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FUNCTIONAL CLASSIFICATION OF RURAL ROADS IN SERBIA

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Abstract: In order to revise the existing classification of rural roads in Serbia, which is rather old and defined on administrative criteria, the research developed a proposal for functional classification and categorization of primary rural roads. This resulted in four classes of rural roads based on their basic function and, with the introduction of five spatial accessibility levels, road classes are subdivided in eight road types. Based on the Serbia State Spatial Plan data, centers of gravitation together with border crossings are classified in four categories and desire lines of major transport function levels are defined. Based on this information and traffic count data the proposal of new primary rural road network in Serbia reduces the total length of the existing one with approximately the same overall accessibility level. Proposed categorization of rural roads as primary, regional and local ones is founded on functional classification and coincides with reorganization of governmental structure in Serbia.

Keywords: functional classification, categorization, rural roads.

1. Introduction

Rural road network is a basic transportation system which provides accessibility and interconnections of spatially distributed land uses either directly or indirectly by providing access to terminals of other transport modes (rail, air, water). In order to form efficient and safe road network functional classification is a basic step. The fundamental classification of rural roads is based on their function closely related to spatial development. Road function, design characteristics and road use ought to be harmonized (Jaarsma, 1997).

Traditional approach, predominantly based on traffic movement criteria (volume and speed), tends to treat traffic and roads as its very purpose thus neglecting their main purpose - to serve and provide for efficient, reliable and sustainable economic, social, spatial etc. development by providing the access with minimum impact on the environment. Accessibility to spatially dispersed resources should prevail over the efficiency of road network to provide the demand – supply equilibrium while accessibility should become a conceptual framework in the spatial and transportation planning process (Straatmeier, 2008).

Functional classification of rural roads is a starting point of all activities in planning, design, construction and maintenance of rural roads. Separate standards (i.e. VSS, 2007) or first chapters of design guidelines (i.e. AASTHO, 2001) are defining the

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procedures for functional classification of rural roads; such approach is typical for all the countries in the world although with varying criteria and terminology reflecting specific characteristics and needs of each country. Moreover, existing functional classification of roads should be revised through time in order to reflect substantial changes in spatial development and/or traffic demand pattern and transportation system policies as well (Gerlach, 2006). Different functional classes and types of roads imply different design criteria and road characteristics thus directly influencing road construction costs (Vander Giessen et al., 2009) which are to be present within policy level decision making process.

Rural roads in Serbia were classified more than 35 years ago as primary, regional and local roads mainly on administrative and traffic volume criteria. With Public Roads Law (2005) new administrative classification is introduced (state roads I order, state roads II order and local roads) defining jurisdictions in road network and introducing the need for the functional classification and categorization of rural roads. Two coordinated documents are produced recently in order to provide the basis of decision making process. The Functional Classification Guidelines (Maletin and Andjus, 2008) define road classes and types followed by planning and design criteria (i.e. design speed, level of service etc.). Road Categorization Criteria (Tubic and Maletin, 2008), based on functional classification, define criteria for administrative classification of rural road network in Serbia together with a proposal for the assignment of road management responsibilities to different governmental levels. The research presented in this paper is based on methodology and results of both studies.

2. Rural Roads Classes and Types

Rural roads classes emerge from basic rural road function while rural road types are defined according to the spatial level of basic function provided (Fig. 1).

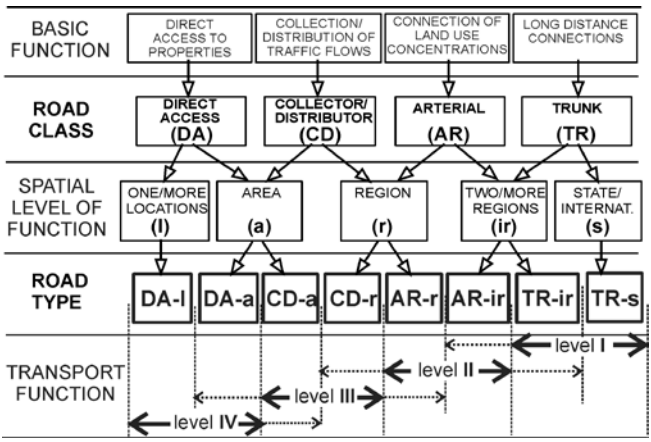

Fig. 1.
Rural Road Classes and Types According to Functional Classification in Serbia

