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PORTABLE ADAS CALIBRATION ZONE ASSESSMENT DEVICE: DESIGN, MEASUREMENT METHODOLOGY AND SERVICE APPLICATION

Summary. *Calibration accuracy for Advanced Driver Assistance Systems (ADAS) is a safety-critical process whose outcome is determined by aspects ranging not only from calibration equipment and technician proficiency levels, but also the physical properties of the workspace: the floor levelness, ambient illumination, and the absence of glare sources. Although the increasing number of ADAS calibrations carried out in service workshops and in mobile settings, there is no standardized portable instrument for the rapid pre-calibration audit of those environmental parameters. In this paper, the design, operating principle of the portable ADAS calibration zone assessment device, and its service application are discussed. The proposed instrument includes a high-precision inclinometer mounted on a three-point disc plate for floor slope measurement at nine spatially distributed reference points, a lux-meter mounted on a height-adjustable carriage for illumination measurement at the calibration target plane, and an optional narrow-field tube* *attachment for directed glare assessment. A microcontroller-based computing unit with an embedded display collects sensor input, compares the readings with OEM-defined thresholds, and provides a structured environment passport. It addresses a well-established gap between full calibration stations and manual ad-hoc checks; significantly decreases calibration failures attributable to environmental non-conformance; and works in fixed workshop and mobile (roadside) service scenarios. Reference performance thresholds, measurement workflow, and representative service implications are discussed.*

Key words: *ADAS calibration, floor levelness, illumination measurement, glare assessment, inclinometer, lux-meter, calibration zone audit, portable instrument, service workshop, environment passport.*

Introduction. Over the last year, Advanced Driver Assistance Systems (ADAS) have become standard equipment across a wide range of new passenger and light commercial vehicles, including forward-collision warning, automatic emergency braking (AEB), lane-keeping assistance, adaptive cruise control, and surround-view monitoring [7; 12].

The working performance of these systems relies on the right synchronization and calibration of cameras, radar transceivers, ultrasonic sensors, and LiDAR units for their alignment among the vehicle coordinate frame and among themselves. Miscalibration, even at sub-milliradian scale, can lead to systematic errors in object detection, range estimation, and lane boundary projection that can reduce the safety performance of these systems [4; 8].

However, the burgeoning fleet of ADAS-equipped vehicles generates a demand for calibration services across the aftermarket and dealership arena [1; 14]. Calibration is carried out in fixed service bays, but increasingly in mobile locations - roadside, at bodyshop partners, and at fleet depots.

In all deployment contexts, the OEM calibration protocol specifies environmental prerequisites to be met before the calibration sequence begins. These prerequisites consistently address three physical parameters: (1) floor levelness, represented as the max allowable slope in degrees or millimetres per metre of a vehicle footprint; (2) ambient illumination (minimum and maximum lux levels at the calibration target plane); and (3) absence of glare or intense localised light sources which can saturate camera sensors or displace target feature detection [9; 16].

In present workshop practice, ambient compliance is usually checked informally – and often by sight, or at a single moment, or not at all. This results in a well-documented set of calibration failures and unstable calibration results that are traceable not to equipment failure, but to environmental nonacceptance.

A 0.3° slope in one wheel position versus another is not noticeable to the eye but crosses the ±0.2° line stipulated by some OEMs when calibrating static cameras. Likewise, lighting that seems adequate on a subjective measure may fall below the 500 lux threshold needed for reliable target pattern detection, or suffer from a glare source in the sensor field of view that the technician cannot view from the technician's line of sight [6].

Current calibration stations, like the Autel IA700, offer inclinometers and optical compensation approaches that partially tackle floor non-conformity, but they are full calibration systems: not portable audit instruments. They only measure floor conditions at the instrument's own footprint, they do not map the vehicle footprint zone into a grid, and they do not include illumination measurement as a defined compliance parameter. Also, their size and logistical needs do not allow a pre-visit assessment tool that could be used in mobile service sites [16].

