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ISO/IEC 17020 Accredited inspection body - Accreditation certificate BELAC No. 016-INSP

1. **SUBJECT** : **DRIVER DROWSINESS AND ATTENTION WARNING SYSTEMS-COMPONENT VERIFICATION** 2021/1341

2. **REF.** : Report number : **H2360855129/044-TR** No. of pages : 1 of 13 No. of annexes : 1

3. **GENERALITIES** :

Make of Component : MOVON CORPORATION

Commercial Name : MDSM-22S

Type : MDSM-22S (Driver Safety Monitoring System)

Name and address of the manufacturer :

Movon Corporation
7, Seolleung-ro, 94-gil,
Gangnam-gu, Seoul
Korea

4. **TESTS** :

Date and place	:	24-27.10.2023, 30-31.10.2023, 01-03.11.2023 TOSFED Izmit Korfez Race Circuit – IZMIT – KOCAELI - TURKIYE
Applied document(s)	:	Annex-1:MOVON MDSM-22S DDAW, validation document issue date: 2023.11.09
Inspector	:	Mr. O. OZGOREN | Vinçotte – ITAC Mr. A. YILDIZ | Vinçotte – ITAC Mr. S. KESKIN | Vinçotte – ITAC Mr. B. ERBILEN | Vinçotte – ITAC
Manufacturer's representative	:	Mr. D. So Mr. J. Yeom
Location of E-mark	:	Bottom case of the control box

5. **CONCLUSIONS** :

The tests were carried out according to the following specifications:

- Commission Delegated Regulation (EU) 2021/1341 of 23 April 2021
- Regulation (EU) 2019/2144 of the European Parliament and of the Council of 27 November 2019 as last amended.

The models presented comply with the requirements to be applied.

This report has been prepared as requested by Movon for assessment of correct functioning of DDAW system. However, it is not possible to use it to apply or comply type approval requirements of (EU) 2021/1341 as a Component approval or STU approval for DDAW system without vehicle application. The verification assessment shall be confirmed by the Technical service/Approval Authority to fulfill all requirements of Regulation.
This system is applicable to all vehicle categories in case of confirming of mounting conditions.

Date : 2023.11.24 Signature :

VINÇOTTE nv/sa
Okan Özgoren
Automotive Certification

ANNEX I

PART 1 - Technical requirements for the driver drowsiness and attention warning (DDAW) systems

REQUIREMENTS

Characteristics concerned and prescriptions to apply	References	Conformity	Not applicated	Value
General technical requirements	**2.**			
A driver drowsiness and attention warning (DDAW) system shall monitor a driver's level of drowsiness and alert the driver through the vehicle human machine interface (HMI).	2.1.	x		
The DDAW system shall be designed to avoid or minimise the system error rate under real driving conditions.	2.2.	x		
Privacy and data protection	2.3.	x		
The DDAW system shall function in normal operation mode without the use of biometric information, including facial recognition, of any vehicle occupants.	2.3.1.	x		
The DDAW system shall be designed in such a way that it shall only continuously record and retain data necessary for the system to function and operate within a closed-loop system.	2.3.2.	x		
Any processing of personal data shall be carried out in accordance with Union data protection law.	2.3.3.		x	
Specific technical requirements	**3.**			
DDAW system control	**3.1.**			
It shall not be possible for the driver to manually deactivate the DDAW system.	3.1.1.	x		
It may however be possible for the driver to manually deactivate the DDAW system HMI warnings. Following manual deactivation of the DDAW System HMI warnings, it shall be possible for the driver to re-activate the system HMI warnings by taking no more than the same number of actions as were required to deactivate it.			x	
The DDAW system shall be automatically deactivated in the situations pre-defined by the manufacturer. Such situations include, for instance, the deactivation of the warnings by the driver (point 3.1.1.). The DDAW system shall be automatically reactivated as soon as the conditions that led to its automatic deactivation are no longer present.	3.1.2.	x		
The DDAW system, including HMI warnings, shall be automatically reinstated to normal operation mode upon each activation of the vehicle master control switch. The vehicle manufacturer can choose to add a condition to such automatic reinstatement: upon the driver's door having been opened or the vehicle being switched off for a maximum period of 15 minutes.	3.1.3.	x		

Characteristics concerned and prescriptions to apply	References	Conformity	Not applicated	Value
The DDAW system shall be automatically activated above the speed of 70 km/h.	3.1.4.	x		
Once activated, DDAW system shall operate normally within the speed range of 65 km/h to 130 km/h or the vehicle's maximum allowed speed, whichever is lower. The DDAW system shall not be automatically deactivated at a speed of above 130 km/h (although the system's behaviour can be adapted to the degraded situation).	3.1.5.	x		
There shall be less than 5-minute delay between the vehicle meeting the activation criteria set out in points 3.1.4., and the DDAW system beginning to actively monitor driver drowsiness.	3.1.6.	x		
If warning is provided during the learning phase of the DDAW system (allowing for calibration of the system parameters to best fit driver's behaviour and driving pattern), the learning phase is considered over.	3.1.7.	x		
The learning phase activation time shall start once all the conditions for the activation of the DDAW system referred to in points 3.1. and 3.2. are met.		x		
Environmental conditions	**3.2.**			
The DDAW system shall operate effectively during the day and night.	3.2.1.	x		
The DDAW system shall operate in absence of weather conditions limiting the system's operation.	3.2.2.	x		
At a minimum, the DDAW system shall work effectively on a multi-lane divided road, with or without a central divide, when lane markings are visible on both sides of the lane.	3.2.3.	x		
Monitoring driver drowsiness	**3.3.**			
The DDAW system shall provide a warning to the driver at a level of drowsiness which is equivalent to or above 8 on the reference sleepiness scale set out in the Appendix (Karolinska Sleepiness Scale, hereinafter referred to as 'KSS').	3.3.1	x		Level 7 on KSS
The DDAW system may provide a warning to the driver at a level of drowsiness which is equivalent to level 7 on KSS. In addition, manufacturer may implement an information strategy on the HMI prior to the warning. Detailed requirements for the validation of the DDAW system by the manufacturer are set out in Part 2.		x		

