

*D. Data Analysis Technique*

The data analysis technique employed in this study aims to process, interpret, and compare the results of pavement structure design and cost evaluation based on two design methods, namely the Pavement Design Manual (MDP) and the Component Analysis Method. The analysis was conducted using a quantitative approach with a comparative framework, relying on technical data collected from the research site as well as supporting documents. This approach enables a systematic evaluation of design outcomes, highlighting differences in structural performance and cost efficiency between the two methods.

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The Pavement Design Manual (MDP) 2017 was issued by the Directorate General of Highways, Ministry of Public Works and Housing (PUPR), as an official guideline for pavement structure planning in Indonesia. This document replaced the earlier 2013 edition and was intended to simplify the design process, enhance technical consistency, and adapt to soil and traffic conditions in tropical regions.

The pavement structure model applied in this study refers to the typical design provided in MDP 2017, which is evaluated to determine whether it meets the criteria for perpetual pavement.

Following the selection of flexible pavement alternatives, the detailed design stage involves calculating the structural elements of the pavement. The objective is to ensure that the pavement construction meets quality standards, design life, safety requirements, and cost allocation. The MDP 2024 represents the updated guideline for pavement design in Indonesia, replacing MDP 2017 and its supplement.

This method employs a mechanistic-empirical approach, integrating technical analysis with empirical field data. The revision was introduced to produce more accurate, durable, and resource-efficient pavement designs that reflect current traffic demands and local material characteristics.

In this study, the calculation of flexible pavement thickness was carried out using MDP 2024, which provides a more precise framework by considering multiple technical parameters, including subgrade conditions, average daily traffic (ADT/LHR), traffic growth factors, and design service life. The calculation process involves systematic steps such as field data collection, assessment of existing conditions, and selection of appropriate pavement structures.

The final outcome of applying MDP 2024 is an optimal recommendation for pavement layer thickness, designed to accommodate traffic loads throughout the design life while ensuring cost efficiency and practical implementation.

## IV. RESULTS

The research location is situated along Adam Malik Road, within the administrative area of Palu City, Central Sulawesi Province. Adam Malik Road is considered a strategic urban corridor that connects the city center with residential areas, educational facilities, and local commercial zones. Functionally, this road is classified as a secondary collector road, serving local traffic flows while supporting community mobility and the distribution of goods at the city scale.

Adam Malik Road has a total length of approximately 1.420 kilometers, with a carriageway width ranging between 5.0 and 5.5 meters. The road is equipped with shoulders on both sides, each measuring 1.0 meter in width. The current pavement surface consists of flexible pavement (hotmix asphalt), which has begun to exhibit signs of deterioration such as longitudinal cracking and wheel path rutting. These conditions indicate a decline in pavement performance, thereby necessitating technical evaluation for rehabilitation or upgrading to ensure continued serviceability and structural reliability.

Adam Malik Road serves as a connector between Tanggul Selatan Road and Dewi Sartika Road. The daily traffic volume along this corridor is relatively high, dominated by two-wheeled vehicles and light vehicles, with the presence of several heavy vehicles such as freight trucks. The strategic function of this road makes it a priority within the city's infrastructure improvement program, particularly in supporting smooth transportation, enhancing road user safety, and ensuring efficiency in local logistics distribution.

The surrounding environment is characterized by dense residential areas and active community-based economic activities. Consequently, pavement design must take into account factors such as driving comfort, minimal disruption during construction implementation, and cost efficiency to avoid excessive burden on the municipal budget. These considerations highlight the importance of adopting a pavement design approach that balances technical performance with socio-economic sustainability.

### *A. Subgrade CBR Data*

The California Bearing Ratio (CBR) is used to measure the bearing capacity of the subgrade against load penetration. The CBR value, expressed as a percentage, is obtained through laboratory or field testing by comparing the strength of the soil with that of a standard material (crushed stone). CBR is one of the key indicators in pavement thickness design, as it reflects the ability of the subgrade to withstand traffic loads transmitted from the pavement layers above.

