

# Standardization and Vehicle Regulation

## Aspects of Camera Monitor Systems

Matthias Esser

**Abstract** Inside and outside rearview mirrors provide drivers of motor vehicles a field of vision that is relevant for safe driving behavior in several driving situations. This is one of the reasons why mirrors are a legal requirement almost everywhere in the world. UN Regulation No. 46 is the first regulation that permits all mandatory mirrors for passenger cars, commercial vehicles and buses to be replaced by camera monitor systems (CMS). The amended regulation is based on the new international standard ISO 16505 “Ergonomic and performance aspects of Camera Monitor Systems—Requirements and test procedures”. This chapter describes the relevance and impact of vehicle regulations and standards on vehicle development. On this basis, the development process of standards and regulations is examined using the examples of ISO 16505 and UN Regulation No. 46. It then proceeds to analyze today’s regulatory constraints with regard to CMS for passenger cars and highlights the basic boundary conditions which have to be considered within the development process to ensure product compliance with the relevant regulations. The chapter concludes with an overview of how future activities could contribute to regulation and standardization of CMS.

**Keywords** Camera monitor system • Replacement of rearview mirrors • Standardization • Developing standards ISO 16505 • Vehicle regulations • Developing vehicle regulations • Vehicle certification • UN Regulation No. 46 • Requirements for camera monitor systems

### List of Acronyms

AA	Arbeitsausschuss (Technical Committee)
AC	Administrative Committee
ACEA	European Automobile Manufacturers’ Association
AIS	Automotive Industry Standard
AK	Arbeitskreis (Working Group)

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ANSI	American National Standards Institute
BAST	Bundesanstalt für Straßenwesen (Federal Highway Research Institute of the Republic of Germany)
CD	Committee Draft
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
CFR	Code of Federal Regulations
CLEPA	European Association of Automotive Suppliers
CMS	Camera Monitor System
CMVR	Central Motor Vehicle Rules
CMVSS	Canadian Motor Vehicle Safety Standard
CS	ISO Central Secretariat
DIN	Deutsches Institut für Normung (German Institute for Standardization)
DIS	Draft International Standard
DKE	Deutsche Kommission Elektrotechnik Elektronik Informationstechnik in DIN und VDE (German Commission for Electrical, Electronic and Information Technologies of DIN and VDE)
EC	European Community
ECE	Economic Commission for Europe
EMC	Electromagnetic Compatibility
EN	European Standard
ETSI	European Telecommunications Standards Institute
EU	European Union
FDIS	Final Draft International Standard
FMVSS	Federal Motor Vehicle Safety Standard
FTA	Free Trade Agreement
GB	National Standard
GEB	Group of Experts on Noise
GEE	Group of Experts on Lighting and Light-Signaling
GEPE	Group of Experts on Pollution and Energy
GERF	Group of Experts on Brakes and Running Gear
GESG	Group of Experts on General Safety
GESP	Group of Experts on Passive Safety
GR	Groupe des Rapporteurs (Group of Experts)
GRB	Working Party on Vehicle Noise
GRE	Working Party on Lighting and Light-Signaling
GRPE	Working Party on Pollution and Energy
GRPS	Working Party on Passive Safety
GRRF	Working Party on Brakes and Running Gear
GRSG	Working Party on General Safety Provisions
HMI	Human Machine Interface
IEC	International Electrotechnical Commission

IG	Informal Group
IS	International Standard
ISO	International Organization for Standardization
ITC	Inland Transport Committee
ITU	International Telecommunication Union
JAMA	Japan Automobile Manufacturers' Association
JAPIA	Japan Auto Parts Industries Association
KBA	Kraftfahrtbundesamt (German Federal Motor Transport Authority)
KMVSS	Korean Motor Vehicle Safety Standards
MEMA	Motor & Equipment Manufacturers Association in the USA
MLIT	Ministry of Land, Infrastructure and Transport
MLTM	Ministry of Land, Transport and Maritime Affairs
MOLIT	Ministry of Land, Infrastructure and Transport
MTF	Modulation Transfer Function
NA	Normenausschuss Automobiltechnik (Automotive Standards Committee)
NCAP	New Car Assessment Program
NGO	Non-Governmental Organization
NHTSA	National Highway Traffic Safety Administration
NP	New Work Item Proposal
OICA	Organisation Internationale des Constructeurs d'Automobiles (International Organization of Motor Vehicle Manufacturers)
PRC	People's Republic of China
PWI	Preliminary Work Item
R.E.3.	Consolidated Resolution on the Construction of Vehicles
SAE	Society of Automotive Engineers
SC	Subcommittee
TC	Technical Committee
TCMV	Technical Committee Motor Vehicles
TS	Technical Specification
UN	United Nations
UNECA	United Nations Economic Commission for Africa
UNECE	United Nations Economic Commission for Europe
UNECLAC	United Nations Economic Commission for Latin America and the Caribbean
UNECOSOC	United Nations Economic and Social Council
UNESCAP	United Nations Economic Commission for Asia and the Pacific
UNESCWA	United Nations Economic Commission for Western Asia
UNO	United Nations Organization
UN-R	UN Regulation (annexed to the 1958 Agreement)
USA	United States of America

VDA	Verband der Automobilindustrie (German Automobile Industry Association)
VDA NA	VDA Normenausschuss Automobiltechnik (VDA Automotive Standards Committee)
VDE	Verband der Elektrotechnik und Elektronik und Informationstechnik (Association for Electrical, Electronic and Information Technologies)
WG	Working Group
WP.29	UNECE World Forum for Harmonization of Vehicle Regulation (formerly: UNECE Working Party 29)

1 Standards and Regulations

1.1 Requirements for Vehicles

This section introduces requirements necessary for incorporation into the early phases of the development of a vehicle (see Fig. 1).

A vehicle has to comply with vehicle regulations. This is verified by the manufacturer within the vehicle certification process. There are several types of different requirements the manufacturer needs to address in appropriate form. These include

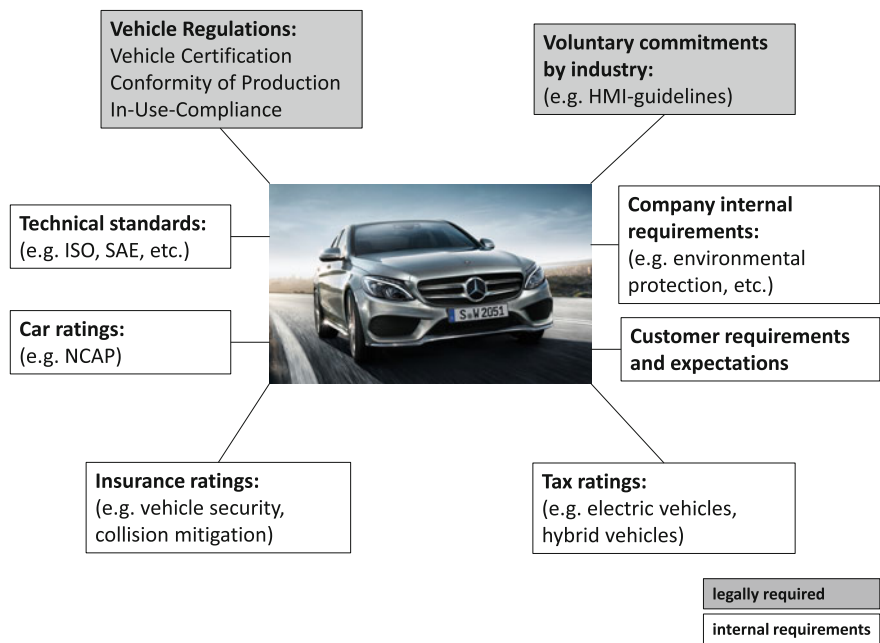


Fig. 1 Requirements for vehicles (© Daimler AG)

technical requirements such as standards, defining the state-of-the-art development. Other examples are customer and competition requirements, including tax ratings that allow tax savings for customers, if the vehicle fulfills certain criteria. The same applies to insurance ratings which have an impact on the insurance ranking of the vehicle (insurance premium rate). The following sections focus on vehicle regulations and standards, as both of these have a significant impact on camera monitor systems.

1.2 Standards

To understand the importance of ISO 16505, this section provides an overview of what a technical standard is, including its relevance for and impact on vehicle development.

“A standard is a document that provides requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for their purpose” (source [5]).

Standards are established under defined rules (see e.g. all parts of DIN 820 series), either in-house (e.g. Mercedes-Benz Standards), within associations (e.g. VDA, SAE), on the national level (e.g. DIN, ANSI), the European level (EN) or the international level (e.g. ISO, IEC) (see Fig. 2).

Revision of Standards

Standards document the state of the art and are revised on a regular basis (the exact timing depends on the rules of the individual organization). The content of ISO standards is reviewed at least every 5 years to reflect the state-of-the-art

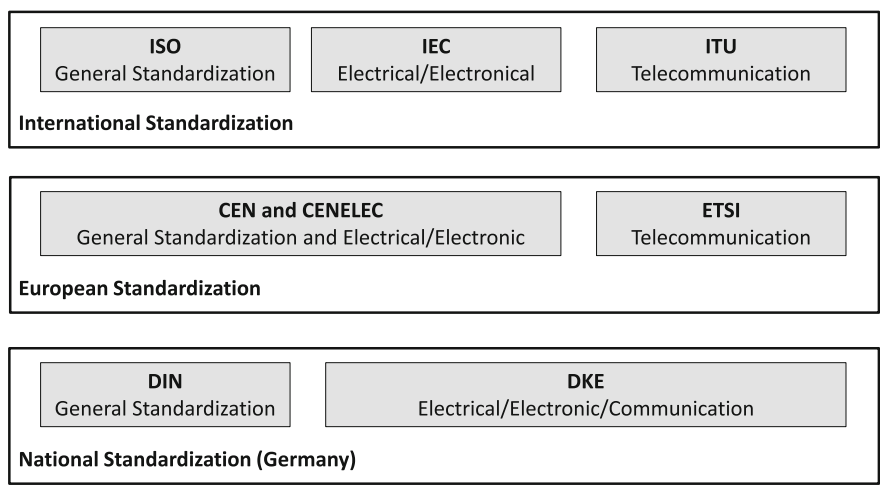


Fig. 2 Some standardization bodies in which VDA NA is involved, source [40]

development. The technical experts of the responsible working group evaluate whether a particular standard needs a revision or if it perhaps even needs to be withdrawn (see [41]).

### ***Legal Relevance***

The application of standards is not directly legally binding. However, they are used in court (e.g. in product liability cases) to determine current technological state of the art. The current level of scientific and technical knowledge has to be considered for product development. If the product deviates from applicable standards, the manufacturer should prepare a justification (engineering judgment) of why it is still in line with current state-of-the-art technology. Especially for new technologies and innovations, even drafts of standards may be relevant during the product development.

Standards may become part of the legal requirements. As soon as a standard is referred to in a regulation, compliance is mandatory. For legal compliance, the exact standard version mentioned in the regulation has to be used. Therefore, the date of issue mentioned in the regulation has to be thoroughly checked.

With the publication of the new international standard ISO 16505 “Ergonomic and performance aspects of Camera Monitor Systems—Requirements and test procedures” in April 2015 (see [9]), a state-of-the-art replacement of mirrors by CMS was defined for the first time ever.

## ***1.3 Developing ISO Standards***

This section explores how ISO standards are developed. Such background information is important to understand the development process of ISO 16505, which is outlined subsequently in Sect. 1.4.

ISO standards are developed by technical expert working groups (WGs), which are organized into Technical Committees (TCs) and Sub Committees (SCs) (see [7], p. 15). There are more than 250 TCs in total and each of them is responsible for specific subjects (see [6]).

The technical experts are sent by ISO’s member countries and are e.g. representatives of the industry, NGOs, governments, Technical Services and other stakeholders (see [6]). The ISO members are countries (individuals or companies cannot become ISO members) and each country can only be represented by a single institution (which is typically the national standard body, e.g. DIN for Germany). Table 1 shows the different types of ISO full membership.

