Innovative Bridge Information System (BIS) Applied in Structural Categorization and Advanced Seismic Upgrading of Existing Bridges in R. Macedonia

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SUMMARY
The newly created bridge information system (BIS) successfully serves as an innovative tool for multi purpose integral technical and functional management of all bridge structures within the integral national road network of the Republic of Macedonia. It involves storing of all essential data to be used for different technical and measurement purposes. The methodology for creation of the new bridge information system is harmonized with the latest world experience and the general instructions specified by the World Bank. The global objectives and the concept of the developed innovative bridge information system are: (1) control and maintenance of vital structures; (2) planning of revitalization of existing structures; (3) planning of future development of road traffic and (4) improvement of functioning of communication lines.

Keywords: Bridges, bridge information system, seismic vulnerability, seismic upgrading of bridges

1. FOREWORD

Accurate and complete information has an essential importance in making all kinds of decisions in different state sectors of a modern society. Information provided in due time is very important for the activities which need precise planning of essential activities, engagement of extensive material and financial resources, successful and efficient management of available resources as well as providing of complete and appropriate services to the users. To make a proper and timely decision, it is necessary to possess accurate, relevant and, above all, accessible information. After processing of such information, corresponding rational and proper decisions can be made. It is certain that exact, timely and rational solutions can successfully be made only if corresponding and complete information is provided.

Particularly important infrastructure systems for which objective information is of paramount importance are certainly the transportation systems, not only because of the range of related problems but also because of the complexity of factors that is increased in proportion with the importance of the systems themselves.

Bridges as capital structures are of primary importance for the transportation systems in addition to tunnels, high embankments, big cuts and alike. Hence, there arises the need for timely information on the main characteristics of these structures and their conditions at any moment of their serviceability life, including the level of possible damage to certain constituent elements as well as inventory of all previously completed repair and other works.

The new successfully realized software system and its subsystems enable successful inventory and monitoring of the conditions of the vital structural systems on modern road networks and give a considerable contribution to the satisfying of the need for important different types of information in the specified domain.

2. INNOVATIVE BRIDGE INFORMATION SYSTEM (BIS)

To avoid software limitations, there has been followed the predefined idea about development of a specific and integral software system that will enable complete inventory, wide application, specific selection and processing of information on all the essential components of the road systems in the Republic of Macedonia. For that purpose, a corresponding and original methodology for processing of data has been developed. This methodology, along with the developed information system, has led to the creation of an integral system that can successfully respond to modern international requirements in the corresponding domain on one hand, and the specific requirements dictated by the concrete domestic conditions, on the other hand. The world experience that has so far been gathered in the domain of created information systems on vital engineering structures within the various world road networks has been applied and the instructions given by the International Bank of Reconstruction and Development from Washington (USA) have been used and incorporated in the implemented methodology.

2.1. General Objectives of the Bridge Information System (BIS)

The main objective of this new system was creation of a data base for inventory and monitoring of conditions of vital structures within the road network of the Republic of Macedonia. The very way of acquisition of corresponding data and their subsequent processing enables obtaining of accurate and timely information that will be of a high importance for making optimal technical and economic decisions in this sector.

Following the recommendations by World Bank, the integral road network and its road constituent sections has first been defined. Then, all the necessary data on all types of structures along these sections have been collected. The importance of the individual sections of the road network has been defined based on a number of criteria among which the main criterion was the intensity of traffic. Monitoring of the conditions of these facilities is more than necessary particularly in the case of road sections associated with the highest risks related to safety and potential large economic losses in case of disruption of their functioning. The road network consists of all road sections on which bridges of vital and strategic importance are located, as well as, road sections that can serve as alternative roundabouts if the main road sections become impassable out of any reason.

2.2. Basic Concept of Bridge Information System in the Republic of Macedonia

In different countries of the World, basic concepts in this domain are considerably different from each other. Also, the recommendations given in the World Bank's instructions are mainly of a general type and define the need for establishment of a general structural review of elements that are taken into account and are available in making some important decisions. This point to the need for establishment of databases and subsequently systems for management of the road networks and associated structures. According to the World Bank's guides, each developing country should have its own, developed optimal set of official documents, as well as, corresponding instructions, procedures and manuals that will be adapted to its own specific needs.

The integral road network considered in the concrete case of development of a data base involves all the existing main and regional roads of the Republic of Macedonia. The structures, whose conditions are monitored by means of the data base, are situated along the defined and adopted road network. The road network itself is defined by a corresponding original topology of its corresponding identification elements, in accordance with the defined needs. In accordance with the same concept, there have been selected types of vital structural systems situated along the defined network whose conditions are successfully monitored in the course of time using the specific options of the information system.