Characteristics concerned and prescriptions to apply	References	Conformity	Not applicated	Value
The DDAW system shall analyse other vehicle systems for detection of drowsy driving indicators. Such driving indicators may include but are not limited to the following: (a) a reduction in the number of micro-corrections within driver steering, paired with an increase in the number of large and fast corrections; (b) an increase in the variability of a vehicle's lateral lane position.	3.3.2.		x	Camera-based DDAW system
Human Machine interface requirements	**3.4.**			
Warning nature	3.4.1.			
Visual and acoustic or any other warning used by the DDAW system to alert the driver shall be presented as soon as possible after occurrence of the trigger behaviour and may cascade and intensify until acknowledgement thereof by the driver.	3.4.1.1.	x		Visual and acoustic
Can be accepted as acknowledgement by the driver: an improvement of the driving behaviour based on the input used for the DDAW system (strategy to be described in the documentation provided by the manufacturer).		x		
Visual Warning	**3.4.2.**			
The visual warning shall be located so as to be readily visible and recognisable in daylight and at night-time by the driver and distinguishable from other alerts.	3.4.2.1.	x		
The visual warning shall be a steady or flashing indication (e.g. tell-tale, pop-up message, etc.).	3.4.2.2.	x		
Any new symbols developed for the purpose of a DDAW visual warning are recommended to be constructed using similar elements to and keeping coherence with ISO 2575:2010+A7:2017 K.21 and/or ISO 2575:2010 +A7:2017 K.24.	3.4.2.3.	x		
The contrast of the symbol with the background in sun light, twilight and night conditions are recommended to be in accordance with ISO 15008:2017.	3.4.2.4.	x		
The following visual alert and background colour combinations should not be used: red/green; yellow/blue; yellow/red; red/violet.	3.4.2.5.	x		
Acoustic warning	**3.4.3.**			
The acoustic warning shall be easily recognised by the driver.	3.4.3.1.	x		
A majority of the acoustic warning shall fall within the frequency spectrum of 200-8 000Hz and amplitude range of 50-90 dB.	3.4.3.2.	x		
If speech alerts are utilised, the vocabulary used shall be consistent with any text used as part of the visual alert.	3.4.3.3.	x		
The audible portion of the alert shall last for at least the duration that allows the driver to understand it.	3.4.3.4.	x		

Characteristics concerned and prescriptions to apply	References	Conformity	Not applicated	Value
DDAW failure warning	**3.5.**			
A constant visual failure warning signal (e.g. warning reflecting the relevant Diagnostic Trouble Codes (DTC) for the system, tell-tale, pop-up message, etc.) shall be provided when there is a failure detected in the DDAW system as a result of which the DDAW system does not meet the requirements of this Annex.	3.5.1.	x		see Validation report No: MDSM-22S Version2.2.0
Temporary visual failure warning signal can be used as complimentary information to the constant optical failure warning signal				
There shall not be an appreciable time interval between each DDAW self-check, and subsequently there shall not be a delay in displaying the failure warning signal, in the case of an electrically detectable failure.	3.5.2.	x		
Upon detection of a non-electrical failure condition (e.g. sensor obscuration, excluding temporary obscuration such as caused by sun glare), the failure warning signal as laid down in point 3.5.1. shall be displayed.	3.5.3.	x		
Failures that activate the warning signal mentioned in point 3.5.1., but which are not detected under static conditions, shall be retained upon detection and continue to be displayed from start-up of the vehicle after each activation of the vehicle master control switch, for as long as the failure or defect persists.	3.5.4.	x		
Provisions for periodic roadworthiness tests	**3.6.**			
For the purpose of periodic roadworthiness tests of vehicles, it shall be possible to verify the following features of the DDAW system: (a) Its correct operational status, by visible observation of the failure warning signal status following the activation of the vehicle master control switch and any bulb check. Where the failure warning signal is displayed in a common space (the area on which two or more information functions/symbols may be displayed, but not simultaneously), it must be checked first that the common space is functional prior to the failure warning signal status check; (b) Its correct functionality and the software integrity, by the use of an electronic vehicle interface, such as the one laid down in point I.(14) of Annex III of Directive 2014/45/EU of the European Parliament and of the Council, where the technical characteristics of the vehicle allow for it and the necessary data is made available. Manufacturers shall ensure to make available the technical information for the use of the electronic vehicle interface in accordance with Article 6 of Commission Implementing Regulation (EU) 2019/621.	3.6.1.		x	

Characteristics concerned and prescriptions to apply	References	Conformity	Not applicated	Value
At the time of type-approval, the means to protect against simple unauthorised modification of the operation of the failure warning signal chosen by the manufacturer shall be confidentially outlined in the assessment of the technical documentation under Part 3. Alternatively, this protection requirement is fulfilled when a secondary means of checking the correct operational status of the DDAW system is available.	3.6.2.		x	

PART 2 - Test procedures for validation of driver drowsiness and attention warning (DDAW) systems

REQUIREMENTS

Characteristics concerned and prescriptions to apply	References	Conformity	Not applicated	Value
Validation testing by the manufacturer	**1.**			
General requirements	1.1.			
Manufacturers shall carry out validation testing to ensure that DDAW systems are able to monitor driver drowsiness in a manner which is accurate, robust and scientifically valid.	1.1.1.	x		
The validation testing of the DDAW shall meet the requirements set out in points 2 to 8. The manufacturer shall document the validation process in the documentation package to be provided by the manufacturer in accordance with Part 3.	1.1.2.	x		
Testing requirements	**2.**			
Validation testing shall take place using human participants. Alternatively the data used for the validation shall derive from behaviour data collected with human participants.	2.1.	x		
Any validation testing that includes a human participant operating a motor vehicle in a real-world, non-simulated road environment, shall have a safety backup.	2.2.	x		
If validation testing is performed in a simulator, the manufacturer shall document its limitations with regard to real-world open road testing for the purpose of testing the DDAW system. Such documentation will include comparison of primary input data, used for the DDAW system, from the simulator and primary input data from the vehicle in real conditions and analysis of the validity of the simulated validation's results.	2.3.		x	
Test sample	**3.**			
Each test participant shall generate at least 1 true positive or 1 false negative event as referred to in points 5.1.4. and 5.1.5. The total number, obtained by the sum of true positive events and false negative events, shall be equal to or higher than 10. The minimum sample size of participants shall be 10 participants. It is allowed to run more than one test per participant in order to acquire more data for a given participant.	**3.1.**	x		see Validation report No: MDSM-22S Version2.2.0
The sensitivity per participant shall be calculated first for each participant, then the average sensitivity and its standard deviation shall be calculated from the values of sensitivity per participant.		x		
It is explicitly allowed to provide results from a subgroup of participants of a larger test to include only participants fitting the description above.			x	
All the results from participants fitting the requirements of point 3.1. shall be accounted for the validation. Excluding results from participants with at least 1 true positive or 1 false negative is not allowed.	3.2.	x		