### ***Timeline for ISO Standards***

ISO provides three different development tracks to develop an ISO standard (see Table 2). Figure 3 shows the process for creating an ISO standard. The important milestones on the roadmap towards an International Standard (IS) are: Proposal new

Table 1 ISO full membership, see [7], pp. 9 and 19

	Full member (member bodies) (can chose whether to participate in any TC as a P- or O- member)	
	P-member	O-member
Participation	Actively participating and influencing standardization work in TCs	Observe TC's work
Comments	Are expected to submit comments	Can submit comments
Votes	Are expected to cast ballots	Can cast ballots
Can adopt ISO standards nationally	Yes	
Can sell ISO standards nationally	Yes	

Table 2 Options for development of an ISO standard, see [7], p. 29

Option	Development track	Time to DIS (months)	Time to publication (months)
1	Accelerated	12	24
2	Standard	24	36
3	Extended	36	48

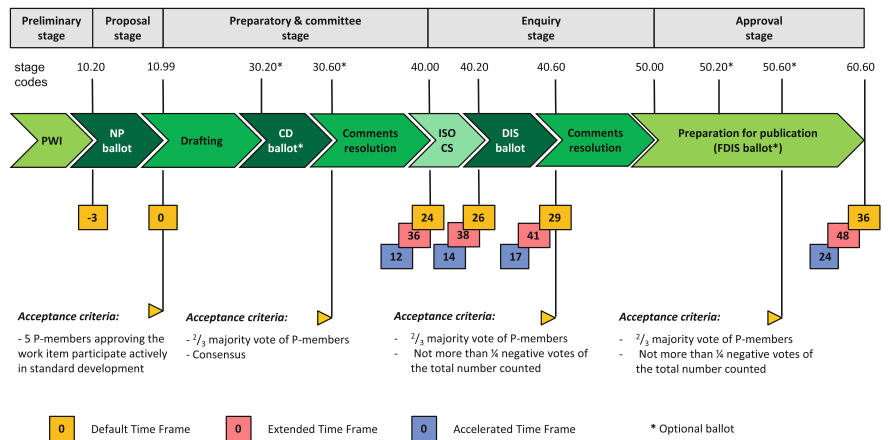
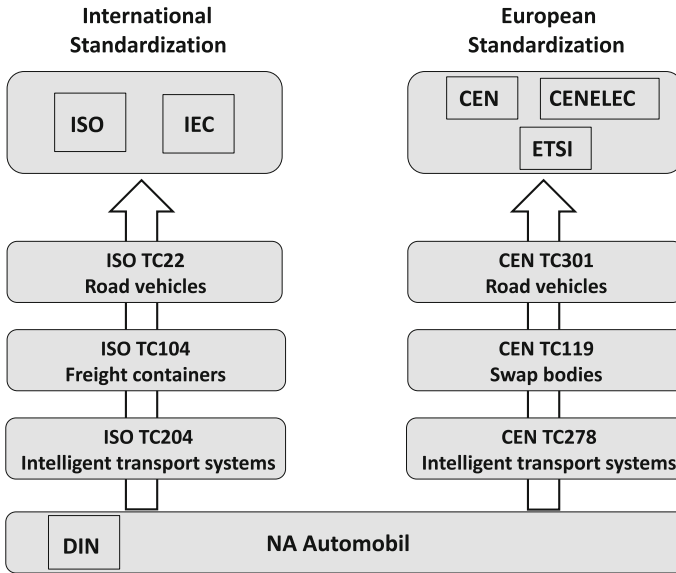


Fig. 3 Developing ISO standards, source [40], p. 15



**Fig. 4** NA's activities in automotive standardization, *source* [40], p. 5

project (NP), Committee Draft (CD), Draft International Standard (DIS) and Final Draft International Standard (FDIS). Each milestone has an international stage code (see [8]).

### ***Representation of National Interests Exemplified by Germany***

The members of an ISO Working Group usually prepare national comments and positions on an ISO standards project within national mirror working groups. These groups belong to the national standards organization (e.g. DIN for Germany).

In Germany, the VDA “Normenausschuss Automobiltechnik” (NA) acts in place of DIN within TCs of ISO and CEN dealing with motor vehicles (see Fig. 4). The NA is organized in several national subcommittees similar to the organization of the TC for road vehicles in ISO and keeps the members in Germany informed about current standardization activities.

## ***1.4 Developing ISO Standard 16505***

Figure 5 shows the development timeline of ISO 16505. After the New Work Item Proposal was submitted, it took five years before the International Standard ISO 16505 was published. After registration of the Final Draft International (FDIS), the project faced a delay of approximately 6 months before the FDIS ballot was started because several formal and editorial questions had to be clarified.



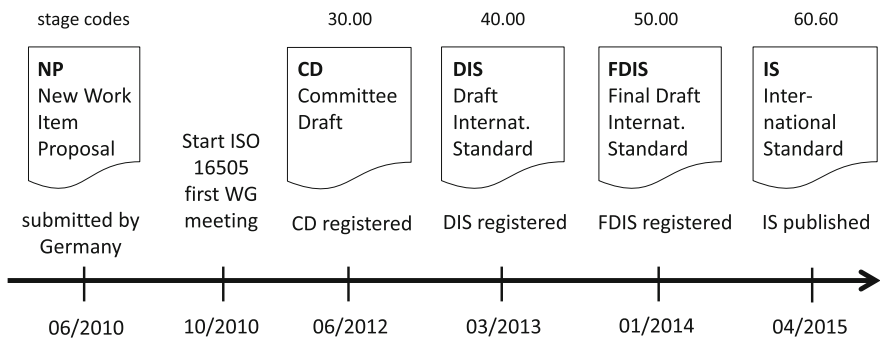


Fig. 5 Timeline for development of ISO 16505

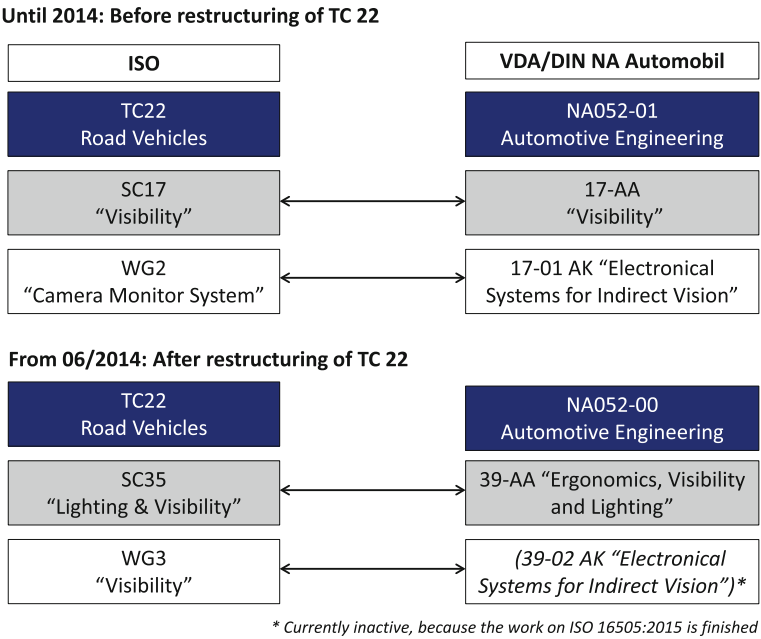


Fig. 6 International and national committee structure for developing ISO 16505

Figure 6 shows the international committee structure in ISO for developing ISO 16505. The expert group was TC22/SC17/WG2 "Camera Monitor Systems". After WG2 had finished its work on ISO 16505 in 2014, TC22 was restructured. As a consequence, the subject ISO 16505 was attributed to TC22/SC35/WG3 "Visibility" within this new structure.

Using the example of Germany, Fig. 6 shows how the international standardization work of ISO is mirrored by national working groups. As explained in

Sect. 1.3, Germany’s interests are represented within ISO by the VDA NA Automobil. For camera monitor systems, the working group “Electronic Systems for Indirect Vision” is in charge of ISO 16505.

1.5 Vehicle Regulations and Certification

To understand the importance of UN Regulation No. 46, this section gives an overview of what a vehicle regulation is, including its relevance and impact for the vehicle development.

A technical standard like ISO is not sufficient for CMS to become officially approved for the use on public roads. Therefore, a legal framework is needed which defines the minimum requirements when rearview mirrors are replaced by CMS.

Legal Relevance

Within the framework of vehicle certification, a vehicle manufacturer demonstrates that a vehicle or a system installed in the vehicle complies with the requirements of the relevant regulation. The vehicle certification is different from a certification of a company and its processes, such as certification according to ISO-9000ff or TS 16949, because vehicle certification is mandatory by law whereas certification according to ISO-9000ff is typically a mutually agreed part of an intercompany relationship (Quality Management). Table 3 gives an overview of comparison between standards and vehicle regulations.

There are several hundred vehicle regulations worldwide, prescribing minimum requirements with regard to different functions or systems of a vehicle. Vehicle regulations basically address environmental topics (e.g. exhaust emissions, fuel consumption, noise, etc.), passive safety topics (e.g. restraint systems, different crash configurations, pedestrian protection, etc.) and active safety topics (e.g. braking and steering systems, lighting, rearview mirrors, etc.).

These requirements are not necessarily harmonized internationally. In addition, the certification procedures for the different markets can be different, thus making it necessary to conduct independent certification activities for individual markets.

Table 3 Comparison between standards and regulations

	Standards	Vehicle safety regulations
Purpose	Define the state of the art “to ensure that materials, products, processes and services are fit for their purpose” (source [5])	Define minimum requirements to ensure road traffic safety
Content	Requirements, recommendations, design/product specifications, test procedures	Requirements and test procedures, administrative provisions
Issuer	Individual standards organization	Authorities
Legal relevance	No (Yes, in case a standard is referred to in a regulation)	Yes

**Revision of Vehicle Regulations**

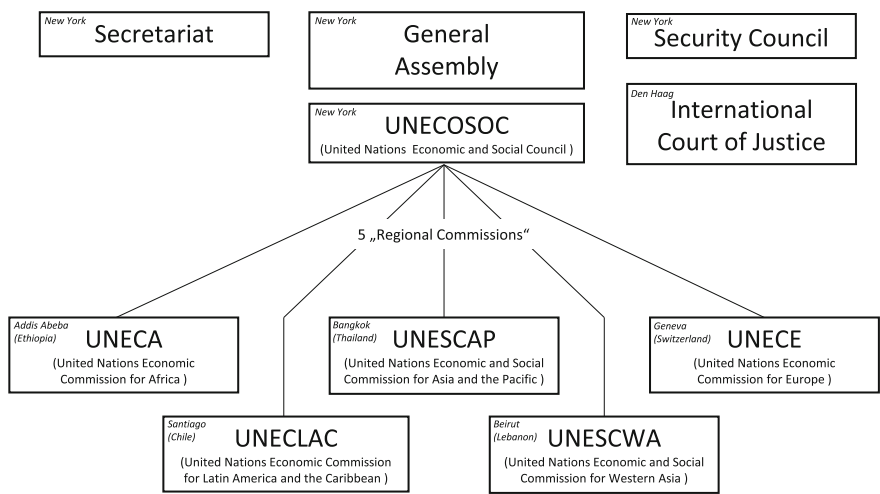
The creation of new regulations and the further development of existing regulations can have several triggers and motivations. These include enhancement of safety, reduction of environmental pollution, alignment of the regulations with the latest technologies, and harmonization of the regulations, including consideration of regional differences. For CMS, an update of UN Regulation No. 46 was necessary to align with the new technology and to permit it as a compliance option.

**1.6 Developing UN Regulations**

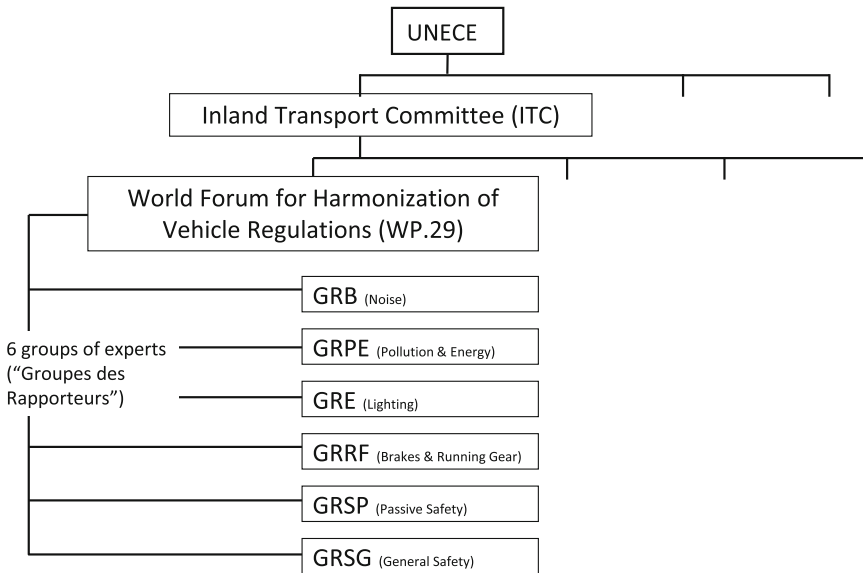
This section explores how UN Regulations are developed. Such background information is important to understand the development process of UN Regulation No. 46 towards CMS, which is outlined subsequently in Sect. 1.7.

UN Regulations (formerly ECE-Regulations) are significantly important in an international context. They are created by working groups of the so-called United Nations Economic Commission for Europe (UNECE). As shown by Fig. 7, the UNECE is a subcommittee of the United Nations Organization (see [24,39]).

The legal framework for the adoption and enforcement of UN Regulations is known as the 1958 Agreement and was established in 1958. With its latest revision from 1995 (see [37]), non-UNECE countries are also allowed to participate in the vehicle regulations work. As of September 2015, the 1958 Agreement had 52 signatories, including the European Union and its member states, as well as Australia, Japan, Russia, Turkey and many others. A complete list of the current signatories is shown in Annex A.



**Fig. 7** Integration of UNECE in UNO



**Fig. 8** Organization of WP.29, *source* Based on [42], p. 10

Within UNECE, Working Party 29 (WP. 29) is called the World Forum for Harmonization of Vehicle Regulations. The functional work is organized by six groups of experts (Groupe des Rapporteurs, GR-Groups) (see Fig. 8). The results of those six groups are presented at WP.29 sessions, which are held three times per year. WP.29 reviews and discusses the proposals that the expert groups submitted.

It is up to each Contracting Party to decide whether or not to adopt a UN Regulation and apply it on a national level. However, once a certain UN Regulation is adopted, approvals for the corresponding regulation granted by other Contracting Parties must automatically be accepted (“mutual recognition”). A reason why Contracting Parties may decide not to adopt a UN Regulation is usually that they have established their own national requirements that are not entirely covered by the respective UN Regulation. If they do not adopt it, mutual recognition is not necessary.

### ***Participation in WP.29***

Any member country of the United Nations can participate as a full member or in a consultative capacity in WP.29 and become a Contracting Party to the 1958 Agreements (see [42], p. 3).

