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Using Road Characteristics Database to Support Protocol-Specific Track Identification for Vehicle Safety Testing

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ABSTRACT – *The growing demand for a structured database to support vehicle safety testing necessitates the systematic identification of road tracks that align with ASEAN NCAP protocols. This study aims to develop a Road Characteristics Database underpinned by a standardized data model and data dictionary, addressing a critical gap in harmonizing real-world road environments for testing applications. The methodology followed a structured five-step process. First, a thematic literature review, document analysis, and on-site inspections were conducted to extract attributes from ASEAN NCAP and other testing frameworks. Second, these attributes were analyzed and validated through pattern recognition and statistical testing, leading to the construction of a harmonized data model aligned with international NCAP standards. Third, survey instruments were designed based on the validated attributes, and in the fourth step, these instruments were applied to real-world road segments, resulting in the development of a data model and confirmation of protocol suitability. Finally, a PHP-based user interface was implemented and linked to a MySQL database, enabling structured data entry, validation, and query functions. The results produced a validated set of 32 road infrastructure attributes, subsequently expanded into a standardized data dictionary containing 52 harmonized parameters. Seven candidate tracks were identified, supporting up to 25 NCAP test protocol scenarios, with each track accommodating two to five test types depending on its characteristics. Work is ongoing to expand the database to 50–60 tracks. The user interface was tested successfully, with statistical validation confirming strong reliability (average score = 0.85; standard deviation = 0.26). Future enhancements will integrate advanced analytics and intelligent search tools, enabling users to identify road segments by specific testing criteria and thereby improving efficiency, interoperability, and decision-making in vehicle safety assessments.*

KEYWORDS: Data model, NCAP, road characteristics, road survey, safety database, vehicle testing

1. INTRODUCTION

The automotive industry faces ongoing challenges in ensuring vehicle safety and efficiency across diverse and complex road conditions. A key limitation in current safety testing is the absence of a standardized, comprehensive database that captures the full spectrum of real-world road characteristics. In countries such as Malaysia, road data remains fragmented across agencies, collected through siloed systems, and often stored in non-standardized formats (iRAP, 2022). This fragmentation leads to inconsistencies in test outcomes and hampers comparability across testing environments and regions. The lack of a centralized, standardized database further complicates the identification of road segments that meet the precise conditions required for vehicle safety testing. To address this gap, this study proposes the development of a centralized Road Characteristics Database aligned with the ASEAN New Car Assessment Protocol (NCAP), which serves as the benchmark for vehicle safety assessments in Malaysia.

This study focuses on seven ASEAN NCAP test protocols (ASEAN NCAP, 2025), namely Autonomous Emergency Braking (AEB) Car-to-Car, AEB Car-to-Motorcyclist (AEBCM), Blind Spot Detection (BSD), Auto High Beam (AHB), Adaptive Driving Beam (ADB), Blind Spot Visualization (BSV), Lane Support Systems (LSS), and Advanced Rear Visualization (ARV). Each of these protocols specifies distinct requirements for road and environmental conditions, underscoring the critical role of standardized road data in ensuring consistent and reliable testing. By systematically identifying and analyzing the key road characteristics that shape vehicle performance and safety outcomes across varied test environments, this study seeks to develop a standardized and interoperable database.

The proposed road characteristics database systematically captures essential parameters, including road geometry, surface type, condition ratings, signage, lighting, curvature, and other attributes critical to ensuring the validity of safety tests (FHWA, 2020). Such a database is particularly urgent for selecting and validating test tracks that must align with ASEAN NCAP protocol requirements. Beyond serving as a testing reference, it also provides regional spatial data that highlights the potential of specific areas for vehicle assessments. Accurate road network data – including geometric attributes and accessibility conditions – is essential for reliable calculations, and the road database is envisioned as the primary and most accurate source for these inputs (Amalindo et al., 2021).

