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## APPLICATION OF CHANGEABLE MESSAGE SIGNS IN TRAFFIC

### ABSTRACT

*In the Republic of Croatia, changeable message signs are being introduced on high-serviceability roads in order to improve the flow management in the network and increase the traffic safety level. The equipment installed in the past was not set according to the unique criteria, thus resulting in the installation of relatively incompatible equipment set in a disorganised manner. The work presents the basic guidelines in applying changeable message signs, primarily on the Croatian motorways. The types and levels of influence on the traffic are described, and the traffic and weather criteria for the application of changeable message signs are defined. The paper also analyses the principles of installing the changeable message signs on roads and road facilities, recommending priorities in presenting the changeable signs.*

### KEY WORDS

*road traffic, changeable message signs, traffic safety, installation criteria*

### 1. INTRODUCTION

The static traffic signs provide drivers with all the information, vehicle movement restrictions and instructions, as well as other data, offering the majority of traffic information that a driver needs to receive. However, there are special cases when additional timely information about the condition of the traffic flow and meteorological conditions on the road are necessary. Such situations, which are not of a continuous nature, i.e. they occur during the day, week or season, can be presented by changeable traffic message signs (further in the text CMS).

In the Republic of Croatia, over the recent ten years, CMSs are being introduced, i.e. intelligent transport systems which involve interaction between the road users and the authorities managing the traffic flows. Since CMSs represent part of the information system, recommendations had to be developed in order to define such a system.

It is precisely the aim of this paper to present the possibilities of applying CMSs, primarily on the state roads (motorways, high-speed roads) and on other roads as well. The paper also intends to present the previous foreign and national experiences in applying the CMS technology and to provide the traffic and other planners with sufficient information in order to simplify the planning regarding installation of CMSs. The data would also be used by the investors into the facilities and the engineers involved in the maintenance of the system. The goal is also to determine the criteria and the principles for installing CMSs, in order to achieve unique approach to planning and designing of CMSs in the Republic of Croatia.

### 2. GOALS OF INSTALLING CHANGEABLE MESSAGE SIGNS

Goals of installing CMS are of dual nature: they warn the drivers of the road conditions and environmental conditions, that is, of traffic and meteorological conditions on the road and they increase the traffic safety level. They also provide high-quality and timely information about the traffic flow, i.e. the necessary actions that drivers need to undertake so as to simplify the choice of the desired destinations. Additional goals include reduced fuel consumption and reduced negative impact of traffic on the environment.

Timely information about the significant traffic events plays a very important role in increasing the traffic safety and control of traffic flows, especially of those on motorways where traffic flows move at high speeds. Apart from timely information about traffic flow conditions and weather conditions on the road, the information has to be visible, recognisable, short and unambiguous.

Advanced management systems, including also the changeable message signs as their components, provide the possibility of influencing the behaviour of drivers on the roads, i.e. of providing timely deci-

sion-making and implementation of traffic strategy which would currently result in the best response to the traffic flow. Their impact can most generally be divided into CMS systems that act on the network, part of section, interregional intersection or a short section (place).

CMSs in Western Europe are used, first of all, on interurban roads, i.e. out-of-town motorways, with the aim of informing the drivers about road and environmental conditions.

In the USA, CMSs have been applied on the motorways for more than 40 years. The first CMSs were huge, and the messages were changed by inserting the information boards, as sign elements, into the housing grooves. Subsequent technology consisted of rotational prisms and flexible strips, and such CMSs had to possibility of presenting a very limited number of messages.

In the Republic of Croatia the CMSs have been installed at selected parts of the motorways and motorway facilities in order to increase safety in the traffic flows, and in order to divert the traffic flows to state and county roads when motorway sections are closed for certain reasons or in case they are still incomplete. The installation of CMSs has not been performed according to unique criteria and some sections have been therefore left unequipped.

The common characteristic of the installed devices lies in the relative incompatibility, in lack of consistency while installing the equipment, which was installed according to German directives and adopted European standards.