NGOs can participate only in a consultative capacity (see [42], p. 5). Vehicle manufacturers are represented by OICA (Organisation Internationale des Constructeurs d’Automobile) at WP.29 and its GR-Groups. Vehicle component suppliers are represented by CLEPA (Comité de liaison européen des fabricants d’équipements et de pièces automobiles), MEMA (Motor & Equipment Manufacturers Association in the USA) and JAPIA (Japan Auto Parts Industries Association).

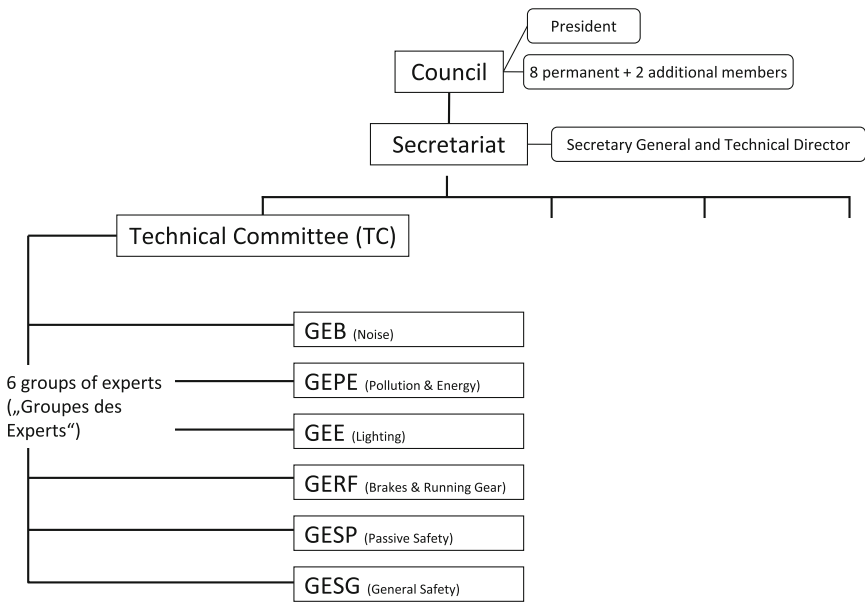
**OICA**

OICA is the only vehicle manufacturers’ association which is accredited by the United Nations. It is not an association of individual vehicle manufacturers. Rather, its members consist of automotive associations of single countries such as Alliance (USA), JAMA (Japan) and VDA (Germany). In 2015, there were 38 members (see [19]).

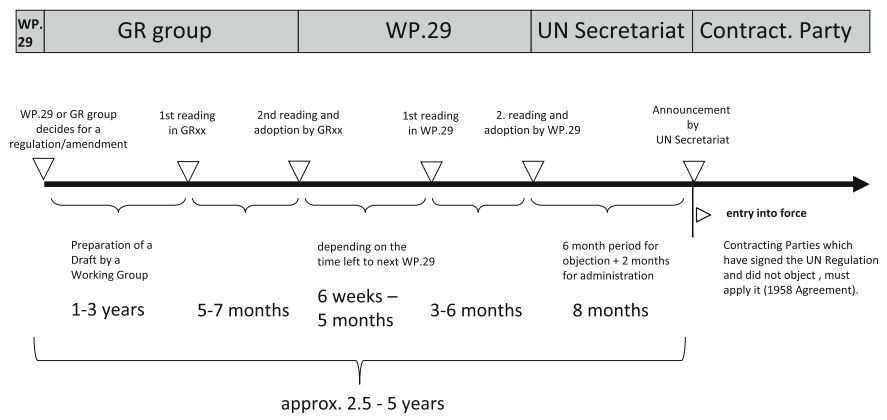
The task of the OICA Technical Committee consists of coordinating the technical activities of its member associations and in particular, of serving as the voice of the associations in WP.29 as well as its GR groups. The TC is supported by its 6 expert groups (Groupe des Experts, GE-Groups, see Fig. 9), which are mirrored to the 6 working groups (Groupe des Rapporteurs, GR-Groups) of WP.29 (see [20]).

**Timeline for UN Regulations**

Unlike under the ISO standards, there is no defined timeframe for developing UN Regulations under the 1958 Agreement. Basically, UN Regulations (new regulations and amendments of existing regulations) are developed by the responsible GR working group. The time the GR groups require to prepare a first working draft depends on the complexity of the topic and the challenge to align potentially different interests/opinions within the group. Figure 10 shows an exemplary timeline for the development of UN Regulations. For new and complex topics, GR groups normally install the so-called Informal Groups. Participants in such Informal Groups are typically representatives of Contracting Parties, technical experts of NGOs, like OICA and CLEPA and as well of Technical Services. The GR groups



**Fig. 9** Organization of OICA’s operation and activities with focus on WP.29



**Fig. 10** Exemplary timeline for UN Regulations

present their working results to WP.29. After adoption, WP.29 forwards the regulation to the UN Secretariat in New York.

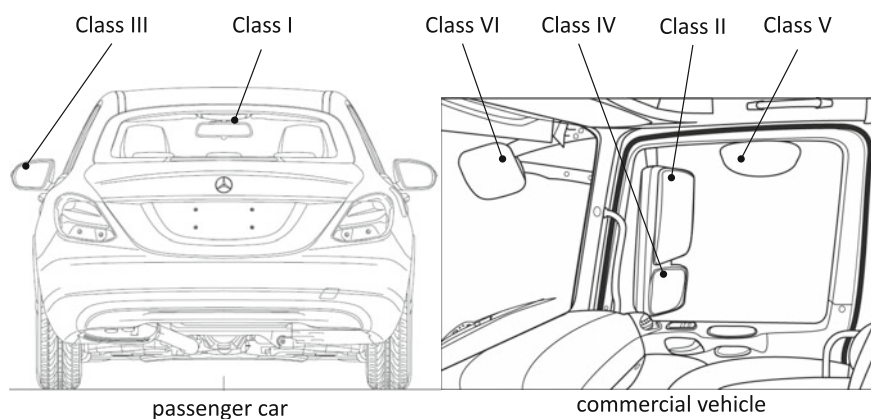
The Secretary-General of the UN will officially publish the adopted regulation following a 6 months period during which the Contracting Parties have the right to object (see [37], Article 7). If no objection is raised, the regulation is accepted. After the 6 months objection period, it takes about another 2 months for the UN Secretariat to formalize the document, before the Secretary-General of the UN officially announces the regulation and it thereby enters into force.

### 1.7 Developing UN Regulation No. 46 Towards CMS

Before the amendment of UN Regulation No. 46 (see [32]), passenger cars had to be equipped with mirrors, in fact with one inside mirror (Class I) and two outside mirrors (Class III); see Fig. 11. The replacement of those mandatory mirrors by CMS was not permitted.

The mandatory mirrors for commercial vehicles were also not permitted to be replaced by CMS, except for the close-proximity mirror (Class V) and the front mirror (Class VI); see Fig. 11. Since 2005, it has been permitted to replace Class V and VI mirrors by CMS which are only used for low speed applications such as maneuvering. Due to the size and installation position of Class V and VI mirrors, no significant fuel savings could be expected by their replacement. For that reason, Class V and VI CMS have only had a limited market penetration (mainly Class VI front camera applications). Figure 12 shows an example for a Class VI CMS.

The development of UN Regulation No. 46 towards including camera monitor systems for devices of Class I, II, III and IV started in 2009, when WP.29 approved the establishment of GRSG Informal Group Camera Monitor Systems (IGCMS) (see Fig. 13).

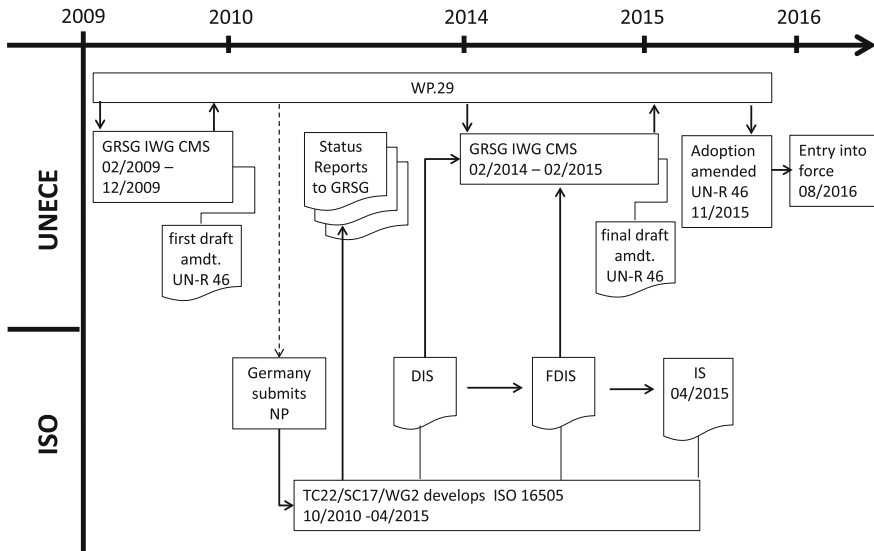


**Fig. 11** Mirror classes in UN Regulation No. 46 (© Daimler AG)



**Fig. 12** Class VI Camera Monitor System (© MEKRA Lang GmbH & Co. KG)

In light of the discussions it became obvious that the development of technical requirements for such a new technology was complicated, and would therefore need further international expertise. Progress was difficult due to the fact that no regulation or standard yet existed which would serve as a basis to develop technical requirements and test procedures. Due to the completely different use cases (especially vehicle speed), the requirements for Class V and VI mirrors were not suitable and sufficient for the other mirror classes. In 2010, the IGCMS ended up presenting a first draft for amendment of Regulation No. 46 which would permit all mirrors to be replaced by a camera monitor system (see [31]). However, regarding the technical requirements for camera monitor systems of the classes other than V and VI, this first draft referred to a new ISO standard (which had not yet been developed).



**Fig. 13** Process for amendment of UN Regulation No. 46

Based on this outcome, Germany triggered a New Work Item Proposal for ISO in June 2010 (see Figs. 5 and 13). It was approved, and TC22/SC17/WG2 held its initial meeting in November 2010. In the following working period, the chair of the ISO working group regularly reported the current status of the ISO activities at GRSG sessions. During the preparation of FDIS, WP.29 approved the reestablishment of the GRSG Informal Group Camera Monitor Systems (IGCMS). The IGCMS restarted its work by reviewing the technical requirements of the DIS. Meanwhile the IGCMS was kept informed on the outcome of the ongoing ISO work on the FDIS, which ran in parallel during the period from 2014 to 2015. In the further course of discussions, it became obvious that a simple reference to the new ISO standard would not be sufficient. While some provisions were regarded as inappropriate for type-approval purposes (e.g. how to deal with recommendations which may lead to different interpretations), others were determined to be unacceptable, or rather insufficient (e.g. point light sources). The first draft amendment of the IGCMS from 2009 therefore needed further modifications. The group managed to provide a final draft proposal to amend UN Regulation No. 46 to GRSG, which was adopted in May 2015 (see [33]). This proposal was then adopted by WP.29 in November 2015 (see [34]). The amended regulation will enter into force around August 2016.

UN Regulation No. 46 is not only accepted by the European member states. As of September 2015, there are 42 UNECE Contracting Parties which have adopted this regulation. Annex B shows the Contracting Parties that signed UN Regulation No. 46 and where CMS can be installed in the future.

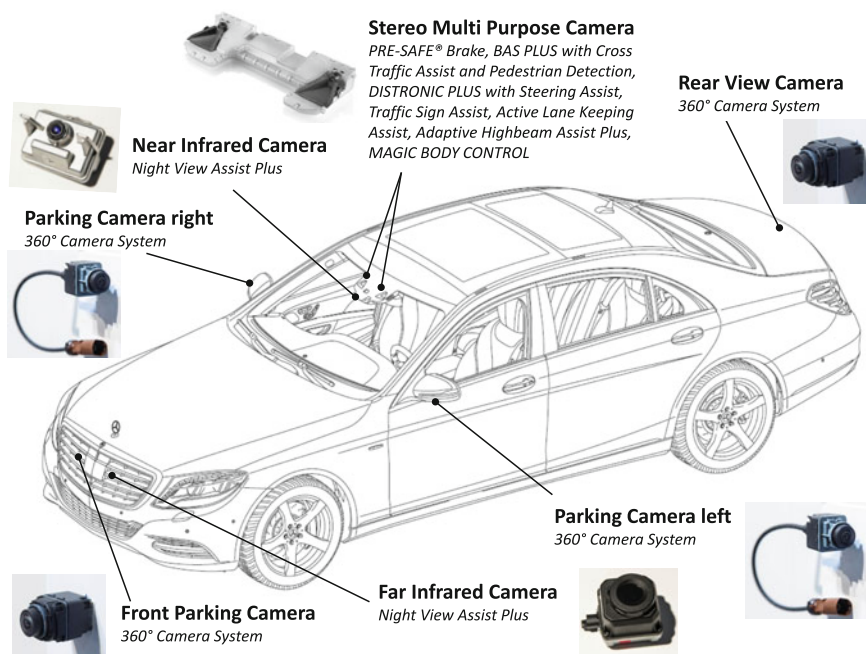
The details of the amended UN Regulation No. 46 are explained in Sect. 3.