2. METHODOLOGY

The development of the Road Characteristics Database followed a structured five-step process. Step 1 involved a thematic literature review, document examination, and feature extraction from ASEAN NCAP protocols, complemented by on-site measurements to identify representative road samples and relevant automotive testing frameworks. In Step 2, attribute identification and analysis were conducted, where metrics were constructed based on vehicle testing protocols, patterns of road characteristics were validated, and statistical analyses were performed to ensure data validity and reliability. This step also included the development of a standardized data model, aligned with major international frameworks such as ANCAP, Euro NCAP, and JNCAP (ANCAP, 2023; Euro NCAP, 2022; JNCAP, 2021). Step 3 focused on designing road survey instruments grounded in the validated attributes. In Step 4, real-world road segments that met the test protocol requirements were systematically identified, documented, and analyzed for consistency, leading to the development of a data model. Finally, Step 5 entailed constructing the database structure, incorporating search and query features, and validating the data entry user interface (UI) functionality. Figure 1 illustrates the overall methodology.

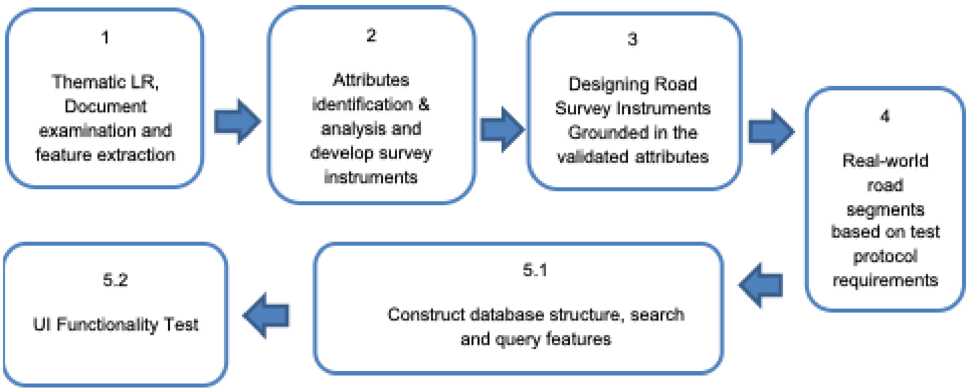

FIGURE 1: Flow of database development

The database captures essential parameters, including track details, geometry, lighting, infrastructure, pedestrian and cyclist considerations, environmental conditions, junctions, and traffic controls. Figure 2 presents the primary components established in Step 2, encompassing eight structured elements of the Road Characteristics Database, systematically classified to capture attributes across urban, suburban, and rural road typologies.

In Step 3, a survey instrument was developed to accurately capture road characteristics, based on attributes identified from a thematic literature review and an attribute analysis. The instrument was refined through several iterations to ensure its parameters were comprehensive and representative of diverse road environments. A pilot study was then conducted to test the instrument's robustness and clarity before full deployment. During this preparatory phase, preliminary assessments were carried out using Google Maps and on-site inspections to verify that the selected road segments met ASEAN NCAP protocol requirements. For Step 4, Jalan Meru Tambahan, a suburban road, was chosen to illustrate the complexity of real-world environments. This corridor traverses multiple land-use zones, including residential, industrial, school, and commercial areas and serves as a key exit route for heavy vehicles traveling from the port to the highway. This creates a heterogeneous mix of users, from private vehicles and motorcycles to heavy transport and pedestrians. The road itself presents physical challenges like cracked surfaces, uneven terrain, stagnant water, and steep inclines. Figure 3 provides an aerial view and visual documentation of these conditions. Following the verification process, the data collection phase was initiated. Simultaneously, in Step 5, a web-based data entry interface was developed using PHP and a MySQL database to facilitate structured, systematic data entry and storage. After the data was collected, a validation process was applied to ensure its consistency and accuracy. The functionality of the interface was also verified before the data was formally entered. This structured and iterative methodology ensures the data's reliability and its suitability for subsequent analysis, which is critical for road safety testing and infrastructure assessment.