The Dynamic Cone Penetrometer (DCP) is a field testing instrument employed to directly measure soil strength and penetration resistance at the project site. The DCP operates by dropping a weight vertically onto a cone-shaped penetration rod and recording the depth of penetration per number of blows. The results of DCP testing can be converted into CBR values using empirical formulas developed from correlations between penetration depth and soil bearing capacity.

DCP testing is particularly advantageous under field conditions because it is rapid, cost-effective, and capable of providing a vertical (layered) profile of soil strength. The CBR value derived from DCP testing, commonly referred to as CBR-DCP, serves as an alternative or complement to conventional laboratory-based CBR testing, thereby enhancing the reliability of subgrade evaluation in pavement design.

The Dynamic Cone Penetrometer (DCP) tests conducted along Adam Malik Road were carried out at several representative points along the segment. The results indicated penetration values ranging from 8 to 44 mm/blow, which, after conversion, corresponded to California Bearing Ratio (CBR) values between 6.8% and 14.0%. At STA 0+200, the CBR value was recorded at 14.0%, representing the highest strength among the tested locations. In contrast, the lowest value was observed at STA 0+400, with a CBR of 6.8%, indicating

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relatively weak subgrade conditions. At STA 0+600, the CBR was measured at 9.8%, while at STA 0+800, the value reached 12.5%. Finally, at STA 1+000, the CBR was found to be 7.5%.

Overall, the field test results demonstrate that the subgrade strength along Adam Malik Road varies considerably, ranging from moderate to relatively weak conditions. This variability highlights the importance of incorporating localized adjustments in pavement thickness design to ensure structural reliability and cost efficiency across different segments of the road.

*B. Traffic Volume Data*

Traffic volume is one of the key parameters in pavement structure design, as it reflects the intensity of traffic loads that must be sustained by the pavement layers throughout the design life. The Average Daily Traffic (ADT/LHR) is calculated based on the number of vehicles passing through a road segment in one day, averaged over a specific period. This data is used to determine traffic classes in pavement design methods, both in the Pavement Design Manual (MDP) 2017 and the updated MDP 2024.

In traffic analysis, the determination of peak-hour traffic volume and the Annual Average Daily Traffic (AADT/LHRT) refers to the Indonesian Highway Capacity Manual (PKJI). The calculation of LHRT is based on traffic survey data, adjusted by applying the k-factor. Traffic volume estimation must be conducted realistically, and manipulation of traffic data for economic justification is strictly prohibited. In cases of uncertainty, technical planners are required to conduct independent rapid surveys to verify the data.

The traffic survey conducted along Adam Malik Road in 2024 (24-hour count) revealed that motorcycles dominate the traffic flow, with a total of 9,197 units per day. Passenger cars, including sedans, jeeps, and station wagons, accounted for 1,386 units, while minibuses were recorded at only 20 units. Light commercial vehicles such as pick-ups, micro trucks, and delivery vans contributed 390 units. Larger vehicles were less frequent, with only 2 large buses, 48 two-axle trucks (5 tons), 66 two-axle trucks (8 tons), and 13 three-axle trucks observed. No articulated trucks or semi-trailers were recorded during the survey period.

Overall, the traffic composition indicates a high dominance of two-wheeled and light vehicles, with relatively low volumes of heavy trucks. This distribution highlights the functional role of Adam Malik Road as a secondary collector road primarily serving local mobility, while still accommodating limited freight transport.

*C. Road Condition Survey Data*

The road condition survey in this study was conducted as part of the preliminary planning stage to obtain primary data reflecting the existing physical state of Adam Malik Road. The main objective of the survey was to assess geometric characteristics, pavement type, level of damage, and service life, which serve as the basis for technical analysis and pavement thickness calculations.

Based on the existing condition data of Adam Malik Road using the Surface Distress Index (SDI) method, the segment between STA 0+000 and STA 0+250 was classified as minor damage, while the segment between STA 0+250 and STA 1+420 was categorized as severe damage. The SDI calculations revealed that the initial 250 meters of the road exhibited relatively low distress values, dominated by minor cracking and limited potholes. In contrast, the remaining 1,170 meters showed significantly higher SDI scores, characterized by wide cracks, numerous potholes, and wheel path deformation, indicating substantial structural deterioration.

