SURFACE VEHICLE INFORMATION REPORT

J2808™ JUN2024

Issued 2007-08
Revised 2024-06

Superseding J2808 JAN2017

Lane Departure Warning Systems: Information for the Human Interface

RATIONALE

This SAE Information Report has been revised to clarify sections and update references to include new research on this topic.

TABLE OF CONTENTS

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
SAE WEB ADDRESS: **http://www.sae.org**

For more information on this standard, visit
https://www.sae.org/standards/content/J2808_202406

1. SCOPE

The lane departure warning (LDW) system is a warning system that alerts drivers if they are drifting (or have drifted) out of their lane or from the roadway. This warning system is designed to reduce the likelihood of crashes resulting from unintentional lane departures (e.g., run-off-road, side collisions, etc.). This system will not take control of the vehicle; it will only let the driver know that he/she needs to steer back into the lane. An LDW is not a lane-change monitor, which addresses intentional lane changes, or a blind spot monitoring system, which warns of other vehicles in adjacent lanes.

This informational report applies to original equipment manufacturer and aftermarket LDW systems for light-duty vehicles (gross vehicle weight rating of no more than 8500 pounds) on relatively straight roads with a radius of curvature of 500 m or more and under good weather conditions.

1.1 Purpose

SAE J2808 was created as a companion to ISO 17361 for the purpose of providing more detailed driver vehicle interface guidance for these systems.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J2944 Operational Definitions of Driving Performance Measures and Statistics

SAE J3063 Active Safety Systems Terms and Definitions

SAE J3280 Guidelines for Haptic Interaction in a Driver Vehicle Interface

2.1.2 ISO Publications

Copies of these documents are available online at https://webstore.ansi.org/.

ISO 7000:2019 Graphical Symbols for Use on Equipment - Registered Symbols

ISO 17361:2017 Intelligent Transport Systems - Lane Departure Warning Systems - Performance Requirements and Test Procedures

2.1.3 Other Publications

Belz, S.M., Robinson, G.S., and Casali, J.G. (1999). A new class of auditory warning signals for complex systems: Auditory icons. *Human Factors, 41*(4), 608-618.

Brown, S. (2005). *Effects of Haptic and Auditory Warnings on Driver Intersection Behavior and Perception* [Master of Science thesis]. Virginia Polytechnic University.

Campbell, J.L., Hooey, B.L., Camey, C., Hanowski, R.J., Gore, B.F., Kantowitz, B.H., and Mitchell, E. (1996). *Investigation of alternative displays for side collision avoidance systems* (Report No. DOT HS 808 579). U.S. Department of Transportation, National Highway Traffic Safety Administration.

Campbell, J.L., Richard, C.M., Brown, J.L., and McCallum, M. (2007). *Crash warning system interfaces: human factors insights and lessons learned* (Report No. DOT HS 810 697). U.S. Department of Transportation, National Highway Traffic Safety Administration.

Cicchino, J.B. (2018). Effects of lane departure warning on police-reported crash rates. *Journal of Safety Research*, *66*, 61-70. https://doi.org/10.1016/j.jsr.2018.05.006.

Delphi-Delco Electronic Systems (2000). *Automotive collision avoidance system (ACAS) program* (Report No. DOT HS 809 080). U.S. Department of Transportation, National Highway Traffic Safety Administration.

Federal Highway Administration (2023). *Roadway departure safety.* U.S. Department of Transportation, Federal Highway Administration. https://highways.dot.gov/safety/RwD.

Graham, R. (1999). Use of auditory icons as emergency warnings: evaluation within a vehicle collision avoidance application. *Ergonomics*, *42*(9), 1233-1248.

Green, P., Kang, T., Alter, M., Best, A., and Lin, B. (2011). *Driver Performance with and Preferences for Lane Departure Warning System Feedback: Steering Wheel Torque vs. Vibration* (UMTRI Report No. UMTRI-2011-11). University of Michigan Transportation Research Institute.

Harder, K.A., Bloomfield, J., and Chihak, B.J. (2003). *The Effectiveness of Auditory Side- and Forward-Collision Warnings in Winter Driving Conditions* (Report No. MN/RC 2003-14). Minnesota Department of Transportation.

Ho, C., Spence, C., and Tan, H.Z. (2005). *Warning signals go multisensory* [Conference paper]. HCI International 9.