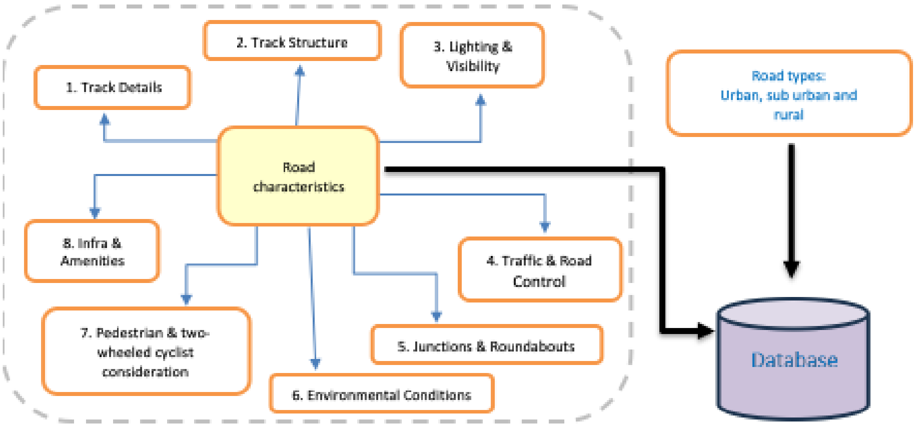

FIGURE 2: Main components in the data structure

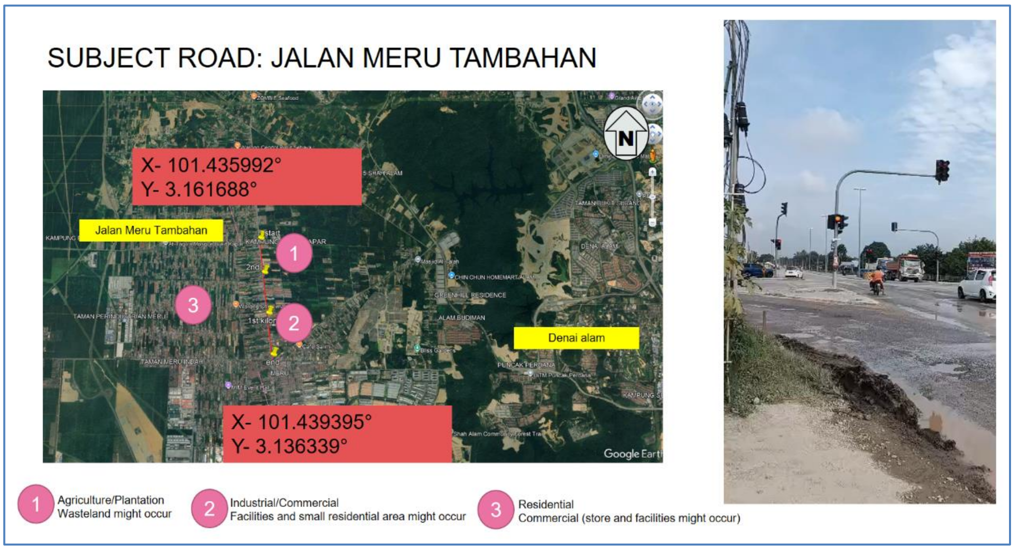

FIGURE 3: Example environment detail of Jalan Meru Tambahan

3. RESULTS AND DISCUSSION

This section presents the outcome of each step.

3.1 Data Model and Dictionary

This study focuses on seven ASEAN NCAP test protocols: AEB Car-to-Car, AEB Car-to-Motorcyclist (AEBCM), Blind Spot Detection (BSD), Auto High Beam (AHB), Adaptive Driving Beam (ADB), Blind Spot Visualization (BSV), Lane Support Systems (LSS), and Advanced Rear Visualization (ARV). Each protocol was reviewed for both explicit requirements and implicit assumptions regarding the road conditions specified for testing. A total of 32 initial parameters were identified, including six common across four or more protocols: lane width, surface type, slope specification, overhead structures, ambient temperature, and peak braking coefficient. An additional 18 parameters were protocol-specific, such as junction presence in AEBCM and lane marking visibility in LSS. Due to ambiguities in the documentation, further refinement was carried out through cross-comparison with other NCAP protocols. A data cleansing process was then conducted to remove redundancy and standardize terminology, resulting in a data dictionary comprising 52 distinct, well-defined attributes. These attributes were incorporated into structured road survey forms to guide data collection aligned with the operational and geometric requirements of each test protocol's track selection criteria. The final output was translated into a formal data model to support database development for test track identification.