According to the survey conducted by the Public Works Department of Palu City, approximately 82% of the total road length falls under the severe damage category, while the remaining 18% is classified as minor damage. Technically, this condition places Adam Malik Road in the category of “functionally unfit” based on commonly applied infrastructure evaluation standards. Severe damage typically includes structural deformation, large potholes, wide cracks, and foundation layer failures, all of which directly affect road user comfort and safety.

This situation necessitates technical intervention in the form of road improvement, either through rehabilitation or complete reconstruction, to restore the optimal service function of the road. Consequently, the road condition data provide a strong foundation for formulating technical policies and budget allocations in support of infrastructure improvement programs in the region.

*D. Pavement Thickness Analysis Using MDP 2017*

The analysis of pavement thickness using the Pavement Design Manual (MDP) 2017 was conducted to determine the appropriate flexible pavement structure for Adam Malik Road in Palu City, considering the subgrade conditions and traffic volume. MDP 2017 adopts a semi-empirical approach based on design tables, with two primary parameters: the California Bearing Ratio (CBR) of the subgrade and the traffic class of heavy vehicles.

Traffic growth was calculated by referring to the average annual traffic growth rate for collector roads in Indonesia, which is set at i = 3.5% per year. The cumulative traffic growth multiplier is divided into two periods: 2 years and 18 years. Thus, the actual traffic growth factor for the period 2025–2027 is 2.04, while for the period 2027–2045 it is 24.50.

The directional distribution factor is used to divide traffic volume based on travel direction (e.g., outbound and inbound). In MDP 2017, it is assumed that traffic is evenly distributed between the two directions (50:50), unless survey data indicate otherwise. Therefore, the factor is set at 0.5.

The lane distribution factor determines the proportion of heavy vehicles passing through the design lane, which is the lane most frequently used by heavy traffic. According to Table 2.4 of MDP 2017, for a one-lane one-way road, the lane distribution factor is set at 1.0 (100%).

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According to the Flexible Pavement Design Manual (MDP) 2017, specifically Chart 3B for flexible pavement design with granular base layers.. The calculated design load over a 20-year period is 1,845,410.45 ESA5, which falls under the FFF1 pavement structure category, as the value of 10^6 ESA5 is less than 2.

Based on this classification, the recommended pavement structure is as follows:

- AC-WC (Asphalt Concrete – Wearing Course) = 40 mm
- AC-BC (Asphalt Concrete – Binder Course) = 60 mm
- Aggregate Base Layer Class A (LPA) = 400 mm

Thus, the total pavement thickness is 47 cm, consisting of AC-WC = 4 cm, AC-BC = 6 cm, and LPA = 40 cm.