### 3. CHANGEABLE MESSAGE SIGNS

CMSs can be designed by means of several *technologies*, i.e. in the form of rotating lamellas, rotating prisms, movable tapes, optical fibres (fibre-optics), illuminated fields added to regular signs, light-emitting diode (LED) and liquid crystal displays (LCD), whereas technologies based on lasers (laser scan) and holographs are still being tested. Basically, CMSs can be divided into two basic groups.

- a) *continuous signs* (retroreflective and with illuminated background), i.e. signs with continuous display. This is a CMS composed of solid letters or symbols. The only way of changing the details on the front of the sign is to either remove one series of symbols/letters and replace these by others, or to have multiple surfaces that can be rotated (e.g. rotating prisms);
- b) *non-continuous signs*, that is, signs with non-continuous display are CMSs whose front surface is composed of individual elements which can have at least two statuses. By changing the status of single

elements various designs of letters and symbols on the same surface can be achieved (e.g. symbol designed in LED technology).

This means that CMSs should be distinguished according to the design between those with completely mechanical change and the CMSs with active luminous traffic symbols.

The CMSs with mechanical change can represent all traffic signs of original forms and colours and in any size.

For active luminous CMSs the design is applied according to the principle of luminous screen and the traffic sign is composed of single pixels. As a rule, the signs with luminous screen are produced by means of optic fibres or LED technology. The contents of the traffic signs (depending on the light technology) on the active luminous CMSs have to be represented in negative. The coloured parts of the traffic signs are then represented in precise colours.

The message is also important, and it influences the quality of information transfer, since clarity, length and form of message are the basic elements that determine the reading time.

Research has shown that the average reading time of one shorter word written on CMS (for drivers not used to this type of signalling) is one second.

When CMSs are designed as continuous signs (rotating lamellas, rotating prisms), the content of the front panel changes by the rotation of multiple surfaces. The basic state is called also the zero state. Generally, the signs with continuous display of messages have limited display possibilities. They are usually designed so that they provide the possibility of presenting up to three messages.

By changing the status of single elements, the non-continuous signs (designed by the optic fibre technology, light emitting diodes) can display a greater number of messages (usually up to 16). If they are designed using liquid crystals, the number of messages (i.e. displays) is limited by the installed software. In the additional part of the CMS it is possible to display five to seven characters (e.g. 15 °C, ↑ 2 km ↑, 70 km/h etc.). The CMSs are set so that they meet the visibility requirements.

The traffic-information system controls the CMSs. This is a distributive management system, which means that the management logic is distributed to remote stations or substations, which can thus operate autonomously on the basis of the gathered input data. The master centres, remote stations and substations communicate through the local communication network.

Each remote station (substation) has to operate autonomously, which is important in case when there is error in communication with the centre or other stations. Remote stations and substations are linked to

the systems for measuring traffic flow characteristics and for measuring the data on weather conditions as well as with the automatic system for video control and traffic analysis and the CMSs. The data on traffic and weather conditions are obtained by means of a sensor, measuring probes and other devices.

#### **4. CHANGEABLE MESSAGE SIGNS IN CONTROL AND SAFE PERFORMANCE OF TRAFFIC FLOWS ON MOTORWAYS**

According to the field of operation, CMSs can influence the traffic network of a certain zone range, interregional intersections, parts of sections, and short sections of motorways (places). Figure 1 shows all the levels affecting the traffic.

##### **4.1. Influence of the changeable message signs on the network**

The CMSs which influence the network are used in order to distribute the traffic optimally to the available routes in a certain network. The changeable signposts can organise and direct the vehicles avoiding the congestion points, i.e. in case of need, alternative routes can be recommended to the traffic participants supplying additional explanatory information.

Such CMSs are suitable at places where there is great possibility of saturation on the main road (e.g. emphasised frequency of congestion and queuing hours per year). Therefore, the capacities on the alternative route have to be available in the foreseeable future, suitable situation for detour has to be provided, along with a satisfactory high-share of traffic that can be diverted (transit traffic).

Diverting of traffic may be undertaken due to a closed road (when there is no possibility of diverting traffic from one roadway to another), the whole section, bridge, tunnel (e.g. when one tunnel tube is constructed and is closed) as well as because of congestion.