The current paper fills this void by outlining the design, measurement methodology, and service application of a portable ADAS calibration zone assessment device — a tripod-mounted sensor-integrated measuring device providing a mapping/characterisation of floor levelness, illumination at target height, and glare risk in a defined calibration zone and a formal compliance report output.

The device can be carried in the standard technician vehicle, configured in less than five minutes, and run independently from any specialized metrology knowledge. It is used in fixed and mobile service and produces repeated records of environmental condition — referred to as an environment passport – which can be used as evidence of calibration precondition compliance.

Background and Related Work

1. Environmental Prerequisites for ADAS Calibration

The sensitivity of ADAS sensors based on cameras to illumination is already well established. Li et al. (2023) which compared pedestrian detection performance to the standardised test environment showed quantifiable loss of sensitivity under low-light conditions where ambient illumination dropped below 300 lux, with AEB activation distance reduced by up to 18%.

Because sensor performance is light dependent, the IIHS AEB test protocols [7] require controlled lighting conditions. For a service calibration routine, the low-light requirement does not preclude the calibration process yet leads to calibration settings optimized for an artificially dim environment, which results in deterioration of real-world performance by using lower illumination levels of calibration settings.

The flat floor level affects the geometric properties of static camera calibration directly. Finally, the relative values of camera mounting angles, vehicle pitching at the calibration point and how angle of the calibration target in the camera field of sight are related: the slope of the floor of the car of θ° will generate an effective camera pitch error of θ° that is indistinguishable, from the standpoint of the calibration algorithm, from a physical camera miscalibration point of view.

Typical OEM calibration texts define ideal floor slope values of 0.1° - 0.5°, depending on sensor type and the accuracy of the calibration process [6; 16].

A third risk factor in the environmental range is glare from windows, overhead luminaires, as well as specular surfaces in the workshop. Wide-angle surround-view cameras (such as the ones used in the Intelligent Around View Monitor (I-AVM) systems of existing vehicles) are especially prone to this, because their wide field of view inevitably captures relatively more of the ambient environment.

A glare source at much higher luminance than target pattern saturates image regions, displaces the computed centroid of target features, and terminates calibration routines with a false error flag or, worse, an incorrect parameter set [2; 3].

2. Existing Instrumentation and its Limitations

The systematic calibration of multi-sensor ADAS systems with LiDAR-camera and radar–camera pairings has been widely investigated over the last few years [10; 15; 19; 20]. However, this work is primarily centred around the calibration algorithms themselves - targetless techniques or deep-learning-based ones or track-to-track associations - and not on the environmental conditions under which those algorithms perform accurately.

Inclinometers and floor-compensation algorithms are built into commercial calibration systems like the Autel IA700. The IA700 employs six HD cameras and a motorised crossbar to calibrate with in-the-moment floor compensation. Though, this system takes floor tilts in only at the instrument site, not on the vehicle's entire footprint. Illumination is not used as a compliance parameter.

Its size requires transportation in a large vehicle, precluding use as a pre-visit audit tool at mobile locations. Other commercial systems (Hella GUTMANN, Bosch DAS 3000) have similar limitations: they are calibration systems with incidental environmental sensing, and not environmental assessment instruments.

Lux-meters and bubble levels, available as separate tools, are completely ad hoc as an ADAS calibration audit methodology. One point measurements do not represent the vehicle footprint zone. There is a lack of a common nine-point grid protocol and a pre-defined threshold comparison method with no structured format of output.

Since no specific portable audit instrument has been developed, the process of environmental compliance verification before calibration has had no objective repeatable way for workshop operators to evaluate compliance.

3. Reference Platforms and Sensor Technologies

Rövid et al. (2025) present a reference platform for ADAS camera system evaluation that illustrates the significance of carefully managed and detailed test environments in producing reliable calibration results [16]. Their contribution supports the view that the measurement environment is itself a variable that must be quantified and controlled. Ding et al. (2024) propose a machine-vision-based approach to vehicle coordinate system reconstruction in end-of-line ADAS calibration, which necessitates a thorough understanding of vehicle position and floor geometry - a requirement that presupposes floor levelness assessment [6].