Characteristics concerned and prescriptions to apply	References	Conformity	Not applicated	Value
The participants shall correspond to the targeted demography for the vehicle (for example, participants with a valid license to drive the vehicle on which the DDAW system is installed).	3.3.	x		
None of the 10 participants of the minimum sample size shall be involved in the development of DDAW system. One of the acceptance criteria, of point 8, shall be met with and without results from the additional participants involved in the DDAW system development.	3.4.	x		
Environmental conditions	**4.**			
At a minimum, the system shall be tested in the day and night conditions from point 4.1.1. or 4.1.2., and record at least a true positive event in each conditions (overall, not for each participant tested in the condition). It is not necessary for each participants to test both conditions.	4.1.	x		3(Day+Night) and 4 Night
Systems not affected by light do not need to meet the minimum number of true positive event in each conditions indicated above.				
For non-simulated road environment testing: (a) Day: testing shall start after sunrise and before sunset; (b) Night: testing shall start after sunset and before sunrise.	4.1.1.	x		
For simulated road environment testing: (a) Day: conditions diffuse with ambient light (ISO 15008: 2017); (b) Night: condition of low ambient illumination under which the adaptation level of the driver is mainly influenced by the portion of the road ahead covered by the vehicle's own headlights and surrounding street lights, and display and instrument brightness (ISO 15008: 2017).	4.1.2.		x	
Measuring drowsiness	**5.**			
Application of KSS	5.1.	x		
The participant's level of drowsiness shall be measured using the KSS.	5.1.1.	x		
Participants shall be trained on the KSS before they apply it as part of the DDAW system validation testing.	5.1.1.1.	x		
The training process shall be the same for all participants.				
The training process shall be clearly documented in the evidence dossier supplied to the technical service in accordance with Part 3.				
The standardised wording in the Appendix to Part 1 shall be used and all levels of the KSS shall be labelled.	5.1.1.2.	x		
Measurements shall be obtained during the testing at intervals of approximately 5 minutes, where each measurement obtained shall be assumed to cover the previous 5 minutes. The recommended intervals does not apply before the participant provide a first self-assessment rating at level 6 or above on the KSS.	5.1.2.	x		

Characteristics concerned and prescriptions to apply	References	Conformity	Not applicated	Value
During the validation tests, it is recommended to mute the warning from the DDAW system, to prevent changes of the status of the participant before the next self-assessment. The time at which the warning from the DDAW is provided (muted or not) shall be recorded to clearly establish if it is a true positive event.	5.1.3.	x		
Any warning from the DDAW system shall be treated as a true positive event if the participant previous or next rating is at a KSS level of 7 or above.	5.1.4.	x		
Once a true positive event occurred, the data points after this event shall be considered irrelevant for this specific test. If the participant restarted the test after a rest, it shall be considered a different dataset (with the same participant).				
If a participant rating is below the drowsiness threshold referred to in point 3.3.1. of Part 1 and the subsequent rating is above or equal to the drowsiness threshold (e.g. a sequence of rating can be 6-8 or 7-8), either:	5.1.5.	x		
a) the DDAW system provides a warning and it shall be treated as a true positive and end the specific test as in point 5.1.4.; or		x		
b) the DDAW system does not provide a warning and it shall be treated as a false negative, unless the testing continues for at least an extra testing time interval, and the participant provide either of the following self-assessment:				
- During the extra testing interval, if the participants provide a self-assessment above or equal to the drowsiness threshold again, the reading shall be treated as a false negative (e.g. sequence of rating can be 7-8-8, 7-9-9 or 7-9-8);				
- During the extra testing interval, if the participants provide a self-assessment at the KSS level 7, the data point shall be treated as true negative and marked as an outlier (e.g. sequence can be 6-8-7, 7-8-7 or 7-9-7). All outliers shall be documented in the documentation package;				
- Without prejudice to other situations which can be excluded, during the extra testing interval, if the participants provide a self-assessment below the KSS level of 7, the data points from this specific test shall be excluded from the overall testing data results as the drowsiness ratings of the participant are likely unreliable (e.g. sequence of rating can be 7-8-6 or 6-8-6). It is recommended to provide an additional training session to the participant after such a result.				

Characteristics concerned and prescriptions to apply	References	Conformity	Not applicated	Value
Alternative measurement(s)	**5.2.**		x	
Manufacturers may use an alternative measurement(s) to validate a DDAW system under the following conditions: (a) If the alternative method directly monitors the participants' state, such as Electroencephalogram (EEG) or PERCLOS (percentage of eyelid closure). (b) If the alternative method fit the measurement described in the point 5.1. except for the drowsiness scale used and/or the time interval used; (c) If the measurement is performed by sleep video analysis performed by at least 3 raters (sleep experts), who do not interact with the participant and each other before the rating process is finalised. The time interval of this method shall not exceed 5 minutes.	5.2.1.			
Where alternative measurements to KSS are used to determine the participant's level of drowsiness, the manufacturer shall provide evidence that the chosen measurement is a valid and accurate means to assess driver drowsiness, and that the drowsiness threshold used in the validation testing is equivalent to a KSS level referred to in point 3.3.1. of Part 1	5.2.2.			
If the alternative measurement uses a different time interval than the one specified in point 5.1.2, point 5.1.5. shall apply, where the intervals of assessment are equal to or shorter than 15 minutes and above or equal to 5 minutes.	5.2.3.			
If the time intervals are longer than 15 minutes, the technical services may consider raising the requirements from point 8.1(a) and point 8.1(b) by the amount set out in point 8.1(c) to better allow for a correct assessment of the driver's drowsiness.	5.2.4.			
Complementary measurements	**5.3.**		x	
Manufacturers may use complementary measurement(s) to KSS or the alternative measurement(s) to validate a DDAW system, which shall be duly documented in the documentation package under Part 3. Where sleep expert video analysis are used as a complementary measurement, at a minimum two raters and an inter-rater reliability test shall be conducted, and the results shall be included in the documentation package. The facial cues and body movements/behaviours for each level of drowsiness on the KSS shall be demonstrated (usually it is a confidential document).				

Characteristics concerned and prescriptions to apply	References	Conformity	Not applicated	Value
Alternative drowsiness threshold	**6.**		x	
If alternative measurements to KSS are used to validate a DDAW system, the manufacture shall state the threshold being used and provide evidence detailing the equivalency between the threshold and a KSS level of 8.	6.1.			
If the alternative measurement uses a scale which has fewer descriptive levels than the KSS, the equivalence between the alternative scale and the KSS shall refer to the lowest corresponding level when compared to the KSS. The only exception is for the level of the alternative scale that includes the equivalency to a KSS level of 8, in which case it shall refer to the highest corresponding level when compared to the KSS.				
For example, if the alternative scale level '4' corresponds to a range between '6 and 7' on the KSS, a '4' on the alternative scale shall be considered a '6' on the KSS.				
If an alternative scale level 'A' corresponds to a range between '6,5 and 8,5' on the KSS, an 'A' on the alternative scale shall be considered an '8' on the KSS.				
If a complementary measurement is used in addition to KSS or to an alternative measurement to validate a DDAW system, the manufacturer shall state the threshold being used and provide evidence detailing the equivalency between the threshold and a KSS level of 8.	6.2.			
Test results	**7.**			
Test data shall only be discarded by the manufacturer before any statistical analysis is conducted in any of the following cases: (a) there is an error in carrying out the testing procedure; (b) the participant's KSS ratings are deemed unreliable; (c) insufficient data is collected for a participant (e.g. length of trial was too short or participant did not generate at least 1 true positive event or 1 false negative event).	7.1.	x		
The manufacturer shall document any errors that occur during testing shall be documented as part of the evidence in the documentation package, separate from the test results, along with the erroneous data and, if applicable, the reason for excluding a participants' data from the statistical analysis.	7.2.	x		