However, in the defined innovative concept, an upgrading of the basic has been made by extension of types of structures that are of interest for monitoring of their conditions. Taking into account the domestic needs and factors as well as the corresponding long years of experience related to the

domestic road network, extension of types of structures whose conditions are completely monitored by the information system, has been introduced. More concretely, in addition to bridges with viaducts, overpasses and underpasses, the innovative information system in the Republic of Macedonia also involves road tunnels, high embankments and high cuts, which represent a very important and useful upgrading.

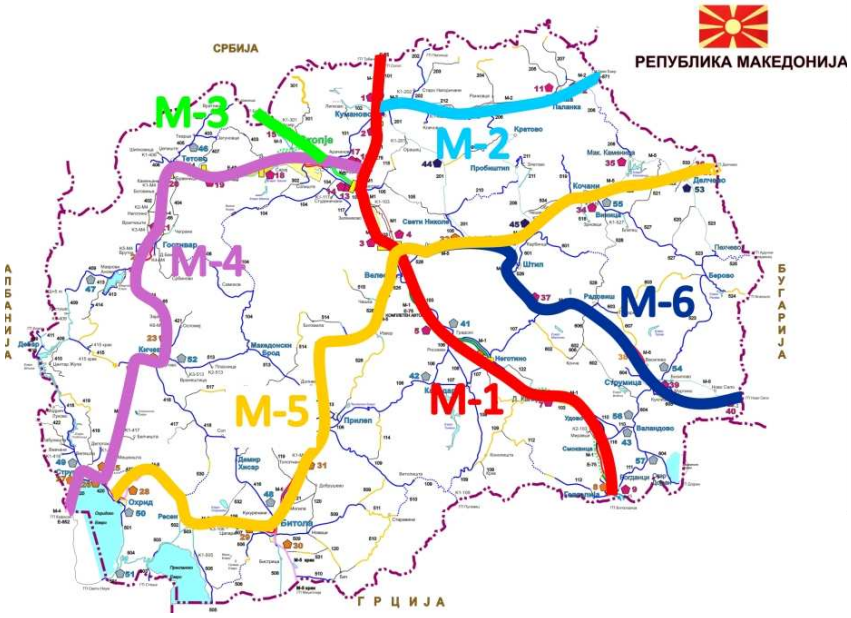


Figure 1. Main road sections in the Republic of Macedonia

In this way, three types of information systems have been defined. These refer to three types of road structures with own three different data bases. The integrated three systems constitute the new information system that enables monitoring of the conditions of all the structures. Concretely, the developed new information system contains the following subsystems:

(1) Data base on road bridges;
(2) Data base on road tunnels;
(3) Data base on high embankments and high cuts.

The data base on road bridges involves all structures of the type of bridges, which means that viaducts, overpasses and underpasses are also included in addition to bridges. In accordance with the set out general and specific goals, the information system is designed such that each of the three data bases that are its constituent parts contains in itself two essentially different types of data as follows: (1) Data that are invariable in the course of time and (2) Data that are variable in the course of time. In this way, two different types of data sub-bases are defined within each database as follows:

(1) A data sub-base that contains inventory data on the structures (time invariable type of data), and;
(2) A data sub-base that contains data from general main inspections of the structures (time variable type of data).

Inventory data on structures essentially represent all the main administrative and technical data on each registered structure. These data have the character of permanent, i.e., invariable data from the aspect of time. The acquisition and classification of these data is done through filling out the appropriately elaborated new typified inventory forms for each structure taken separately. Adequately to the number of defined individual data bases, three specific types of typified inventory forms have been elaborated as follows:

(1) Typified inventory form for road bridges;
(2) Typified inventory form for road tunnels;
(3) Typified inventory form for high embankments and high cuts.
With the acquisition of inventory data on all the stated road structures by means of filling out the inventory forms, a quality “identity card” of each structure is obtained and stored in the corresponding typified database.

The second type of included data is data obtained by realization of the introduced standard general main inspection of structures that involves in situ inspection of all their structural components. The general main inspection is carried out at a specified pre-defined time period (one or two years).

From the day the structures were built until today, due to different climatic and traffic conditions, the structures themselves have gradually and continuously been exposed to ageing and dilapidation.

In most cases, aging does not affect all the structural elements of the structures equally so that some elements are more intensively and faster degraded than others. Hence, the general main inspection of structures enables obtaining of data, which will be used for successful monitoring and recording the extent of degradation of all the structural components, as well as, comparison of their conditions in respect to the conditions during the previously done inspections. Unlike the inventory data, this data are of temporary character and are associated with the date of their acquisition. The acquisition of data is done in situ by professionals and by filling out special purpose standard forms for general main inspections for each structure taken separately. Adequately to the number of typified data bases, there are three types of typified forms for general main inspection as follows:

(1) Form for general main inspection of road bridges (with viaducts, overpasses and underpasses);
(2) Form for general main inspection of road tunnels, and,
(3) Form for general main inspection of high embankments and high cuts.