Basic rural road functions cover a wide range from direct access to land uses along the road to efficient movement of vehicles in the traffic flow. They are classified as follows:

- **direct access** to specific locations and/or areas along the road, connections to/from local centers and to/from sections of collector-distributor roads (**DA**),
- **collection/distribution** of several access road traffic flows in order to direct them to/from area or region centers or to/from sections of higher functional level roads, connections of area centers (**CD**),
- **connection** of area centers with region centers, between region centers and connection to/from sections of roads with highest functional level (**AR**),
- **long distance connection** between state (international) centers and/or spatially separated most important regional centers (**TR**).

Introducing five spatial levels of basic accessibility function, from location to state and international level, eight functional types of rural roads are defined (Fig. 1). Defined classes and types of rural roads should serve four different levels of transport function importance.

Unique basic function of a certain rural road section is virtually impossible to achieve and, in any case, would be spatially, economically and environmentally unacceptable. Therefore, certain mixing of functional tasks is necessary and requires the definition of primary and secondary function of a certain road section (Fig. 2). As a rule, two hierarchically adjacent basic functions and spatial levels should be combined; in special cases (i.e. natural or build up constraints) three functions could be combined as a temporary solution.

ROAD CLASS	ROAD TYPE [a]	BASIC FUNCTION: DIRECT ACCESS TO PROPERTIES	COLLECTION/ DISTRIBUTION OF TRAFFIC FLOWS	CONNECTION OF LAND USE CONCENTRATIONS	LONG DISTANCE CONNECTIONS
DIRECT ACCESS ROAD (DA)	DA-l	●	○		
	DA-a	●	◎	○	
COLLECTOR DISTRIBUTOR ROAD (CD)	CD-a	◎	●	○	
	CD-r	○	●	◎	○
ARTERIAL ROAD (AR)	AR-r	○	◎	●	○
	AR-ir		○	●	◎
TRUNK ROAD (TR)	TR-ir		○	◎	●
	TR-s			○	●

(a):
l - local
a - area
r - regional
ir - interregional
s - state (international)

● PRIMARY FUNCTION
◎ SECONDARY FUNCTION
○ SPECIAL CASE

Fig. 2.
Primary and Secondary Function of Rural Roads in Serbia by Functional Classes and Types

3. Overall Planning Characteristics of Rural Roads

Overall planning characteristics of functional classes and types of rural roads are illustrated on Fig. 3 together with general relation of primary, secondary and other functions. Besides the rural road basic functions there are other functions (Fig. 3) that are not the classification criteria but follow the road functional class. Services for road users (i.e. fuel stations, rest areas, vehicle services etc.) are normally provided for all functional classes according to the specific restraints and requirements.

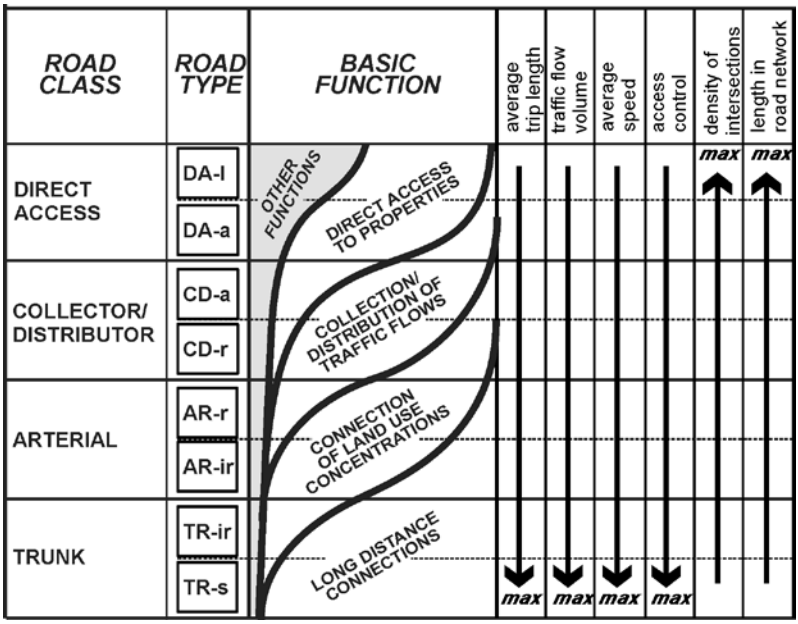

Fig. 3.
Overall Planning Characteristics of Rural Roads Functional Classes and Types in Serbia