## 2 Regulatory Situation for CMS in Regulations Other Than UN-R 46

### 2.1 General Aspects

Many of today's vehicles are already equipped with several camera systems (see Fig. 14). Rearview cameras, which are installed at the rear part of the vehicle, support the driver during parking and maneuvering scenarios. 360°-visibility systems are composed of several single cameras installed around the vehicle and whose single images are fused to provide the driver with an enhanced field of vision during low speed applications such as parking and maneuvering. Mono- and stereo-cameras, installed in the upper section behind the windshield, are used to detect traffic signs, lane markings and objects to assist the driver in exercising the longitudinal and lateral control of the vehicle. Furthermore, night view systems with infrared cameras have been on the market for several years. The installation of such driver assistance systems is not required by technical vehicle regulations and the camera systems which form a part of it have not been covered by the scope of regulations so far (except in the USA where the installation of rearview cameras will become mandatory for passenger cars and light trucks as of 1 May 2016, see Sect. 2.5).



**Fig. 14** Cameras in the Mercedes-Benz S-class (V222) (© Daimler AG)

In contrast, camera monitor systems covered by ISO 16505 aim to replace the inside and outside mounted mirrors, which are legally required.

The preceding Sect. 1.7 focused specifically on the regulatory situation with respect to the amended UN Regulation No. 46. The following will analyze to what extent a replacement of mandatory mirrors would be in line with the current vehicle regulations in major markets that have not adopted UN Regulation No. 46.

## ***2.2 Camera Monitor Systems in China***

Regulation for indirect vision: GB 15084-2013 (devices for indirect vision) (see [21]).

The content of the regulation is based on the requirements and test methods as defined in UN Regulation No. 46. For that reason, mirrors are also mandatory in China and their replacement by CMS (except for Class V and VI devices) is not yet addressed.

### ***Regulatory Activities to Enable CMS***

In the past, GB 15084 was updated within a certain period in order to incorporate the latest amendments of UN Regulation No. 46. The last amendment is from 2013. A further update in the near future does not appear to be a priority for the authority. Therefore, an update and upgrade of GB 15084 to allow camera monitor systems is not to be expected in the near future.

## ***2.3 Camera Monitor Systems in Japan***

Regulation for rearview mirrors: Safety Regulation Art. 44 (see [12]).

Mirrors must be present. Their replacement by CMS is not yet addressed.

Since 2005, Japan's vehicle requirements include a unique field of vision (see [11]): A cylinder (height: 1 m; diameter: 0.3 m) must be visible to the driver either by direct or indirect vision when positioned adjacent to the immediate front of the vehicle and to the passenger side. Vehicles with high front fenders have to be equipped with an additional fender mirror (see Fig. 15) in order to fulfill this requirement, because the cylinder would not be visible at some positions neither by direct nor by indirect vision through the outside mirror on the passenger side. The regulation permits the use of camera monitor systems to detect the cylinder. Such an additional fender mirror may therefore be replaced by a CMS.

### ***Regulatory Activities to Enable CMS***

Japan as a Contracting Party of the 1958 Agreement intends to adopt UN Regulation No. 46 in the near future. On that basis, the approval of CMS in place of rearview mirrors would become possible in Japan.

**Fig. 15** Fender mirror of Mercedes-Benz G-Class (G463), right hand drive for Japan (© Daimler AG)



## ***2.4 Camera Monitor Systems in South Korea***

Regulation for rearview mirrors: KVMSS Art. 50 (see [14]).

Rearview mirrors must be present. Their replacement by CMS is not yet addressed.

Since July 2011, Korea and the EU have entered into a free trade agreement (FTA) which also includes motor vehicles and parts. As a proof of compliance with Korean obligations under the FTA, Korea accepts some regulation approvals according to UN Regulations (and vice versa). Within the last three years, the EU and Korea have increasingly harmonized regulations to UN Regulations. In case of Article 50 (driver's visibility through rearview mirrors), the FTA prescribes that UN Regulation No. 46 is accepted as equivalent to the vehicle certification. It would therefore be permissible for vehicles which are exclusively imported from the EU to Korea to be equipped with CMS instead of mirrors as long as the CMS has an approval according to UN Regulation No. 46.

### ***Regulatory Activities to Enable CMS***

As of the completion of this chapter, Korean regulatory activities had yet to permit the replacement of rearview mirrors by CMS.

## ***2.5 Camera Monitor Systems in the USA and in Canada***

Regulation for rearview mirrors: FMVSS 111 (see [16]), CMVSS 111.

Rearview mirrors must be present. Their replacement by CMS is not yet addressed.

For passenger cars and light trucks (up to 4536 kg) the installation of rearview video systems (camera and monitor) will become mandatory in order to survey an area of 3 m width and 6 m length behind the vehicle (see [17]). By introducing this regulation, the National Highway Traffic Safety Administration (NHTSA) aims to

address crashes with pedestrians in the area immediately behind the vehicle while backing up. The introduction period lasts from 1 May 2016 until 1 May 2018 (100 % compliance).

### ***Regulatory Activities to Enable CMS***

In March 2014, the Alliance of Automobile Manufacturers and Tesla Motors, Inc. petitioned the agency (NHTSA) to update and upgrade FMVSS 111 to permit camera-based systems as a compliance option (see [1]). As the agency is expecting safety benefits in order to permit CMS, additional safety benefit studies (see e.g. [3]) have been submitted by the Alliance. As of the completion of this chapter, the dialogue between the automotive industry and NHTSA is still ongoing. As this topic is not included in NHTSA's rulemaking plan (see [18]), the requested update and upgrade of FMVSS 111 is not likely to happen in the near future.

## ***2.6 Exemption Procedures***

In special cases (e.g. new technology which is not in line with the applicable regulations), it is possible to get a special authorization for a certain vehicle type. An example is the Volkswagen XL1 equipped with CMS instead of rearview mirrors and already produced in a small series (see [23]). In the following sections, an analysis of exemptions for new technologies (like e.g. CMS) will be presented. As such exemption procedures are country-specific, two examples are given by focusing on the European- and on the US-market.

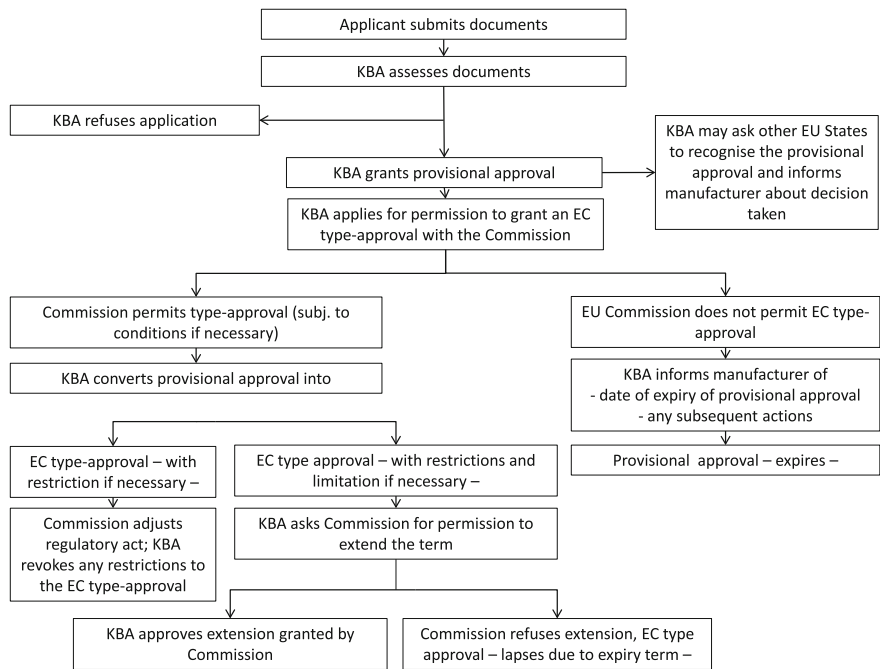
### **2.6.1 Europe**

#### ***Article 20: Exemptions for New Technologies or New Concepts***

Article 20 of the European Directive 2007/46/EC for vehicle type approvals (see [4]) foresees the possibility of obtaining exemption approvals if a technology does not comply with one or more regulations that are required for type approval (see Fig. 16). The manufacturer will apply for an exemption in the EU member state of their choice. If the member state decides to support the application, it may grant a provisional approval, which is however restricted to the territory of the member state that granted the approval (the "grantor"). The other member states may then be approached by the grantor of the approval and be asked if they are also willing to accept the provisional approval.

In the next step, the grantor informs the European Commission and applies for an EC whole-vehicle type approval, including the new technology. The following information must be submitted to the EU-Commission:

- An explanation, why a certain requirement cannot be fulfilled;
- Supporting documents which show that the new technology ensures the same level of safety and environmental protection as the existing ones;



**Fig. 16** Granting of EC type approval for new technologies or concepts, *source* [10], p. 5

- A description of the conducted tests and results which led to the conclusion that the same level of safety and environmental protection is ensured;

Based on the information provided, the EU Commission decides whether or not to authorize the application. The regulatory committee TCMV (Technical Committee Motor Vehicle), consisting of representatives of the EU Commission and the EU member states, assists the EU Commission in its decision-making. Due to a large number of stakeholders within the TCMV, the outcome of the decision-making is somewhat difficult to predict. The manufacturer cannot be certain whether the provisional approval will in the end become a regular vehicle type approval.

If TCMV grants the approval for exemption, it immediately has to start taking action for the amendment to the affected regulation in order to allow a certification without exemption procedures.

An approval for exemption is valid for a minimum of 36 months.

**Article 23: National Small Series**

According to Article 23 of the Directive 2007/46/EC, a manufacturer can apply for a national small series to EU member states. This procedure can also be a fallback solution if TCMV does not accept an exemption according to Article 20.

For small series, the authority can define alternative national requirements, when a specific regulation of the Directive 2007/46/EC cannot be complied with. In such

**Table 4** Comparison of exemption procedures according to Directive 2007/46/EC, *source* Based on [23], p. 18

Article 20: New technologies	Article 23: National small series
– Ensure the same level of safety and environmental protection	– Ensure the same level of safety and environmental protection
– EU Commission is involved	– EU Commission is not involved
– Provisional type approval with national validity (approval by other EU member states is optional)	– National type approval without restrictions/limitations (approval by other EU member states is optional)
– After decision of the EU Commission: EC type approval is granted (may be subject to restrictions/limitations) or not granted (expiration of the provisional type approval)	– Number of vehicles is limited to only 100 per year per member state
– If EC type approval is granted: Update of the affected regulatory act	

a case, the member state requests the manufacturer submit the same information as mentioned above to explain that a same level of safety and environmental protection as the existing technologies is ensured.

A national type approval of small series is restricted within the territory of the member state that granted the approval, but the member state can individually send the small series approval to other member states and ask for their acceptance. For passenger cars (M1), a national small series is limited to only 100 vehicles per year per member state. It is therefore not a real option for mass production vehicles; it could be however, an option for a limited edition or for concept cars. Table 4 gives an overview of comparison between exemption procedures according to Article 20 and Article 23 of the Directive 2007/46/EC.

### 2.6.2 USA

According to 49 CFR part 555 (see [15]), a manufacturer can petition the National Highway Traffic Safety Administration (NHTSA) for an exemption from the Federal Motor Vehicle Safety Standards (FMVSS) if a new safety technology innovation does not comply with certain requirements of these safety regulations. The manufacturer must explain in detail from which standards and which particular requirements of the affected FMVSS regulation the exemption is requested. Further, they must prove that the new technology ensures the same level of safety as vehicles with technologies that comply with the regulation.

If NHTSA grants the exemption for a certain technology, the manufacturer is allowed to sell 2500 vehicles in the USA within any 12 months’ period. Generally, the duration of the exemption is temporary for a maximum of two years. In special cases where two years are not economically reasonable, a maximum of three years are granted.

NHTSA is cautious about granting such exemptions and does not actively promote them, since due to the low number of vehicles it is difficult to establish statistically significant data that could prove the safety benefit of a technology.

## ***2.7 Summary Current Regulatory Situation***

Camera systems optionally installed as comfort systems in addition to the mandatory rearview mirrors (e.g. parking cameras) are not subject to current regulations, the exception being rearview cameras in the USA as of 2016.

Current regulations in countries that have not adopted UN Regulation No. 46 do not yet permit CMS to replace legally required mirrors on the driver and passenger sides, as well as inside mirrors for passenger cars. So far, CMS have only been permitted to replace the fender mirror, which may be necessary to comply with the Japanese close-proximity field of vision.

Some countries have established exemption procedures enabling new technologies not compliant with applicable vehicle regulations to be certified under defined conditions and restrictions. In such a case, evidence has to be shown to the authority that the new technology offers at least the equivalent safety level as existing technologies.

UN Regulation No. 46 is the first regulation worldwide to allow the replacement of the mandatory rearview mirrors by CMS. The details of the amended regulation are explained in Sect. 3.

# **3 Requirements for CMS in UN Regulation No. 46**

## ***3.1 General Aspects***

This section outlines the general structure and the requirements of UN Regulation No. 46. It shall serve as a basis to understand the requirements that were developed for CMS.

### ***Scope***

UN Regulation No. 46 sets out provisions for devices for indirect vision and their installation in vehicles of the category M, N and L (with bodywork).

Devices for indirect vision are primarily mirrors and camera monitor systems.

Vehicle categories are defined in Resolution R.E.3. (see [25]): Category M includes vehicles, which are intended for the carriage of passengers—it includes passenger cars (M1) and buses (M2 and M3). Category N includes vehicles which are intended for the carriage of goods, meaning commercial vehicles—it is divided into the subcategories N1, N2 and N3, according to the maximum vehicle mass. Category L includes vehicles with less than four wheels (e.g. motorbikes) and some special lightweight and low speed/low power vehicles with four wheels.