##### **4.2. Influence of changeable message signs on the interregional intersection**

The devices affecting the interregional intersection should improve the flow of traffic and increase safety on a certain interregional intersection. CMS at the intersection is set in order to maintain the continuity in the main traffic flow and to make merging of the incoming flows into the intersection easier.

In order to maintain the continuity of the main traffic flow and to improve the connecting of incoming

flows, the CMSs are used to control the flows at the approach to the motorway.

For easier merging of incoming flows into the intersection, depending on the traffic, speed limit signs are installed on the main flow which maintains the continuity of the passage through the intersection.

In case of the situation when traffic flows vary regarding the intensity (the main traffic flow becomes secondary, and vice versa), the main traffic flow may be assigned traffic lanes in order to maintain the main flow.

##### **4.3. Influence of changeable message signs on parts of sections**

The CMSs that influence the driving conditions on a motorway section, serve to achieve increase in the traffic safety and to improve the traffic flow by arranging the CMSs along a part of the section, i.e. the motorists are subjected to the influence of messages about dangers and providing instructions.

As a rule, the influence on a part of the section (parts without facilities, bridges, viaducts, tunnels and all the intersections except the interregional ones), can refer to the speed limit, ban on overtaking, warning of congestion, warning of special dangers (traffic accident, road works, etc.), warning of danger due to weather conditions (fog, wet or slippery road, wind) and the obligatory traffic lane / closing of a traffic lane.

The preconditions for installing the CMSs on the motorway sections are realised in case of an above-average number of traffic accidents, above-average traffic density causing frequent and severe standstills, i.e. when on a certain part of the section an above-average number of traffic accidents occurs caused by weather conditions or potential danger (e.g. due to fog).

For the influence on a section the CMSs are used to warn of congestion, and they are suitable for short-term to mid-term use - e.g. in front of the road works.

In case of a traffic accident and a closed roadway, it is possible to maintain the continuity in the traffic control by reducing the speed limit and diverting traffic to another roadway. On road sections with bridges and viaducts, by monitoring the current weather situation and forecast of the environmental and road conditions, it is possible to warn the users of the increased danger due to slippery roadway. Also, by monitoring the traffic situation in tunnels, the CMSs can help in safer control of traffic flows through tunnels. If justified, the introduction of CMSs at intersections can influence the speeds of vehicles passing the intersection. Information can also be provided related to the roadway condition. The influence of CMSs on the section is achieved by the CMSs that are set at entrances into the zone of obstructions of traffic flows as well as by