With lower functional classes of roads providing for direct access and/or collection/distribution of traffic flows (**DA, CD**) these functions also comprise movement and stopping of public transport buses, bicycles and pedestrian movements, different activities in roads right-of-way etc. The other road functions should not interfere with dominant traffic function of arterial (**AR**) and trunk roads (**TR**) to provide the movement of vehicles at required level of service while, with collection/distribution and especially direct access roads, the other functions could be even more important than vehicle movement.

Longest average trip lengths (Fig. 3) are present on long distance connection roads (**TR-s**, **TR-ir**) with reduction of average trip length with hierarchically lower road types. Hierarchically higher road types should accommodate higher traffic volumes and provide higher average traffic flow speeds. In order to provide adequate volumes, speed levels and traffic safety, access control

should be more severe and complete with higher road classes and types. This aspect is a fundamental one in all the countries and specific guidelines are developed (i.e. TRB, 2003) in order to define and coordinate traffic demands (i.e. volume and speed) with land use development along road section. Access control is one of the major problems in road network supply characteristics in Serbia today; numerous direct accesses even to primary rural road sections are the main cause of relatively poor level of service and safety on major portion of road network in Serbia today.

Number and density of intersections is the main element of access control thus ensuring adequate volume and speed characteristics of traffic flow. Therefore, intersection density is the highest with direct access roads (**DA**) with lower values for higher functional types. The same general relation occurs with total length of road types within the rural road network on state or regional level.

In order to ensure the hierarchy within the road network, it is necessary to follow the principle of providing connections between different road classes and types; each road class should have connections with roads of the same class and one higher or one lower road type (Fig. 4). Special cases (i.e. natural or build up constraints) can be accepted as a temporary solution.

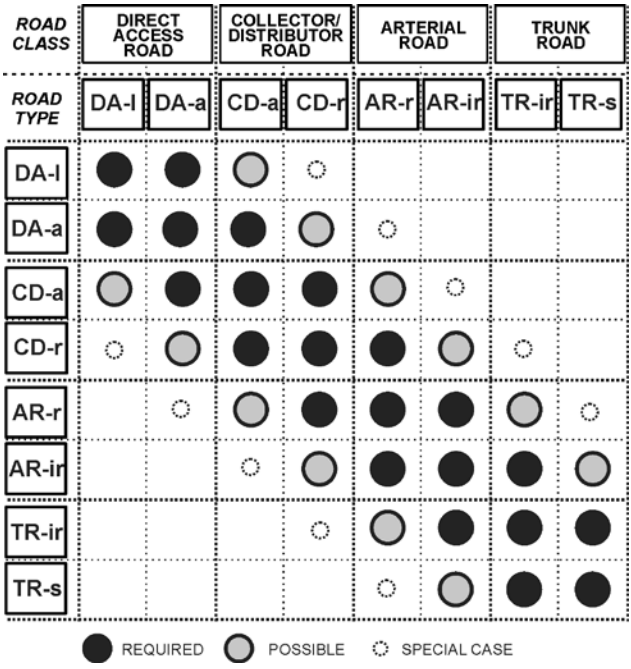

Fig. 4.
Connections between Rural Roads Functional Classes and Types in Serbia

4. Spatial Plans and Functional Classification of Rural Roads

Due to the fact that rural road function evolves from concentrations of land uses in space and time, functional classification of road sections is an integral part of relevant spatial plan. Therefore, functional classification is not given once for all but it should be revised and modified to reflect the changes in spatial and/or road network development. Relevant spatial plans are defined according to spatial level of road function (Fig. 5). Besides the road general route, it is important that nodal points of rural road network, namely number and overall locations of intersections, are defined in the relevant spatial plan also.