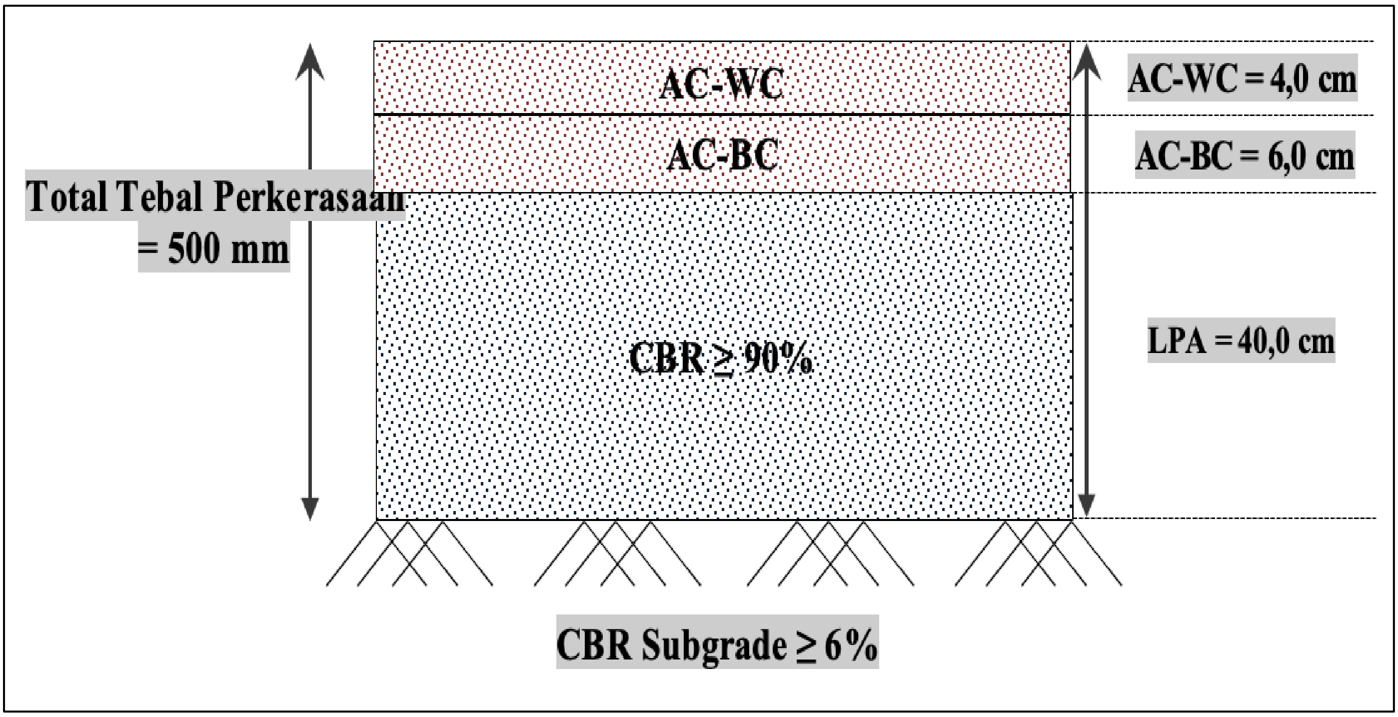

Fig 2 Pavement Structure of Adam Malik Road Based on MDP 2017

This configuration reflects the structural requirements for Adam Malik Road under the projected traffic load and subgrade conditions, ensuring adequate serviceability throughout the design life.

*E. Pavement Thickness Analysis using MDP 2024*

The Cumulative Equivalent Standard Axle (CESA) represents the total traffic load calculated based on the equivalence of standard axle loads over the pavement's design life. This concept is fundamental in pavement design, as it ensures that the structure is capable of withstanding the cumulative effects of traffic loading. CESA is used to determine both the thickness and the type of pavement materials required. A high CESA value indicates the need for stronger pavement layers to resist heavy traffic loads, whereas a lower CESA value allows for lighter pavement structures.

Traffic growth is projected annually throughout the pavement's design life, which in this study is set at 20 years. The cumulative traffic growth multiplier is divided into two categories: actual growth and normal growth. Thus, the traffic growth factor is 3.11 for the period 2025–2028 and 22.71 for the period 2028–2045.

The lane distribution factor (DL) is used to adjust cumulative traffic loads (CESAL) on roads with two or more lanes in one direction. Although most heavy vehicles may use the outer lane, some will also occupy inner lanes. For this study, with the assumption of one lane per direction, the lane distribution factor is set at 1.0 (100%).

The directional distribution factor (DD) accounts for how traffic is divided between two directions on a two-way road without a median. In this case, traffic is assumed to be evenly distributed, resulting in a factor of 0.5.

The Vehicle Damage Factor (VDF) is a parameter used in pavement design to quantify the relative impact of different vehicle types on pavement deterioration compared to a standard axle load. VDF values vary depending on axle configuration and load distribution, with heavier and multi-axle vehicles contributing disproportionately to pavement wear.

By incorporating VDF into the CESA calculation, the analysis accounts for the varying degrees of damage caused by different vehicle categories, ensuring that the pavement design is both realistic and technically robust.

Flexible pavement design focuses on how the road structure is able to withstand traffic loads by gradually distributing stresses to the underlying layers without

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experiencing structural failure. Vehicle loads are transferred from the surface layer to the base course and finally to the subgrade. Each layer is designed to resist the stresses it receives, with the upper layer constructed from the strongest material since it bears the highest load.