High-precision inclinometers for floor levelness measurement in the required range of 0–2° with resolution ±0.01° are commercially available, such as the Jewell DXI-100/200 series, which offers an electrical output signal proportional to tilt angle and can be integrated into a portable computing platform. Lux-meters with digital output interfaces - like the Seeed Studio S-Light-02 - offer illumination measurement in the range appropriate for ADAS calibration (100-10,000 lux) with sufficient accuracy to make threshold comparisons. The availability of these sensor components, combined with low-power microcontroller platforms, establishes the technical feasibility of the proposed device.

Device Design and Component Description

1. Overall Architecture

The portable ADAS calibration zone assessment device (hereinafter: the device) is a tripod mounted instrument consisting of five main functional elements: a vertical mast (1) with a height-adjustment mechanism; a support assembly (2) as the base; a tilt measurement unit containing an inclinometer sensor (3) mounted on a three-point disc plate (10) attached to the base of the mast; an illumination measurement unit containing a lux-meter sensor (4) mounted on a height-adjustable carriage (8) at the upper part of the mast; and a computing unit (6) with integrated display and power supply (5) . For directed glare assessment, the illumination measurement unit can be supplemented with an optional tube attachment (7). These elements are functionally interconnected as schematically shown in Figure 1 and summarized in Table 1.

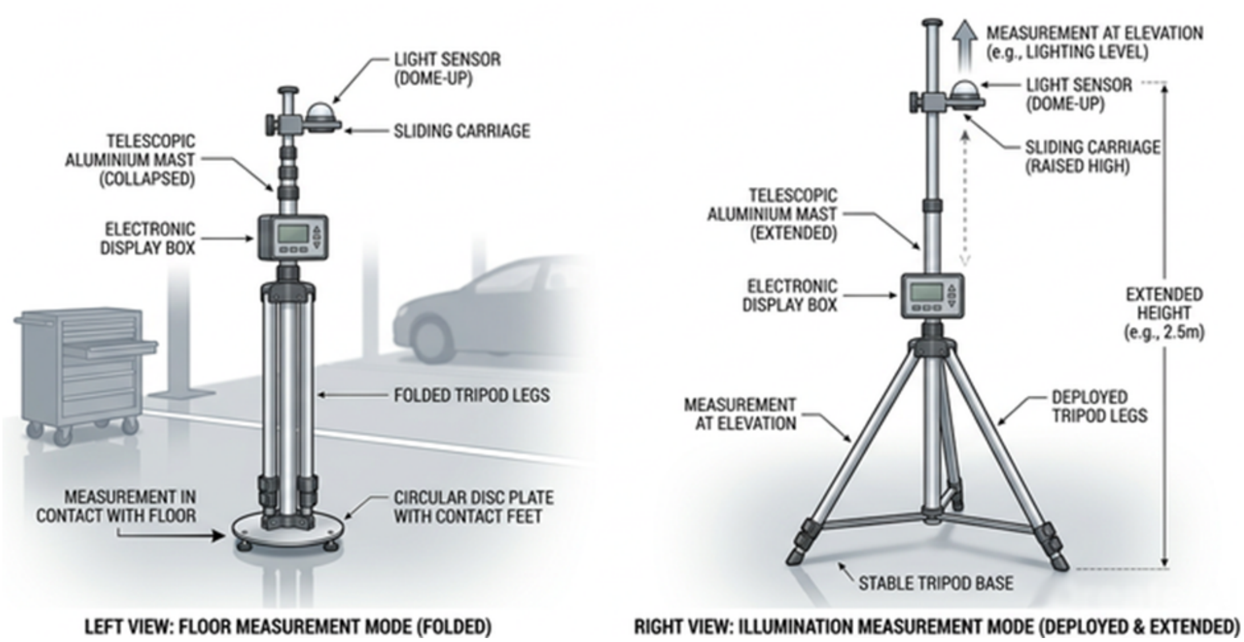

Fig. 1. Portable ADAS calibration zone assessment device: (a) floor levelness measurement mode with tripod legs folded and disc plate in contact with floor; (b) illumination measurement mode with tripod deployed and lux-meter carriage raised to target height