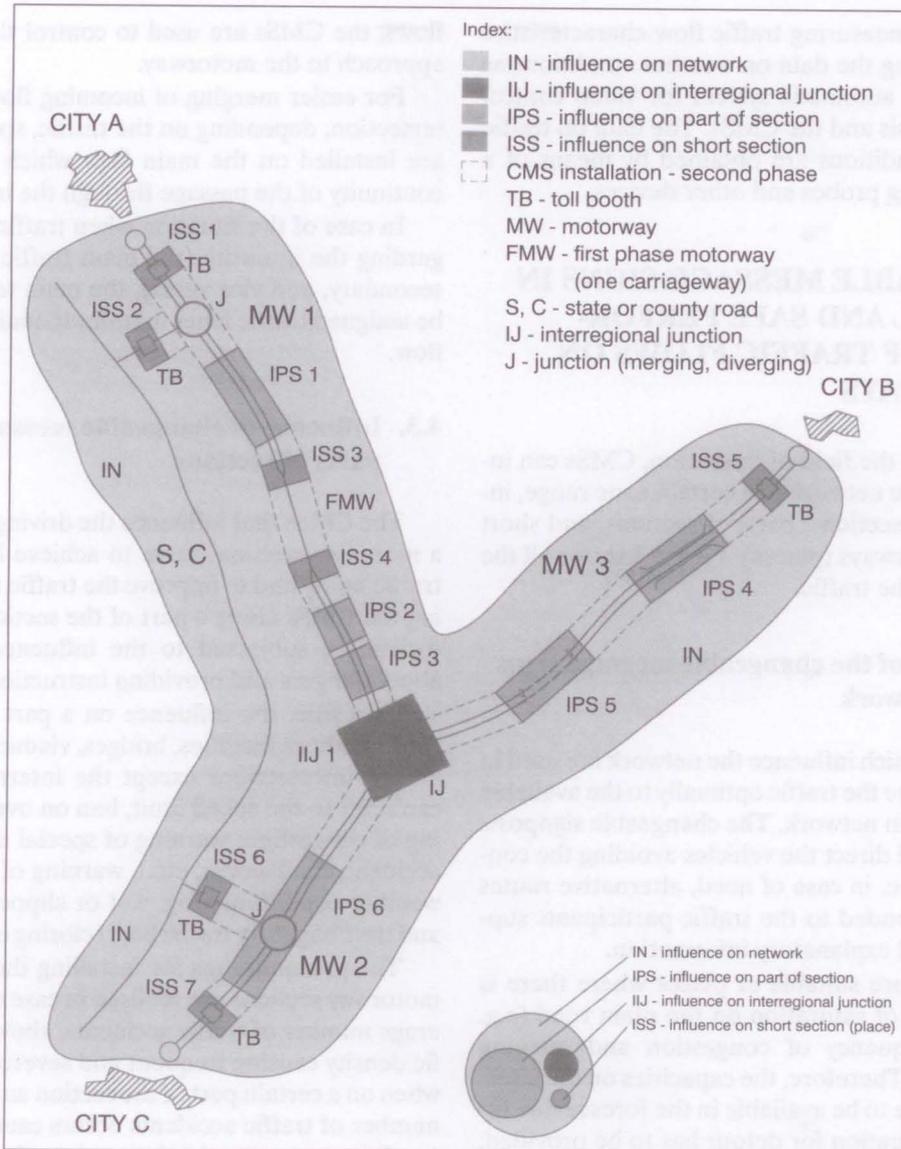


Figure 1

CMSs that inform about the termination of these zones of obstructions.

The CMSs that influence the parts of sections include also the devices for alternate regulation of traffic directions (applied in towns).

#### 4.4. Influence of changeable message signs on a short section (place)

Changeable signs can affect also very short sections of the motorway /places/ (or lower serviceability roads) which are not defined as parts of sections and as a rule the CMS-affected zones are smaller than 250 m.

The systems that influence short sections are intentionally set at places with frequent occurrence of accidents, which cannot be reconstructed by other measures (e.g. warning of overspeeding before narrow

curves or upon entering inhabited areas, using the devices that display speed limits) or at places where the microclimate is such that this kind of influence on the traffic is preferable, i.e. at other dangerous places.

### 5. CRITERIA AND PRINCIPLES OF APPLYING CHANGEABLE MESSAGE SIGNS

From the economy point of view, the installation of CMSs should be restricted to those areas where, based on local conditions (traffic and meteorological), quantitatively and qualitatively satisfying effects may be expected. Attention should be paid to a reasonable benefit-cost ratio (investment and operational).

### 5.1. Visibility criteria for installing changeable message signs

CMS is installed at a location where it is visible so that it is easily identified and read by the drivers (vertical and horizontal visibility of the traffic sign must be insured). CMS must be located so that the drivers, after perceiving the sign and understanding the message, have enough time to change the direction, i.e. enough time to prepare and react according to the sign instruction.

As a rule, the CMSs outside the closed inhabited areas have to be visible from a distance of 200 m and at this distance it must be visible whether it is a sign of instruction, signpost or danger. The essential contents of CMSs, such as e.g. type of instruction, danger or recommendation i.e. information have to be unambiguously recognisable (legible) from a distance of at least 150 m.

On the roads outside inhabited areas the signs should be designed and set so that their messages for motor vehicle drivers are visible up to a distance of 35 m from the location of installation, before it becomes invisible due to the angle of view.