### ***Classes of Devices for Indirect Vision***

In order to support drivers in driving and maneuvering their vehicles safely, a sufficient rearward field of vision is required. The characteristics of the vehicles (e.g. dimension, geometry, driver's seating position and relevant driving maneuvers) for and within each category can vary widely. When comparing passenger cars and commercial vehicles, it becomes obvious that devices for indirect vision have a significant importance in commercial vehicles because direct vision is rather limited and blind spots are larger. Also commercial vehicles have much larger dimensions which makes it more difficult to maneuver them safely. Different minimum fields of visions must therefore be attributed to each vehicle category. UN Regulation No. 46 includes seven different classes of devices for indirect vision (see Table 5) and regulates which of them are compulsory and which are optional for each of the different vehicle categories. For a typical passenger car (M1), one Class I and two Class III devices (each on driver and passenger side) are mandatory.

The amended UN Regulation No. 46 enables the use of camera monitor systems instead of mirrors for Class I, II, III and IV devices. Class V and VI CMS have already been possible since 2005 (see Sect. 1.7). Their requirements remained unchanged. The required mirrors for Class VII devices (only relevant for category L with body work) will be the only ones which cannot be replaced by CMS. This is partly due to the fact that the scope of ISO 16505 in its initial version from 2015 is limited to devices for vehicle categories M and N, and therefore does not include Class VII devices.

### ***Requirements in UN Regulation No. 46***

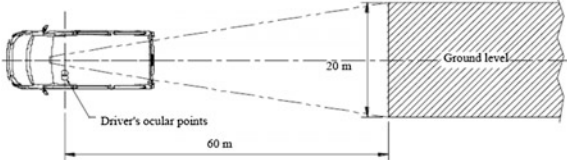
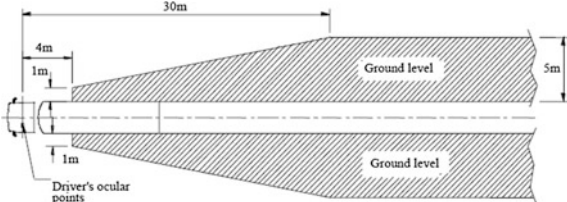
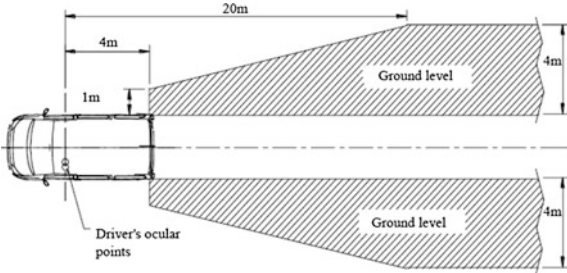
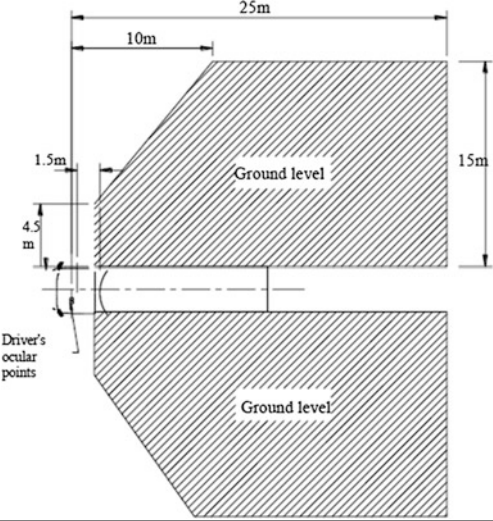
The requirements of UN Regulation No. 46 can be separated into two categories (see Fig. 17).

On the one hand there are technical requirements with regard to the component (device) itself. With the exception of the mechanical requirements (e.g. radius of external projections and impact absorption), the optical requirements and tests are individually designed for mirrors and camera monitor systems, because both systems have completely different characteristics that cannot be evaluated with the same tools and processes.

On the other hand, UN Regulation No. 46 includes requirements with regard to the installation of a device for indirect vision in a vehicle. The field of vision, which a device provides to the driver for a specific vehicle, mainly depends on its installation position. While the required fields of vision for each class are the same for mirrors and CMS, there are several other installation requirements that are specifically designed for the different technologies of mirrors and camera monitor systems.

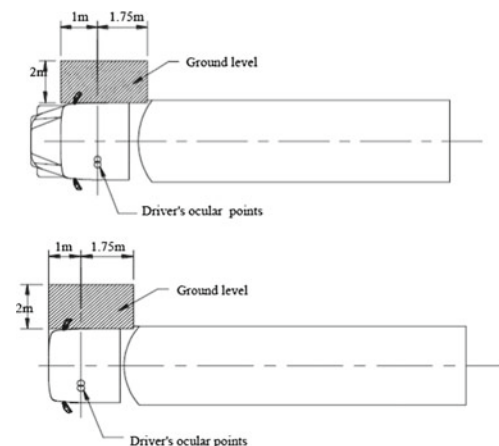
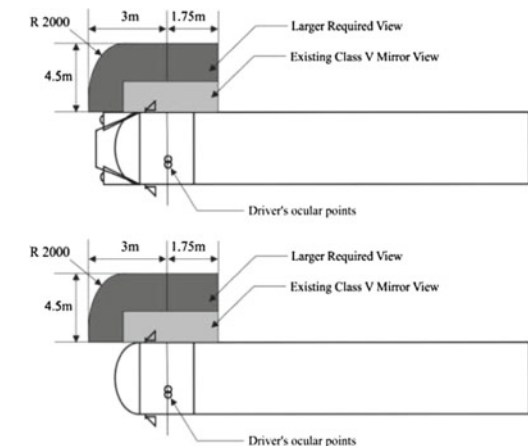
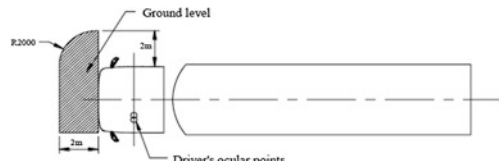


**Table 5** Overview of device classes and their required field of vision, *source* [32]

Class	Device	Field of vision
I	Rear view	
II	Main rear view	
III	Main rear view	
IV	Wide-angle view	
V	Close-proximity view	

(continued)

Table 5 (continued)

Class	Device	Field of vision
		<p>(a) Devices which are situated less than 2.4 m above the ground</p>  <p>(b) Devices which are situated <math>\geq 2.4</math> m above the ground</p> 
VI	Front view	

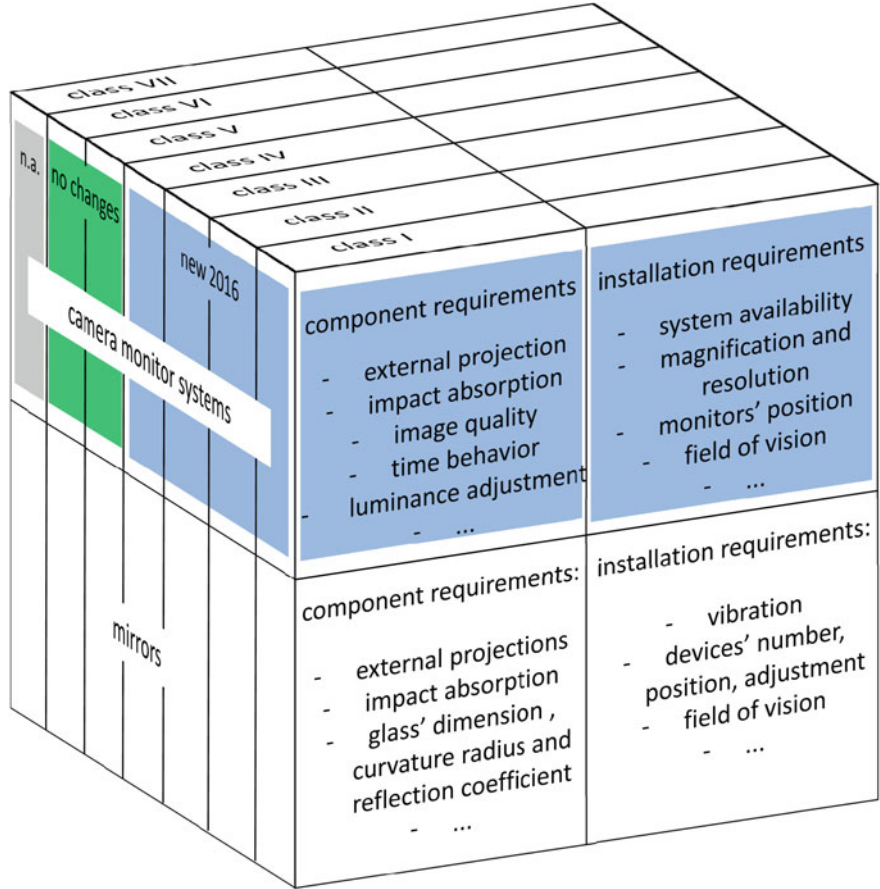


Fig. 17 Overview structure of UN Regulation No. 46

3.2 Requirements for Class I–IV Camera Monitor Systems

This section will give an overview of the new requirements for Class I–IV CMS as defined by the amended UN Regulation No. 46 (see [34]). It does not include each and every requirement and is not a substitution for the detailed study of the regulation necessary for the appropriate development and certification of a CMS. As explained in Sect. 1.7, the requirements and test methods of UN Regulation No. 46 are based on ISO 16505, but the final amendment draft included some modifications which were made by the Informal Group CMS. This section focuses on requirements which have a main impact on the implementation of a CMS into a vehicle. Furthermore, it gives an overview of different regulatory requirements and test methods in comparison to ISO 16505 including the impact on the system design that result from these modifications.

### 3.2.1 Mechanical Requirements

The mechanical requirements for CMS were basically carried over from mirrors to CMS. Accounting for the danger of head impact injury, the devices for indirect vision under UN Regulation No. 46 must have the following characteristics:

- Deflection occurs when hit by an obstacle (energy absorption) to reduce the impact,
- mounting may break away but without leaving sharp edges (radius  $> 2.5$  mm),
- and additionally for camera monitor systems, the camera lens does not break.

These requirements are verified by a dynamic impact test with a pendulum that impacts the device. In order to pass the test, the pendulum must continue to swing after the impact within a minimum angle of  $20^\circ$  to the vertical. For this reason, outside mirrors for passenger cars (Class III) typically have a folding mechanism which ensures that the mirror housing deflects appropriately. CMS usually have a smaller camera holder design which does not foresee an installation space for a folding mechanism.

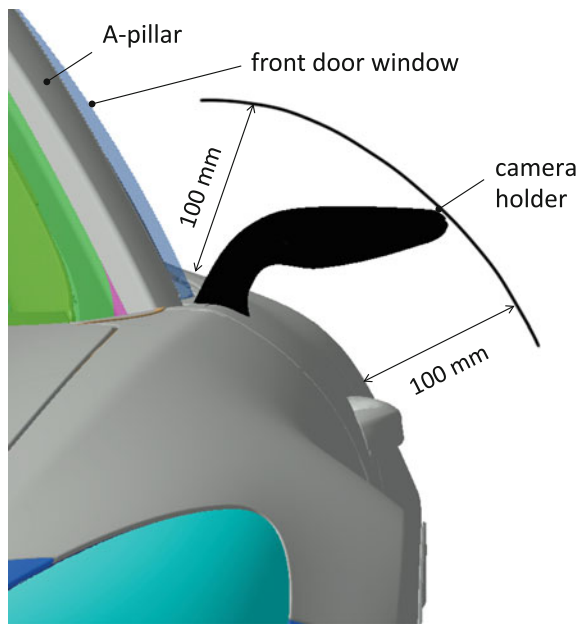
UN Regulation No. 46 includes some exemptions for the different mirror classes under which the impact test is not required. If, for instance, the installation height for devices of Class II–IV exceeds 2 m, the impact test is not required. In case of Class III mirrors for passenger cars, this exemption is practically irrelevant, but there are other configurations which are exempted from the pendulum test:

#### ***100 mm Exemption***

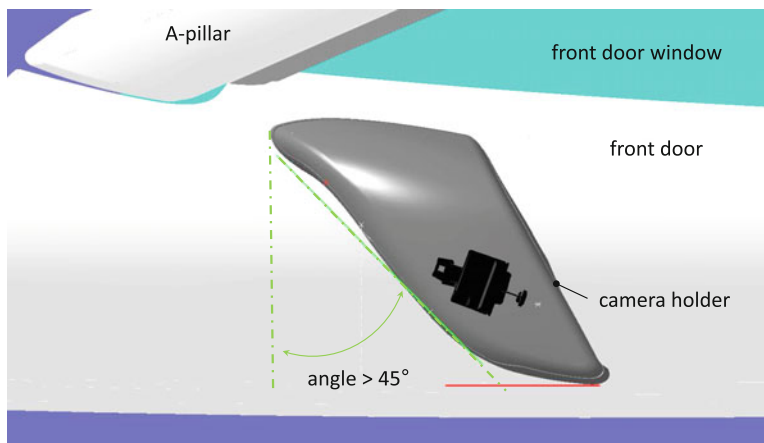
- No impact test is required for devices that do not protrude “more than 100 mm measured beyond the circumscribing bodywork” (source [34]).
- The measurement is conducted as described in UN Regulation No. 26 (see [30]) (see Fig. 18). The protrusion is measured via the perpendicular relating to the circumscribing bodywork and the device must not protrude more than 100 mm into the respective direction.

