INSPECTION AND QUANTITATIVE ASSESSMENT OF VEHICLE LIGHTING AND SIGNALING SYSTEMS

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Abstract: This paper examines modern diagnostic methodologies and regulatory benchmarks for evaluating external lighting and light-signaling devices during mandatory vehicle technical inspections in the Republic of Uzbekistan. Proper optical performance of headlamps, fog lamps, and signaling indicators is critical for nighttime visibility and collision prevention. Based on the technical provisions of Cabinet of Ministers Resolution No. 125 and state safety standards (UzDSt / GOST R 51709), the study outlines an instrumental testing framework utilizing digital luxmeters and optical beam-aiming testers. Key photometric parameters—including luminous intensity, low-beam cutoff inclination, chromaticity compliance, and turn-signal flashing frequency—are systematically structured into a standardized assessment matrix. Furthermore, the research proposes integrating automated digital data logging from optical diagnostic stands into the unified electronic inspection registry to eliminate subjective visual judgments, prevent oncoming driver glare, and improve defect detection accuracy across diagnostic stations.

Keywords: vehicle technical inspection, external lighting devices, light-signaling systems, luminous intensity, cutoff angle, luxmeter, optical beam tester, road traffic safety.

Annotatsiya: Ushbu maqolada O‘zbekiston Respublikasida transport vositalarini majburiy texnik ko‘rikdan o‘tkazish jarayonida tashqi yoritish va yorug‘lik signalizatsiya qurilmalarini diagnostika qilish usullari hamda me’yoriy baholash mezonlari tadqiq etilgan. Vazirlar Mahkamasining 125-sonli qarori va amaldagi davlat standartlari asosida raqamli lyuksmetr hamda optik faralarni sozlash stendlaridan foydalangan holda yorug‘lik kuchi, yaqinni yoritish nurining og‘ish burchagi va miltillash chastotasini aniqlashning tizimli tartibi yoritilgan. Diagnostika natijalarini raqamli qayd etish orqali subyektiv baholashga chek qo‘yish va tungi yo‘l-transport hodisalarining oldini olish bo‘yicha amaliy tavsiyalar ishlab chiqilgan.

1. Introduction

Active safety of motor vehicles relies heavily on the operational reliability of external lighting and light-signaling systems. During dusk, nighttime, and adverse meteorological conditions such as fog or heavy precipitation, headlamps provide the primary visual channel for the driver to perceive road geometry, pedestrians, and obstacles. Simultaneously, position lamps, brake lights, direction indicators, and hazard warning signals communicate vehicle dimensions and driver intentions to surrounding road users.

In Uzbekistan, rapid motorization and continuous renewal of the national vehicle fleet—comprising halogen, xenon (HID), and modern LED optical modules—have introduced new challenges for technical maintenance and regulatory oversight. Improperly aimed low-beam headlamps, unauthorized aftermarket installation of high-intensity discharge lamps in reflector housings, and

degraded optical lenses frequently cause severe glare for oncoming drivers while reducing effective road illumination. Under Cabinet of Ministers Resolution No. 125 (dated 9 March 2021), accredited technical inspection stations are mandated to verify lighting compliance using calibrated instrumental equipment rather than relying solely on visual checks.

The objective of this study is to systematize the diagnostic stages, photometric tolerance limits, and defect classification criteria for vehicle lighting and signaling systems, and to substantiate a digital protocol for recording instrumental measurement data during periodic technical inspections.

2. Materials and Diagnostic Methodology

To ensure objective and reproducible assessment of vehicle optical equipment, the inspection process is structured into three sequential phases: (a) preparatory verification of vehicle positioning and electrical supply, (b) visual and functional inspection of signaling circuits, and (c) instrumental photometric testing of main headlamps and fog lamps.

Prior to photometric measurements, strict preparatory conditions must be satisfied to prevent geometric distortion of the light beam. The vehicle is positioned on a flat, horizontal diagnostic bay with a longitudinal and transverse slope not exceeding 3 mm/m. Tire pressures are verified against manufacturer specifications, the suspension is settled, and the vehicle is loaded in its curb weight condition (with the driver or equivalent ballast on the driver's seat). If the vehicle is equipped with a manual headlamp leveling adjuster, the control switch is set to the zero ('0') reference position, while automatic leveling systems are checked for sensor responsiveness. All measurements are conducted with the engine idling to maintain nominal alternator charging voltage (13.8–14.4 V for 12 V systems and 27.6–28.8 V for 24 V systems).

Instrumental diagnostics are performed using an optical headlamp beam tester (regloscope) equipped with a built-in digital luxmeter and laser alignment visor. The optical axis of the tester is aligned parallel to the longitudinal symmetry plane of the vehicle at a fixed distance of 300–500 mm from the headlamp diffuser. The device projects the beam pattern onto an internal graduated screen, enabling direct measurement of the horizontal and vertical coordinates of the light-dark cutoff line as well as peak luminous intensity (in candelas, cd) or illuminance (in lux, lx) at standardized control points.