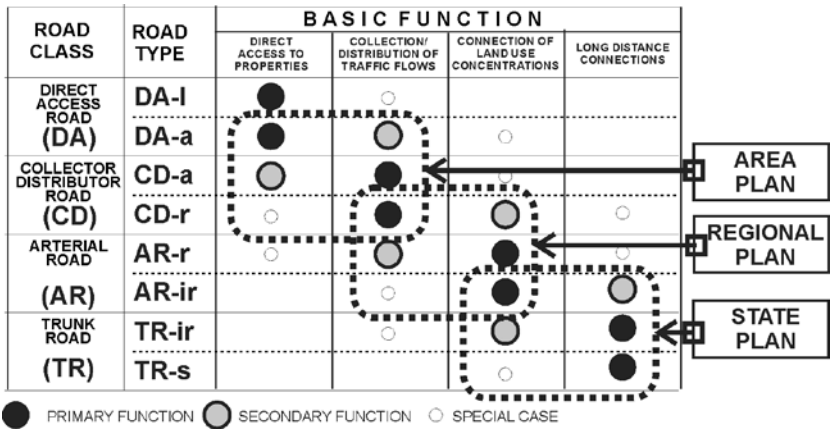

Fig. 5.
Relevant Spatial Plans for Functional Classification of Rural Roads in Serbia

Highest classes and types of rural roads (**TR-s, TR-ir** and most important interregional arterials **AR-ir**) are defined within the State Spatial Plan together with general location of intersections with roads of regional importance. Regional Spatial Plan comprises functional classification of rural roads with regional importance (the remaining **AR-ir, AR-r** and most important collector/distributor roads **CD-r**). Routes and connections with roads classified in the State Spatial Plan are the input for the Regional Plan; any new connections of regional roads to trunk roads have to be authorized by authorities responsible for the State Spatial Plan and trunk road network management having in mind that each connection substantially causes the decline of the service level and safety.

Spatial plan for the area being the part of a region should follow the same principles as previously defined in functionally classifying the remaining **CD-r** and roads serving the area in question (**CD-a** and most important **DA-a**). Direct access roads (remaining **DA-a** and **DA-l**) and their characteristics usually belong to the design phase of land use development. The non categorized roads (i.e. agricultural, forest etc.) should be developed more or less independently with constraint of their connection to categorized roads of access class (**DA-l, DA-a** and in special cases **CD-a**).

5. Centers of Gravitation and Transport Function Levels in Serbia

Origins and destinations of freight and passenger trips are not uniformly distributed in space thus reflecting the patterns of spatial development. They are concentrated in the centers of gravitation with intensities proportional to land use intensities in these centers. There are four categories of centers of gravitation in Serbia:

- **first order centers (I)** are urban settlements with population more than 100,000 in continually urbanized area attracting everyday gravitation within time radius of 45-60 minutes trip length,
- **second order centers (II)** are urban settlements with population 50,000 – 100,000 in continually urbanized area attracting everyday gravitation within time radius of 30-45 minutes trip length. This category also includes major tourist areas with longer duration of visits (i.e. spas, skiing centers, resorts etc.) with minor seasonal variation and major terminals of other transport modes (international airports and ports, long distance railway stations and nodes); both outside continually urbanized areas,
- **third order centers (III)** comprise urbanized settlements with population 10,000 – 50,000 in the area attracting everyday gravitation within time radius of 15-30 minutes trip length. This category includes minor tourist areas with short visits (mostly weekend) and dominating seasonal variation of demand and minor terminals of other transportation modes (domestic airports, local ports, railway stations for domestic intercity traffic etc.),
- **fourth order centers (IV)** are local centers including settlements with population 500 – 10,000, minor tourist and recreation facilities, local railway stations for regional traffic etc.

Border crossings in Serbia are categorized in following:

- **international** used by traffic flows to/ from two or more states,
- **state** with dominating traffic flows to/ from bordering states,
- **regional** serving traffic flows that connect two bordering regions in different states,
- **local** for short distance traffic movements across the border.