According to the Flexible Pavement Design Manual (MDP) 2017, specifically Chart 3B for flexible pavement design with granular base layers (Table 2.12), the calculated design load over a 20-year period is 931,231.56 ESA5. This value falls within the FFF2 pavement structure category, as the cumulative load is in the range of 10^6 ESA5 ≥ 2–4.

Based on this classification, the recommended pavement structure is as follows:

- Asphalt Concrete – Wearing Course (AC-WC) = 60 mm
- Aggregate Base Layer Class A (LPA) = 200 mm
- Aggregate Base Layer Class B (LPB) = 150 mm

Thus, the total pavement thickness is 470 mm (47 cm), consisting of AC-WC = 6 cm, LPA = 20 cm, and LPB = 15 cm.

This configuration ensures that the pavement structure can adequately sustain the projected traffic load while maintaining durability and serviceability throughout the design life.

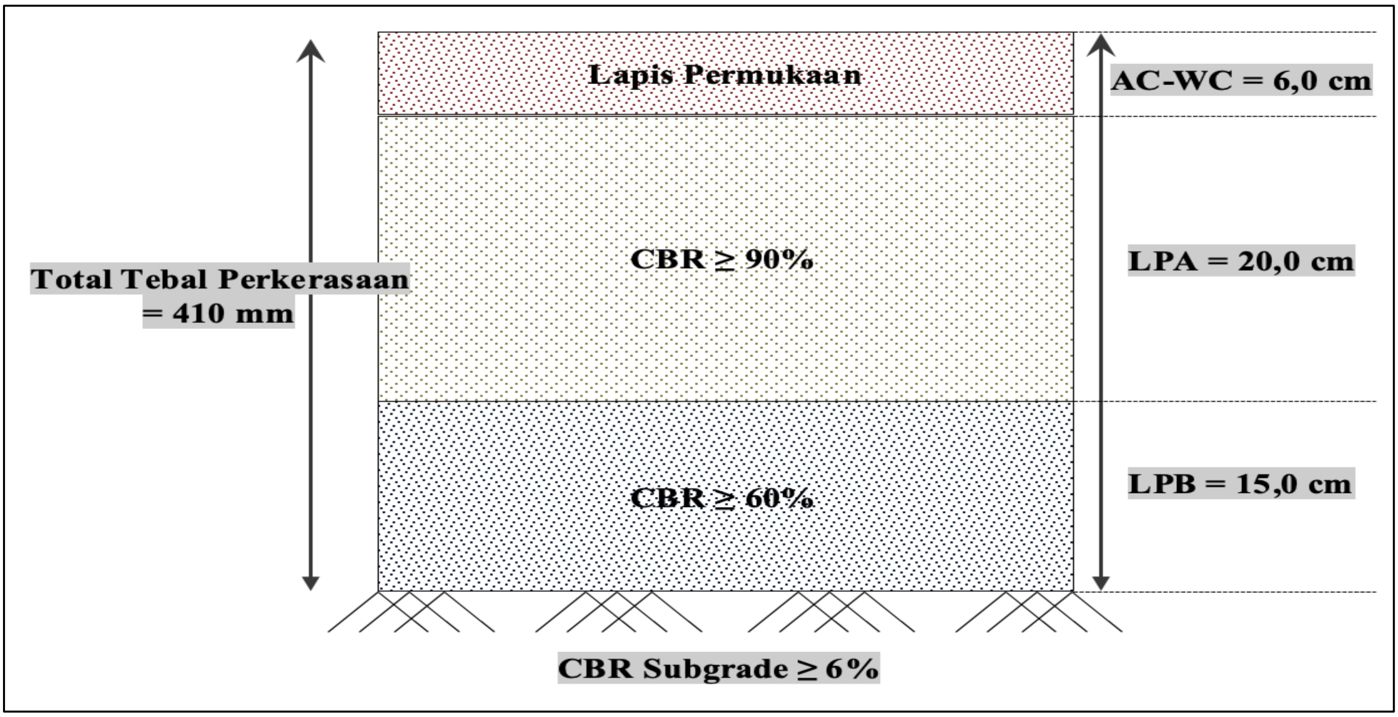

Fig 3 Pavement Structure of Adam Malik Road Based on MDP 2024

*F. Component Analysis Method*

The design of flexible pavement using the Component Analysis Method begins with determining the design traffic load. This load is then calculated using logarithmic functions to obtain the cumulative traffic effect. The pavement design process under this method applies numerical equations and relies on a trial-and-error approach to determine the Pavement Thickness Index for each layer. The logarithmic value of the design traffic load is compared against a set of coefficients representing surface condition factors and the material strength (Resilient Modulus) of each layer. In this analysis, the resilient modulus values are derived from the asphalt surface, the upper base course, and the lower base course.