Ho, C., Tan, H.Z., and Spence, C. (2005). Using spatial vibrotactile cues to direct visual attention in driving scenes. *Transportation Research Part F: Traffic Psychology and Behaviour*, *8*(6), 397-412.

Kochhar, D.S. and Tijerina, L. (2006). *Comprehension of haptic seat displays for integrated driver warning systems* [Conference proceedings]. Human Factors and Ergonomics Society 50th Annual Meeting. Santa Monica, CA, USA.

Kozak, K., Pohl, J., Birk, W., Greenberg, J., Artz, B., Blommer, M., Cathey, L., and Curry, R. (2006). *Evaluation of lane departure warnings for drowsy drivers* [Conference proceedings]. Human Factors and Ergonomics Society 50th Annual Meeting, Santa Monica, CA, USA.

LeBlanc, D., Sayer, J., Winkler, C., Ervin, R., Bogard, S., Devonshire, J., Mefford, M., Hagan, M., Bareket, Z., Goodsell, R., and Gordon, T. (2006). *Road Departure Crash Warning System Field Operational Test: Methodology and Results* (UMTRI Report No. UMTRI-2006-9-1). University of Michigan Transportation Research Institute.

Olsen, E.C.B. (2004). *Lane change warning design guidelines* [Conference proceedings]. Human Factors and Ergonomics Society 48th Annual Meeting, Santa Monica, CA, USA.

Pomerleau, D., Jochem, T., Thorpe, C., Batavia, P., Pape, D., Hadden, J., McMillan, N., Brown, N., and Everson, J. (1999). *Run-Off-Road Collision Avoidance Using IVHS Countermeasures* (Report No. DOT-HS-809-170). Prepared by Carnegie Mellon University for the NHTSA and U.S. Department of Transportation.

Sayer, T.B., Sayer, J.R., and Devonshire, J. (2005). *Assessment of a driver interface for lateral drift and curve speed warning systems: Mixed results for auditory and haptic warnings* [Conference paper]. Third International Driving Symposium on Human Factors in Driver Assessment, Training, and Vehicle Design, Rockport, ME, USA.

Selcon, S.J., Taylor, R.M., and Shadrake, R.A. (1992). *Multi-modal cockpit warnings: Pictures, words, or both?* [Conference proceedings]. Human Factors Society 36th Annual Meeting, Santa Monica, CA, USA.

Shutko, J. (2001). *An Investigation of Collision Avoidance Warnings on Brake Response Times of Commercial Motor Vehicle Drivers* [Unpublished thesis]. Virginia Polytechnic Institute and State University.

Stanley, L.M. (2006). *Haptic and auditory cues for lane departure warnings* [Conference paper]. Human Factors and Ergonomics Society 50th Annual Meeting, Santa Monica, CA, USA.

Suetomi, T. and Niibe, T. (2002, October). *A human interface design of multiple collision warning system* [Conference paper]. 9th World Congress on Intelligent Transportation Systems, Chicago, IL, USA.

Suzuki, K. and Jansson, H. (2003). An Analysis of Driver's Steering Behaviour During Auditory or Haptic Warnings for the Designing of Lane Departure Warning System. *JSAE Review*, *24*, 65-70.

Tijerina, L., Jackson, J.L., Pomerleau, D.A., Romano, R.A., and Petersen, A.D. (1995). *Run-off-road collision avoidance countermeasures using IVHS countermeasures. Task 3 final report - volume 2* (Report No. DOT HS 808 502). U.S. Department of Transportation, National Highway Traffic Safety Administration.

Zador, P.L., Krawchuk, S.A., and Voas, R.B. (2000). *Final report - Automotive collision avoidance system (ACAS) program* (Report No. DOT HS 808 080). U.S. Department of Transportation, National Highway Traffic Safety Administration.

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

Beruscha, F., Augsburg, K., and Manstetten, D. (2011). Haptic Warning Signals at the Steering Wheel: A Literature Survey Regarding Lane Departure Warning Systems, Haptics-e. *The Electronic Journal of Haptic Research*, *4*(5).

Federal Highway Administration (2016). *Integrating Speed Management within Roadway Departure, Intersections, and Pedestrian and Bicyclist Safety Focus Areas.* U.S. Department of Transportation, Federal Highway Administration. https://safety.fhwa.dot.gov/speedmgt/ref_mats/fhwasa16017/app_a_ch4.cfm

Gordon, T., Sardar, H., Blower, D., Ljung Aust, M., Bareket, Z., Barnes, M., and Nobukawa, K. (2010). *Advanced crash avoidance technologies (ACAT) program - Final report of the Volvo-Ford-UMTRI project: safety impact methodology for lane departure warning-Method development and estimation of benefits* (Report No. DOT HS 811 405). U.S. Department of Transportation, National Highway Traffic Safety Administration.