Application of gravitation centers and border crossings categorization criteria on Republic of Serbia existing situation results in spatial distribution of gravitational centers as presented on Fig. 6 together with transport function levels **I** and **II** desire lines.

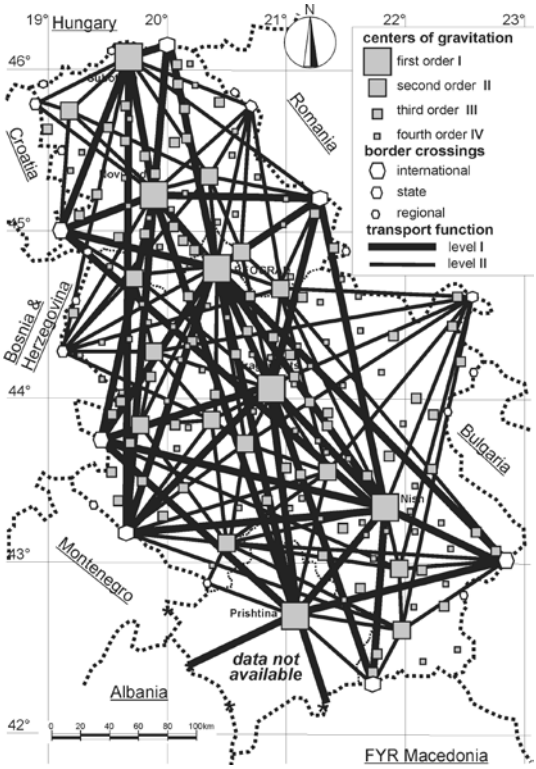

Fig. 6.
Centers of Gravitation and Transport Function Levels in Serbia

Presented centers of gravitation are highly correspondent to classification of urban areas in the State Spatial Plan (Stojkov et al., 2010) which complies with European Union criteria (Nomenclature of Territorial Units for Statistics – NUTS). Belgrade is the only NUTS II level urban area in Serbia and four urban settlements are of NUTS III level. The other urban settlements belong to Local Administrative Units – LAU categories LAU I and LAU II.

Differences between urban settlements classification in State Spatial Plan and gravitation centers (Fig. 6), which occur with lower level classes (NUTS III, LAU I and LAU II), are the result of inclusion of tourist areas and transportation terminals in close proximity to an urban settlement in definition of gravitation centers order. Tourist centers and transportation terminals outside urban areas are classified as gravitation centers separately based on previously defined criteria and available statistical data (STAT. YEARB. SER., 2009).

6. Functional Classification of Serbia Road Network Proposal

Application of functional classification criteria on existing primary rural road network in Serbia followed the principle of hierarchy; the first step was to define trunk roads predominantly serving level

I transport function. The network of trunk roads (type **TR**-s) is composed of existing, under construction and planned motorway sections so it can be defined as primary **A**-road network (Fig. 7). With completion of motorway sections **A**-road network would eventually form a separate functional class. The shaded surface is 15 kilometers wide on each side of the road indicating an area of more or less direct access provided by road sections in question.

Next two road types (**TR-ir** and most important **AR-ir**) are superimposed on the road network of the highest level. These road sections accommodate the rest of the level **I** transport function and the most important connections of the level **II** transport function. This network is composed of existing two lane – two way roads and can be defined as primary **B**-road network. The shaded surface is 10 kilometers wide on each side of the road indicating an area more or less direct access provided by road sections in question.

