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Considerations on the geometric design of low-volume roads

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Summary

Technical, economic and social criteria have to be considered for justifying the adequacy of the new low volume roads, in Romania. The high investment costs in this field are the consequence of the non satisfactory viability state, which characterizes the majority of the local road network of Romania, where graveled roads represent more than 25,000 km, and earthy roads represent more than 8,500 km. Only 10% of the local roads are modernized, 30% are provided with semi-permanent pavements, and most of them have an exceeded service life. In accordance to a "strategic policy" design of the infrastructure of a local road is justified for a minimum of 15 years service life, while the "tactic policy" may be adopted when designing the road structure. The paper presents the design principles of low-volume roads, taking into account the local conditions. There are emphasized the following: the local road functions - both public and social ones, the required conditions for the geometric design, the importance of multi-criteria methods as economical tools .The design principles according to the Romanian technical provisions for horizontal and vertical alignment, and that of the cross sections are also discussed. The concept of the ecological resistance is also presented .The conclusions emphasize that both design and construction of a low volume road has to be framed into the concept of durable development.

KEYWORDS: geometric design, low volume roads, ecological resistance, multi-criteria analysis

1. INTRODUCTION

According to the official classification, most of Romanian low volume roads are local ones and they are subdivided as county or communal roads. The design of a low volume road, aimed to ensure the accessibility and mobility of people in localities placed in rural or small urban areas involves both technical and an economical aspects. The economical aspect is emphasized by the actual poor technical condition of the existing local road network. According the technical

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classification, the low-volume roads are usually included in the 4th and 5th classes. The hourly traffic flow corresponds to the 50th hour of the year. Function of the specific of the road, in case of a staged construction strategy, the design traffic flow corresponding to the 100th - 200th hour may be adopted.

2. DESIGN PRINCIPLES

The design speed has not an intrinsic meaning; its significance is correlated to the safety and comfort parameters. These parameters have to be correlated with the road function, in order to assure a reasonable the ratio between the technical provisions of both low and high volume/speed roads.

The adoption of minimum design parameters, (e.g. R_H- the radius of curve in horizontal alignment, R_V- the radius of the convex curve in vertical alignment, etc) does not lead compulsory, to the most economic alignments.

The design of the infrastructure of a local low volume road according to a "strategic policy" is justified for a minimum of 15 years service life.

A "tactic policy" may be adopted when designing the road structure over 3…5 years, with the provision of adequate structures, capable to permit the practice of successive strengthening technique, according to the traffic evolution.

The design and construction of the road route in plan, is usually justified for final design parameters, while the construction of the road may be realized in stages if this approach is justified from technique and economic point of view. Also lateral safety zones must be provided as important elements related to the environmental impact, according to the durable development concept.

The exceptional values of the geometric functions should be adopted in order to avoid some very expensive works and/or for the protection or the fitness of the route on the compulsory points.

The criteria for the evaluation of various design alternatives and of the opportunity of the scheduling of investments have to be completely different from those adopted for important roads, because in the rural media, the road fulfills not only a "public" function, but first of all a " social service ", similar to those schools or a medical centers, etc. In this respect, some criteria related to the social function of a local road could not be quantified from an economic point of view, so that the role of multi-criteria methods of analysis to be increased and in some cases to become compulsory for analysis of such projects.

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3. THE DESIGN SPEED

The design speed is correlated to the technical road class and also to the relief type, as it is presented in Table 3.1.

TABLE 3.1. Design Speeds for Low-Volume Roads

Technical Classe	Design Speed (km/h) for:						Remarks
	Flat area		Hilly area		Mountain area		
	A	B	A	B	A	B	
IV	60	50	40		30(*)	25	(*) A 20 km/h speed is required in the main curve of a serpentine
V	50	40	40	25	25(*)		

The speed values from the "A" column may be increased with maximum 20 km/h if no supplementary costs were involved. The difference between the design speeds of two adjacent running sections must not exceed 10-20 km/h. The base speed defined as the minimum design speed along the road route, must not be less then the speed values specified in column B. These values are admitted in case of severe conditions of the route or may be imposed by the adjacent road environment conditions.