In pavement design, traffic loads are converted into standard axle loads based on the damage caused by vehicles, expressed through the Vehicle Damage Factor (VDF). The Cumulative Equivalent Single Axle Load (CESA) serves as the basis for flexible pavement design throughout the service life.

For this analysis, the design traffic is standardized to an 8-ton axle load, meaning that vehicles with axle loads below 8 tons do not contribute to pavement deterioration. Consequently, vehicle types such as motorcycles, passenger cars, small vans, and delivery vehicles with axle loads below the threshold are considered negligible in terms of pavement damage. Only heavy vehicles with axle loads equal to or greater than 8 tons are included in the cumulative traffic load calculation, as they represent the primary contributors to pavement wear and structural fatigue.

In the component analysis method, vehicles such as motorcycles and light vehicles with a total axle load of less than 8 tons are considered to have no equivalent load contribution. This means that regardless of the number of such vehicles passing over the pavement, they do not affect the structural performance of the road. Only vehicles with axle loads equal to or greater than 8 tons are considered to contribute to pavement deterioration. These include buses,

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light trucks, medium trucks, heavy trucks, large trucks, semi-trailers, trailers, and articulated trucks.

The calculation of equivalent loads in this study refers to the Bina Marga 2017 guidelines. The design load, denoted as W18, is derived from daily traffic data and converted into standard axle loads over the pavement's design life. This calculation is influenced by several coefficients, including:

- Average Daily Traffic (ADT/LHR)
- Design Life (UR)
- Traffic Growth Factor (i)
- Directional Distribution Factor (DD)
- Lane Distribution Factor (DL)

The design traffic (W18) is obtained by multiplying the cumulative number of vehicles (converted into standard axle loads) by the lane distribution and directional distribution factors. The cumulative axle load over the design life is then used as the basis for determining pavement thickness.

Thus, the cumulative traffic growth factor over 20 years is 28.280, which is applied to the calculation of cumulative equivalent standard axle loads (CESA) for the design traffic.

Knowledge of subgrade strength is essential in pavement design, as it provides the basis for determining the appropriate foundation type for road construction. One of the common field tests used to evaluate subgrade strength is the Dynamic Cone Penetrometer (DCP) test. This test produces California Bearing Ratio (CBR) values, which are then used as the primary input for pavement thickness analysis.

The purpose of obtaining CBR values is to estimate the Resilient Modulus (MR) of the soil, which represents the elastic response of the subgrade under repeated traffic loading. Based on laboratory testing, the lowest CBR value obtained for the Adam Malik Road subgrade was 8.0%. This resilient modulus value serves as a critical input for the component analysis method in flexible pavement design.

Reliability in pavement design refers to the probability that the road will perform satisfactorily under traffic and environmental conditions throughout its design life. Different road classifications are associated with different ranges of reliability. Urban roads generally fall within a range of 50% to 99.99%, freeways between 80% and 99.99%, arterial roads between 75% and 95%, collector roads between 75% and 95%, and local roads between 50% and 80%. Adam Malik Road in Palu City is classified as an urban collector road, and therefore the reliability level adopted in this analysis is 80%. This value reflects a balance between structural safety and economic feasibility, ensuring that the pavement design can withstand expected traffic loads while optimizing construction costs.

Based on the results of calculations using the Component Analysis Method, the initial design produced a surface layer thickness of 6.97 cm, an upper base course thickness of –2.59 cm, and a lower base course thickness of –22.08 cm. Since negative values are not feasible in pavement design, adjustments were made to comply with the minimum thickness requirements specified in the guidelines. The minimum thickness for the asphalt surface layer is 5 cm, while both the upper base course and the lower base course must have a minimum thickness of 15 cm each.