3.1.1 Track Identification for Test Protocols

This section outlines the outcomes from Step 4, which involves the real-world data collection phase. In this step, roads that meet the requirements of the predefined test protocol were identified, assessed, and documented. For the case of Jalan Meru Tambahan, a total of seven tracks were successfully identified as suitable for implementing all seven categories of the test protocol. The initial identification process used Google Maps to examine the broader geographic context, road layout, and surrounding environment. Satellite imagery and visual cues provided a preliminary understanding of the terrain, land use, and traffic conditions surrounding each track, as shown in Figure 4.

Subsequently, a more detailed zoom-in analysis of each road section was conducted to closely observe the physical characteristics of the road and its environment. The results of this focused assessment are presented in Figure 5.

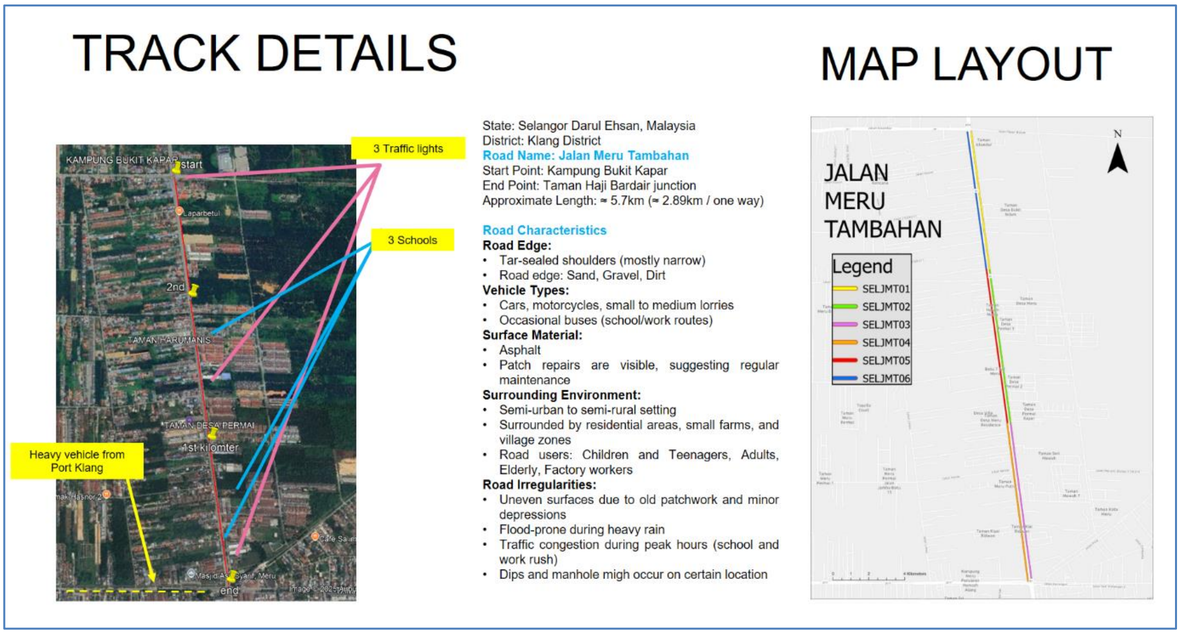

FIGURE 4: Visual representation of the identified road and surrounding environment