Defined in each of the above mentioned forms is a corresponding list of constituent components of the considered type of structures, which are inspected and their conditions evaluated. For complete definition of the information system for monitoring of the conditions of vital structures along the road network, elements that are beyond the defined data bases are also included, namely, the dossiers of the structures. A dossier of a certain structure represents a summary of all data referring to the history of the structure, its initial conditions, then different design and construction documentation as well as documentation on construction. These dossiers also involve different data from additional studies, building code compliance inspection and testing of the materials of the structure, different financial data associated with the construction of the structure, photos shot during construction and alike.

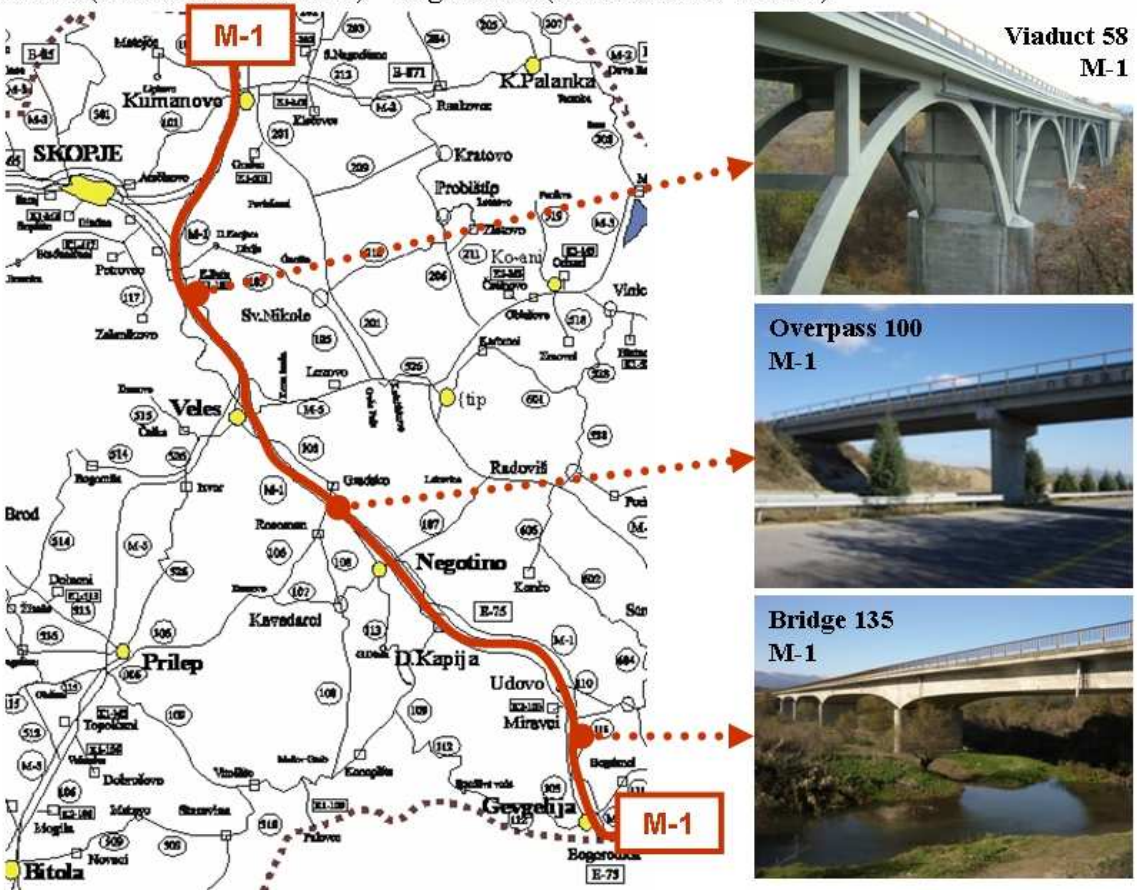
3. DATA BASE ON BRIDGE STRUCTURES (BIS)

Bridge structures represent very important and vital components of road networks, first of all, due to their economic value and strategic importance. The defects and possible damage to bridges as critical elements of the road network may disturb the entire road system of the country and cause extensive losses.

The subsequent figures show the selected main road sections and photos of bridges with the specified total number of structures.