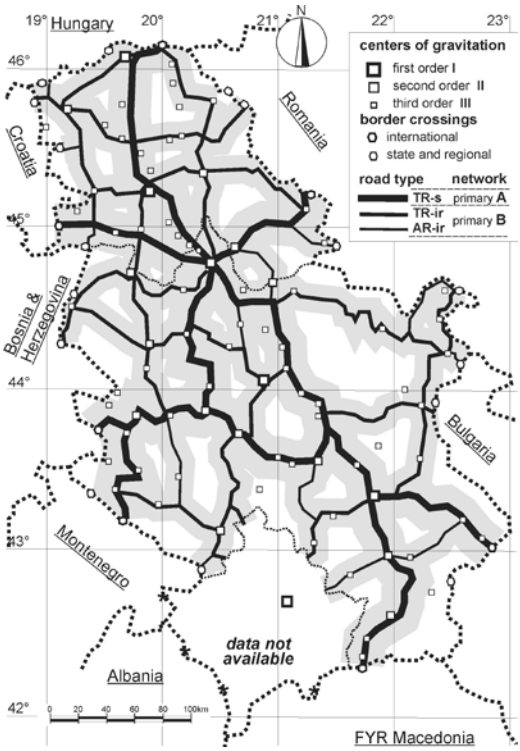

Fig. 7.
Proposal of Primary Rural Road Network for Serbia with the Area of Direct Access Based on Functional Classification

It should be noticed (Fig. 7) that all centers of gravitation of the first and second order (**I, II**) are covered by the area of immediate access, while only few centers of the third order (**III**) are not covered and those being the major tourist centers. Moreover, the shaded

surface covers three fourths (76.5%) of the total Republic of Serbia area (without Kosovo where data is not available) while existing road network covers 77.6% with virtually the same accessibility level provided.

At present, the total length of primary roads in Serbia is 4,560 kilometers out of which 54 kilometers (1.2% of primary network total length) are road sections through urban area of Belgrade (so called **C**-road network) with urban and suburban traffic dominating. Primary **A**-road network (**TR-s**) has the length of 1,316 kilometers (28.85% of the primary network total length) with 453 kilometers of motorways and 853 kilometers of two lane roads. Primary **B**-road network (**TR-ir** and the most important **AR-ir**) comprises two lane roads with total length of 3,190 kilometers (69.95% of primary network total length).

Proposed primary road network (Fig. 7) reduces the total length of roads classified as state roads of first order (I) today by 464,9 kilometers while 86,1 kilometers are added to primary road network (the reduction of 378,8 kilometers or 8.31%). All sections that are reclassified belong to **B**-road network. Typical example, resulting from the up to date practice to avoid any reclassification of roads with new completed sections of motorways, is the old two lane road Belgrade – Novi Sad – border of Hungary built 70 years ago while new motorway is very close (approx. 10 kilometers) and completely parallel to the old road route. Moreover, local governments with scarce budgetary resources tend to transfer the burden of road construction and maintenance to state level through political pressure. This resulted in obvious local roads becoming regional ones and roads with dominant regional traffic classified as primary state roads.

In 2009 sections of primary **B**-roads with total length of 485 kilometers (15.2% of **B**-road network total length) had mean Annual Average Daily Traffic - AADT of 788 vehicles/day; such volume is typical for low volume roads. Some of these sections are reclassified as state roads of II order if they do not affect regional accessibility substantially.

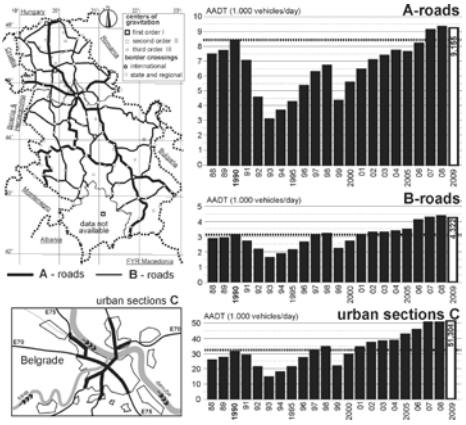

Fig. 8.
Time Series of Mean AADT on Primary Roads in Serbia

Demand and supply analyses of primaries by three networks (**A, B** and **C**) are already established approach (Maletin and Tubic, 2005) and new data (FTTE, 2010) from traffic counters are included annually. Mean value of Average Annual Daily Traffic – AADT is used as an indicator of traffic demand changes over time (Fig. 8). Main supply characteristics of roads (i.e. number of traffic lanes, width of roadway, design speed, alignment etc.) experienced only minor changes in time period analyzed.