FIGURE 5: Example of track for Test Protocol – AHB, BSV, LSS AND ARV

This step served as a verification phase to ensure that the selected roads met all criteria before proceeding to physical site visits. A structured checklist was used to guide the verification process, assessing elements including road gradient, visibility, pedestrian access, surface condition, and traffic type. Based on the findings and visual documentation presented in Figures 4 and 5, a story map was developed to enhance the understanding of the visual road characteristics, as it provides a spatial narrative of the study area. This story map integrates visual data, such as satellite imagery, street-level photographs, and road environment context, with structured road characteristics data from the established database. The purpose of the story map is to present the collected information in an interactive, user-friendly format, allowing users to explore the various tracks, their attributes, and the suitability of the corresponding test protocols. It visually links each track to specific road features such as surface condition, lighting, road gradient, signage, pedestrian infrastructure, and vehicle types commonly observed on the routes. The story map also serves as a digital visualization tool that supports planning, analysis, and validation activities by spatially aligning data points with geographic locations. This integration ensures that each road segment is not only documented but also georeferenced to facilitate informed decision-making. The layout and interface of the story map, as shown in Figure 6, provide a detailed, navigable experience, making it easier to interpret complex road data and to connect it to the test protocol framework.

Following the virtual assessments, on-site data collection and inspections were conducted to validate road conditions and confirm their suitability in real-world contexts. Table 1 presents the outcomes of this identification process, detailing seven distinct tracks along Jalan Meru Tambahan and mapping their alignment with the specific ASEAN NCAP test protocols for which each track is suitable.

In total, the study concluded that 25 test protocol scenarios could be implemented across these tracks, with each track supporting between two and five different types of testing, depending on its specific features and road conditions.

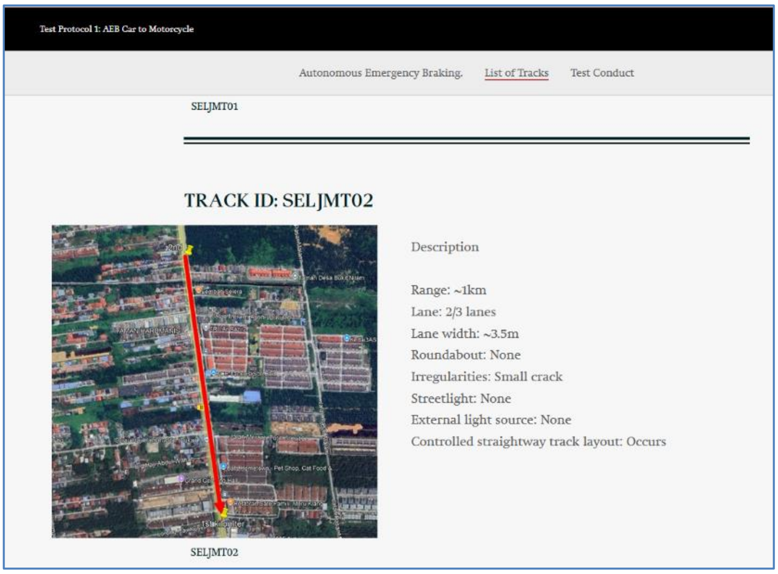

FIGURE 4: Example of the story map

TABLE 1: Track Compatibility at Jalan Meru Tambahan

Track No	Test Protocol	TP1	TP2	TP3	TP4	TP5	TP6	TP7
	Track ID	AEB Car to Motorcycle	BST	AHB	BSV	AEB Car to Car	LSS	ARV
TRACK 1	SELJMT01	✓				✓		✓
TRACK 2	SELJMT02	✓	✓				✓	✓
TRACK 3	SELJMT03			✓	✓		✓	✓
TRACK 4	SELJMT04			✓	✓			
TRACK 5	SELJMT05	✓	✓	✓	✓		✓	✓
TRACK 6	SELJMT06	✓		✓		✓	✓	✓
Total		4	2	4	3	2	4	5

3.2 Database and User Interface Design

The UI is friendly and organized according to thematic categories, such as road geometry, traffic control, lighting, surface conditions, and pedestrian-related features. Figure 7 illustrates a screenshot of the data entry screen developed as part of this step. Dropdown menus and pre-defined fields help enforce data consistency and reduce ambiguity in user inputs. It supports not only accurate data collection and storage but also efficient data retrieval for decision-making and safety testing.