Table 1

Principal components of the portable ADAS calibration zone assessment device

Component	Designation	Primary Function
Vertical mast	(1)	Height-adjustable structural carrier for all measurement units; telescopic aluminium construction
Support assembly (tripod)	(2)	Three-leg base providing stable freestanding support; legs fold upward for disc-plate-only mode
Inclinometer sensor	(3)	Two-axis floor tilt measurement at nine grid reference points; mounted on disc plate (10)
Disc plate	(10)	14–16 cm diameter platform with three-point contact feet providing defined, repeatable contact geometry with the floor
Lux-meter sensor	(4)	Ambient and directed illumination measurement; mounted on height-adjustable carriage (8)
Height-adjustable carriage	(8)	Slides vertically along mast (1); locked at target height by clamp (9)
Tube attachment (optional)	(7)	Narrow-field-of-view attachment for directed glare measurement; snap-fit onto lux-meter housing
Computing unit	(6)	Microcontroller with embedded display; acquires sensor data, applies thresholds, displays results, stores records
Power supply	(5)	Rechargeable battery integrated with computing unit; powers sensors and display autonomously

2. Mechanical Structure

Vertical mast (1) is made from high-strength aluminium alloy. A telescopic locking mechanism allows stepless height adjustment, permitting deployment across the full range of ADAS calibration target heights encountered in passenger vehicle service, between 0.5 m and 1.8 m from floor level. At the lower mast level, a pair of right-angle brackets mounted to a clamping collar supports the disc plate (10) perpendicularly to the mast axis. The disc plate (10) is circular, 14–16 cm in diameter. The bottom face has three point-contact feet (three bolts with spherical heads, locked with counter-nuts) spread out at equal angular intervals. This three-point geometry ensures deterministic contact with the floor surface, eliminating rocking errors that would otherwise affect inclinometer readings. The inclinometer sensor (3) rests on top of the disc plate, fixed to the plate axis and centred on the plate axis.

When the device is in its illumination measurement mode, the tripod support assembly (2) offers three-leg freestanding stability. For monitoring floor levelness, the tripod legs are folded upward against the mast and secured with a strap, so that the mast is supported exclusively through the disc plate (10), allowing the inclinometer reading to represent the floor condition only at the measurement point, rather than that of the tripod leg positions.

3. Tilt Measurement Unit

The inclinometer sensor (3) delivers two-axis tilt measurement with ±0.01° resolution and ±10° range, which is considerably greater than the ±0.5° range relevant for ADAS calibration zone assessment. The sensor generates an electrical output signal that is proportional to the angle of tilt and is read by means of a digital interface from the computing unit (6). The sensor is supplied by the integrated power supply (5). The three-point contact geometry of the disc plate guarantees that the measured tilt is a faithful representation of the local floor plane at the measurement point. This is analogous to the manner in which a stylus of a coordinate measuring machine samples a surface at a defined contact geometry. The computing unit records the tilt readings at each of the nine reference points in the calibration zone grid and calculates the maximum tilt observed, the mean tilt and identifies the worst zone within the 3,000 × 2,000 mm vehicle footprint rectangle.

4. Illumination Measurement Unit

The lux-meter sensor (4) is installed on the height-adjustable carriage (8), which travels vertically along the mast (1) and is secured at the required height by clamp (9). The carriage position is set to the height of the calibration target centre for the respective vehicle and ADAS system under review. The sensor detects ambient illumination with an integrated white dome diffuser and gives a cosine-corrected output (representing illumination available at the surface area of interest). Illumination values are transmitted to the computing unit (6) via a digital interface and displayed in lux.