Primary **A**-road network mean AADT is approximately twice higher than mean AADT on **B**-road network in the years after 1991. In the base year 1990 this ratio was 2.75. Mean AADT value for the year 1990 occurred in 2007 on **A**-roads and in 2001 on **B**-roads and urban sections **C** due to rather slow return of international transit trips, modest increase of long distance trips and higher increase rates of suburban and urban trips in Serbia.

In the year 2009, **A**-roads served 42.07% of total vehicle kilometers while **B**-roads and urban sections **C** served 48.26% and 9.67% respectively. Certain degree of demand concentration on **A**-roads network results in 2009 AADT value greater than 12,000 vehicles/day counted on 22 motorway sections with total length of 265.8 kilometers. On **B**-road network 2009 AADT value approximately 10,000 vehicles/day occurs on 4 sections only with total length of 73.4 kilometers. High 2009 AADT values causing congestion together with substantial rates of yearly increase on urban sections (**C**, Fig. 8) indicate that two priority actions are needed: change in Belgrade transportation policy towards the radical improvement of public transport and construction of planned motorway bypasses as well.

7. Categorization of Serbia Road Network Proposal

Categorization of rural roads, or administrative classification, should define jurisdictions over rural road network and be compatible with functional classification (Fig. 9).

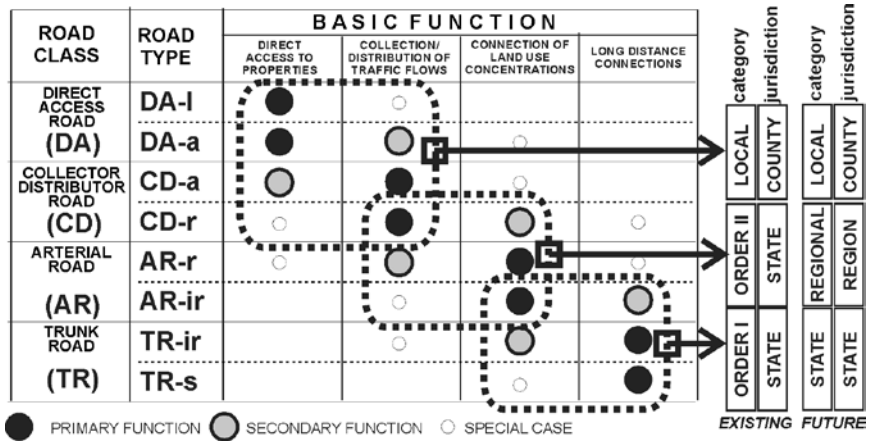

Fig. 9.
Coordination of Functional Classification and Categorization of Rural Roads in Serbia

At present rural roads are classified as state roads of first and second order (I, II) and local ones thus reflecting the absence of regional authorities in the existing governmental organization in Serbia. The recommendation for future categorization and jurisdictions (Fig. 9) is reflecting actual discussions on regional development policies and reorganization of governmental structure in Serbia with introduction of regional authorities. It is understood that regional authorities will have the jurisdiction over regional roads and will be provided with adequate financial and professional resources in order to accept transfer of jurisdictions from state level successfully. Local roads should stay with local authorities.

8. Conclusion

The existing classification of rural roads in Serbia, mostly based on administrative criteria, is substantially outdated by spatial and road network development. The research suggests that the first step should be a functional classification of rural roads with the introduction of spatial criteria followed by categorization (or administrative classification) closely related. Detailed criteria and procedures are defined in both research documents (Maletin and Andjus, 2008; Tubic and Maletin, 2008).

Application of defined functional classification and categorization criteria on existing rural road network in Serbia presently includes primary roads only. The proposal suggests the reduction of existing primary road network by 368.8 kilometers while the area coverage and overall accessibility remain virtually the same.

Within the primary road network two sub networks are distinguished: **A**-road network comprising existing, under construction, designed or planned rural motorway sections with primary function to serve international and state level traffic flows and **B**-road network comprising sections of main rural two lane roads primarily accommodating interregional traffic flows. Traffic count data and trends support the formation of these sub networks of primary rural roads in Serbia.

Further research will concentrate on regional rural roads network where reduction of total length of regional roads is reasonably expected. The proposal of regional roads classification should be finalized in order to coincide with new governmental organization in Serbia.

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