Abstract: In the paper the concept analysis of the self-explaining (SER) roads and possibility of their establishment in the Republic of Slovenia is discussed. Nowadays, the self-explaining roads have been recognised as one of the basic concepts in the system of sustainable traffic safety. The first part of the paper briefly describes the goals and results of the European research programmes, which have dealt with this area (e.g. European joint research project within the ‘Safety at the Heart of Road Design’, financed by ‘ERA-NET ROAD – Coordination and Implementation of Road Research in Europe’). The main purpose of the paper is the description and analysis of the concept of the self-explaining roads. A basic definition and assumptions, characteristic terminology and conditions for implementing a self-explaining road network are given. The concept of forgiving roads is also outlined, which, together with self-explaining roads, forms the basis for planning preventive traffic-safe roads. Both concepts are combined with basic principles in the Dutch concept of sustainable traffic safety. The last part of the paper consists of an analysis of the existing road network/existing categorisation of public roads in the Republic of Slovenia, and includes a proposal for the systematic establishment of a traffic-safe self-explaining road network.

Keywords: self-explaining roads, sustainable traffic safety, forgiving roads, categorisation

1. INTRODUCTION

The paper describes the issue of road designing and maintenance. The main problem with the majority of roads is that they have been designed, constructed and maintained in accordance with traffic and technical requirements, which are implemented in a deficient, inconsistent and outdated legislation. The impact of proper road and roadside design on safe behaviour of traffic participants has often times been neglected.

In Europe a new concept of road designing was developed at the beginning of the 21st century as a response to the decline in traffic safety. Human beings are positioned as the central and the most important factors of traffic safety, altogether with their limited abilities.

The new concept of road designing is included in the Dutch concept of sustainable traffic safety, which places prevention at the forefront, underlining it as more important than the curative traffic safety. A set of five guiding principles has been developed to achieve sustainably safe road traffic. (Prestor, 2014)
Table 1: Sustainable Safety principle (Wegman, 2006)

<table>
<thead>
<tr>
<th>Sustainable Safety principle</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functionality of roads</td>
<td>Monofunctionality of (through roads, distributor roads, or access roads) Hierarchically structured road network</td>
</tr>
<tr>
<td>Homogeneity of traffic load</td>
<td>Equality in speed, direction, and mass at medium and high speeds</td>
</tr>
<tr>
<td>Homogeneity of speed</td>
<td>Injury limitation through a forgiving road environment and anticipation of road user behaviour</td>
</tr>
<tr>
<td>Homogeneity of direction</td>
<td>Road environment and road user behaviour that support road user expectations through consistency and continuity in road design</td>
</tr>
<tr>
<td>Forgiving roadside</td>
<td>Ability to assess one’s task capability to handle the driving task</td>
</tr>
</tbody>
</table>

The concepts of self-explaining and forgiving roads are included in the guiding principles of road designing in accordance with sustainable safety.

Forgiving roads are planned, designed and executed in such a way as to prevent traffic users’ mistakes or lessen the severity of traffic accidents.

Apart from mentioning some EU research programmes, the central theme of the paper is the concept of self-explaining roads, the analysis of the existing road network in the Republic of Slovenia and a proposal for their establishment in the existing network in the Republic of Slovenia. (Prestor, 2014)

2. EU RESEARCH

When a lack of coordinated traffic research in Europe had been detected, »ERA-NET ROAD – Coordination and Implementation of Road Research in Europe« was established with a purpose of systematic exchange of information and examples of good practice. The research programme »Safety at the Heart of Road Design« was financed within the ERA-NET ROAD. The goal of the research programme »Safety at the Heart of Road Design« was to improve traffic safety by disseminating the concepts of self-explaining and forgiving roads, which take human factors into account. The research programme »Safety at the Heart of Road Design« was divided into five research projects:

- IRDES – Improving Roadside Design to Forgive Human Errors
- EuRSI – European Road Safety Inspection:
- RISMET – Road Infrastructure Safety Management Evaluation Tools (Road Safety Audit – RSA, Road Safety Inspection – RSI, Black spot safety management – BSM, Impact assessment of investments and road safety measures – RIA, Monitoring road user behaviour, Conflict studies and naturalistic driving studies, In-depth accident studies)
- SPACE – Speed Adaptation Control by Self Explaining Roads
- ERASER – Evaluations to realise a common Approach to Self-Explaining European Roads.