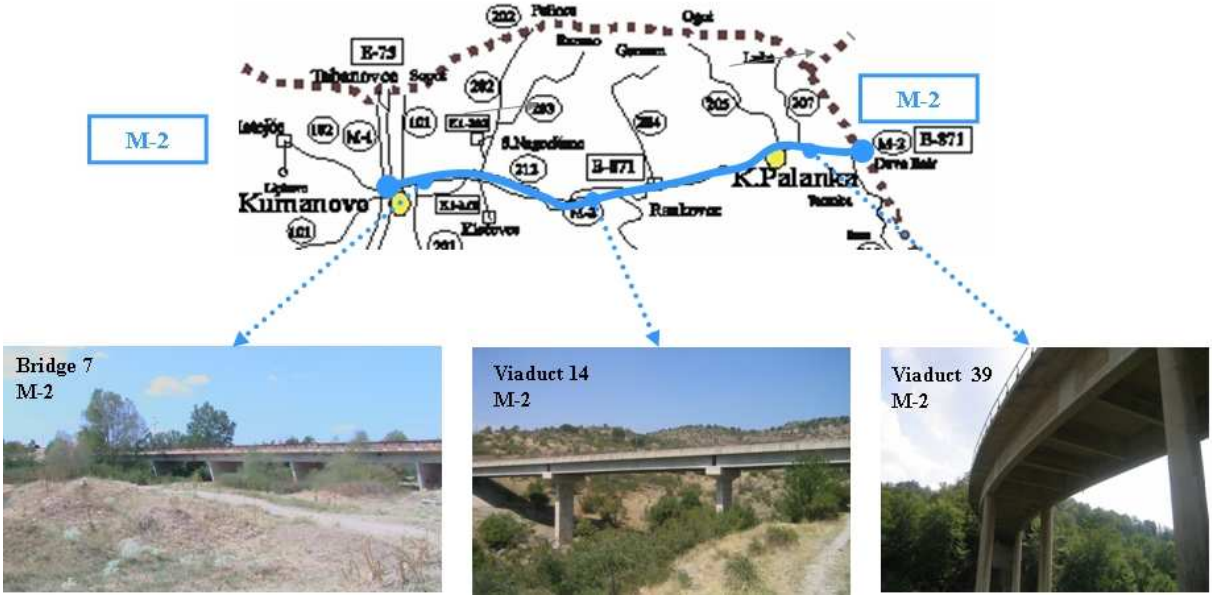
Main road M-1 **Total number of structures 151**

Tabanovce (Serbia border section) - Bogorodica (Greece border section)



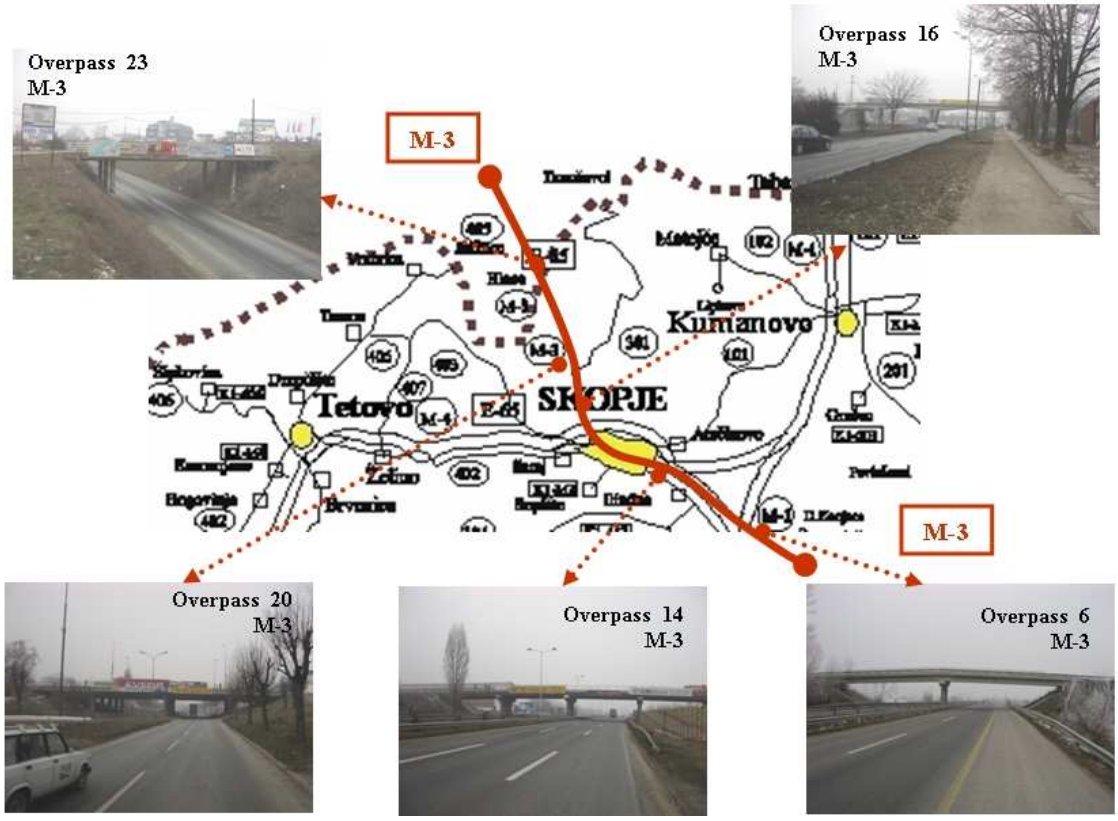
Main road M-2 **Total number of structures 40**