Characteristics concerned and prescriptions to apply	References	Conformity	Not applicated	Value
Acceptance criteria	**8.**			
A DDAW system shall be deemed effective by the technical services if the following requirement (a) or (b) is satisfied as modified, if necessary, by requirements (c) for tests using interval time above 15 minutes and (d) for tests performed in a simulated environment:	8.1.	x		
(a) the average sensitivity is above 40 % (Sensitivity calculated from the average of the sensitivity of all participants)		x		
(b) the lower bound from the 90 % confidence interval of the sensitivity results shall be above 20 %. It means that 95 % of the participants statistically have more than 20 % average sensitivity, this is verified by satisfying the equation: $Average\,(Sensitivity) - 1.645 \times \frac{Standard\ Deviation\ (Sensitivity)}{\sqrt{Number\ of\ participants}} \geq 20\%$		x		
(c) the requirement listed in sub-point (a) is increased by 5 % and the requirement listed in sub-point (b) is increased by 2,5 % if the testing method does not use an interval time equal to or shorter than the 15 minutes possible in point 5.2.3 (upper bound possible between the recommended measurement the alternative measurement).			x	
(d) the requirement listed in sub-point (a) is lowered by 5 % and the requirement listed in sub-point (b) is lowered by 2,5 % if the testing method is performed on an open road.			x	
If the DDAW system requires a learning phase, the acceptance criteria listed in point 8.1. shall exclude results obtained during the learning phase or for 30 minutes after the condition for activation of the DDAW are fulfilled, whichever is shorter.	8.2.	x		

PART 3 - Procedures for assessment of technical documentation and verification testing by the approval authorities and technical services N.A.

The verification process is responsibility under the Vehicle Manufacturer itself.

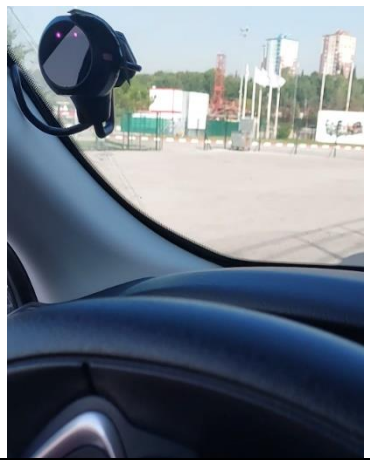
FACILITIES AND EQUIPMENT

The facilities and equipment used to carry out the inspections are in compliance with the requirements of the applied Regulatory Act(s).

TEST VEHICLE SPECIFICATIONS

Type :	356
Identification number :	NM435600006W84276

PHOTOS



Driver Drowsiness

Validation Tests

The document was prepared in accordance with EU Directive 2021/1341
This document is only for technical service(s) and authority(ies) for being granted type approval

November 9, 2023

MDSM-22S version2.2.0

Contests

FIGURES

TABLES

ABBREVIATIONS

EU : European Union
DDAW : Driver Drowsiness and Attention Warning
KSS : Karolinska Sleepiness Scale
TOSFED : Türkiye Otomobil Sporları Federasyonu
DSM : Driver Status Monitor
PERCLOS : Percentage of Eye Closure

1. Purpose of the Document

Driver Drowsiness and Attention Warning (hereinafter DDAW) is one of the new safety requirements introduced by Regulation (EU) 2019/2144.

This document shows a validation study carried out by MOVON to test the performance of the DDAW system in detecting driver drowsiness, as required by the European General Safety Regulations and the applicable delegated regulation as of April 23, 2021 [1].

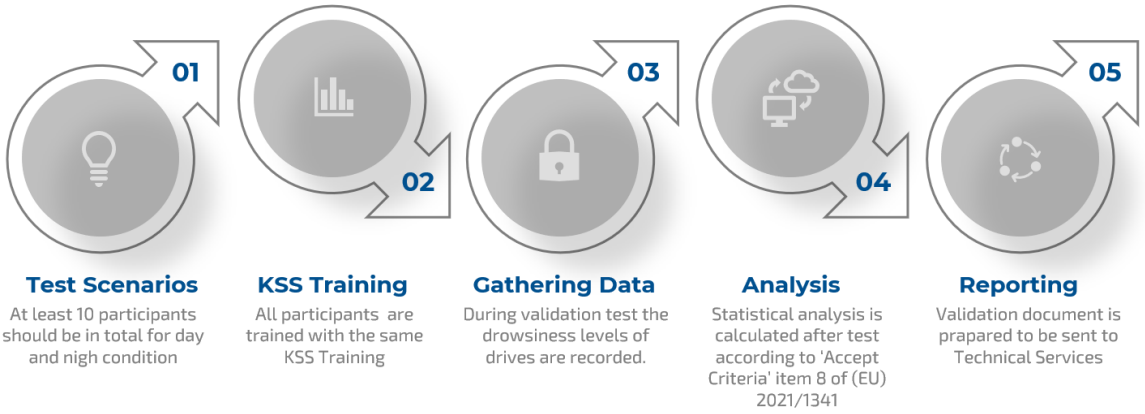


Figure 1. Validation test workflow

2. Data Collection Methods

A DDAW system may have more than one primary and secondary metrics.

On MOVON DDAW system, there is a only primary metric as input, which is MDSM-22S camera dataset. This is able to provide enough to cover wide variety of drivers using vehicle in day/night light on its own. Vehicle speed, as secondary metric, is just used for the activation of camera.

On the other hand, during validation test, MOVON team also completed a work to collect high-quality real-life drowsiness data, with the Karolinska Sleepiness Scale (hereinafter KSS).

In summary, datasets are gathered in two ways for validation:

1. Dataset generated based on the driver's sleepiness level by DDAW system
2. Dataset obtained by asking the driver about the level of sleepines using the KSS

[1] https://eur-lex.europa.eu/eli/reg_del/2021/1341/oj (EU 2021/1341)

2.1. KSS

The Karolinska Sleepiness Scale (KSS) is a widely used tool for assessing individuals' subjective levels of sleepiness or alertness.

It was developed by researchers at the Karolinska Institute in Sweden and is often used in sleep research, as well as in various fields where monitoring and understanding alertness levels is important, such as transportation.

In the context of DDAW system validation, the European Commission recommends using KSS to measure the self-described level of drowsiness in drivers.