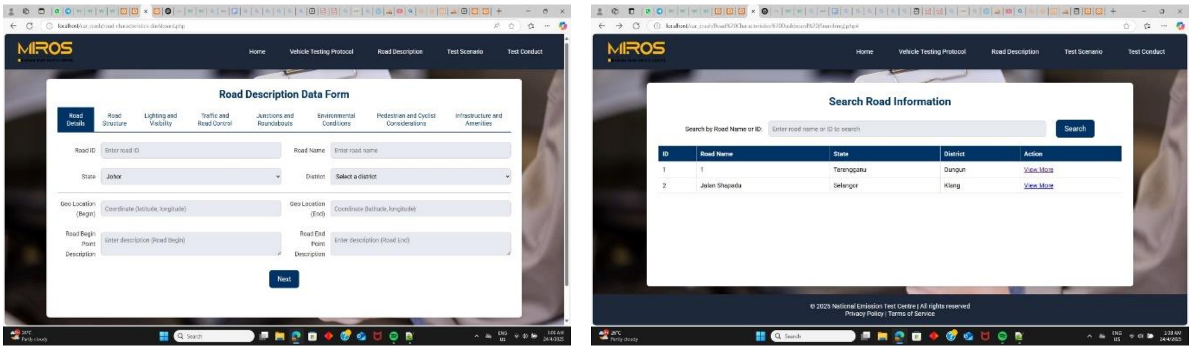

FIGURE 7: Screenshots of the data entry form

The theme-level UI functional testing results provide a structured evaluation by grouping test cases into key functional areas (Table 2). Multi-select & option saving achieved a perfect mean score of 1.00, with no variability, confirming flawless handling of multiple selections. Selection logic & constraints also performed well (mean score 0.88), showing robust enforcement of rules, though minor inconsistencies were observed. Submission validation & required fields (mean score 0.81) indicate generally effective validation, but variability in track-type selection and server-side validation highlight potential risks to data integrity. The most significant concern lies in data range & value testing, which recorded the lowest mean score (0.60) and the highest variability (SD 0.57). This points to inadequate handling of extreme or invalid inputs, representing a critical system risk. Meanwhile, the searching theme scored perfectly, but with only a single test case, its assessment remains insufficient. Further testing is necessary to confirm robustness. The overall average score of 0.85 and the standard deviation of 0.26 reflect strong reliability and readiness, with consistent strengths but also clear areas requiring targeted improvement.

TABLE 2: Functionality test result

Theme	Test Case Description	Mean Score
Submission Validation & Required Fields	Verify final submit fails when a required field on an earlier tab is blank	1.00
	Verify submit performs server-side validation for formats/rules	0.50
	Cannot submit with no Track Type selected	0.25
	Submit is Data cannot be submitted when Name of Junctions is empty	1.00
	Verify that whenever “Other” is selected on any tab, the form requires the specify/description text before submitting	0.83
	Verify Weather Condition is required	1.00
	Verify Accessibility of Amenities is required	1.00
	Duration must be a nonnegative integer	1.00
	Verify out-of-range temps are Data cannot be submitted	0.75
	At least one of Roundabout Type or Junction Type must be chosen	0.75
Selection Logic & Constraints	Slope should allow only one option	0.50
	Slope should allow only one option	1.00
	Ensure only one congestion level is chosen per time slot, and duration is recorded	1.00
	Verify consistency rules	1.00

Theme	Test Case Description	Mean Score
Multi-Select & Option Saving	Verify all protocols can be selected and saved	1.00
	Verify the tab accepts and saves all options ticked/selected (where multiple selections are allowed)	1.00
	Verify valid selections save successfully	1.00
	Verify the Pedestrian and Two-Wheeled Cyclist tab accepts all multi select options ticked	1.00
	Verify the Infrastructure & Amenities tab accepts all multi select options ticked	1.00
Data Range & Value Testing	Extreme numeric values tested	0.20
	Valid values on tab are accepted, persisted, and saved	1.00
Searching	Search Functionality and Filter Validation - 5 searching exercises	1.00
	Average	**0.85**
	Std Dev	**0.26**