The SPACE and ERASER research projects dealt with the issue of self-explaining roads, with the emphasis on the measures, influencing the selection of speed.
In the SPACE research project the existing literature was studied, expert committees' opinions were acquired, experts' workshops were organised and driving in a simulator performed. On the basis of the above, the measures on the self-explaining roads, which have the biggest potential for managing with safe speed, were defined.

The ERASER research project confirmed the basic principle of homogeneity within each category and heterogeneity among categories and produced a computer application helping to make decisions about measures for slowdown and adjusting speed on regional roads. The application is available on the web site [http://www.swov.nl/enquete/Eraser/Tool.php](http://www.swov.nl/enquete/Eraser/Tool.php) and can be adapted to the requirements of individual road operator. (ERA-NET, 2012)

3. THE CONCEPT OF SELF-EXPLAINING ROADS

The beginners of self-explaining roads are Theeuwes, J & Godthelp, H, who in 1992 published an article titled “Begrijpelijkheid van de weg”, which means "understandable roads" in the Dutch language. The authors used an English term “self–explaining roads” because they believed that the term “understandable roads” would not appropriately describe complex mental processes.

The self–explaining roads concept has spread across the world (The Netherlands, Denmark, Germany, Great Britain, Australia, New Zealand...). Google research showed that already more than half a million web sites contains the term "self-explaining roads".

By definition, the self-explaining roads are roads which only by their form induce traffic safe behaviour of all participants in traffic.

The characteristic terminology of self-explaining roads is categorisation, perception and expectation, road atmosphere, harmonised standardisation, understandable road designing, readability, psychological traffic calming, consistency and feasibility.

The key terms in the self-explaining roads concept are categorisation and perception and consequentially, the expectations of the traffic participants.

Categorisation is a way of how people try to recognise, understand and distinguish objects. There are several theories on how people categorise objects. The categorisation of road network is based on the theory of prototypes. The basis of the Prototype theory is an assertion that road users develop a prototypic detection of road types in case when the physical appearance of certain road environment is homogeneous and physically different from other types of road environment. Improper categorisation of roads is dangerous because it causes false expectations of road users. (Prestor, 2014)

Perception is a sensory detection of the world around us and includes recognition of stimuli from the environment and also reactions to the impact of these stimuli. Through the perception process we acquire information about things from the environment and interpret them. Perception does not create the world around us, but it also enables us to function in our environment. (Studio Bračevac, 2010)

The goal of the self-explaining roads is the design of the road environment, which is aligned with expectations. An interaction between the appropriate drivers' expectation and the road environment constitutes traffic atmosphere, which is a condition for safe behaviour.

The self-explaining roads connect the categorisation of road network and expectations of road users. The traffic environment shall induce the right expectation in the road users, regarding presence and behaviour of other participants in traffic, as well as regarding their own behaviour. In order to reach this goal, clearly separated categories of roads should be implemented, whereby each road category should clearly define a special behaviour of all participants in traffic. Characteristic road categories system should meet the following conditions (Matena et al., 2006; SWOV, 2007):
Each category should consist of unique road elements (homogeneous within one category and different from all other categories);

Each category should require unique behaviour for a specific category (homogeneous within one category and different from all other categories);

Unique behaviour displayed on roads should be linked to unique road elements;

The layout of crossings, road sections, and curves should be linked uniquely with the particular road category;

One should choose road categories that are behaviourally relevant;

The same road category should connect the road section, which is psychologically interpreted as a whole.

There should be no fast transitions going from one road category to the next

When there is a transition in road category, the change should be marked clearly (e.g., with rumble strips);

When teaching the different road categories, one should not only teach the name of, but also the behaviour required for, that type of road;

Category-defining properties should be visible at night as well as in the day-time.

The road design should reduce speed differences and differences in direction of movement.

Road elements, marking, and signing should fulfil the standard visibility criteria.

The traffic management systems should be clearly connected with special road categories.