The KSS is a straightforward self-report scale that helps individuals rate their current level of sleepiness on a scale from 1 to 9, with 1 being very alert and 9 being very sleepy. The scale is designed to capture an individual's subjective perception of their alertness at a specific moment in time. Here's an illustration of the KSS ratings:

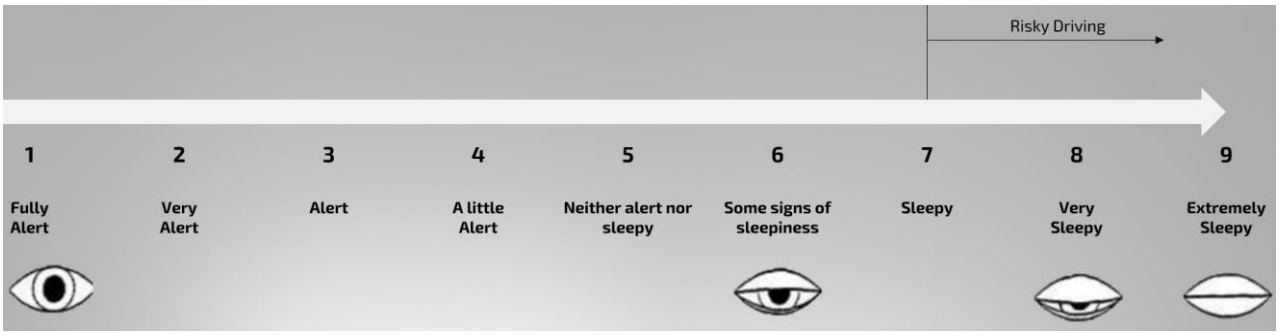


Figure 2. Validation test Karolinska Sleepiness Scale(KSS)

Validation tests has been taken place with human participants(drivers) on operating a motor operating a motor vehicle in a real-world (non-simulated road environment). There is a safety backup(co-pilot) to gather KSS data during validation test by using pre checklist. Meanwhile, safety backup also intervenes if the driver becomes drowsy, so that he or she can no longer safely control the motor vehicle.

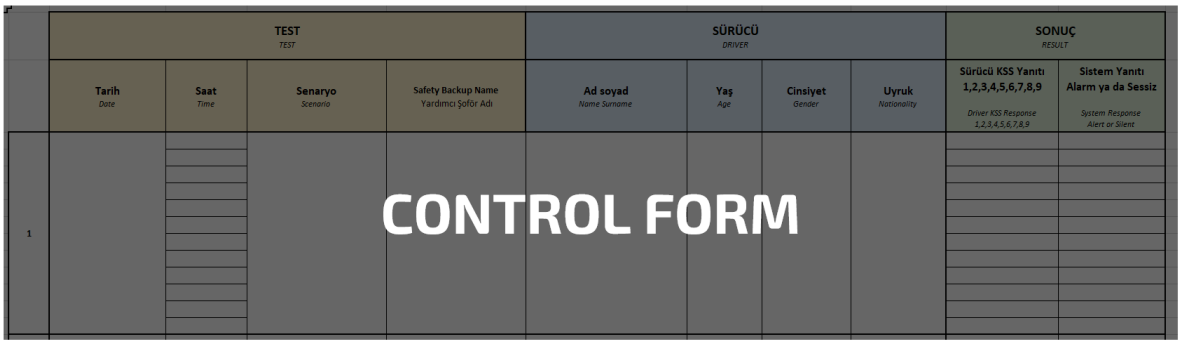


Figure 3. Control form for validation test

2.2. Test Conditions & Preparation

The validation tests have been performed during different conditions[1] in TOSFED İzmit Körfez Race Circuit, Türkiye.

The one of most important parts is MDSM-22S camera was attached near A-pillar on driver side of left handed 2022 Model FIAT EGEA – M1 category of vehicle with 5 seating capacity, manual, and diesel. (type approval no: TR*2007/46*8351*07 and VIN number: NM435600006W84276)

The tests took place both daylight and night-time with a very wide range of scenarios.

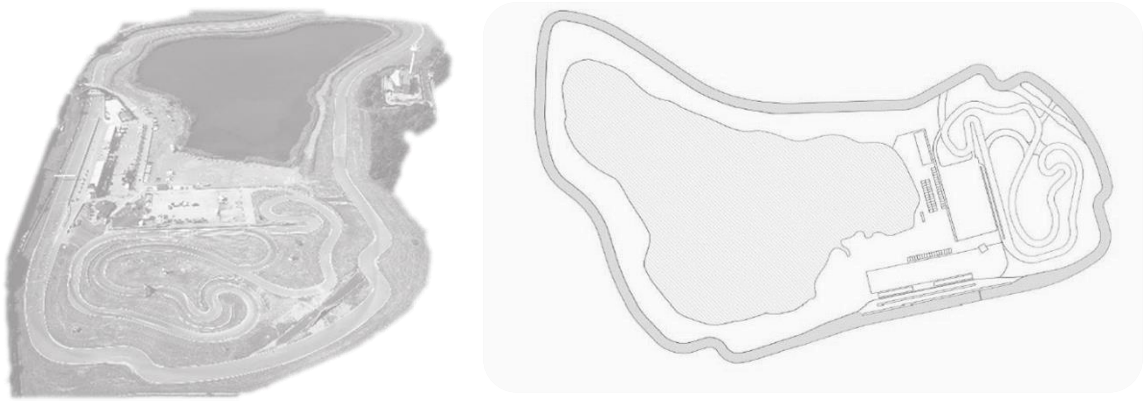


Figure 4. Outermost main runway

It is known that there are more driving accidents at night than during the day due to fatigue/insomnia. That's why we decided to keep the number of night-time drivings are more than daylight's. But, to be sure the effects of enviromental on drivers' drowsiness, needed to test both. The system calculates drowsiness without using vehicle data (vehicle speed, yaw, steering angle, etc.) and the DDAW system works in regardless of road lane...multi-lane divided road, with or without a central divide… Last but not least, since camera is installed indoors and facing toward the driver's face it is not directly affected by weather condition.

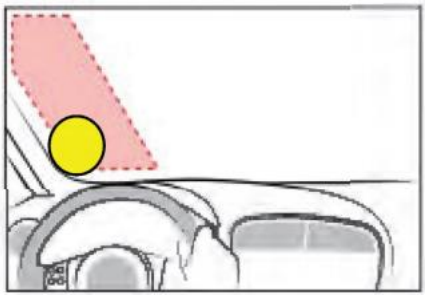


Figure 5. Under the driver's face positioned next to the A-Pillar, the camera look upwards at 1º - 20º

[1] Enviromental conditions according to (EU) 2021/1341
- Day: testing shall start after sunrise and before sunset,
- Night: testing shall start after sunset and before sunrise

It is confirmed by MOVON that the Driver State Monitoring system does not use biometric information in accordance with the EU DDAW regulation and operate within a closed loop system.

SD card was only used for validation test to keep log files. Normally the system operates regardless of the presence of an SD card. The SD card is used only for updates during production and maintenance. While recording system logs and videos for DDAW testing, no records are stored on the SD card in OEM products.

On validation drivings, a display screen is placed in front of the safety-backup. This screen displays the image captured by the DSM camera. The screen also includes visual warnings when drowsy detected. This allows the safety-backup to assess instantly whether the driver is drowsy or not. And, this is important during verification tests and ensures safe driving.(see Figure 6)

The activation of the system is provided in line with the speed data received from CAN. The "CAN Reader" in the DDAW system provides the activation of the system. To read vehicle CAN information without a direct connection, no wire-cutting, peeling, or soldering required to instal this contactless CAN reader, ensuring a quick install and no damage to the vehicle. (see Annex 2 for further specification of products - lens,memory, input voltage, power consumption, etc.)

On validation tests, the activation vehicle speed is determined 60km/h. Once activated, as long as the speed does not fall below 60 km/h, the system keeps going to record the moments when the driver is asleep in the log file as data.