3.3 Discussion

This study presents the development of a relational database using PHP and MySQL, integrated with validated survey instruments and querying features. The database incorporates 52 validated parameters covering five key domains: road geometry, lighting, surface condition, pedestrian infrastructure, and environmental context. This level of detail makes the database particularly suited for vehicle safety testing applications, especially those guided by ASEAN NCAP protocols. This database bridges that gap by standardizing road attribute data to align with test protocol conditions and real-world testing scenarios. The strength of this database is listed in Table 3.

The structured database of road characteristics can serve as a foundational resource for research in active safety systems, while also enabling further innovation through the integration of intelligent search and query features. From an industrial standpoint, the study offers practical value for regulatory agencies and safety assessment bodies, such as the Malaysian Institute of Road Safety Research (MIROS). The developed database supports the design and construction of standardized, protocol-specific test tracks tailored to the requirements of New Car Assessment Programs (NCAP), including ASEAN NCAP. By enabling more consistent and representative testing environments, the initiative enhances the reliability, reproducibility, and transparency of vehicle safety evaluations within the region. The system demonstrates maturity in multi-select functionality and validation mechanisms but requires focused enhancements to handle data ranges and ensure validation consistency. Addressing these weaknesses will strengthen data integrity, improve user confidence, and reinforce overall system resilience, supporting its progression toward full operational deployment. In software quality assurance, a test pass rate above 80% is generally accepted as a benchmark for stable performance, while scores approaching or exceeding 85% reflect a mature system with well-implemented features and minimal critical defects (Metridev, 2023). According to Humanetics (2024), systems that consistently pass functional and usability tests are more likely to meet regulatory benchmarks and user expectations, especially in safety-critical domains such as automotive testing.

TABLE 3: Key strengths of the database

Element	Description of project
Data Structure & Format	This study develops a relational database using PHP and MySQL, integrated with validated survey instruments and search/query features, offering better scalability and modular design.
Attribute Completeness	This database includes 52 validated parameters, covering geometry, lighting, surface, pedestrian, and environment, making it more comprehensive, extracted based on vehicle safety testing protocols ASEAN NCAP and cross-checked with other NCAP protocol documents.
Integration Readiness	This data UI is designed with future integration in mind and can support analytics, intelligent querying, and interoperability with vehicle testing platforms.
Purpose Alignment	This database is specifically designed to support vehicle safety testing, addressing a critical gap in the standardization of real-world road samples for test protocol validation, a dimension often overlooked in prior studies. The underlying data model is scalable and can be extended to other countries by adopting the ASEAN NCAP protocol, thereby enabling the creation of a unified corpus of road track data within a single standardized database.

4. CONCLUSION

This research advances the field by proposing a road characteristics database model that addresses the gap between real-world road environment variability and standardized vehicle safety testing. The proposed model is intended to serve as a reference framework for ASEAN regulatory bodies, automotive manufacturers, and road safety researchers in developing consistent and context-relevant testing environments. By integrating vehicle testing with standardized data and a comprehensive road characteristics database, the study supports enhanced vehicle safety, improved testing efficiency, and greater reliability in performance outcomes. Looking ahead, the 52 standardized road attributes identified in this study will form the foundation for designing the data structure and developing a functional road data management system. These attributes will be instrumental in identifying real-world road segments suitable for specific test protocols. These characteristics will guide the identification of real-world road segments suitable for specific test protocols, beginning with the establishment of a structured data collection form aligned with track selection criteria. Overall, the database design established in this step serves as the backbone of the road characteristics system. It supports not only accurate data collection and storage but also efficient data retrieval for decision-making and safety testing. Future enhancements may include analytics and intelligent search tools that enable users to identify road segments based on specific vehicle testing criteria, thereby improving the overall efficiency of safety assessment processes.

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