Houser, A., Pierowicz, J., and Fuglewicz, D. (2005). *Concept of Operations and Voluntary Operational Requirements for Lane Departure Warning Systems (LDWS) On-board Commercial Motor Vehicles.* (FMCSA Technical Report FMCSA-MCRR-05-005). U.S. Department of Transportation, Federal Motor Carrier Safety Administration.

Lin, B.T.-W. and Green, P. (2013). *Measurements of Driver-Assistance Warning-Signal Characteristics in 2013 Cars* (UMTRI Report No. UMTRI-2013-03). University of Michigan Transportation Research Institute.

Najm, W.G., Koopmann, J., Boyle, L., and Smith, D. (2002). *Development of Test Scenarios for Off-Roadway Crash Countermeasures Based on Crash Statistics* (U.S. DOT Technical Report DOT-HS-809 505). U.S. Department of Transportation, National Highway Traffic Safety Administration.

Navarro, J., Mars, F., and Hoc, J.M. (2007). Lateral control assistance for car drivers: a comparison of motor priming and warning systems. *Human Factors*, *49*(5), 950-960.

NHTSA (2007). *Fatality Analysis Reporting System (FARS).* U.S. Department of Transportation, National Highway Traffic Safety Administration, National Center for Statistics and Analysis.

Shah, R., Nowakowski, C., and Green, P. (1998). *U.S. Highway Attributes Relevant to Lane Tracking* (UMTRI Report No. UMTRI-98-34). The University of Michigan Transportation Research Institute.

3. DEFINITIONS

3.1 DEPARTURE (ISO 17361:2017)

Situation in which the outside of one of the front wheels of a vehicle or of the leading part of an articulated vehicle - or, in the case of a three-wheel vehicle, the outside of one of the wheel's axles with the widest track - is crossing lane line delineation.

3.2 EARLIEST WARNING LINE (ISO 17361:2017)

Innermost limit of the warning threshold.

3.3 HAPTIC WARNING (ISO 17361:2017)

Warning that stimulates the driver's sense of touch, vibration, force, and motion.

EXAMPLES: Steering wheel motion, steering wheel vibration, seat and pedal vibrations, etc.

3.4 LANE (SAE J2944)

Part of the traveled way intended for use by a single line of moving vehicles and usually delineated by pavement markings to guide drivers and reduce potential traffic conflicts.

NOTE FROM ISO 17361: The area of roadway that a vehicle would be expected to travel along in the absence of any obstruction without the driver's desire to change the path of travel.

3.5 LANE BOUNDARY (SAE J2944)

Physical or implied indicators on the traveled way that define the lateral edges within which a vehicle moving single file in the same direction is expected to drive, except when passing, changing lanes, or exiting the traveled way.

NOTE FROM ISO 17361: Borderline of the lane, situated at the center of a visible lane marking or, in the absence of a visible lane marking, determined by incidental visible road features or other means such as GPS, magnetic nails, etc.

3.6 LANE DEPARTURE (SAE J2944)

Period when some part of the vehicle is no longer in the travel lane until all tire contact patches are back inside the lane of travel or the vehicle comes to a stop before returning to the lane, excluding lane changes and turning maneuvers.

NOTE FROM ISO 17361: The point of departure across the lane boundary.

3.7 LANE DEPARTURE WARNING (SAE J3063)

Warning given to the driver in accordance with the lane departure condition in the absence of suppression requests.

3.8 LANE DEPARTURE WARNING (LDW) SYSTEM (SAE J3063)

A system that monitors the vehicle's position within the driving lane and alerts the driver as the vehicle approaches or crosses lane markers.

NOTE: This warning is typically multimodal and can include an auditory alert, visual alert, haptic vibration, or any combination thereof.

Variants:

- Some systems also provide a warning when the vehicle approaches or crosses the road edge in the absence of lane markers.
- Some systems provide a warning for oscillations or drifting within the driving lane.

Refer to ISO 17361:2017.

3.9 LATEST WARNING LINE (ISO 17361:2017)

The outermost limit of the warning threshold.