### 5.2. Traffic and weather criteria for installing changeable message signs

The study of conditions of traffic flows and the traffic structure, as well as conditions present in the road environment results in the correct selection of the type of influence on the traffic and on the influence scope i.e. location (section, bridge, tunnel, intersection, critical spot, etc.).

The analysis of the data (design documentation, available studies) is used to decide which measure (or several measures) of influencing the traffic will be applied, i.e. whether the CMSs will be introduced in phases. The introduction of influencing the network is most certainly the primary measure, since it may divert the flows to alternative roads. However, all the types of influences on traffic have to comply with the visibility criteria and the traffic and meteorological criteria.

For the influence of CMSs in the network, the traffic criterion is completely satisfied, so that the meteorological criterion is not considered. For the application of this measure, continuous and non-continuous CMSs are used, that are set at intersections of interregional and regional significance as well as all the other intersections.

The influence of CMSs on the intersection means the control of the main and secondary traffic flows at interregional intersections when the flows have to be harmonised due to the traffic intensity. The interregional intersection is the intersection of two or

more European routes, and therefore it needs to be equipped by CMSs of continuous and non-continuous types.

The traffic safety is increased and the traffic flow at sections improved by the influence of CMSs by means of non-continuous signs on the parts of sections displaying signs of dangers and instructions, as well as the additional information (e.g. distance from standstill, wind speed, warning of fog, etc.).

Part of the motorway section means an open section (without any facilities), part of motorway section with a facility (such as a bridge, viaduct, tunnel) or section which includes also an intersection (i.e. merging and diverging lanes).

If CMSs are installed in phases, then the section that satisfies simultaneously several criteria has the priority.

Just one of the traffic or meteorological criteria needs to be satisfied for the application of CMSs. The traffic criteria include: the traffic flow which has reached 40% of the service capacity, frequent congestions (level of service is often D, E, and F), difficult merging (or diverging) of traffic at sections including intersections, frequent accidents, the share of heavy cargo traffic exceeding 25% of total traffic, the roadway has the third lane for slow vehicles, i.e. longitudinal gradient is greater than 3.6%, the length of single objects (bridge, viaduct) is greater than 250 m or there are two or more objects of smaller length but following each other at a distance of up to 1000 m, the traffic is slowed down due to road works, slowing down of traffic in order to reduce noise (if this is the optimum solution during seasons), roadway in longitudinal gradient is  $>3\%$  along with the share of cargo traffic greater than 15%, or the length of the tunnel exceeds 500 m.

The meteorological criteria include: frequent occurrence of lateral gusts of wind, frequent fog, i.e. reduced visibility, the section may be in the zone of frequent precipitation (rain, snow), or it may be in the zone of frequent occurrence of ice on the roadway, or the CO concentration in tunnel may exceed the allowed level.

The CMSs influencing the short section (place) act intentionally at places where the traffic safety is to be improved, i.e. information provided for the drivers by means of non-continuous CMSs. Such a system can act autonomously. The system can be set at places such as border crossings, sites of road works, dangerous points (facilities shorter than 250 m), toll booths at motorways, whereas C/B analyses need to be made for other places. The meteorological criterion is satisfied when the micro-climate is essentially different from the micro-climate of a wider zone through which the road is passing.

## 6. PRINCIPLES FOR INSTALLING CHANGEABLE MESSAGE SIGNS ON MOTORWAYS AND HIGH-LEVEL SERVICEABILITY ROADS

### 6.1. Network management

CMSs of continuous type influencing the network, are installed 250 m before intersections and at the beginning of the diverging lanes. At a distance of 250 m, the continuous CMSs are mounted on a portal, and at the beginning of the diverging lanes they are mounted on a console at the tip of the dividing island. Partial CMSs can be mounted also at a distance of 1000 and 500 m before the intersection.

The continuous CMSs need to be set also on alternative roads, to which the traffic flows may be diverted in case of stopping the traffic on the motorway. The aim is to prevent traffic from entering the motorway in case it is not functioning.

Non-continuous CMSs are set at about 750 m before the intersection and immediately after the intersection. In case of grade-separated intersections, the influence on the part of the section is for both traffic flows.