2.3. Driving Scenarios

During the dataset collection, 20 participants[1] took part in various driving scenarios. All drivers were given the task to stay for at least 20-24 hours without sleeping without caffeine 4 hours before driving and to complete(if possible) a 2-hour drive

Figure 6. Safety backup with control form during validation test driving in TOSFED

[1] None of participants are involved in the development of DDAW system.

KSS training was prepared and documented for drivers and co-pilots and given to them. Before the test, drivers completed a few adaptation drive tour within 10 minutes and made sure that the KSS scale was learned well.

In addition, a sleep habits survey was filled out for each driver, and people with significant sleep problems were excluded from the test.

Table 1. Numbers of validation test

Test Driving	Drivers	Conditions	Scenarios	Gender	Age Range
40 in total 1 is non-safety(rainy) 3 are non-acceptable	20 different participant	3 (Day+ Night) and 4 Night	9 different driving case	Male & Female	18-39

The total number of acceptable (calculable results) tests is 36. It demonstrates that it is permissible to run more than one test per participant in order to collect more reliable data for a given participant. Details will be explaining on “MOVON Drowsiness Analysis” section of this document.

Please keep in mind that eye closure and yawning are taken into account during the validation test. Other indicators such as - rubbing eyes, rubbing face, slapping face, rubbing forehead, singing, eye muscles tightening were not analysed.

2.4. KSS Recording

The verbal method of asking was used to assess the sleepiness level of the participants. But considering their potential stimulation effect, asking period is set to every 10 minutes.

The use of the Karolinska Sleepiness Scale was an important part of the study, so it was critical that the participants were familiar with it and could use it appropriately to describe their level of sleepiness.

On the other hand, whenever the system gives an alert, the safety backup should asked about the status of driver. Multiple parameters affect the system's threshold to give alert. If eyes are closed more than 80%, it is considered as the eye closure. If the driver keeps their eyes closed continuously for more than 1.5 seconds or accumulated time of closed eyes exceeds 6 seconds within a 60-second interval, a warning is issued and when 2 yawns are detected within 1 minute.

The logical relationship between the DDAW system and the KSS level is: KSS 6 is evaluated before entering a light sleepy state. The widely produced fatigue characteristics yawning and prolonged eye closure time(s) are used to define the transition from KSS 6 to 7. If the driver has a KSS level of 7,8,9, the DDAW system will give a warning.

3. Drowsiness Analysis

MDSM-22S offers robust drowsiness and yawning warning because of its algorithm so it is implementing face recognition even at various vehicle environments such as sunlight, night and driver's facewears like mask, hat, sunglasses. It detects and calculates head position detection (x,y,z), face direction detection (yaw, pitch, roll), and eye opening/mouth opening/closing. During validation test, both drowsiness analysis and yawning analysis were took into account.

Input data:

- Camera image is used for driver's face detection, facial landmarks detection, and facial orientation estimation.
- Vehicle speed is used for the activation speed of each DSM function.

Figure 7. Algorithm processing steps

Drowsiness analysis:

- Using the detected facial landmarks, the system assesses the open and closed status of the eyelids.
- After the system is activated, it analyzes the driver's eye blink patterns for approximately one minute to determine the size of the eyelids when the eyes are open and when they are closed.
- If the eyes are closed more than 80%, it is considered as the eye closure.

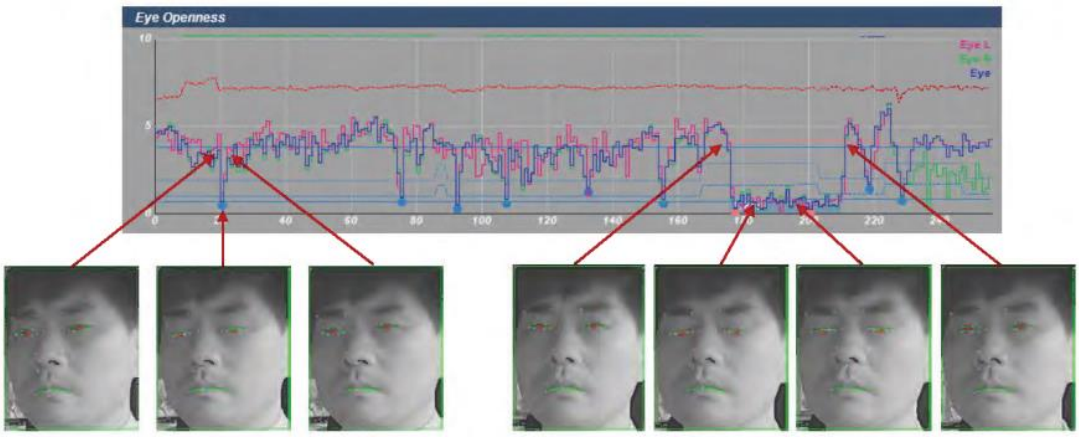


Figure 8. Detecting drowsines

Drowsiness warnings occur in two scenarios:

1. İf the driver keeps their eyes closed continuously for more than 1.5 seconds, a warning is issued.

   This is considered a dangerous situation, as at a speed of 100 km/h, 1.5 seconds corresponds to covering 42m without being aware of the road conditions.

   In such cases, the warning is issued not only for drowsiness but also for attention purposes.

2. If the accumulated time of closed eyes exceeds 6 seconds within a 60-second interval, a warning is triggered.

   As drivers become fatigued, their eye blink duration tend to be longer, leading to an increase in PERCLOS.

   However, to reduce false positives caused by tester exhibiting rapid and frequent eye blinks, the system accumulates time only when the duration of eye closure is 200 milliseconds or longer.

Yawning analysis:

- The system estimates mouth openness using detected facial landmarks, and a warning is triggered if yawns are detected twice within one minute.

Situation	condition	Camera LED				Sound		Remark
		R	G	O	Status	Sound	Duration	
Power ON	Power ON			o	Solid			The Board Green LED turns on simultaneously
Standby mode	during loading			o	Solid			
	malfunction occurs	o			Solid			
	Block the camera	o			Solid			
	Set boot completed					alert sound	1 second	
	When the vehicle speed is lower than the setting speed			o	Solid			
	When the vehicle speed is equal to or higher than the setting Speed		o		Solid			
Drowsiness warning	close eye situation occurrence			o	blink	strong alert sound	1 second	Until the situation of closing eyes
	If it occurs twice within 30 seconds			o	blink	alert sound	1 second	
Yawning	When a yawn occurs			o	blink			
	More than 2 times in 1 minute			o	blink	Short Beep	0,5 second	1 time

Figure 9. LED and sound situation

3.1 Statistical Analysis

Validation tests were performed with a total of 20 different Turkish participants who have experienced driver licence.

As statisctical analysis method described in under title Acceptance Criteria-item no 8.1 of (EU) 2021/1341 was used. In this analysis method, system outputs(datasets) are compared with KSS measurement results.

If the DDAW system gives a fatigue warning to a driver who has been determined to be tired by the KSS measurement method, the result is classified as TP (True Positive).