#### ***Exemption for Integrated Devices with a Frontal Reflecting Area of Maximum $45^\circ$***

- The device is integrated into the bodywork and its frontal reflecting area has an angle of less than  $45^\circ$  with the longitudinal median plane of the vehicle (see Fig. 19).
- In terms of complying with the regulation, a device is “integrated” when it is mounted flush with the body shell (e.g. no projecting bars, connecting links and eyes) and does not project beyond the bodywork in the corresponding section plane (see Fig. 20).



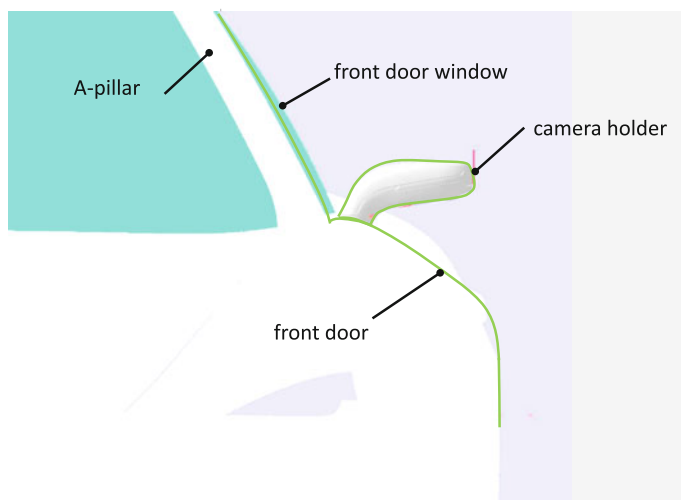
**Fig. 18** How to measure the protrusion of parts (© Daimler AG)



**Fig. 19** Frontal reflecting area of max. 45° (© Daimler AG)

**3.2.2 Functional Component Requirements**

The functional component requirements focus on image quality. While the functional requirements for Class V and VI CMS mainly include luminance contrast and blooming, there are several new requirements for Class I–IV CMS due to different



**Fig. 20** Device integrated into the bodywork (© Daimler AG)

use-cases that have to be covered. For the definitions and symbols, the regulation refers to ISO 16505. The same applies to the test procedures unless otherwise specified in UN Regulation No. 46.

It should be noted that some component tests on image quality need vehicle-specific information: Standard and extended isotropy range depend on the monitors' design viewing direction, which in turn depends on the position of the monitor in relation to the driver's eye point. The new measurement procedure to determine the relevant luminance for the luminance contrast requirement depends also on the vehicle layout (see below).

### ***Monitor Isotropy***

The provisions regarding monitor isotropy are carried over from ISO 16505 without modifications.

### ***Luminance and Contrast Rendering***

The requirements in ISO 16505 are based on ISO 15008; UN Regulation No. 46 introduces several modifications.

While ISO 16505 requires a luminance contrast of 5:1 for night conditions, UN Regulation No. 46 sets out a more severe value of 10:1 (except for systems which include both technologies CMS and mirror) in order to address the needs of older drivers.

Furthermore, the test method for verifying the contrast under daylight conditions with diffuse ambient light has been changed. While ISO 16505 (as prescribed in ISO 15008) defines a light source of  $1500 \text{ cd/m}^2$ , UN Regulation No. 46 defines a range of from  $1500\text{--}4200 \text{ cd/m}^2$  which takes into account some worst case scenarios. Meanwhile, UN Regulation No. 46 introduces a new procedure on how to define the applicable value within this range. This new procedure considers the fact

that the relevant luminance, which monitors are exposed to, and its reflection to the driver's eyes are dependent on the whole vehicle layout (in particular the vehicle openings such as windows or sunroofs, including their dimensions and position).

### ***Grey Scale Rendering***

As ISO 16505 includes neither requirements nor test methods, both are newly introduced in UN Regulation No. 46.

### ***Color Rendering***

The provision regarding color rendering is carried over from ISO 16505 without modifications.

### ***Artifacts: Smear***

ISO limits smear to maximally 50 % of the maximum luminance value of the image. UN Regulation No. 46 defines a more severe value of maximal 10 % to be in line with the existing requirement for Class V and VI CMS.

### ***Artifacts: Blooming and Lens Flare***

Both ISO 16505 and UN Regulation No. 46 limit blooming and lens flare areas to maximally 25 % of the displayed image.

### ***Artifacts: Point Light Sources***

While ISO 16505 includes a qualitative requirement without test procedure, UN Regulation No. 46 introduces a severe quantitative requirement (two light sources with an intensity of 1750 cd and a distance of 1.3 m have to be distinguishable as two different light sources at a distance of 250 m) and a corresponding test procedure (point light source detection factor and point light source contrast factor).

### ***Sharpness and Depth of Field***

Both the requirements for sharpness and depth of field are carried over from ISO 16505 to UN Regulation No. 46 without modifications.

### ***Geometric Distortion***

While ISO 16505 includes a qualitative requirement, UN Regulation No. 46 defines a limit of 20 % relative to the recto-linear or pinhole projection for Class I, II and III CMS. Regarding the test method, UN Regulation No. 46 refers to Annex G.3. of ISO 16505.

### ***Flicker***

Both ISO 16505 and UN Regulation No. 46 require the monitor to be free from flicker for 90 % of the user population. While ISO 16505 does not include a test procedure, UN Regulation No. 46 introduces a test method by referring to the decision method that is described in Annex B of ISO 13406-2:2001.

### ***Time Behavior: Frame Rate***

The requirement is carried over from ISO 16505 to UN Regulation No. 46 without modifications.

***Time Behavior: Image Formation Time***

Both ISO 16505 and UN Regulation No. 46 require an image formation time of less than 55 ms at a temperature of  $22\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$ . While ISO 16505 does not include a test procedure, UN Regulation No. 46 introduces one which is already included in ISO 9241-305:2008.

***Time Behavior: System Latency***

The requirement is carried over from ISO 16505 to UN Regulation No. 46 without modifications.

**3.2.3 Installation Requirements**

While the installation requirements for Class V and VI CMS focus mainly on the field of vision, there are several new requirements for Class I–IV CMS due to the different use-cases that are covered. For the definitions and symbols, the regulation refers to ISO 16505. The same applies to the test procedures unless otherwise specified in UN Regulation No. 46.

***System Availability***

Both UN Regulation R 46 and ISO 16505 require a warning to the driver if the system is not able to operate (e.g. CMS failure/malfunction). UN Regulation No. 46 requires that the field of vision is permanently visible to the driver as long as the ignition is on. A temporary switch-off therefore is not permitted, even in specific traffic situations where the vehicle does not move (e.g. stopped at a red light).

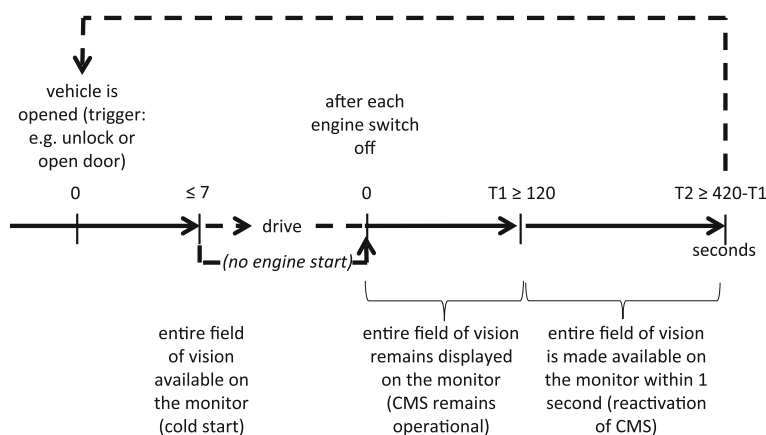
While ISO 16505 defines a switch-on time for a cold start for maximum of 7 s, UN Regulation No. 46 defines additional use-cases to ensure that the rearward field of vision is made available in a reasonable time frame, even if occupants of the vehicle do not leave immediately after switching off the engine (see Fig. 21). After each engine switch-off, the CMS shall continue to show the required field of vision for a minimum of 120 s ( $T_1$ ). Between  $T_1$  and a minimum of 300 s ( $T_2 \geq 420 - T_1$ ), the entire field of vision must be made available within 1 s. UN Regulation No. 46 does not specify in detail how long the CMS must remain operational, if the engine is not switched on after the cold start. A reasonable approach in terms of complying with the regulation would be to start counting  $T_1$  as soon as the entire field of vision is available on the monitor after the cold start.

UN Regulation No. 46 foresees the possibility of allowing the manufacturer to deviate from the concept for activation and deactivation as shown in Fig. 21, provided that an alternative coherent safety concept can be shown and is accepted by the Technical Service.

***Default View***

The requirement is carried over from ISO 16505 to UN Regulation No. 46 without modifications.





**Fig. 21** System availability—activation and deactivation

### Overlays

ISO 16505 permits overlays within the required field of vision as well, provided they are only temporary, transparent and related to driving. The two limiting aspects, “temporary” and “related to driving” are carried over to UN Regulation No. 46. It additionally requires that overlays are only allowed to display *rearward* driving-related information.

Regarding the size of the overlays, UN Regulation No. 46 stipulates more severe requirements which restrict the practical possibilities for system designs with overlays. While ISO 16505 does not regard transparent and temporary overlays as an obstruction, UN Regulation No. 46 considers any kind of overlay (regardless of their transparency) within the required field of vision as an obstruction. Therefore, UN Regulation No. 46 introduces limits for the allowed size of overlays:

The area size of each single overlay (e.g. icon, label, colored line etc.) is limited to a maximum of 2.5 % of the area which displays the minimum required field of vision.

In addition, the total area of all obstructions within the required field of vision is limited to a maximum of 15 % for devices of Class I and 10 % for all other device classes. It should be noted that these values already existed for mirrors. For Class I devices, they address obstructions due to backlight wipers, heating elements, etc. and for all other classes of devices obstructions due to bodywork, door handles etc. Therefore, not only overlays, but also all the other relevant obstructions fall under those limits. The amount of those other relevant obstructions mainly depends on the vehicle layout and positioning of the devices for indirect vision. Sports cars with wide rear fenders typically come close to the 10 % obstruction of the required field of vision in the outside mirror. In case of camera monitor systems that are supposed to have even shorter camera holders, the obstruction might even increase for bodyworks of the same type. Therefore, further obstructions in the form of reasonable overlays are unlikely to be included for some vehicle types. For the

**Table 6** Comparison of the requirements for overlays within the required field of vision

ISO 16505	UN Regulation No. 46
Only transparent	Any overlays (regardless of their transparency) are considered as an obstruction
Only temporary	Only temporary
Only driving related visual information	Only rearward driving related visual information
Size unlimited	Maximal size of each overlay is 2.5 % of the area which displays the minimum required field of vision
	Overlays have to be included when calculating the obstructions within the required field of vision (obstructions are limited to a maximum of 15 % for devices of Class I and to a maximum of 10 % for all other device classes)

calculation of the overlays' total obstruction, the worst-case scenario is relevant, which means the biggest obstruction where one or more overlays are displayed at the same time. Table 6 gives an overview of comparison between the requirements for overlays of ISO 16505 and UN Regulation No. 46.

### ***Magnification Factor***

For CMS of Class I and III, the minimum magnification factor is carried over from ISO 16505 to UN Regulation No. 46 without modifications.

For CMS of Class II and IV, the minimum magnification factor in UN Regulation No. 46 is higher than that of the required values in chapter "[Magnification and Resolution](#)" of ISO 16505. The newly defined values are based on ISO's Annex 3, in which recommendations concerning commercial vehicles are formulated.

### ***MTF (Resolution)***

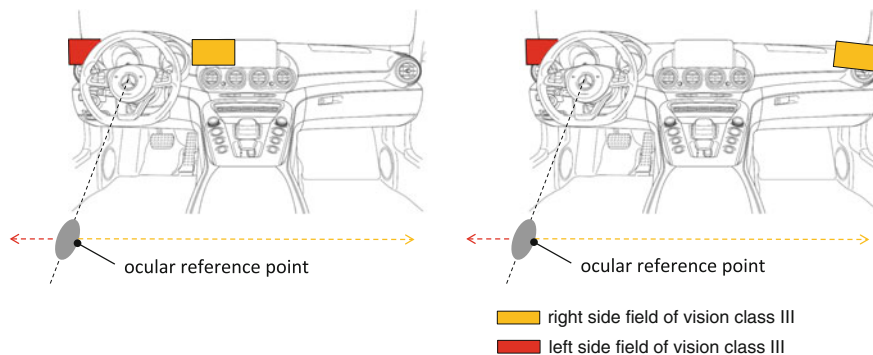
The requirement is carried over from ISO 16505 to UN Regulation No. 46 without modifications.

### ***Magnification Aspect Ratio***

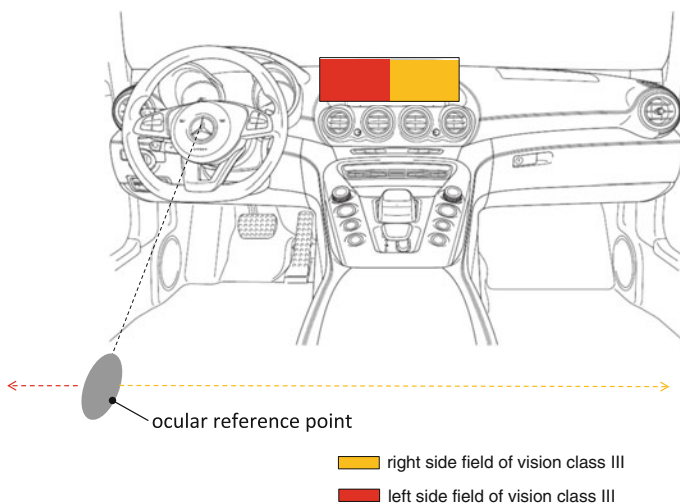
The requirement is carried over from ISO 16505 to UN Regulation No. 46 without modifications.