The establishment of self-explaining road network with the goal of reducing unintentional incidents must be accompanied with systematic and interdisciplinary measures concerning infrastructure and education of users (Figure 1).

Figure 1. Procedure for establishment of the self-explaining road network (Matena et al., 2006; SWOV, 2007)
4. ANALYSIS OF THE EXISTING CATEGORISATION OF ROADS IN SLOVENIA

On the basis of an SER analysis (self-explaining roads) categorising the road network in the Republic of Slovenia, it was established that motorways and expressways are generally built according to SER principles. Motorways and expressways differ from other types of roads mainly in their distinctive road elements, characteristic behaviour and separate directions of travel, and as such fulfil the basic condition of homogeneity within one category and the condition of heterogeneity among different categories. The SER analysis of national and local roads established the following:

- Categories of national and local roads in the republic of Slovenia are not planned with typical road elements to provide homogeneity within an individual category and heterogeneity among different categories,
- Specific behaviour is not determined for individual categories of national and local roads (homogeneity within one category and heterogeneity among different categories),
- The typical behaviour of road users is not related to typical road elements,
- The regulation of crossroads, road crossings, road sections and road bends is undoubtedly related to the specific road category,
- The categorisation of the road network does not correspond to the behaviour of road users,
- The same road category only partly links road sections which are psychologically interpreted as one unit,
- There are no quick transitions between different road categories, transitions between road categories or road connections are not clearly or distinctly marked,
- In giving notifications and information on different road categories, the rules on road safety behaviour for individual categories are not clearly presented in terms of specifying the road category’s denomination,
- Road elements not typical for an individual road are also clearly visible at night;
- The road design and planning in itself prevents differences in speed and directions of traffic,
- Road elements, traffic equipment and traffic signalisation meet the criteria of applicable visibility standards,
- Traffic control systems clearly related to individual road categories do not exist. (Prestor, 2014)

On the basis of the analysis, it was established that the basic rule of homogeneity within one category and heterogeneity among different categories is not taken into account in the design of the existing road network (exceptions being motorways and expressways) and that a system of credible speed limits according to road categories is also not established.

On the basis of the SER analysis of the road network in the Republic of Slovenia, it can be concluded that the national and local road network in the Republic of Slovenia is not categorised and regulated according to the SER principles of road planning.

Not taking into account the criterion of road categorisation by traffic functions, the administrative and political criterion of road categorisation causes traffic functions to be mixed leading to multifunctional roads and thus to a vague road network in general. (Prestor, 2014)
5. PROPOSAL FOR INTRODUCING SER IN SLOVENIA

On the basis of the findings of the SER analysis of the national and local road network in the Republic of Slovenia, it was established that SER principles are violated in the majority of cases, since the principles are not implemented or taken into account.

Regarding the evaluated status of the road network in the Republic of Slovenia, where, according to the national road administration, at least 65% of roads are in a poor or even very poor condition and the majority of municipal roads are in a similar state, it can be concluded that the Republic of Slovenia provides a very poorly maintained road network that needs to be systematically modified.

Based on foreign practices, the improvement of the road network needs to pursue the following steps: (Prestor, 2014)

5.1. Road categories in the national and local road networks need to be re-classified according to SER principles:

On the basis of the analysis of the existing road network, three basic traffic functions of national and local motorway network are proposed for the entire network: through roads, distributor roads and access roads. (Prestor, 2014)

The fourth remote traffic function encompassing motorways and expressways remains, since the implementation of motorways and expressways has been, or will be, adequately approaching the SER principles. (Prestor, 2014)

5.2. The traffic mode of the entire road system needs to be prepared:

The distribution of traffic loads in the Slovenian road network was changing over the years of motorway construction. After the construction of the majority of main motorway network sections, it is reasonable to draw up a traffic model of the entire road system in Slovenia that will serve as one of the bases for determining the traffic functions of individual roads. Apart from actual traffic loads, their structure and distribution, the traffic model needs to consider construction, technical, traffic, economic and environmental parameters, and spatial as well as road-safety conditions. The upgrade of the traffic model and management of traffic flows in the road network will be achieved by the implementation of an intelligent transport system. (Prestor, 2014)

5.3. The maximum travel time to the constructed motorway network for every location in the RS needs to be determined (tp < 45 min):

Travel times in Germany are determined according to the importance of urban centres. It has to be pointed out that Germany is a larger and more developed country in terms of traffic.