The optional tube attachment (7) is a snap-fit cylindrical collar with an internal diameter 1–2 mm greater than the external diameter of the lux-meter dome housing. Having fitted a tube, the effective field of view for the sensor is limited in size from near-hemispherical to around a 15–25° half-angle cone (depending on tube length), allowing direct measurement to a focused suspected glare source. The ratio of the directed (peak) to the ambient (background) measurement provides a quantitative glare risk index: the Peak/Ambient ratio is a significant reflection of a localised high-luminance source which adversely affects the camera calibration quality if markedly above 1.0.

5. Computing Unit

The computing unit (6) is a microcontroller-based module with an integrated LCD or OLED display mounted to the mast at a reading-convenient height of 150–190 cm. It includes: an analog-to-digital conversion interface for the inclinometer sensor; a digital bus interface for the lux-meter sensor; non-volatile memory for measurement record storage; a user interface consisting of control buttons and the embedded display; and, optionally, a wireless communication module (Bluetooth or Wi-Fi) for data transfer to a smartphone or tablet application. It displays real-time sensor readings, applies configurable pass/fail thresholds, and provides an audible or visual alert when a measurement exceeds a limit. After completing a nine-point floor survey and a target-height illumination measurement, the computing unit produces a structured summary of the results - the environment passport - that contains all measurement values, the applied thresholds, the pass/fail status for each parameter, the date and time, and an operator-entered zone identifier.

Materials and Methods

1. Reference Grid for Floor Levelness Assessment

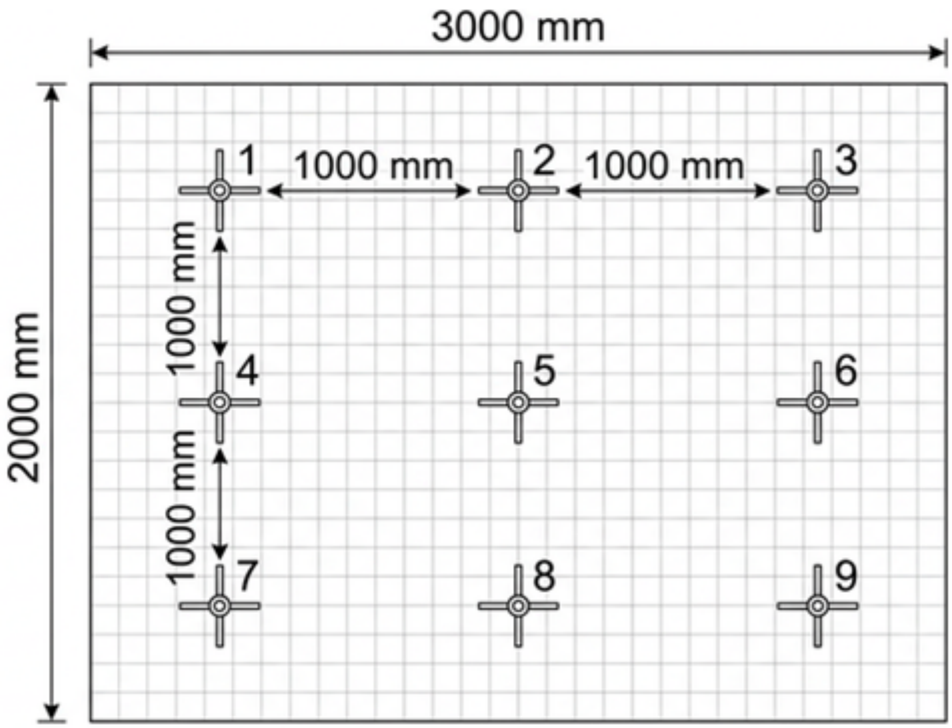

Fig. 2. Nine-point reference grid (3,000 mm × 2,000 mm) for floor levelness and ambient illumination survey

Note: numbers 1–9 indicate measurement sequence; crosses mark the three-point disc plate contact positions

The floor levelness test protocol is calculated by means of a 3 × 3 measurement grid of points in a rectangular area of 3,000 mm × 2,000 mm, which refers to the floor area that a regular passenger car fills during calibration. An operator then marks nine reference points (numbered 1 through 9) at the intersections of that grid onto the floor surface with chalk or removable tape (See Figure 2). The spacing corresponds to 1,000 mm in the longitudinal direction and 1,000 mm in the lateral direction, with the outermost points 500 mm from each edge of the rectangle.