After applying these adjustments, the overall pavement structure was standardized to meet the minimum requirements, ensuring that the Structural Number (SN) obtained is equal to or greater than the design SN. The final pavement design consists of three layers: Layer 1 – Asphalt Concrete Wearing Course (AC-WC) with a thickness of 5 cm, Layer 2 – Aggregate Base Class A with a thickness of 15 cm, and Layer 3 – Aggregate Base Class B with a thickness of 15 cm.

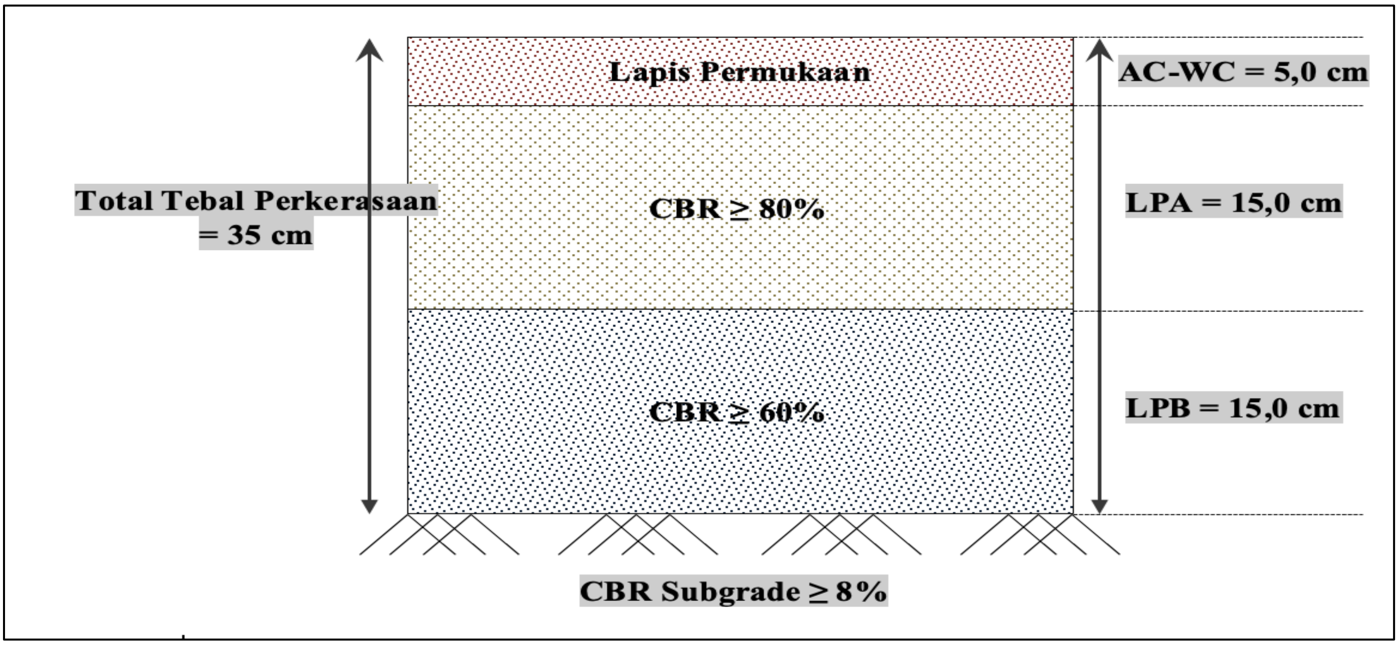

Fig 4 Pavement Structure of Adam Malik Road Based on Component Analysis Method

### G. *Cost Estimation Planning using MDP 2017, MDP 2024 and the Component Analysis Method*

Cost estimation planning is a critical stage in the implementation of construction projects, particularly in road improvement works. In this study, two approaches to cost estimation were applied based on the Manual of Pavement Design (MDP), namely the 2017 edition and the updated 2024 edition, in order to provide a comparative overview of the estimated costs produced by each method.