Table 2. Event Matrix for obtained test data (KSS and system data)

Event	Driver Drowsy	DDAW System Detected Sitiuation
True Positive (TP)	Yes	Alert
True Negative (TN)	No	Silent
False Positive (FP)	No	Alert
False Negative (FN)	Yes	Silent

In order to determine the “Event Types”, the matrix, as shown in Figure 11, is used by matching the log data&videos and KSS datasets from the drivers' driving .

n(TP)[1] and n(FN)[1] are used statistically (it means for both event driver is actually sleepy.) according to acceptance criteria, of Point 8 of DDAW delegated regulation.

The following equations are calculated:

i. $$\text{Sensitivity} = \frac{n(TP)}{n(TP)+n(FN)} \text{ x } 100\ \%$$

ii. $$\text{Average(Sensitivity)} = \frac{\sum \text{Sensitivity}}{\text{Number of participants}}$$

iii. $$\text{Standart Deviation(Sensitivity)} = \sqrt{\frac{\sum(\text{Sensitivity} - \text{Average(Sensitivity)})^2}{\text{Number of participants}}}$$

iv. $$\text{Average(Sensitivitiy)} - 1.645 \text{ x } \frac{\text{Standart Deviation(Sensitivity)}}{\sqrt{\text{Number of participants}}} \geq 20\%$$

For the DDAW system to pass the tests successfully, the sensitivity results must be above 20%, which is the lower limit of the 90% confidence interval. This means that 95% of the respondents statistically have an average sensitivity of more than 20% and this result must be achieved according to equation.

[1] It means for both event driver is actually sleepy

3.2 MOVON Drowsiness Analysis

With 20 participants, 40 driving tests were planned. (see figure 12) Each test participant was supposed to generate at least one TP or FN event during the drive. As a result, 36 out of 40 test results(events) were found to be calculable, 4 test were removed as outliers.

i. $Sensitivity = \frac{n(TP)}{n(TP)+n(FN)}\ x\ 100\ \%$

- See **Figure 12** for each participants' sensitivity

ii. $Average(Sensitivity) = \frac{\sum Sensitivity}{Number\ of\ participants}$

- The number of valid samples is 36, and the average sensitivity is **95,84%.**

∑ (Sensitivity) =	3450,1
Number of acceptable test driving =	36
Average (Sensitivity) =	95,84

iii. $\text{Standart Deviation(Sensitivity)} = \sqrt{\frac{\sum(\text{Sensitivity}-\text{Average(Sensitivity)})^2}{\text{Number of participants}}}$

- The Standard Deviation (Sensitivity) value was determined as **0,1006.**

iv. $\text{Average(Sensitivitiy)} - 1.645\ \text{x}\ \frac{\text{Standart Deviation(Sensitivity)}}{\sqrt{\text{Number of participants}}} \geq 20\%$

- The sensitivity results were calculated according to above equation and confirmed as **93,08**≥ 20%.

Table 3. Sensivity result table of all participants

	Driver	Condition	n(TP)	n(FN)	Sensitivity % [TP/ (TP+FN)]*100
1	Participant 1	Normal Day	1	0	100,0
2	Participant 2	Normal Day	0	0	discarded: TP / FN did not occur
3	Participant 3	Sunset	2	0	100,0
4	Participant 4	Normal Night	8	0	100,0
5	Participant 5	Normal Night	3	0	100,0
6	Participant 6	Normal Night	10	1	90,9
7	Participant 7	Sunrise	0	0	discarded: TP / FN did not occur
8	Participant 8	Normal Day yawnning	4	1	80,0
9	Participant 9	Normal Day	1	1	50,0
10	Participant 10	Normal Day	17	0	100,0
11	Participant 11	Sunset yawnning	18	1	94,7
12	Participant 12	Normal Night	7	0	100,0
13	Participant 13	Normal Night	0	0	discarded: TP / FN did not occur
14	Participant 14	Normal Night	2	0	100,0
15	Participant 15	Sunrise	10	0	100,0
16	Participant 16	Normal Day	9	0	100,0
17	Participant 1	Normal Day	7	1	87,5
18	Participant 3	with sunglasses	8	0	100,0
19	Participant 3	with polarized sunglasses	8	3	72,7
20	Participant 17	Sunset	10	2	83,3
21	Participant 4	Normal Night	7	0	100,0
22	Participant 5	Normal Night	8	0	100,0
23	Participant 6	Normal Night	1	0	100,0
24	Participant 18	Sunrise	3	0	100,0
25	Participant 3	Normal Night	3	0	100,0
26	Participant 12	Normal Night	5	0	100,0
27	Participant 5	Normal Night	6	0	100,0
28	Participant 6	Normal Night	10	0	100,0
29	Participant 4	Normal Night	10	0	100,0
30	Participant 18	Normal Night	9	0	100,0
31	Participant 15	Normal Night	15	0	100,0
32	Participant 13	Normal Night	11	0	100,0
33	Participant 3	Normal Night	10	1	90,9
34	Participant 12	Normal Night	15	0	100,0
35	Participant 5	With Mask	19	0	100,0
36	Participant 6	Sunrise	18	0	100,0
37	Participant 4	Normal Night	-	-	discarded : risky driving heavy rainy
38	Participant 13	Normal Night	3	0	100,0
39	Participant 19	Normal Night obstruction in front of the cam	9	0	100,0
40	Participant 20	Sunrise	20	0	100,0

4. Conclusion

This document affirms the robustness and reliability of MOVON DDAW system.

The comprehensive validation testing process, including performance assessments and driving scenarios, demonstrated that the system meets or exceeds all specified requirements.

Notably, the successful validation of key functionality, such as detecting drowsiness, underscores the effectiveness of our design and development efforts. The minimal deviations observed during testing were promptly addressed and resolved, showcasing the responsiveness of our quality control measures.

In conclusion, the result of the validation tests is quite safe and meet the acceptance criteria requirement of DDAW regulation. Furthermore, these validated results instill confidence in the product's performance in real-world conditions. The success of this validation test demonstrates our dedication to providing our stakeholders with a high-quality and dependable solution.

Annex 1 – Equipment List of The MDSM-22S System

No.	Component	Photo
1	Control(PCI) Box	
2	DSM Camera	
3	Main Cable	
4	Power Cable	
5	Accessories (screws, tapes, camera joint etc.)	
6	CAN Reader	
7	Cradle (for dashboard installation)	

*Component details are available on written request by e-mail to MOVON
** UNECE R10 certificate is available on written request to by e-mail to MOVON
*** System schematic block diagram is on page 11/37 of UNECE R10 certificate

Annex 2 – Technical Controls Before Validation Tests

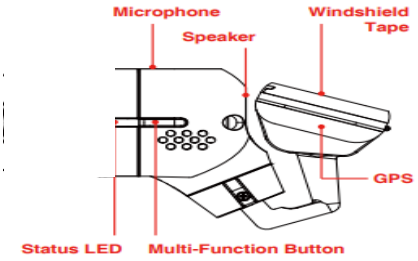
Technical controls were implemented for safe and accurate test execution.