Dolno Konjare - Deve Bair (Bulgaria border) section



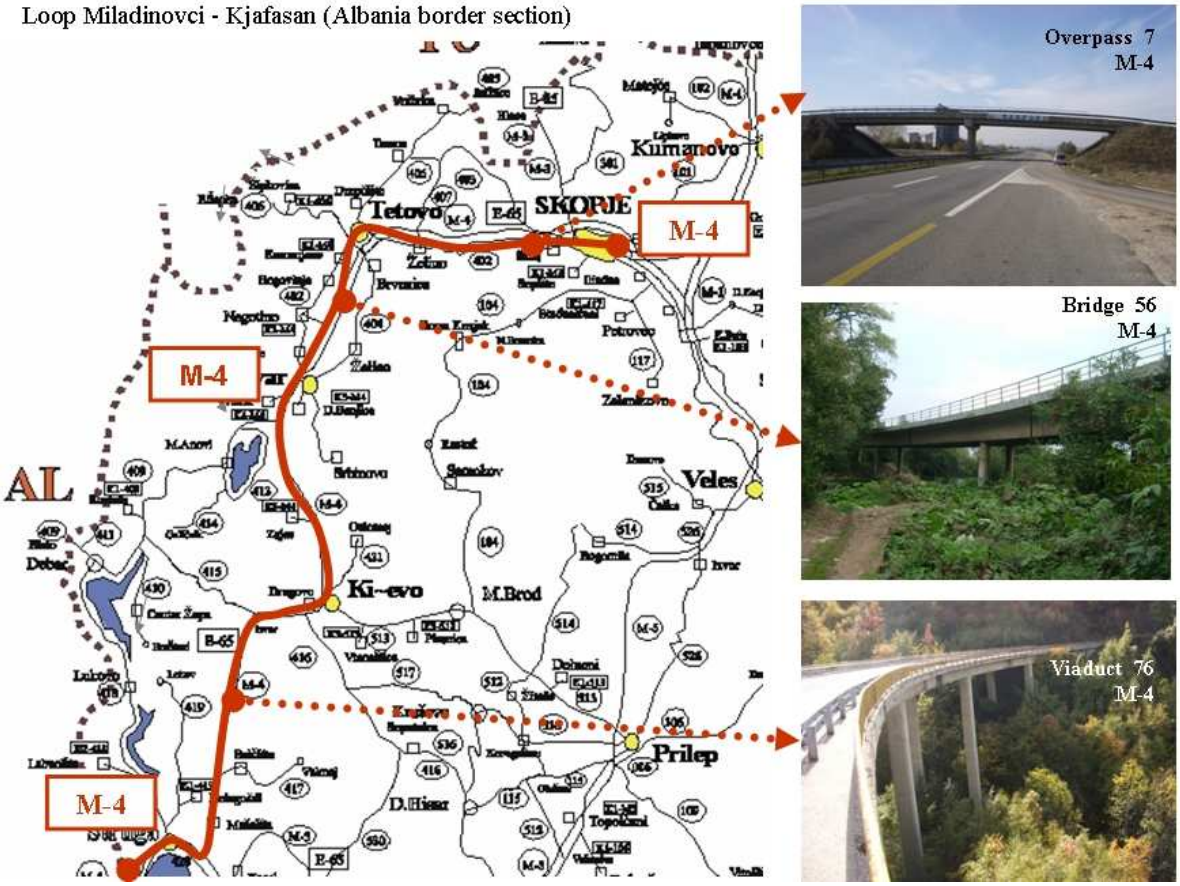
Main road M-3 Total number of objects 30

Loop Petrovec - Blace (Serbia border section)