The MDP 2017 has long served as a reference in preparing road construction cost estimates, employing a unit price approach combined with an analysis of material requirements, equipment, and labor. In contrast, the MDP 2024 represents a refinement of the earlier method, incorporating adjustments to actual field conditions, advances in construction technology, and updated unit price policies that are more adaptive to market dynamics and implementation efficiency.

The calculation process in this study utilized technical data obtained from road condition surveys, work volumes, and established technical specifications. The cost components analyzed included preparatory works, earthworks, pavement works, drainage, and other complementary works. Each component was calculated based on the Unit Price Analysis (AHSP) corresponding to the respective version of the MDP.

Based on the geometric survey, Adam Malik Road in Palu City has a width of 5.5 meters and a length of 1,420 meters. The work volume was calculated by multiplying the surface area by the thickness of each layer, including aggregate base courses, asphalt surface layers, and drainage excavation. This approach allowed for more accurate volume estimation, which was then used as the basis for preparing the Bill of Quantities (RAB) for Adam Malik Road.

The results revealed differences in both the total cost and pavement thickness between the MDP 2017, MDP 2024, and the Component Analysis Method. These differences are attributed to updated labor and material coefficients, as well as variations in pavement thickness, which directly affect construction costs.

For AC-WC, the MDP 2017 method produced an estimated cost of Rp. 7,739,010,060, while the MDP 2024 method yielded a lower estimate of Rp. 6,270,761,799. This reduction reflects efficiency in material analysis, updated calculation coefficients, and adjustments to more relevant unit prices. It is important to note, however, that MDP 2017 specifies a total pavement thickness of 50 cm, whereas MDP 2024 specifies 41 cm. The greater thickness in MDP 2017 results in higher material volumes and costs, reflecting a more conservative design approach oriented toward long-term structural capacity, with layered asphalt courses such as AC-WC and AC-BC. In contrast, MDP 2024 adopts a more efficient approach by simplifying the pavement structure and optimizing the function of granular base layers. Although the thickness of AC-WC in MDP 2024 increased from 40 mm to 60 mm, the elimination of the AC-BC layer reduced the overall thickness and cost.

The Component Analysis Method produced the smallest pavement thickness, with AC-WC = 5 cm, Upper Base Course = 15 cm, and Lower Base Course = 15 cm, resulting in a total thickness of 35 cm (350 mm). The estimated cost using this method was Rp. 5,708,044,446, the lowest among the three approaches. This outcome is directly related to the reduced pavement thickness compared to MDP 2017 and MDP 2024.

## V. CONCLUSION

➢ *Based on the Findings and Discussions Presented in this Study, the Following Conclusions can be Drawn:*

- Based on the results of the flexible pavement structure design analysis conducted with reference to the Manual of Pavement Design (MDP) editions of 2017 and 2024, as well as the Component Analysis Method, new pavement configurations were obtained for Adam Malik Road. Using the MDP 2017 method, the pavement structure consists of an Asphalt Concrete Wearing Course (AC-WC) with a thickness of 4 cm, an Asphalt Concrete Binder Course (AC-BC) with a thickness of 6 cm, and an Upper Base Course (LPA) with a thickness of 40 cm. In contrast, the MDP 2024 method produces a structure comprising an AC-WC layer with a thickness of 6 cm, an Upper Base Course (LPA) with a thickness of 20 cm, and a Lower Base Course (LPB) with a thickness of 15 cm. Meanwhile, the Component Analysis Method results in a structure consisting of an AC-WC layer with a thickness of 5 cm, an Upper Base Course (LPA) with a thickness of 15 cm, and a Lower Base Course (LPB) with a thickness of 15 cm.
- For the AC-WC layer work, the MDP 2017 method produced a cost estimate of Rp. 7,739,010,060, while the MDP 2024 method showed a lower value of Rp. 6,270,761,799. The Component Analysis Method resulted in a cost estimate of Rp. 5,708,044,446, which is the lowest price compared to the MDP 2017 and 2024 methods for AC-WC layer work. This is because the pavement thickness calculated using the Component Analysis Method produces the thinnest pavement compared to the MDP 2017 and 2024 methods.

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