### ***Monitor Arrangement***

The requirements of UN Regulation No. 46 are more restrictive than those of ISO 16505. While the location of the displayed field of visions in ISO 16505 is related to the monitor arrangement itself (left side field of vision to be displayed on the left side of the monitor arrangement and right side field of vision to be displayed on the right side of the monitor arrangement), UN Regulation No. 46 defines the allowed arrangement relative to the driver's ocular reference point (left side field of vision to be displayed left of the ocular reference point and right side field of vision to be displayed right of the ocular reference point). According to the UN Regulation No. 46 monitor arrangements similar to that of current outside mirrors may be



**Fig. 22** Examples for permitted monitor arrangements of a Class III CMS (© Daimler AG)



**Fig. 23** Example for a monitor arrangement of Class III CMS which is not permitted by UN R-46 (© Daimler AG)

installed (see Fig. 22). Central monitor arrangements, which show both left and right side in a center position of the vehicle, are not permitted (see Fig. 23).

### ***Decreasing Accommodation***

The requirement is carried over from ISO 16505 to UN Regulation No. 46 without modifications.

### ***Functional Safety***

Because camera monitor systems are safety-relevant electronic systems, ISO 16505 generally requires their functional safety needs to be covered within the development process. ISO 16505 therefore refers to other existing standards that address functional safety.

UN Regulation No. 46 does not include this reference to other standards. Rather, it includes its own framework to support a methodology which is appropriate to avoid or control systematic and random failures of software and hardware. Therefore, it includes several criteria which are verified by the Technical Service for establishing an appropriate safety concept including documentation and verification. The key requirement of the safety concept is to ensure that the driver is informed (e.g. by a warning signal) in case of any electric/electronic malfunction of the CMS. A similar approach for functional safety was already successfully taken for UN Regulations No. 79 (Steering Equipment), No. 13 (heavy vehicle braking) and No. 13-H (braking of passenger cars) which include the so called Annex for complex electronic vehicle control systems to ensure a safe operation of such systems within the vehicle. Chapter “[Functional Safety of Camera Monitor Systems](#)” gives an in-depth analysis for functional safety topics of a CMS.

## 4 Other Relevant UN Regulations for CMS

Besides UN Regulation No. 46, there are some other UN Regulations which also affect the integration of a CMS into the vehicle. This section outlines other requirements that have to be taken into consideration within the development process to ensure product compliance with the relevant regulations.

### 4.1 *UN Regulation No. 10 (Electromagnetic Compatibility)*

UN Regulation No. 10 (see [26]) includes requirements regarding electromagnetic compatibility (EMC) i.e. emission of and immunity to electromagnetic radiation. As camera monitor systems are safety relevant electronic systems, their performance has to be resistant against magnetic or electrical fields. For that reason, UN Regulation No. 46 requires camera monitor systems to be in compliance with the technical requirements of Regulation No. 10.

### 4.2 *UN Regulation No. 21 (Interior Fittings)*

As explained in Sect. 3.2.1, UN Regulation No. 46 includes requirements to address, on the one hand, impacts of occupants on inside mounted devices for indirect vision (e.g. inside mirror Class I), and on the other hand, impacts of other road users (e.g. pedestrians) with outside mounted devices for indirect vision (e.g. outside mirror Class III). The impact requirement is verified with a dynamic pendulum test. UN Regulation No. 46 clarifies that monitors of a CMS are exempted

from the pendulum test, as long as the vehicle has an approval according to UN Regulation No. 21.

UN Regulation No. 21 (see [29]) establishes requirements for avoiding injuries that result from an occupant's physical impact on the interior fittings. The regulation is limited to vehicles of category M1 (passenger cars). While the inside rearview mirror is exempted from UN Regulation No. 21 (rationale: energy dissipation is already covered by the pendulum test of UN Regulation No. 46), the CMS' monitors are within the scope of the regulation and therefore need to be considered. UN Regulation No. 21 includes several requirements (e.g. projections' radius of curvature, hardness of materials and energy dissipation of materials) that are related to different head impact zones. Therefore whether and which requirements and tests are applicable for CMS monitors' cannot be answered in general terms. This depends on the position of the monitors in the interior of the vehicle.

As a consequence, the integration of the monitors needs careful evaluation in order to ensure that the relevant head impact requirements of UN Regulation No. 21 can be fulfilled.

#### ***4.3 UN Regulation No. 48 (Installation of Lighting and Light-Signaling Devices)***

UN Regulation No. 48 (see [35]) establishes requirements regarding the installation of lighting and light-signaling devices for vehicle of categories M and N, including their trailers (category O). The purpose of the regulation is to ensure, first, a minimum lighting of the road and, second, that a vehicle can be sufficiently recognized by other road users. For passenger cars (M1), the regulation requires e.g. the presence of two side direction indicator lamps. When installed on a vehicle, those lamps must comply with specific requirements on geometric visibility (angles) and photometry (illuminance). For some passenger cars, the side direction indicators are integrated into the housing of the outside mirrors (Class III). If mirrors are replaced by a CMS, the direction indicators need to be repositioned.

As a consequence, the repositioning of the direction indicators calls for careful evaluation in order to ensure that the relevant requirements of UN Regulation No. 48 are fulfilled.

#### ***4.4 UN Regulation No. 95 (Lateral Collision Protection)***

UN Regulation No. 95 affects CMS such that after the impact test "no interior device or component shall have sharp projections or jagged edges which noticeably increase the risk of occupants' injury" (source [36], p. 12). This requirement is relevant for the integration of the monitors into the vehicle interior.

## 4.5 UN Regulation No. 125 (Forward Field of Vision)

UN Regulation No. 125 (see [27]) makes provisions on the 180° driver's field of vision to the front and is limited to vehicles which belong to category M1 (typical passenger cars). The purpose of the regulation is to ensure a sufficient direct field of vision for the driver.

### *Current Text of the Regulation*

For the assessment of obstructions (e.g. caused by monitors) within the forward driver's field of vision, UN Regulation No. 125 defines

- three planes (to the front, left and right side) which start from eye point V2 and decline 4° to the horizontal
- a horizontal plane which starts from eye point V1

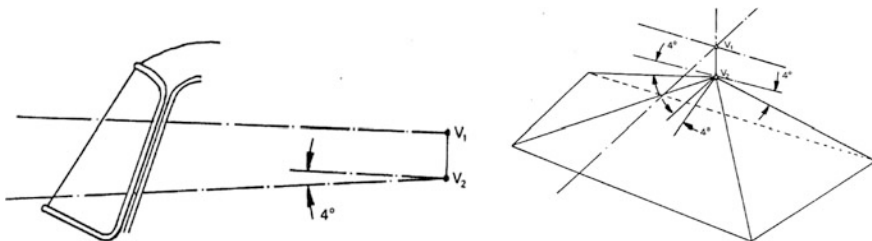
Between the 4° and the horizontal plane, no obstruction is allowed except for “A” pillars, vent window division bars, *rearview mirrors* and windscreen wipers (see Fig. 24).

As an alternative, UN Regulation No. 125 includes the option, that the conical projection of all obstructions (except for “A” pillars, vent window division bars, *rearview mirrors* and windscreen wipers) between the forward 4° plane and another plane, which declines 1° on a defined “area S” do not exceed more than 20 % of the total area S (see Fig. 25). This option only addresses obstructions that fall under the forward 4° plane. It cannot be applied for obstructions to the sides (e.g. upper edge of the doors).

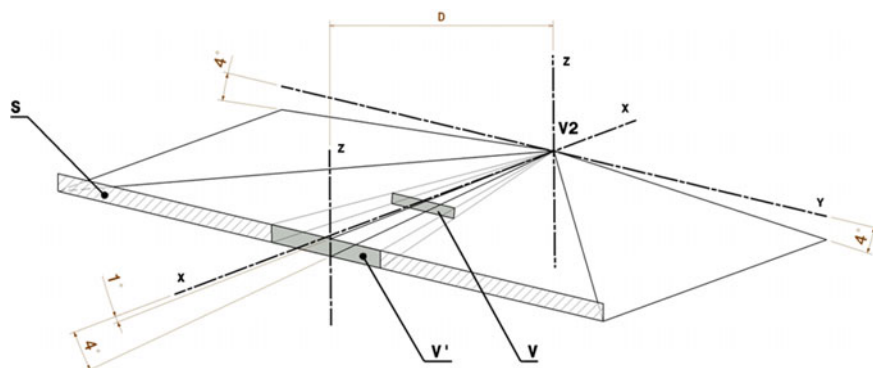
The current text of the regulation only excludes rearview mirrors from the obstruction requirement. Other devices for indirect vision such as CMS fall under this requirement. Regarding CMS, the above-mentioned requirements would impact the integration of the monitors inside the vehicle and the camera-holder which is mounted to the vehicle exterior.

### *Impact on the Monitor Integration*

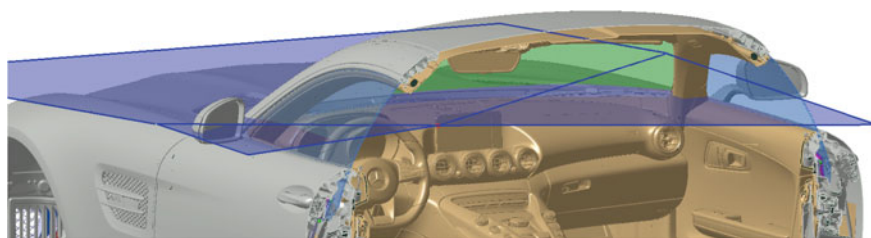
Figure 26 shows an example of where the 4° plane is located in a typical sports car. Due to the low seating position and the relatively high upper edges of the front door, it becomes obvious that the limited available space between dashboard and



**Fig. 24** Horizontal and 4° planes, source [27]



**Fig. 25** Conical projection of obstructions between the 4° and 1° plane on area S, source [27]



**Fig. 26** 4° planes at Mercedes-AMG GT (C190) (© Daimler AG)

those planes would not allow a reasonable integration of additional monitors for a CMS. The same applies for normal passenger cars.

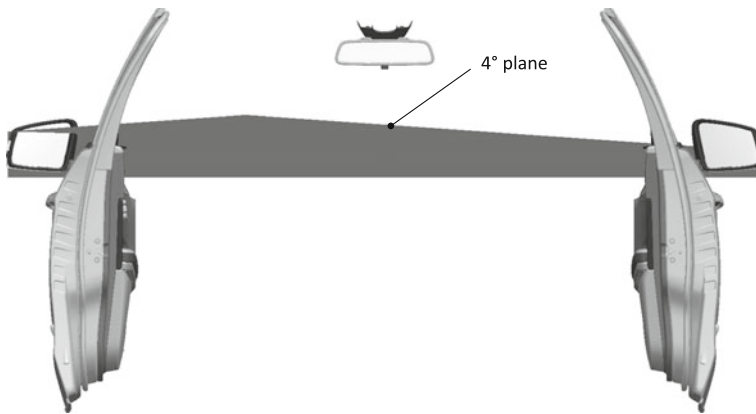
### ***Impact on the Camera Holder***

As mentioned above, rearview mirrors are exempted from the obstruction assessment. Figure 27 shows an example where the outside mirrors (Class III) of a typical passenger car are located in relation to the 4° planes which decline to the side of the vehicle. In order to fulfill the required field of vision, rearview mirrors (and as well cameras) need to be mounted in a certain height above the ground level. For that reason, the outside mirrors on both driver and passenger side usually intrude above the 4° plane.

### ***Amendment of Regulation No. 125 Towards CMS***

In parallel to the amendment of UN Regulation No 46, a proposal for amendment of UN Regulation No. 125 was prepared by the Informal Group Camera Monitor Systems to address the above-mentioned conflicts with CMS (see [28]).

As a result, “cameras including their holders and housings which are mounted to the vehicle exterior” (source [28]) were added to the list of exemptions for the obstruction assessment.



**Fig. 27** Location of the outside mirrors relative to the 4° plane at Mercedes-Benz E-class (W212) (© Daimler AG)

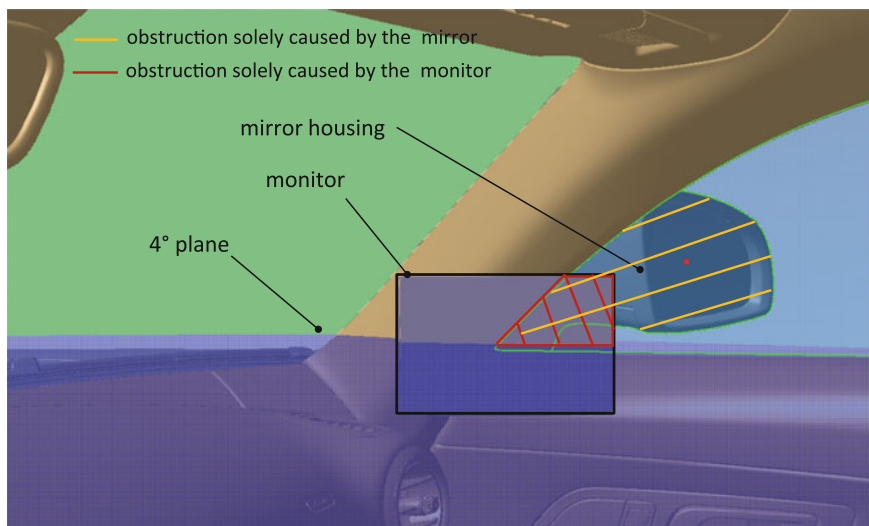
While a certain installation height for the camera is needed to secure the required field of vision, for which reason an exemption is necessary, a monitor could have been installed in such a way that it fulfills the requirement for obstructions. Therefore, it was not the intention to add the monitors of a CMS to the list of exemptions in order to ensure that a CMS serves to improve the driver's forward field of vision. Compared to the current rearview mirrors, no improvement in terms of obstruction would have been ensured otherwise.