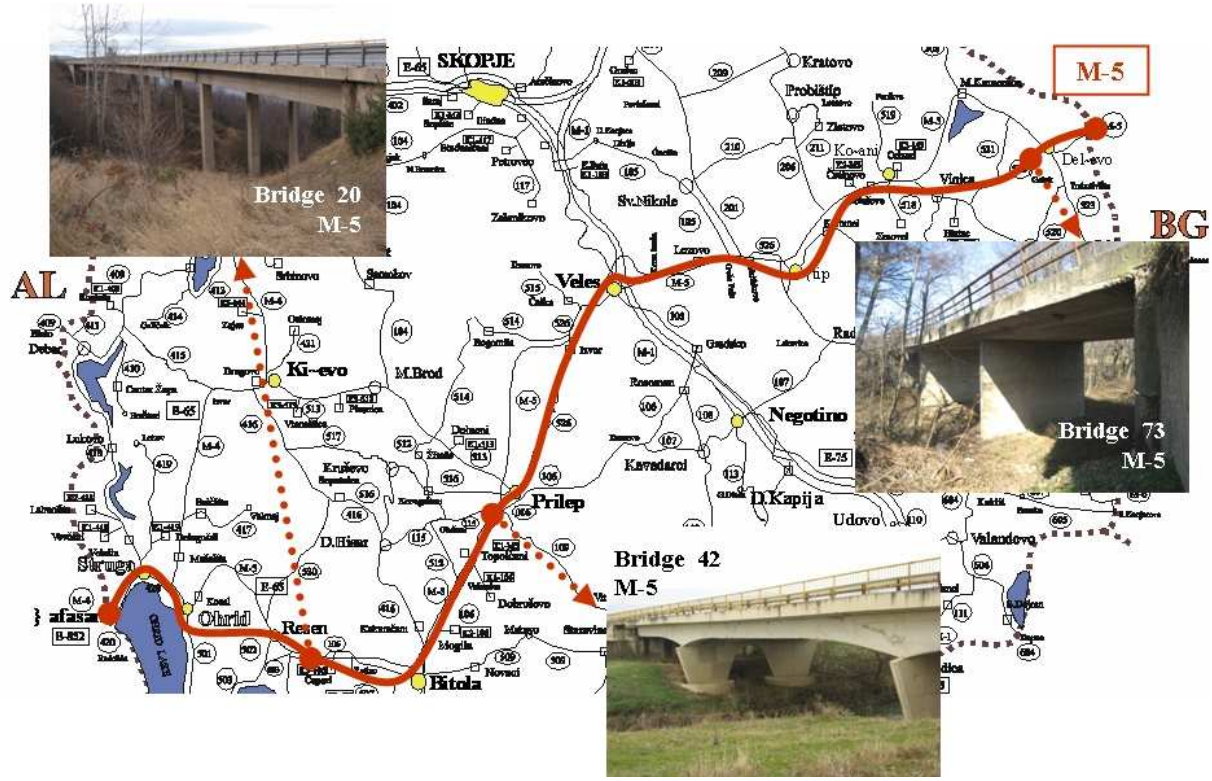
Main road M-4 **Total number of objects 111**

Loop Miladinovci - Kjafasan (Albania border section)



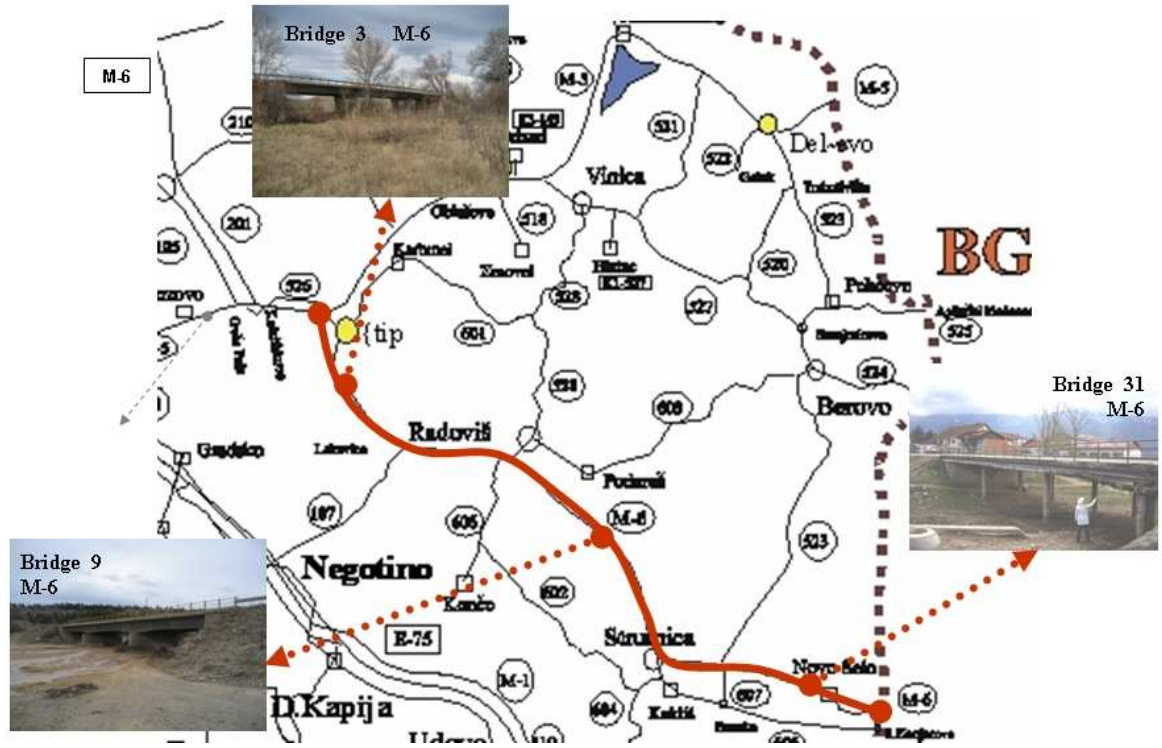
Main road M-5 **Total number of structures 86**