At each reference point, the operator folds the tripod legs of the device upward and positions the disc plate (10) so that its centre coincides with the grid point, then waits 1–2 seconds until the inclinometer reading stabilises before pressing the Save button on the computing unit. The two-axis tilt vector recorded at each point is held by the computing unit. The computing unit calculates and displays: (a) the highest tilt magnitude observed across all nine points; (b) the mean tilt across all nine points; (c) the sub-zone in the grid that performed the worst; and (d) the pass/fail based on the threshold which is configured (default: 0.3° maximum tilt, configurable to OEM-specific values). Passive ambient illumination is recorded at every floor measurement point, thus creating a spatial illumination map of the zone as a by-product of the floor survey.

2. Target-Height Illumination Assessment

To assess illumination at the calibration target plane, the operator uses the device in tripod mode while keeping the tripod legs extended for stability. Carriage (8) is adjusted to the height of the calibration target centre for the vehicle model and calibration procedure - approximately 0.8 m to 1.4 m for windshield-camera calibration. The lux-meter sensor (4), without the tube attachment, is oriented horizontally toward the target position. The operator starts the measurement, waits 3-5 seconds for stabilisation, and records the result.

A minimum of three to five measurement locations within the target zone (left, centre, right, and optionally upper/lower) are recommended to determine the illumination uniformity. The computing unit estimates and presents the mean, minimum, and maximum illumination values at the measurement locations and the illumination uniformity ratio (minimum/maximum). Reference levels: minimum illumination ≥ 500 lux, maximum illumination ≤ 3,000 lux (to avoid sensor saturation), uniformity ratio ≥ 0.6. These values are consistent with thresholds reported in OEM calibration files as well as IIHS and NHTSA testing instructions [7; 13].

3. Glare Assessment Protocol

In the event that the calibration procedure fails, or the response is unstable, and that the floor and illumination parameters are within specification, the glare from localised light sources is a cause. The glare assessment protocol uses the tube attachment (7) on the lux-meter sensor (4). The operator, then, points the sensor - tube attached - toward each possible source of glare in sequence: windows, overhead fluorescent or LED luminaires, glossy wall surfaces, and reflective equipment. For each direction of measurement, the peak directed measurement is recorded by the computing unit. The glare risk index is computed as:

Glare Risk Index = Peak directed measurement (lux) / Ambient background measurement (lux)

A Glare Risk Index substantially exceeding 1.0 - in practice, values above 5.0 are considered significant - indicates a source likely to impair camera calibration. The operator records the direction of the glare source and takes remedial action (closing blinds, repositioning a luminaire, placing a matte screen) before retrying the calibration.

The Environment Passport: Documentation and Service Application

1. Concept and Content

A key output of the device is the environment passport - a structured, timestamped record of the environmental conditions at the calibration location. The environment passport contains: operator and location identification; date and time of measurement; results of the nine-point floor survey (individual tilt readings, maximum, mean, worst zone, pass/fail); results of the target-height illumination survey (individual lux readings, mean, minimum, maximum, uniformity ratio, pass/fail); and, if conducted, glare assessment results (peak readings by direction, Glare Risk Index, pass/fail). The passport is stored in the non-volatile memory of the computing unit and can be printed, exported as a PDF via a connected smartphone application, or transmitted by email directly from the computing unit if the optional wireless module is fitted.

The environment passport serves multiple purposes in the service workflow. It provides the technician with an objective pre-calibration compliance check, replacing informal visual inspection. It provides the workshop owner with documentary evidence of calibration precondition compliance in the event of a customer dispute or insurance claim. It supports quality management systems in multi-bay workshops by enabling periodic environmental surveys of each bay and tracking changes over time (e.g., floor settlement, changes in lighting infrastructure). For mobile service operations, it demonstrates to the customer that the calibration was performed in a location that met the required environmental standards.