Warnings, camera position and e-mark were checked before tests.

Acoustic warning was measured by a class 1 sound lever meter(Larson Davis 831), which has valid calibration certification. Measured dB of acoustic warning is 71.0 dB value that can be easily perceived by the driver and compliance with Acoustic Warning paragraph 3.4.3.2. of (EU) 2021/1341

Failure warnings were tested in the event of an obstruction in front of the camera, a lack of electricity, and an absence of information from the CAN line.

- When occured an obstacle in front of camera, the acoustic warning sounds, if systems is active(above speed 60km/h). [1] Otherwise(if system is deactive), no warning sounds.
- When a lack of CAN line occured, the status LED of camera turns red colour.



The DDAW system's camera has its own microphone and LED light.

The camera position[2] was checked before drivings to gather data properly. As stated before on Figure 5 of this document, the DSM camera is recommended to be attached next to A-Pillar and be positioned under the driver's face, so the DSM camera would look upwards to a driver's face by about 1º - 20º

E-mark sign belong to UNECE R10 type approval(E11*10R06/01*11872*00) was checked and it is located at bottom side of main control box.

[1]The system is deactivated when the camera is obstructed, and it is immediately activated upon obstruction removal.

[2] In case of mounting of camera in the vehicle as described, it is suitable to use all vehicle categories

Annex 3 – MDSM-22S Manual Guidebook

1. General Information

It is AI-powered edge-level fleet camera system for Driver Safety and Monitoring which offers Drowsiness Warning.

It has the compact DMS camera which is separate from the main control box considering the narrow vehicle space. Cameras and video recording, It can be calibrated on Smartphone app via Wi-Fi and send videos to Smartphone.

2. Product Spec.

AP	Quad Cortex-A7@1GHz
Image Sensor	1/2.8 inch CMOS Image Sensor
Interface	Ethernet Wi-Fi RS232 GPIO Trigger (Vibration)
SD Card	Max. 128GB
Power Consumption	Max. 8.4W (12V/24V)
Operating temperature	-20°C to 70°C (-4°F to 158°F)
2nd Camera	HD (TVI), 5V
Calibration	Smartphone app

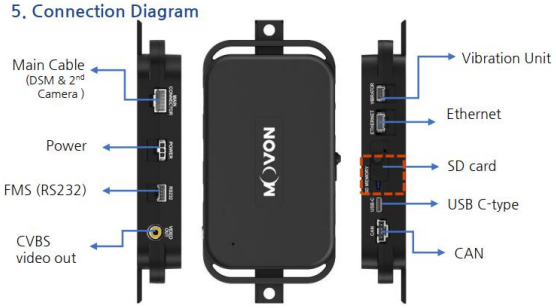
3. Product components (standard)

Control(PCI) Box | DSM Camera | Main Cable | Power Cable

4.Other Accessories

Contactless CAN Reader | Cradle (For dashboard)

5. Connection Diagram



MOVON

Components Description

1. Control Box

Control Box is implementing a driver face t racking and analysis in a real time.

2. DSM Camera

It is AHD 720 (TVI) camera with a built-in speaker and microphone. And its cradle has a GPS module inside.

3. Main Cable (Y cable)

It is connected to both the DSM camera (10pin connector) and the in-cabin camera (4pin BMW DIN Jack).

4. Power Cable

It consists of 3 wires Constant Power, IGN(ACC) Signal and GND.

Color	Label	Connection Description
Red	IGN	To ignition (ACC) power (Turns off when key is at OFF)
Yellow	Power	Battery power line
Black	GND	To ground source

5. Accessories

Main Accessory	Q'ty
One screw for tightening a camera joint fastener	1
Two screws for fixing a control box on the top of dashboard	2
Two 3M Tapes for attaching a control box on the top of the dashboard.	2
Hex Key to screw anti-tamper for a SD card	1
Additional Camera Joint for Truck/Bus	1

6. CAN Reader

To read vehicle CAN information without a direct connection. No wire-cutting, peeling, or soldering required to install this contactless CAN reader, ensuring a quick install and no damage to the vehicle.

7. Cradle(For dashboard)

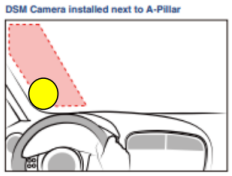
This is an accessory component that allows the product to be mounted on the dashboard when the product cannot be mounted on the windshield of the vehicle due to laws or the vehicle's interior installation environment.

VINÇOTTE

Recommended Position

1. DSM Camera position

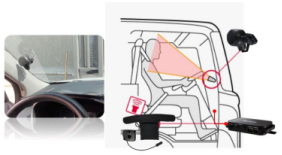
DSM camera is recommended to be attached next to A-Pillar and be positioned under the driver's face, so the DSM camera would look upwards to a driver's face by about 1º - 20º



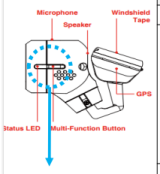
2. Control box position

A control box is supposed to be positioned under the dashboard. But, if you want to put it on the top of the dashboard, you can tighten screws and use 3M tapes to fasten the control box on the top of the dashboard.

Examples



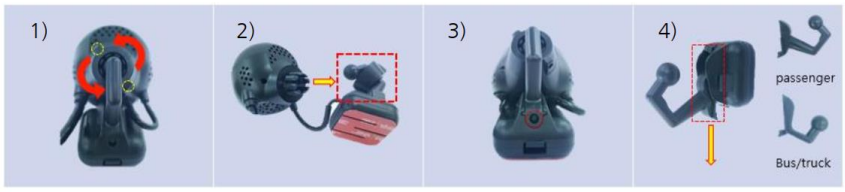
LED Status



Situation	condition	Camera LED R	Camera LED G	Camera LED O	Status	Sound	Duration	Remark
Power ON	Power ON			o	Solid			The Board Green LED turns on simultaneously
Standby mode	during loading			o	Solid			
	malfunction occurs	o			Solid			
	Block the camera	o			Solid			
	Set boot completed					alert sound	1 second	
	When the vehicle speed is lower than the setting speed			o	Solid			
	When the vehicle speed is equal to or higher than the setting Speed		o		Solid			
Drowsiness warning	close eye situation occurrence			o	blink	strong alert sound	1 second	Until the situation of closing eyes
	If it occurs twice within 30 seconds			o	blink	alert sound	1 second	
Yawning	When a yawn occurs			o	blink			
	More than 2 times in 1 minute			o	blink	Short Beep	0.5 second	1 time

Appendix

1. How to change DSM camera's Joint?



1) Loosen a cradle joint bolt in counterclockwise direction
2) Take apart a camera from a cradle
3) Unscrew the bolt at the bottom of a cradle
4) Push the cradle joint down and take it apart and then replace it.

MDSM-22 has two types of camera joint; one is fitted into a passenger car or SUV or VAN. The other is fitted into a bus and truck.

2. How to detach DSM camera from the mounting plate ?

1) Please press the locking key of a cradle in the opposite direction.
2) If pushing upwards the camera, the cradle mounting plate is detached from the camera and cradle.