3.10 ON/OFF STATE INDICATION

The LDW system shall provide the driver with visual indication of the LDW on/off status. A concurrent auditory indication may also be used in addition to the visual indication. Such indication may be provided by, for example, the presence or absence of an indicator (e.g., light, symbol, graphic, or text display), by the presence or absence of back lighting, or by use of distinct colors for such indicator.

3.11 RATE OF DEPARTURE (V) (ISO 17361:2017)

The subject vehicle's approach velocity at a right angle to the lane boundary at the warning issue point.

3.12 ROAD/ROADWAY (SAE J2944)

Portion of a traffic way improved, designed, or ordinarily used for vehicular travel and parking lanes, which may or may not include the usable shoulder.

3.13 ROAD BOUNDARY (SAE J2944)

Outermost edges of the roadway.

3.14 SENSITIVITY ADJUSTMENT

User adjustment of lane departure warnings to come sooner versus later (or closer versus farther away from road/lane boundaries).

3.15 STRAIGHT ROAD

Road with a radius of curvature of 500 m or more.

3.16 SYSTEM INCAPABLE (ISO 17361:2017)

A state of the system in which it is unable to warn the driver of a lane departure due to temporary conditions.

3.17 TIME-CRITICAL WARNING

Warning that changes as the warning condition becomes closer in time.

NOTE: Time-critical warnings can also be thought of as escalating warnings.

3.18 TRAFFICWAY (SAE J2944)

Any right-of-way open to the public as a matter of right or custom for moving persons or property from one place to another, including the entire width between property lines or other boundaries.

3.19 TRAVELED WAY (SAE J2944)

Portion of the traffic way for the movement of vehicle, exclusive of shoulders and bicycle lanes.

3.20 WARNING CONDITION (ISO 17361:2017)

A condition in which departure across the warning threshold occurs.

3.21 WARNING THRESHOLD (ISO 17361: 2017)

Location where the warning is issued on the road which corresponds to a warning trigger point set in the system.

4. HUMAN INTERFACE

4.1 Warning Levels

Escalating warning levels are not realistic for lane departure warning systems, as "…the time course of lane departure events will typically not allow for a graded series of warnings - several warnings of increasing urgency." Refer to Pomerleau et al. (1999).

Systems with imminent versus cautionary warning levels are intended to convey the likelihood of a crash caused from a lane departure. Lane departures with a high likelihood of a crash (imminent) might be presented differently than departures with a low likelihood of a crash (cautionary). Systems that determine these levels usually have additional information about the driving environment, such as the identification of dashed versus dotted lane markings, blind-spot monitoring, or side-collision warning systems.

For systems with any type of warning levels, care should be taken to determine whether the drivers find the levels understandable, confusing, or useful.

4.2 Warning Presentation Modality

ISO 17361, clause 4.3.3, the international standard for LDW systems, requires that LDW systems present haptic and/or auditory warnings.

4.2.1 Visual

Effectiveness

- Visual warnings can be useful as status indications (refer to Olsen, 2004) and to help drivers understand the meaning of lane departure warnings (refer to LeBlanc et al., 2006). For lane departure warnings, the visual modality should be used as a secondary modality only. This is consistent with the international standard for LDW systems.

Type

- The ISO 7000 document includes a standard visual icon for LDW. The icon in Figure 1 is from ISO 7000:2019-2682:

Figure 1 - LDW icon, from ISO 7000:2019-2682

Location

- LeBlanc et al. (2006) displayed a visual alert on the left side of the instrument panel, seen through the steering wheel. Four out of 25 focus-group participants questioned after field testing with this visual alert suggested that the display be moved toward the center of the dashboard or in a head-up display.

- A central limitation of visual warnings, when not used with other modalities, is that they cannot be relied upon to convey the intended information precisely when needed. For example, a driver reading a street sign can miss a visual warning in plain sight if his or her attention is closely focused on the sign (refer to Campbell et al., 2007).

4.2.2 Haptic

Effectiveness

- Haptic warnings have been found to be effective in alerting drivers quickly (refer to Ho et al., 2005 and Zador et al., 2000).

- Evidence suggests that drivers can respond faster to haptic (vibrotactile) warnings than to visual or auditory warning signals (refer to Ho et al., 2005 and Stanley, 2006).

- Haptic warnings are more easily detected than visual warnings, assuming that the body is in contact with the surface providing the tactile feedback. Haptic warnings can be created so they do not disturb the passenger(s) (refer to Ho et al., 2005 and Sayer et al., 2005).