4. SPECIFIC GEOMETRIC CONDITIONS

4.1. Horizontal alignment.

The lengths of progressive connections are established based on the dynamic comfort criteria, the optical comfort criteria being not justified for the local roads, because of the limited speeds. The exclusive use of the clothoid is not justified in case of high frequency of compulsory points, under difficult relief condition, in the protected zones at the crossing rural localities (this last one being a general characteristic of low-volume road network in Romania). Other progressive transition curves can be used as follows:

- The clothoid with a variable modulus defined by the equation:

$$\rho s^n = A^{n+1} \tag{4.1}$$

The acceleration rate, j is defined as:

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$$j = v^3 \frac{n \cdot s^{n-1}}{A^{n+1}} \; [m/s^3] \tag{4.2}$$

where:

ρ [m] is the curvature radius of the arc s, n is an exponent resulted from the conditions imposed by the connection, v is the vehicle speed expressed im m/second. The equation (3.1) corresponds to a family of curves, enabling the adoption of rational and efficient solutions for the road route.

- The circular arc of double radius enables the reduction of the progressive transition length, leading to a value of j coefficient greater then 0.5 m/sec$^{3;}$
- The cubic parabola for the easiness of the field operations;
- The acceleration-deceleration curves which may assure the conditions of progressive transitions for zonesr with frequent changing the design speed (situation which may be often encountered in case of local roads)

4.2. Vertical alignment.

Special gradients are adopted on limited distances only when climatic conditions are favorable .The solution involving the traveling of the ascending grades by inertia, with the reduction of the vehicle speed according the prescribed limits, may be taken into consideration even if this solution is not recommended from the point of view of the optical comfort. Emergency spurs may be also considered for particular cases of significant extended gradients The necessary stopping sight distance must be correlated with the maintenance conditions according to the pavement type. Thus, a poor maintenance and severe damaged road surfaces or a with a reduced skid resistance will require longer braking distances.

4.3. The transverse profile

Any widening is provided at the interior of the curve, but in exceptional cases the following solutions may be considered:

- Widening of each traffic lane;
- Widening of the carriage way, on both sides.

In case of small cuttings (depth of cut less than 2 meter), the adoption of 1/10 slope will be justified in agriculture zones, in all areas susceptible for drifting snow and for the crossing of the agriculture areas in order to assure the acces of agriculture equipment.

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5. THE USE OF MULTI-CRITERIA, MULTI-ATRIBUTE METHODS FOR THE ANALYSIS OF VARIOUS PROJECT ALTERNATIVES.

Each project alternative is characterized in terms of various max/min criteria, either numerical or qualitative ones for the last ones being adopted an adequate value scale. Some examples of the multi-criteria analysis are presented in Table 5.1.

TABLE 5.1. Examples of Criteria for Multi-Criteria Decisions

Criteria		
Maximum	Technical	Traffic volume / Induced traffic Design speed /Base speed Minimum radius/ the average value in horizontal alignment Compensated earthwork volumes
	Social	The rate of people with following accessibility: 30 minutes for daily activities; 60 minutes for weekly activities 120 minutes for monthly activities
Minimum	Technical	The effective/equivalent length of the route; The total length containing maximum/exceptional gradients; The weighted average gradient through total length ; The earthwork volume: total/ worked under adverse, or unfavorable conditions;
	Economical	The value of the total investment; Actualized total cost; Equivalent costs ; The term for the recovering of the initial investment;
	Social	Number of days with traffic closing during the winter period; Number of days with traffic restrictions during the winter time ; Number of days with traffic closing due to floods;
	Environmental	Agriculture and forest area to be expropriated; Ecological resistance Surfaces temporary extracted from the agriculture circuit.

The ecological resistance R_i enables a global characterization of various project alternatives from the point of view of the environmental impact.

$$Ri = (1{,}0 - C_i^{+})/ C_i^{+} \tag{5.1}$$

Where:

$i = 1,2,\ldots m$

m- the number of the criteria ;

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C_i^+ - the relative difference from the ideal solution, obtained by using the method of Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) ;

The hierarchy of the various alternatives is established according to the ascending R_i values.

6. CONCLUSIONS

- Design of the low volume road infrastructure is justified, based on a strategic planning for a time horizon of minimum 15 years. For the structural design, a tactical planning for a period of 3…5 years may be adopted in case of financial constraints;
- The analysis criteria of various project alternatives and those undertaken for the evaluation of the opportunity and scheduling of investments, applied for local roads must be different from those applied for important roads, because in the rural medium, the roads represent not only a public service but mainly a social one.The use of multi-criteria methods for decision is useful and compulsory in some cases;
- For the appropriate fitness of the road route in the compulsory points, with the avoidance of the protected zones, the use of the special progressive connections is justified;
- Taking into consideration the specific nature of the areas crossed by the local road routes- rural localities, the road impact on the environment must represent one of the most significant design criteria.

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