Setting of CMSs at the intersections themselves, in order to influence the traffic there, has sense only in case of interregional intersections, i.e. only in the situation when intensive main traffic flows need to be let through, so that the secondary flows are let through at the set time intervals. Such cases are rare and these usually occur at very heavy transit routes during the seasonal variations of traffic flows (e.g. during the summer tourist shifts). The interregional intersections are fitted with continuous and non-continuous changeable traffic signs immediately, in the first phase. All other intersections (places where traffic merges and diverges, at-grade intersections) are subject to considering the influence on the sections.

### 6.2. Road section management

The minimum length of the motorway that is to be influenced at parts of sections is 2000 m (except in case when the intersection is included, the distance is 1000 m). Non-continuous signs are installed on portals, which should be located near the removable barrier, so that the traffic, if necessary, could be diverted to an operating roadway. On sections that have a third lane for slow vehicles, the speed limit should be 80 and 60 km/h.

Non-continuous signs are used at motorway bridges and viaducts. They are set on a portal, which is mounted at least 250 m from the object. The length of the object should be greater than 250 m in order to apply this type of influence. The deviation from this

value is possible in case when the object is surrounded by such micro-climate that the installation of CMSs represents a must.

Semi-motorways and fast roads which include bridges (viaducts) of lengths less than 250 m, are fitted with double CMS set on an independent post, whereas the longer objects the CMSs are mounted on a portal. They may be equipped also with additional boards.

If there are two or more objects of lengths less than 250 m, and at a distance of up to 1000 m, they may be understood as parts of sections and equipped with CMSs, i.e. it is possible to influence the traffic along the whole length considered.

The traffic flow management at sections containing tunnels, consists in previous influence on the traffic before entering the tunnel and of the influence of traffic within the tunnel tube, for the tunnels of 500 m and more in length. The speed limit CMS, as a preceding measure, is set at 200 to 250 m before the tunnel portal. In specific situations, the CMSs can be additionally set also at portal supporter with other messages 750 m before the tunnel portal. The traffic lights, SOS system and other systems must be connected into an integral control system.

If the section includes the intersection, it is fitted with CMSs of non-continuous type. Thus, the CMSs influence the main traffic flow and the flow diverging from i.e. merging into the motorway. By reducing the speed of the main flow, the merging of secondary flows may be made easier.

At times of seasonal traffic shifts (e.g. weekends) the CMSs can be used to reduce the speed of the main transit flows in urban areas where night noise is emphasised.

The aim of controlling CMSs on short sections (places) on motorways lies in the increase of the traffic safety level. The control of the short section can be connected to the traffic - information system or it can be autonomous, and can be applied on motorways and other roads.

On motorways it is applied at tollbooths, at border crossings, and on dangerous spots (zones in length of up to 250 m) and on other roads. When it is applied as autonomous CMS which influences a dangerous spot, the information in the additional board needs to determine the part of the section to which the sign is to be applied. It is applied more on other roads, as a measure of calming down traffic or warning of danger on the road, in case of dangerous curves, etc.

## 7. PRIORITIES IN PRESENTING CHANGEABLE MESSAGE SIGNS

The priorities in presenting certain traffic signs should always be determined according to the level of

danger. When several criteria are satisfied at the same time, the situation is included with the lowest vehicle speed limits. In case when two or more situations that

have the same speed limit are simultaneously met, the traffic sign is presented which describes the more dangerous situation.

**Table 1 - Priorities in presenting traffic situations**

HIGH PRIORITY ↓	
including speed limit (100, 80, 60 and 40 km/h)	closing down of a lane
	vehicle changing lanes
	incident
	congestion – queue of vehicles
	internal combustion engine
	fog
	road works
	slippery roadway
	no overtaking for heavy vehicles
	no overtaking for all vehicles
	wind
	all restrictions removed
opened traffic lane	
LOW PRIORITY ↑	

In developing a traffic solution it is necessary to pay attention to whether these restrictions refer to one or both directions. Other traffic signals (in the first place permanent vertical traffic signalling) have to be, in the regulative sense, in compliance with the CMSs. The selection of priorities is presented in Table 1.