2. Workflow Integration

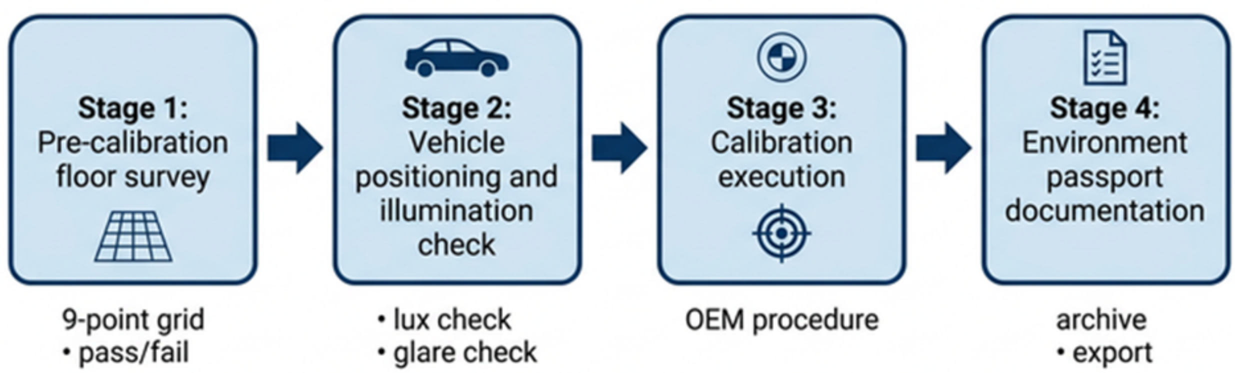

Fig. 3. Recommended four-stage workflow for integrating the portable ADAS calibration zone assessment device into the service process

The suggested process for the incorporation of the device into ADAS calibration service process comprises four steps (See Figure 3):

Pre-calibration environmental survey: Prior to the vehicle placement, a nine-point floor survey is performed, and the result is logged by the operator. If the zone fails, the operator will find another area of the workshop or modify the boundaries and resurvey the area. This takes about 5–8 minutes.

Vehicle position and target location: The vehicle is parked in the surveyed zone and the calibration target is fixed at the OEM-specified distance and position. The operator proceeds to perform the target-height illumination measurement (2–3 minutes). In case the illumination is non-compliant, the operator may adjust lighting settings and re-measure.

Calibration execution: After checking compliance with environmental factors, the calibration procedure will be performed on the calibration system for the workshop (OEM CONSULT, AUTEL, or otherwise). The timestamp of the environment passport is contemporaneous with the timestamp of the calibration process.

Documentation and archiving: An environment passport is exported and archived with the calibration record (vehicle VIN, procedure reference, result). In the event of a calibration failure, the environmental parameters are recorded, which will aid in the analysis of root cause.

3. Mobile and Roadside Application

For the mobile ADAS calibrations, the environment passport offers particular worth. In the absence of an objective pre-calibration audit, mobile operators cannot show - to their own quality management system or the customer - that their calibration has taken place in a compliant environment. The proposed device, designed for single-operator transport and five-minute setup, makes this audit practical for every mobile job. The device, which is a folded tripod with mast, is compact enough to be transported in a standard hatchback or van. The device does not require mains power, operating autonomously on its internal rechargeable battery for a full working day.

Comparative Analysis

Table 2 summarises the functional characteristics of the proposed device in comparison with currently available alternatives: full ADAS calibration stations with inclinometer features, and the ad hoc combination of a spirit level and separate lux-meter.