Loop Podmolje - Delcevo border sestion (Bulgaria border)



Main road M-6 **Total number of structures 35**

Loop Stip - Novo Selo (Bulgaria border)



Based on consistent use of the developed innovative and integral software system as well as detailed and intensive field and analytical activities, there has been established the computer data base on all

main road sections (M-1, M-2, M-3, M-4, M-5, M-5extension and M-6) in the Republic of Macedonia. Its establishment enabled the creation of conditions for application of modern methodology and computer technology for successful and fast communication with the data base on bridges for the purpose of providing information for different specific needs.

The data base on bridges refers to all structures with bridge structural system and contains installed integral data of two different types: (a) data of a permanent character in respect to time and (b) time variable data.

The data which are of permanent character in respect to time are entered through the applied typified inventory form (for example, road section, location, type of structure, number of spans and alike). Here belong also data referring to the components of the bridge substructure as are: type of abutments, type of flank walls and alike as well as data connected with the components of the superstructure and the equipment, as for example, width of the deck structure, type of the deck structure, type of cross-section of the main girders, etc.

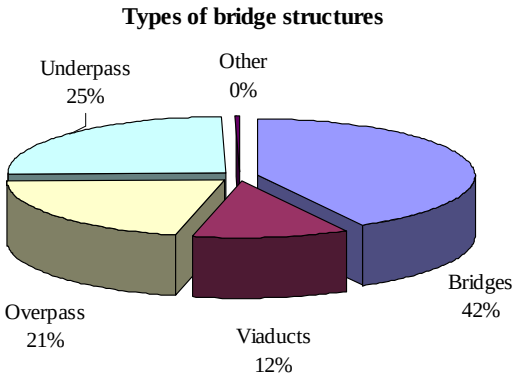


Figure 2. Presence of structures of the type of bridges along main road sections in the Republic of Macedonia expressed in percentage

The total number of bridge structures encompassed by the information system that has lately been established by the Institute of Earthquake Engineering and Engineering Seismology – IZIIS, Skopje are presented in the illustrations. Considered are a total of 459 bridge structures on the main road sections out of which 193 are bridges, 53 are viaducts, 97 are overpasses, 115 are underpasses and 1 is a pipeline. The viaduct on the M-1 road section has the largest length, i.e., a total length of 495.5м. The shortest structure is the underpass located on the M-6 section, with a length of 5.9 m.
The division of the bridge structures per number of spans and their type is shown in Fig. 3.