In the case of Slovenia, the criterion of travel times needs to take into account the fact that remote roads connecting the largest centres are actually already constructed. Most of the remaining road network is connected to the remote connections. For this reason, it is reasonable to form a travel time criterion related to the time necessary to access the first or nearest connection of the existing remote road connection from every local centre. A maximum travel time – tp ≤ 45 min is proposed. (Prestor, 2014)
5.4. It is necessary to determine credible speed limits for individual road categories:

A general administrative speed limit needs to be determined for every road category. All road elements have to be determined and dimensioned according to the speed limit. Speed limits need to be implemented consistently throughout the whole road network, which is a basic condition for the credibility of speed limits of individual road categories.

On the basis of road categories, the determination of general administrative speed limits is proposed, i.e. for through roads 90 km/h, distributor roads 70 km/h and access roads 50 km/h. (Prestor, 2014)

5.5. Typical cross-sections for every road category need to be determined on the basis of road safety:

A typical cross-section is specified for every category. According to the existing roads and the conditions of their construction, a typical cross-section with characteristic elements is created, where the driving lane width is determined according to the interval, depending on the traffic model results. (Prestor, 2014)

5.6. The typical elements of road categories need to be determined:

The condition for determining typical road elements requires these elements to be present in the specific road category. Only longitudinal road elements can be used for typical elements of a road category, i.e. the road layout, longitudinal ground markings and delineators. (Prestor, 2014)

5.7. A system for continuous notifications and information about road safety behaviour on individual road categories needs to be established:

Attracting the attention of road users is one of the SER principles; in other words to continuously inform and educate all road users about road traffic rules. This is particularly true for all changes to rules in road traffic. (Prestor, 2014)

5.8. It is necessary to categorise and standardise SER measures at crossings, bends, crossroads and road sections and SER measures in built-up areas:

According to experience in the Netherlands, the establishment of a new road network categorisation is a complex problem. In introducing new categories and thus new rules of road safety behaviour, roads with multiple traffic functions (grey roads) are considered a special case. In addition to the issue of roads with multiple functions (grey roads), the traffic regulation of individual sections, which needs to follow SER principles, is regarded as very important.

In the light of the foregoing reasons, it is necessary to prepare a set of SER measures for individual road sections which consists of combinations of individual measures. SER measures have to be determined on the basis of road safety criteria. In order for them to be implemented at sections, crossings, bends and crossroads, it is very important that these measures be implemented according to the level of difficulty of individual traffic situations. (Prestor, 2014)
5.9. Travel scheme on the foreseeable road network in the Republic of Slovenia:

The travel scheme on the foreseeable road network in the Republic of Slovenia shows the final destination of vehicles in the SER network. Vehicles travel from point A to point B on an access road with an administrative speed limit of 50 km/h. Vehicles from point B to point C travel on a distributor road with an administrative speed limit of 70 km/h. Vehicles travel from point C to point D on a through road with an administrative speed limit of 90 km/h. The total travel time on access, distributor and through road to the motorway network has to meet the criteria $t_p \leq 45$ min. (Prestor, 2014)
6. CONCLUSIONS

The paper deals with modern approaches to road and road network planning. As well as concept of sustainable traffic safety and the concept of forgiving roads, the principles of the self-explaining roads are described in detail.

The SER analysis of the road network in the Republic of Slovenia, including the proposal for the establishment of SER roads and SER road networks, follows in the continuation.

The final objective of the proposal for the establishment of the self-explainable road network is safe traffic flow, which, as well as road safety conditions, also establishes the conditions for more calm and smooth use of, roads which is also beneficial in terms of environmental pollution as well as the traffic and economic criterion. (Figure 3)

In addition to the consensus of experts, social and political agreement is necessary to implement the concept of self-explaining roads, which significantly affects current road planning, management and usage. With the purpose of including other traffic modalities and means, the consensus needs to establish the conditions for a multi-modal traffic system in the Republic of Slovenia.

4. REFERENCES