Table 2

Comparative analysis: portable ADAS calibration zone assessment device versus existing approaches

Criterion	Full calibration station (e.g. Autel IA700)	Ad hoc spirit level + lux-meter
Floor survey area	Single-point (instrument location only)	Single-point or informal multi-point
Floor survey protocol	No standardised grid protocol	No standardised grid protocol
Illumination measurement	Not included as compliance parameter	Separate instrument; no threshold comparison
Glare assessment	Not included	Not possible
Structured output / report	Calibration record only; no environment audit report	None
Portability	Large system; requires large vehicle for transport	Portable but no unified instrument
Setup time	> 20 minutes	< 5 minutes but incomplete
Proposed device	Nine-point grid survey; full vehicle footprint coverage	Standardised protocol; automated threshold comparison; environment passport; < 8 min setup

Discussion. This proposed device addresses a well-defined instrumentation gap at one point in the ADAS service workflow in which it is needed: the pre-calibration environmental audit. And now the design explicitly limits its design to this operation.

It is not the type used as a calibration equipment, not performing calibration, rather it is a compliance verification tool that allows a go/no-go decision for the compatibility of the workspace before the calibration equipment is installed. This functional restriction is intentionally applied – because it does not try to compensate environmental non-conformance, which is the norm with some calibration stations, it guarantees that the calibration is done in a known-compliant environment, and not in one with partially misused calibration.

The nine-point grid for floor assessment can be seen as an optimization of physical efficiency and time to service. A nine-point survey over a 3 × 3 m area is suitable with 5 minutes from a single operator and provides spatial resolution to record floor slope gradients and local depressions that a single point measurement would fail to record.

The three-point contact geometry of the disc plate also eliminates a major source of measurement artefact - the rocking or bridging of a flat base plate over slightly convex or concave floor surface - that would otherwise cause systematic errors in the inclinometer reading.

The inclusion of glare assessment through the directed tube attachment increases the utility of the device to a class of calibration failures that can be difficult to diagnose without quantitative tools. The Peak/Ambient ratio metric is easy to calculate and interpret, and directing the measuring approach (pointing the tube-mounted sensing material to each potential glare source in turn) does not require some kind of optical expertise from the operator.

In comparison, the technical challenge of analyzing the histograms of the camera raw image for saturation evidence necessitates an approach that requires access and specialist knowledge at the calibration-system level.

A limitation of the current design is that measurements of floor levelness and illumination were made sequentially and in separate instrument combinations (disc-plate mode versus tripod mode). A potential application of this would be to complement the disc-plate measurement with a second inclinometer attached to the tripod legs to measure absolute floor tilt in tripod mode in a single deployed manner.

However, this sequential protocol adds only 2–3 minutes to the overall survey time and is considered acceptable for the target application. The environment passport concept is in line with the growing trend towards documented, traceable service processes in the automotive aftermarket accelerated by growing complexities embedded in vehicle systems, as well as the potential risk of inaccurate alignment in ADAS calibration [11; 17].

With the deeper integration of ADAS systems with vehicle architectures and the advent of OTA-updatable systems like those found on CMF-EV platform vehicles, the demand for systematic, repeatable environmental audit processes will only continue to rise [5; 18].

Conclusion. In this paper, the design, measurement approach and treatment of a portable ADAS calibration zone appraisal system has been discussed. The key achievements are: A portable, single operator instrument that encompasses floor levelness (nine-point grid, three-point disc plate contact geometry), ambient and target-height illumination measurements (height-adjusted carriage), as well as directed glare screening (tube attachment), in a single tripod mount. A standardised nine-point measurement protocol for floor-levelness and spatial illumination (SM) mapping in the vehicle footprint zone and automatic pass/fail comparison against configurable OEM-aligned thresholds. Environment passport: a structured output document with timestamp that indicates environmental compliance before calibration, helpful for archiving quality management issues and customer facing documentation. Achieved applicability to fixed workshop as well as mobile service, setup time ≤ 8min and can run autonomously on an integrated power supply.

The device will serve as a bridging solution between the documented disconnect between a full ADAS calibration station and informal ad hoc checking: a practical, low-cost, repeatable option to a family of calibration failures, that are based on errors that are environmental rather than fault-laden with the equipment or procedures themselves. Future works should develop a standardised threshold database indexed by OEM, sensor type, and calibration procedure and a wireless data transfer solution linking to workshop management applications.

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