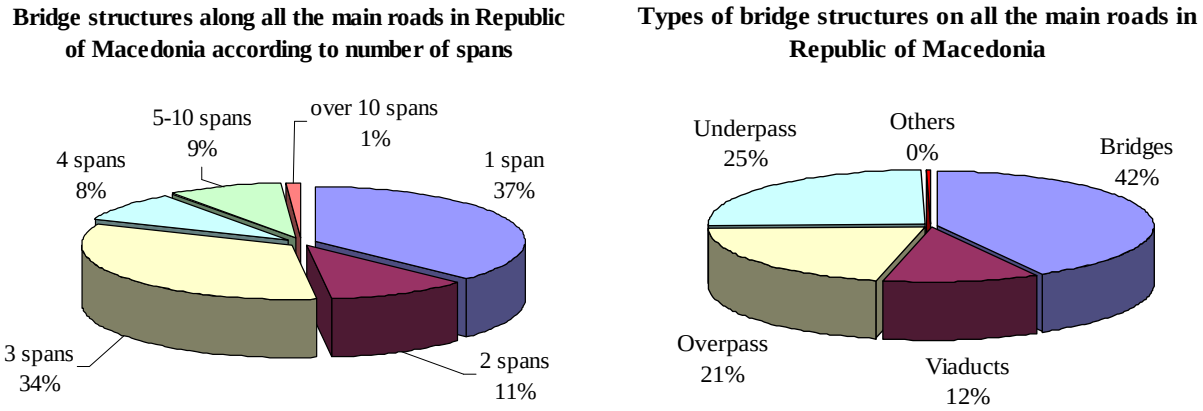


Figure 3. Classification of bridge structures according to number of spans (a) and type (b)

4. IMPLEMENTATION OF RESULTS

The end-users of the project end-products and innovative output resulting from realization of the innovative NATO SfP project are the competent governmental institutions (corresponding ministries) responsible for the project domains and/or for the functioning of the road network in each individual country. The co-directors of this innovative SfP project have successfully established an initial cooperation (in each country) among the respective institutions. The end-users in Macedonia are: 1) the Government in general and 2) the Ministry of Environment and Physical Planning; in Albania: 1) the Ministry of Public Works, Transport and Telecommunication, and 2) the Ministry of Environment, Forest and Water Administration; in B&H: 1) the Federal Ministry of Transport and Telecommunication, and 2) the Ministry of Environment and Tourism; and in Serbia: 1) the Government in general, and 2) the Provincial Secretariat for Architecture, Planning & Civil Engineering. The cooperation will be further extended in the course of the project realization.

5. USE OF BIS FOR OPTIMIZED REDUCTION OF SEISMIC RISK PERTAINING TO BRIDGE STRUCTURES IN REPUBLIC OF MACEDONIA

The newly developed innovative BIS system can be efficiently used for optimized reduction of the seismic risk pertaining to bridge structures. In seismic conditions, damage or failure of these structures may cause serious disturbances in the functioning of the entire society. Given that the BIS system provides very precise data on bridge structures including timely updated data defining their actual conditions, it is possible to perform time-dependent assessment of the actual level of seismic risk related to each individual structure within the entire transportation network. The level of seismic risk and/or vulnerability of bridge structures are evaluated based on the newest seismic hazard maps of Republic of Macedonia. In this way, the cumulative time-dependent seismic risk level of bridge structures is evaluated and used as the main background parameter in the process of elaborating the reliable and optimal seismic risk reduction programs providing efficient reduction of cumulative consequences at regional and national level.

6. CONCLUSIONS

Using new Bridge Information System (BIS), the data base on bridge structures has been created based on elaborated and adapted innovative multi-purpose methodology. All the necessary parameters defining the field of needed information have been established fully in accordance with the specified various need and intended purposes. The key achieved objectives involves data base related to (1) basic domain of proper monitoring of the actual conditions of the existing bridge structures, (2) planning of future revitalization and development of the road traffic, analysis of potential levels of seismic risk related to bridge structures, and what is the most important, (3) the achieved data integration in unique global information system on the road network of the country. On the other hand, the development of such a conceptualized information system will enable a corresponding qualitative and harmonized representation before the international bodies and institutions for investment and development in the field of transportation systems in general.

With the use of the information from the data base created by use of the developed methodology for inventory of bridge structures through the system for management of bridges named as the Bridge Management System (BMS), an opportunity for the realistic assessment of the actual conditions of the bridge structures on the main road sections in Republic of Macedonia has been provided. The processed data can give high quality responses to serve for selection and prioritization of procedures for maintenance and reconstruction of the structures and hence proper allocation of financial resources.

The created data base is of particular value for the presently ongoing research in the frame of the three year international NATO project “Seismic Upgrading of Bridges in Southeast Europe by Innovative

Technologies", whose principal investigator is Prof. Dr. Danilo Ristic, acting also as Partner Country Project Director (PPD), from the Institute of Earthquake Engineering and Engineering Seismology (IZIIS), Republic of Macedonia, representing NATO Partner Countries and NATO Country Project Director (NPD) is Prof. Dr. Uwe Dorka, from the University of Kassel, Germany, representing NATO countries.

ACKNOWLEDGEMENT

Presently, (at IZIIS, Skopje), extensive experimental and analytical research is continued in the frame of the approved new three year NATO Science For Peace Project: *Seismic Upgrading of Bridges in South-East Europe by Innovative Technologies* (SFP: 983828), focused on fundamental research and development of innovative technology for seismic isolation and seismic protection of bridges *(New large-scale scientific and research activity with participation of five countries).*
The extended NATO SfP support for realization of this innovative project is highly appreciated.

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