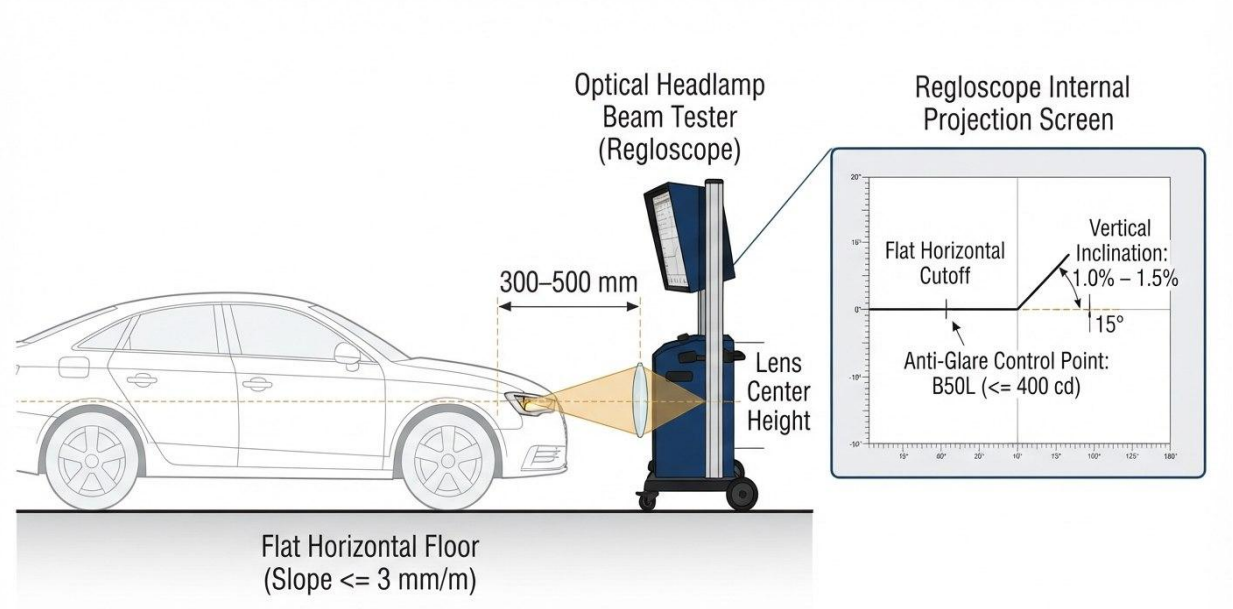


Figure 1: Schematic Setup for Vehicle Headlamp Testing and Beam Pattern Analysis.

3. Normative Parameters and Quantitative Evaluation Criteria

In accordance with national technical regulations governing road vehicle safety (harmonized with UNECE Regulations No. 48, No. 112, and GOST R 51709), each lighting and signaling subsystem must conform to strict geometric, photometric, and colorimetric thresholds. Any deviation beyond permissible tolerances classifies the vehicle as technically non-compliant, requiring defect rectification and a repeat inspection.

Table 1. Technical inspection criteria and normative limits for vehicle lighting and signaling devices

Subsystem / Device	Controlled Parameter	Permissible Normative Value	Inspection Method
Low-beam headlamps	Vertical inclination of light-dark cutoff	1.0% to 1.5% downward (depending on mounting height H)	Optical beam tester
Low-beam headlamps	Luminous intensity in anti-glare zone (point B50L)	Not exceeding 400 cd (max 0.4 lx at 25 m)	Digital luxmeter
High-beam headlamps	Total maximum luminous intensity of all lamps	12,500 cd to 225,000 cd (combined)	Digital luxmeter
Front fog lamps	Vertical downward cutoff inclination	2.0% to 4.0% depending on installation height	Optical beam tester
Direction indicators & hazard lights	Flashing frequency and light color	60 to 120 cycles/min (1.5 ± 0.5 Hz); amber/yellow	Stopwatch / frequency meter & visual check
Stop lamps (brake lights)	Activation response & color	Immediate illumination upon pedal actuation; red	Visual & functional check
Position & license plate lamps	Visibility and light color	Front: white; Rear: red; License plate: white (readable at 20 m)	Visual check in low-light zone

As summarized in Table 1, special attention during instrumental testing is paid to the asymmetry of the low-beam cutoff line. For right-hand traffic, the horizontal left part of the cutoff prevents dazzling oncoming drivers, whereas the right segment rises at a 15° angle to illuminate road signs and the right shoulder. If the vertical inclination is smaller than the lower tolerance limit (beam aimed too high), oncoming drivers experience temporary blinding glare; conversely, excessive downward inclination severely shortens the forward visibility distance.

For signaling devices, electrical continuity and voltage drop across ground connections are critical factors. Corrosion in rear lamp clusters frequently causes cross-grounding faults, where activating the brake light dims the turn indicator or triggers simultaneous flashing of adjacent lamps. Diagnostic inspectors must therefore verify simultaneous operation of brake lights, turn signals, and reverse lamps under load.

4. Digital Integration and Defect Classification

A persistent vulnerability in traditional technical inspection workflows is manual entry of optical test results into diagnostic cards, which creates opportunities for human error or subjective leniency. Modern digital regloscopes are equipped with RS-232, USB, or Ethernet interfaces capable of transmitting raw photometric values directly to the station's central diagnostic server.

Implementing an automated software protocol within the unified 'Technical Inspection' electronic information system enables automated pass/fail validation based on vehicle category (M1, M2, M3, N1–N3) and headlamp light source type (halogen, gas-discharge, or LED). Under this protocol, detected lighting faults are categorized into two severity levels: (1) Critical safety defects (non-functioning low-beam headlamps, missing brake lights, upward-aimed beams exceeding glare limits, or unauthorized blue/red front lamps), which immediately prohibit vehicle operation until repaired; and (2) Minor operational defects (single burned-out license plate bulb or slight fog lamp misalignment), which require mandatory correction within the prescribed re-inspection window.

5. Conclusion

Objective instrumental assessment of vehicle lighting and light-signaling systems is an essential pillar of preventive road safety management. Strict adherence to preparatory vehicle leveling requirements, combined with calibrated optical beam testers and digital luxmeters, ensures accurate verification of cutoff geometry and luminous intensity in compliance with Cabinet of Ministers Resolution No. 125. Integrating direct data transfer from optical diagnostic stands into the centralized inspection database eliminates subjective evaluations, curbs unauthorized lighting modifications, and substantially reduces the risk of nighttime road traffic accidents.

References

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