However, Fig. 26 shows that the required position of the monitors has a fundamental impact on the interior vehicle design, including the dashboard. To realize a display configuration, which complies with the obstruction requirements of Regulation No. 125, completely new interior design concepts are essential which can only be addressed at the beginning of a vehicle development cycle. For existing vehicles or vehicles in development however, such elementary design concepts cannot be addressed. In order to promote and support the installation of CMS on such vehicles, the proposal for amendment of UN Regulation No. 125 introduces a temporary exemption of the monitors (envisaged to expire in September 2021) under the following conditions:

- The vehicle is standard equipped with approved conventional rearview mirrors
- The approved mirrors are optionally replaced by a CMS
- The level of obstruction of the CMS does not exceed the level of obstruction of the mirrors
- The position of the monitors is as close as practical to the position of the rearview mirrors that are replaced.

Figure 28 shows a schematic example comparing the obstruction of a mirror and of a CMS. The monitor intrudes into the 4° plane to the front and to the side. However, the level of obstruction to the driver's forward field of vision is still much lower compared to the obstruction caused by a standard outside mirror. The figure





**Fig. 28** Schematic comparison of the obstructions caused by a mirror and a monitor (© Daimler AG)

also illustrates the challenge to incorporate CMS monitors into current vehicle concepts in such a way that both ergonomic and design requirements are covered.

The proposal for the amendment of UN Regulation No. 125 (see [28]) was approved by GRSG in October 2015 and is likely to be adopted by WP.29 at its March session in 2016.

## 5 Conclusion and Future Activities

This final section will provide an overview of potential future activities on regulation and standardization of CMS.

### *Regulatory Activities in Other Regions*

The amendment of UN Regulation No. 46 (see [34]) was a first step on the way to introducing CMS on a wider scale. Although UN Regulation 46 has been adopted by a significant number of countries (see Annex B), there are still some important markets such as China and the USA that are not covered by it. In a first step, the replacement of mirrors by CMS will most likely remain an option which can be offered in markets that accept the CMS technology. In other markets the same vehicle will have to be equipped with rearview mirrors.

As most of the vehicle manufacturers are keen to sell their products on a global scale, rearview mirrors will remain predominant unless the regulatory framework is harmonized. Otherwise, both technologies would have to be applied during the

vehicle development phase, which is not economically feasible. Especially in Canada, China and in the USA, the issue must be addressed by regulatory activities. The regulatory development in other regions can benefit from the experience vehicle manufacturers will gain from the initial CMS applications, which are likely to be introduced in the UNECE market in the foreseeable future.

### ***Follow-Up Activities on UN Regulation No. 46***

The work on UN Regulation No. 46 is likely to be continued in the future. One possible working item could be Class VII CMS. Neither ISO 16505 nor UN Regulation No. 46 addresses Class VII CMS, which are for instance installed on motorbikes. Because the use-cases for motorbikes differ completely from those of other mirror classes, which among others, are installed on passenger cars or commercial vehicles, it seems reasonable that an ISO expert working group could conduct an initial analysis of individual safety needs for the application of Class VII devices. Based on the outcome, UN Regulation No. 46 can then be modified.

Another issue that calls for a reassessment is the arrangement of monitors as defined by UN Regulation No. 46. This regulation prohibits monitors that are installed in the center of the vehicle and enable the driver to capture both left and right side field of vision. Studies (e.g. [3]) conducted so far have focused on monitor positions similar to those of rearview mirrors to the right and left side of the driver's ocular reference point. For the reassessment, studies to analyze the suitability and acceptance of central monitor arrangements are needed. Because both technologies will be available on the market and car users may switch between cars equipped with either mirrors or CMS, it seems necessary to evaluate if drivers are able to adapt their driving behavior to different arrangements of monitors and mirrors when changing from one type of vehicle to another.

A third issue to be considered is the requirement for overlays. UN Regulation No. 46 defines any overlays as an obstruction in the driver's field of vision, regardless of their transparency. Due to the fact such obstructions are restricted and include obstructions of other parts like bodywork and door handles, the possibilities for the implementation of overlays are rather limited. It would therefore be necessary to evaluate to what extent an overlay with a certain transparency is a de facto negative obstruction in the field of vision, or rather a supporting element that helps the driver to maneuver and drive safely, without limiting the driver's perception in the required field of vision.

### ***Other Relevant Regulations***

Section 4 gave an overview of other UN Regulations which have an impact on the integration of CMS into a vehicle. In this context, the importance of UN Regulation No. 125 regarding the installation of monitors was highlighted. The amendment proposal (see [28]) excludes camera holders and cameras from the forward field of vision requirements. Furthermore, a temporary exemption was added to ease the integration of monitors, provided that their obstruction of the driver's forward field of vision does not exceed the obstruction due to standard rearview mirrors that are replaced. It should be noted, that other countries such as China (see [22]), India

(see [2]) and South Korea (see [13]) have established their own national regulations for the forward field of vision of the driver. However, their requirements were carried-over in the past from UN Regulation No. 125. As a consequence, these regulations need to be updated according to the envisaged amendment of UN Regulation No. 125 (see [28]).

**Future Revision of ISO 16505**

The content of ISO standards needs to be reviewed after a maximum period of 5 years in order to clarify whether the standards still reflect the state of the art (see Sect. 1.2). As explained in Sect. 3, there are some differences between ISO 16505 and the amended UN Regulation No. 46. Some new requirements and test methods (e.g. point light sources) are included in UN Regulation No. 46. At the occasion of the next review of ISO 16505, the experts can have a closer look at the differences in order to work out potential harmonization aspects for both documents.

**Annex A**

See Table 7. **Table 7** Countries parties to the 1958 agreement\*, source [38], pp. 39–40

ECE symbols	Contracting parties	Date of adhesion
E1	Germany <sup>1</sup>	28.01.1966
E2	France	20.06.1959
E3	Italy	26.04.1963
E4	Netherlands	29.08.1960
E5	Sweden	20.06.1959
E6	Belgium	05.09.1959
E7	Hungary	02.07.1960
E8	Czech Republic <sup>3</sup>	01.01.1993
E9	Spain	10.10.1961
E10	Serbia <sup>10</sup>	12.03.2001
E11	United Kingdom	16.03.1963
E12	Austria	11.05.1971
E13	Luxembourg	12.12.1971
E14	Switzerland	28.08.1973
E16	Norway	04.04.1975
E17	Finland	17.09.1976
E18	Denmark	20.12.1976
E19	Romania	21.02.1977
E20	Poland	13.03.1979
E21	Portugal	28.03.1980
E22	Russian Federation	17.02.1987
E23	Greece	05.12.1992

(continued)

**Table 7** (continued)

ECE symbols	Contracting parties	Date of adhesion
E24	Ireland <sup>9</sup>	24.03.1998
E25	Croatia <sup>5,15</sup>	08.10.1991
E26	Slovenia <sup>2</sup>	25.06.1991
E27	Slovakia <sup>4</sup>	01.01.1993
E28	Belarus	02.07.1995
E29	Estonia	01.05.1995
E31	Bosnia and Herzegovina <sup>6</sup>	06.03.1992
E32	Latvia	18.01.1999
E34	Bulgaria	21.01.2000
E35	Kazakhstan	08.01.2011
E36	Lithuania	29.03.2002
E37	Turkey	27.02.1996
E39	Azerbaijan	14.06.2002
E40	The Former Yugoslav Republic of Macedonia <sup>7</sup>	17.11.1991
E42	European Union <sup>8</sup>	24.03.1998
E43	Japan	24.11.1998
E45	Australia	25.04.2000
E46	Ukraine	30.06.2000
E47	South Africa	17.06.2001
E48	New Zealand	26.01.2002
E49	Cyprus <sup>11</sup>	01.05.2004
E50	Malta <sup>11</sup>	01.05.2004
E51	Republic of Korea	31.12.2004
E52	Malaysia <sup>12</sup>	04.04.2006
E53	Thailand <sup>13</sup>	01.05.2006
E54	Albania	05.11.2011
E56	Montenegro <sup>14</sup>	03.06.2006
E58	Tunisia	01.01.2008
E60	Georgia	25.05.2015
E62	Egypt	03.02.2013

\*A daily updated list of the Contracting Parties to the Agreement is available at: [http://www.unece.org/trans/conventn/agreem\\_cp.html#18](http://www.unece.org/trans/conventn/agreem_cp.html#18)

<sup>1</sup>Effective 3 October 1990, the German Democratic Republic acceded to the Federal Republic of Germany

<sup>2</sup>Succession to Yugoslavia, Depositary notification C.N.439.1992.TREATIES-53 of 18 Mar 1993

<sup>3</sup>Succession to Czechoslovakia, Depositary notification C.N.229.1993.TREATIES of 14 December 1993

<sup>4</sup>Succession to Czechoslovakia, Depositary notification C.N.184.1993.TREATIES, received on 20 July 1994

<sup>5</sup>Succession to Yugoslavia, Depositary notification C.N.66.1994.TREATIES-10 of 31 May 1994

<sup>6</sup>Succession to Yugoslavia, Depositary notification C.N.35.1994.TREATIES of 2 May 1994

<sup>7</sup>Succession to Yugoslavia, Depositary notification C.N.142.1998.TREATIES-33 dated 4 May 1998

<sup>8</sup>Approvals are granted by its Member States using their respective ECE symbol

<sup>9</sup>Not Contracting Party to the Agreement, but by virtue of accession to the Agreement by the European Union on 24 March 1998, Ireland applies the same UN Regulations than the European Union

<sup>10</sup>Succession to Yugoslavia, Depositary notification C.N.276.2001.TREATIES-3 dated 2 April 2001

<sup>11</sup>Not Contracting Parties to the Agreement, but by virtue of accession to the Agreement by the European Union on 1 May 2004, Cyprus and Malta apply the same UN Regulations than the European Union

<sup>12</sup>Not bound by Article 10 of the Agreement

<sup>13</sup>Not bound by any of the UN Regulations, nor by Article 10 of the Agreement

<sup>14</sup>Succession to Yugoslavia, Depositary Notification C.N.1346.2006.TREATIES-3 dated 1 Mar 2007

<sup>15</sup>By virtue of accession to the European Union on 1 July 2013, Croatia applies the same UN Regulations than the European Union

## Annex B

See Table 8. **Table 8** Signatories of UN Regulation No. 46, *source* [38], p. 89

ECE symbols	Contracting parties	Date of application
E1	Germany	20.04.1986
E2	France	01.09.1981
E3	Italy	01.09.1981
E4	Netherlands	04.12.1987
E5	Sweden	24.09.1982
E6	Belgium	16.10.1982
E7	Hungary	26.03.1984
E8	Czech Republic	18.09.1982
E9	Spain	24.03.1989
E10	Serbia	18.05.2008
E11	United Kingdom	27.04.1990
E12	Austria	23.07.1990
E13	Luxembourg	01.10.1983
E14	Switzerland	not yet signed
E16	Norway	24.05.1993
E17	Finland	10.08.1982
E18	Denmark <sup>1</sup>	24.03.1998
E19	Romania	03.02.1984
E20	Poland	03.06.1990
E21	Portugal <sup>1</sup>	24.03.1998
E22	Russian Federation	06.03.1988
E23	Greece	03.12.1995

(continued)

**Table 7** (continued)

ECE symbols	Contracting parties	Date of application
E24	Ireland <sup>1</sup>	24.03.1998
E25	Croatia	03.04.2001
E26	Slovenia	01.10.1994
E27	Slovakia	18.09.1982
E28	Belarus	02.07.1995
E29	Estonia	25.07.1999
E31	Bosnia and Herzegovina	not yet signed
E32	Latvia	18.01.1999
E34	Bulgaria <sup>4</sup>	01.01.2007
E35	Kazakhstan	not yet signed
E36	Lithuania	29.03.2002
E37	Turkey	07.07.2000
E39	Azerbaijan	not yet signed
E40	The Former Yugoslav Republic of Macedonia <sup>7</sup>	19.08.2002
E42	European Union <sup>2</sup>	24.03.1998
E43	Japan	not yet signed
E45	Australia	not yet signed
E46	Ukraine	08.10.2002
E47	South Africa	17.06.2001
E48	New Zealand	19.03.2002
E49	Cyprus <sup>3</sup>	01.05.2004
E50	Malta <sup>3</sup>	01.05.2004
E51	Republic of Korea	not yet signed
E52	Malaysia	04.04.2006
E53	Thailand	not yet signed
E54	Albania	05.11.2011
E56	Montenegro	not yet signed
E58	Tunisia	not yet signed
E60	Georgia	25.05.2015
E62	Egypt	03.02.2013

<sup>1</sup>By virtue of accession to the Agreement by the European Union

<sup>2</sup>Approvals are granted by its Member States using their respective ECE symbol

<sup>3</sup>By virtue of accession to the European Union on 1 May 2004

<sup>4</sup>By virtue of accession to the European Union on 1 January 2007

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