The signs can be equipped with additional changeable sub-panels, which describe the danger in more detail. The message of the additional changeable board can contain information, namely, after how many kilometres danger may be expected or what is the length that may represent a dangerous section. Other information may be provided as well, related to the temperature of the roadway, air, wind speed and similar information.

## 8. CONCLUSION

In the world the CMSs have been applied on higher-serviceability roads for more than 40 years.

**Table 2 - Possible vehicle speed limits regarding traffic and weather criteria**

Traffic and weather conditions	Name	Criterion	Speed limit
		traffic	
Queue of vehicles	Congestion 1	28-30 veh/km	100
	Congestion 2	31-39 veh/km	80
	Congestion 3	40-44 veh/km	60
	Congestion 4	> 44 veh/km	40
weather			
ice	ice	water layer > 0,1 mm i °C roadway ≤ °C freezing point	60, 40
fog	FOG 1	190 m ≤ visibility < 290 m	100
	FOG 2	120 m ≤ visibility < 190 m	80
	FOG 3	70 m ≤ visibility < 120 m	60
	FOG 4	visibility < 70 m	40
slippery roadway	WET 1	0,1 mm ≤ water layer < 0,2 mm	100
	WET 2	0,2 mm ≤ water layer < 0,4 mm	80
	WET 3	0,4 mm ≤ water layer < 0,7 mm	60
	WET 4	0,7 mm ≤ water layer	40
	SNOW 1	snow level < 50 mm	60
	SNOW 2	50 mm ≤ snow level	40
wind	WIND 1	10 m/s ≤ wind speed < 12 m/s	100
	WIND 2	12 m/s ≤ wind speed < 14 m/s	80
	WIND 3	14 m/s ≤ wind speed < 16 m/s	60
	WIND 4	16 m/s ≤ wind speed	40

Continuous and non-continuous signs are used, i.e. CMS with mechanical variations and the CMSs with active luminous symbols. In the Republic of Croatia the CMSs have started to be installed some ten years ago, based on foreign experience and guidelines. Because of the specific characteristics of motorways in the Republic of Croatia the criteria and principles for setting CMSs in Croatia have been proposed.

The application of CMSs insures undisturbed traffic flows on the road network and increases the level of traffic safety. The CMSs influence the control of flows in the network, interregional intersections, parts of sections and short sections (places).

The setting of CMSs needs to be the result of a traffic project, i.e. it is necessary to carry out the planning steps: gather data about the road that is to be equipped in order to influence the traffic, ensure visibility of the CMSs, determine whether traffic and meteorological criteria for CMS installation are satisfied, and select the type of influence exerted on traffic. The phases of installing the CMSs need to be developed as well, and all these elements need then to be connected into a unique system. The final steps in planning and installing the CMSs lie in starting the operation, system control and system maintenance.

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#### SAŽETAK

#### PRIMJENA PROMJENLJIVIH PROMETNIH ZNAKOVA

*U Republici Hrvatskoj, na cestama visoke razine uslužnosti uvode se promjenljivi prometni znakovi, kako bi se poboljšalo vođenje tokova u mreži i povećala razina sigurnosti prometa. Do sada ugrađena oprema nije postavljena prema jedinstvenim kriterijima, već su se koristila strana, i stečena domaća iskustva. Posljedica toga je ugrađnja međusobno relativno*

*nekompatibilne opreme koja je neplanski postavljena. U radu su prikazane osnovne smjernice za primjenu promjenljivih znakova, u prvome redu na hrvatskim autocestama. Opisane su vrste i razine utjecaja na promet te definirani prometni i meteorološki kriteriji za primjenu promjenljivih znakova. Razrađeni su principi postavljanja promjenljivih prometnih znakova na cestama i cestovnim objektima i preporučeni su prioriteta u prikazivanju promjenljivih znakova.*

#### KLJUČNE RIJEČI

*cestovni promet, promjenljivi prometni znakovi, sigurnost prometa, kriteriji postavljanja*

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