- Drivers have reported warnings in the haptic modality were less annoying compared to auditory (refer to Stanley, 2006 and LeBlanc et al., 2006) or the auditory-haptic combination (refer to Stanley, 2006). Drivers from Stanley (2006) ultimately preferred the auditory-haptic combination, however, as most preferred to have with LDW systems.

- Haptic feedback alone may not be as effective as including visual and/or audible feedback (refer to SAE J3280).

Type

- The most common are vibration (usually to the seat back, seat pan, or steering wheel) or constant torque (to the steering wheel).

- Drowsy drivers in Kozak et al. (2006) only recognized steering wheel torque warnings 32% of the time.

- Often, haptic warnings for lane departure mimic the sensation of rumble strips. A rumble strip is grooved pavement on a road shoulder or beside a road which, when driven over, causes a strong vibration and noise inside the vehicle. In Kochhar and Tijerina (2006), approximately 55% of participants (n=54) identified a “rumble strip” vibration in the seat pan as a lane departure warning.

Location

- The most common locations for haptic warnings are located on the steering wheel (as vibration or torque) or seat pan or seat back (as vibration).

- Kochhar and Tijerina (2006) suggest putting the haptic warning in the driver’s seat pan to be spatially compatible with the lane departure warnings.

- Kozak et al. (2006) found steering wheel vibration was an effective lane departure warning for drowsy drivers.

- Haptic warnings, especially when presented through a vehicle control (like the steering wheel), can be interpreted as indicating problems with the vehicle. Shutko (2001) found commercial motor vehicle drivers misinterpreted brake-pulse warnings for a vehicle problem. This can cause the driver confusion and even incorrect responses to haptic warnings. In Suzuki and Jansson (2003), 50% of participants had inappropriate (opposite) reactions to lane departure warnings presented as steering wheel torque.

- Although driving performance with a combined haptic and auditory warning showed promise, Tijerina et al. (1995) concluded that participants might have felt overloaded by the combination of steering wheel vibration (0.5 second, square wave, 10 Hz, 1.5 Nm) or torque (1 second, triangle wave, 2 Nm) and a complex tone (0.5 second, 2000 Hz) for lateral warnings.

- Some evidence has shown the combination of haptic and auditory warnings is effective for brake responses. Refer to Brown (2005).

- Directional haptic warnings, which distinguish the source of the warning between right and left, were found to be slightly preferred over non-directional haptic warnings in Pomerleau et al. (1999).

4.2.3 Auditory

Effectiveness

- Auditory warnings (tone and voice) provide faster response times (refer to Delphi-Delco Electronic Systems, 2000) and are superior at attracting attention (refer to Campbell et al., 1996) when compared to visual warnings for SCAS.

- Drivers reported that audio was easy to hear, not annoying, and that they knew what the warning meant when it occurred. Several drivers, however, also reported difficulty in determining from which side the auditory warning was emanating (refer to Campbell et al., 2007.)

- Auditory warnings are perceived to be more annoying compared to visual and haptic warnings (refer to Delphi-Delco Electronic Systems, 2000).

- Drivers from LeBlanc et al. (2006) felt earcon auditory warnings for lane departure systems to be more distracting than visual or haptic warnings.

- Auditory warnings combined with visual warnings enhance performance and reduce time to respond to information (refer to Selcon et al., 1992).

Type

- Types of auditory warnings for SCAS include tonal, voice/speech, and earcons (sometimes called auditory icon).

- Auditory icons (earcons) have been found to be more effective than tone (refer to Belz et al., 1999) or speech (refer to Graham, 1999). Graham (1999), however, found auditory icons of a car horn and of skidding tires more likely to be misinterpreted for brake responses. Harder et al. (2003) recommends a double-beep earcon for side-collision warnings because participants felt the double-beep was more urgent than a single-beep earcon.

Location

- Auditory warnings should be directional to indicate whether the lane deviation is on the left or right to improve driver response time (refer to Suetomi and Niibe, 2002). Directional auditory warnings were also found to be slightly preferred over non-directional warnings by drivers (refer to Pomerleau et al., 1999).

4.2.4 Auditory + Haptic

Effectiveness

- Stanley (2006) found that participants reacted slower to the combination of auditory + haptic (rumble strip sound + seat vibration) compared to haptic alone, although they ultimately preferred the combination of auditory + haptic over separate modalities for LDW systems.